XXII International May Conference on Strategic Management
- IMCSM26 -

# BOOK OF PROCEEDINGS

May, 2026

# IMCSM Proceedings

ISSN 2620-0597

**Volume XXII, Issue (1), (2026)**


An international serial publication for theory and practice of Management Science



**Editor-in-Chief: Prof. dr Đorđe Nikolić**

**Published by University of Belgrade, Technical Faculty in Bor, Department of Engineering Management**

**Belgrade, 2026**

*SCIENTIFIC COMMITTEE*

*LIST OF REVIEWERS*

**Berto Usman,** University of Bengkulu, Indonesia;
**Daniel Pavlov,** "Angel Kanchev" University of Ruse, Bulgaria;
**Darko Stefanović,** University of Novi Sad, Serbia;
**Galia Marinova,** Technical University of Sofia, Bulgaria;
**Isidora Milošević,** University of Belgrade, Serbia.
**Ivan Mihajlović,** University of Belgrade, Serbia;
**Jacques Bazen,** Saxion University of Applied Sciences, Germany;
**Jovan Filipović,** University in Belgrade, Serbia;
**Ladislav Mura,** University of Economics in Bratislava, Slovakia;
**Luminita Parv,** Transilvania University of Brasov, Romania;
**Magdalena Radulescu,** National University of Science and Technology Politehnica Bucharest, Romania;
**Marek Szarucki,** Krakow University of Economics, Poland;
**Mario Carrassi,** University of Bari Aldo Moro, Italy;
**Michael Huth,** Fulda University of Applied Sciences, Germany;
**Milovan Vuković,** University of Belgrade, Serbia;
**Musin Halis,** Kocaeli University, Turkey;
**Nemanja Berber,** University of Novi Sad, Serbia;
**Olesea Plotnic,** Moldova State University, Moldova;
**Pal Michelberger,** Obuda University, Hungary;
**Petra Grošelj,** University of Ljubljana, Slovenia;
**Rita Remeikiene,** Mykolas Romeris University, Lithuania;
**Simon Gao,** Edinburg NapierUniversity, Kingdom;
**Slobodan Aćimović,** University of Belgrade, Serbia;
**Slobodan Radosavljević,** RB Kolubara, Serbia;
**Snežana Urošević,** University of Belgrade, Serbia;
**Stojan Kitanov,** Mother Teresa University, North Macedonia;
**Tomasz Ingram,** University of Economics in Katowice, Poland;
**Vesna Spasojević Brkić,** University of Belgrade, Serbia;
**Željko Stević,** University of East Sarajevo, Bosnia and Herzegovina.

*ORGANIZING COMMITTEE*



**Technical Editor**: Milica Veličković, Technical Faculty in Bor
**Technical Co-Editors:** Aleksandra Radić, Technical Faculty in Bor
Adrijana Jevtić Tomić, Technical Faculty in Bor
Lidija Krstić, Technical Faculty in Bor
**Proceedings cover design:** Danijela Voza, Technical Faculty in Bor



CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

005.5(082)(0.034.2)
005.7:004(082)(0.034.2)
005:502.131.1(082)(0.034.2)

INTERNATIONAL May Conference on Strategic Management (22 ; 2026 ; Beograd)
Book of proceedings [Elektronski izvor] / XXII International May Conference on Strategic Management – IMCSM26, May 2026, [Belgrade] ; [editor-in-chief Đorđe Nikolić]. - Bor : University of Belgrade, Technical Faculty, Engineering Management Department, 2026 (Rača : Presing). - 1 USB fleš memorija ; 9 x 6 cm : tekst, slika. - (Edition IMCSM Proceedings ; vol. 22, issue (1) (2026), ISSN 2620-0597)

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 100. - Preface / editors. - Bibliografija uz svaki rad.

ISBN 978-86-6305-169-0

а) Стратешки менаџмент -- Зборници б) Предузећа -- Управљање -- Зборници в) Информациони системи -- Менаџмент -- Зборници г) Одрживи развој -- Управљање -- Зборници

COBISS.SR-ID 194482

*Gold Donor*

*Exhibitions*

# PREFACE

It is our great pleasure to present the *Proceedings of the 22nd International May Conference on Strategic Management*, a collection of contributions that reflect the dedication, creativity, and scholarly excellence of our academic and professional community.

We would like to express our sincere gratitude to all authors who have contributed their time, knowledge, and enthusiasm to this conference. This year, we are especially proud to highlight that the proceedings include contributions from authors representing more than 30 countries, underscoring the international character and growing impact of the conference. The diversity of topics and perspectives presented here highlights the importance of collaboration and continuous dialogue in addressing contemporary challenges.

We extend our deepest appreciation to our main sponsor, the Ministry of Science, Technological Development and Innovation, for its invaluable support and commitment to advancing research and innovation. We are also grateful to our gold sponsors, Zijin Mining and Zijin Copper, whose generous contributions have significantly supported the successful organization of this conference. In addition, we would like to thank our exhibition partner, MDPI, for their collaboration and engagement in promoting academic exchange.

We also extend our appreciation to the reviewers and members of the organizing committee, whose dedication and careful work ensured the quality and success of the conference. Their efforts have been essential in maintaining high academic standards and in bringing this publication to fruition.

Finally, we thank all attendees for their engagement and for fostering a stimulating and supportive environment. We hope that these Proceedings will serve as a valuable resource and inspiration for future research, collaboration, and innovation.

*Thank you!!*

Editors

# CONTENT

**TRANSFORMATION OF SUPPLY CHAINS INTO DIGITAL VALUE NETWORKS IN THE CONTEXT OF INDUSTRY 5.0: A COMPETENCE-DRIVEN GOVERNANCE PERSPECTIVE**
Slobodan Morača , Angela Fajsi, Marko Milosavljević........................................................ 1

**URBAN PARCEL LOCKERS: SPATIAL DISTRIBUTION AND INSIGHTS**
Milena Ninović, Nataša Čačić ........................................................................................ 17

**THE ROLE OF EUROPEAN BORDER AND COAST GUARD AGENCY (FRONTEX) IN THE EUROPEAN UNION (EU) SECURITY AND THE COOPERATION WITH NATO**
Tryfon Korontzis, Lambros Sdrolias...................................................................................... 28

**HARMONIZING ELEMENTS OF AGILITY FRAMEWORK: PRINCIPLES, DIMENSIONS AND ATTRIBUTES – SYSTEMATIC LITERATURE REVIEW**
Martin Halász , Andrea Janáková Sujová ........................................................................ 34

**CASH TRANSFER RECEIPT AND ENTREPRENEURIAL WEALTH RELATIONSHIP – THEORETICAL REVIEW OF ENABLERS AND BARRIERS**
Kenneth Onyango, Nathaniel Boso, Hellen Otieno............................................................... 53

**LOGISTICS MANAGEMENT AND PERFORMANCE OF SELECTED AGRO-PROCESSING FIRMS IN NORTH CENTRAL, NIGERIA**
Blessing Abecan John , Salim Muhammad Ogaji, Pius Zamwawosayi Yakubu ................ 68

**INTEGRATION OF INFORMATION MANAGEMENT AND CYBERSECURITY AT THE GOVERNANCE LEVEL THE ILGM CONCEPTUAL MODEL BASED ON THE INFORMATION LIFECYCLE (7RS)**
Ghenadie Belinschi .......................................................................................................... 79

**APPLICATION OF CONTENT ANALYSIS AND THEMATIC ANALYSIS IN RESEARCH IN THE FIELD OF BUSINESS AND MANAGEMENT**
Lidija Krstić, Milovan Vuković, Snežana Urošević............................................................. 86

**AUTHENTIC SUSTAINABILITY FILTER (FAS). A NEW METHODOLOGY TO UNCOVER THE PARADOX BETWEEN REGULATORY COMPLIANCE AND THE AUTHENTIC SUSTAINABILITY OF COMPANIES**
Ninel Nesheva-Kiosseva ................................................................................................... 94

**BUILDING SMART REGIONS THROUGH SMART CITY DEVELOPMENT: A STRATEGIC FRAMEWORK FOR SERBIA**
Damir Ilić, Tatjana Ilić-Kosanović, Vladimir Tomašević...................................................... 109

**AN AI-BASED RECOMMENDER SYSTEM FOR OMNICHANNEL RETAIL CAMPAIGN PLANNING: CONCEPT AND PROTOTYPE**
Ankica Borota-Tišma, Draga Tišma ........................................................................... 121

**STRATEGIC ROLE OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT CONCEPTS IN IMPROVING BUSINESS AND MARKET PERFORMANCE**
Stefan Ugrinov, Mihalj Bakator, Sanja Stanisavljev, Dragan Ćoćkalo, Mila Kavalić, Verica Gluvakov.......................................................................................................... 135

**DIGITAL PROTOCOL IN THE AGE OF ARTIFICIAL INTELLIGENCE: TRANSFORMATION, CHALLENGES AND STRATEGIC RECOMMENDATIONS FOR PUBLIC SECTOR MANAGEMENT**
Sande Smiljanov........................................................................................................ 144

**EFFECTIVE MANAGEMENT OF OPPORTUNITIES IN INVESTMENT PROJECTS – APPROACHES, PROBLEMS AND CHALLENGES**
Nadya Marinova – Milanova.................................................................................... 151

**TAX CONTROL AUTOMATION USING SMART CONTRACTS**
Radovan Vladisavljević, Aleksandra Zlatić Tešić, Svetlana Marković............................... 162

**THE CYBERSECURITY FUNDAMENTALS OF ARTIFICIAL INTELLIGENCE**
Zsolt Szabó Mihály........................................................................................................ 172

**SELECTS LOCATIONS FOR COLLECTION CENTER**
Vladimir Stojković, Goran Tepić, Jelena Spajić, Milan Delić, Mirko Djelošević ............ 183

**INDUSTRIAL SYMBIOSIS POTENTIAL IN SOUTHEAST AND CENTRAL EUROPE: A MULTI-CRITERIA ANALYSIS OF SELECTED COUNTRIES**
Anđelka Stojanović, Isidora Milošević, Sanela Arsić, Almudena Muñoz Puche .............. 195

**DIGITAL MANAGEMENT IN ENERGY-INTENSIVE INDUSTRIES**
Muamer Muminović, Petronije Jevtić, Ljiljana Stošić Mihajlović, Marija Mihajlović........ 205

**STRATEGIES FOR DEVELOPING EMPLOYEE DIGITAL COMPETENCIES FOR SUCCESSFUL DIGITAL TRANSFORMATION**
Ljiljana Stošić Mihajlović, Jevtić Miroslava,
Marija Mihajlović, Petronije Jevtić, Muamer Muminović.................................................. 215

**STRATEGIC IMPERATIVES FOR AVAILABILITY AND AFFORDABILITY OF ESSENTIAL MEDICINES IN KENYA: IMPLICATIONS FOR ADVANCING UNIVERSAL HEALTH COVERAGE**
Rosalind Kirika, Joseph Onyango, Jeniffer Orwa............................................................... 226

**COMPARATIVE ANALYSIS OF CAPITAL, LABOUR AND TECHNOLOGICAL RETURNS IN EUROPEAN COUNTRIES**
Aleksejs Hilkevics ........................................................................................................ 237

**OPTIMISATION OF THE NUMBER OF OPERATING WELL PUMPS BASED ON POWER CONSUMPTION**
Al-Sifao A. Al-Sifao, Nikola V. Petrović, Radiša Ž. Jovanović, Uglješa S. Bugarić........... 248

**DIGITAL ANDON AS AN INFORMATION SYSTEM AND ECONOMIC TOOL FOR SUSTAINABLE PRODUCTION**
Slobodan Stefanović, Ivan Sinadinović,
Jasmina Gligorijević, Milan Stefanović ............................................................................ 258

**BUSINESS DIGITIZATION IN WESTERN BALKAN COUNTRIES: TRENDS, GAPS AND CONVERGENCE WITH THE EU**
Jelena Živković, Stefan Zdravković........................................................................... 270

**MAPPING ERP SYSTEM ADOPTION THEORIES: INSIGHTS FROM A BIBLIOMETRIC ANALYSIS**
Aleksandra Radić, Sanela Arsić, Đorđe Nikolić............................................................ 279

**EVALUATION OF MARKETING INDICATORS USING THE IMF SWARA METHOD**
Perica Macura, Željko Stević, Boris Novarlić, Milan Tadić............................................ 289

**GIBSU-HISA: AN ENHANCED INFLUENCE ANALYSIS METHOD FOR GROUP DECISION-MAKING UNDER UNCERTAINTY**
Gregor Dolinar, Petra Grošelj........................................................................................ 299

**THE IMPORTANCE OF APPLYING THE PRINCIPLES OF THE CIRCULAR BIOECONOMY TO ACHIEVE THE SUSTAINABLE DEVELOPMENT GOALS IN SERBIA**
Ljiljana Brašanac-Bosanac , Nevena Čule, Ljubinko Rakonjac,
Aleksandar Lučić, Tatjana Ćirković-Mitrović.................................................................. 309

**STUDENTS' INNOVATIVE BEHAVIOR IN HIGHER BUSINESS EDUCATION: A SOCIAL COGNITIVE PERSPECTIVE ON AI LITERACY AND SELF-EFFICACY**
Ivica Nikolić, Kiril Postolov, Violeta Cvetkoska, Bojan Kitanovikj,
Filip Peovski, Ivona Serafimovska, Nenad Milijić........................................................... 318

**DO HIGHER MATERIAL COMPENSATIONS LEAD TO HIGHER NET PROFIT PER EMPLOYEE?**
Andreja Katolik Kovačević.............................................................................................. 328

**THE MEDIATING ROLE OF EMPLOYEES' JOB SATISFACTION IN THE RELATIONSHIP BETWEEN WORKPLACE DIGITALIZATION AND EMPLOYEES' PRODUCTIVITY: CROSS COUNTRY STUDY**
Milica Ž. Veličković, Silvia Puiu.................................................................................... 340

**THE RELATIONSHIP BETWEEN ORGANIZATIONAL CONTEXT AND IDENTITY OF AN ORGANIZATION AND LEADERSHIP IN HEIS**
Nedeljka Živković, Maja Glogovac, Biljana Tošić, Isidora Milošević............................... 358

**FAILURE MODE AND EFFECTS ANALYSIS: LITERATURE REVIEW AND BIBLIOMETRIC ANALYSIS**
Lidija Krstić, Ivan Jovanović........................................................................................... 367

**MANAGING EMOTIONS FOR BUSINESS PURPOSES: INTERNATIONAL STUDENT COMPARISON**
Daniel Pavlov, Silvia Puiu, Deniza Alieva, Milica Ž. Veličković .................................... 377

**EVOLUTION OF RISK IN GLOBAL FLOWS OF ENERGY TRANSITION**
Slobodan Radosavljević.................................................................................................. 386

**METHODOLOGY FOR IDENTIFICATION AND RISK ANALYSIS OF THE SRS 1300 ROTARY EXCAVATOR IN SURFACE COAL MINING**
Slobodan Radosavljević.................................................................................................. 397

**A COMPARISON OF FORECASTING PERFORMANCE OF SOME PANEL OF VARIOUS COMMODITIES PRICES AND TIME-SERIES MODELS**
Krzysztof Drachal, Mosab I. Tabash................................................................................ 407

**DIFFERENCES IN ENTREPRENEURIAL INTENTIONS BETWEEN YOUNG PEOPLE FROM ENTREPRENEURIAL AND NON ENTREPRENEURIAL FAMILIES: A RUSSIAN BULGARIAN COMPARATIVE STUDY**
Julia Murzina, Elena Zarubko, Daniel Pavlov ................................................................. 424

**OCCUPATIONAL INJURIES AND WORKPLACE SAFETY IN EUROPEAN COUNTRIES: A K-MEANS CLUSTER ANALYSIS**
Aleksandra Radić, Nenad Milijić, Ivica Nikolić................................................................ 434

**FROM URBAN MINING TO DIGITAL PRODUCT PASSPORTS: A STRATEGIC MANAGEMENT PERSPECTIVE ON END-OF-LIFE BATTERIES IN EUROPE**
Mario Carrassi, Stefania Massari , Marcello Ruberti........................................................ 444

**EMBEDDING SUSTAINABILITY THROUGH DESIGN THINKING: EVIDENCE FROM THE ORSÙ INNOVATION LAB CASE**
Mario Carrassi, Anna Argese, Matteo Lacorte, Carlo Castrignano, Andrea Gelao ........... 457

**DIGITAL TRANSFORMATION CHALLENGES IN SERBIAN AND HUNGARIAN SMES: AN INDEX-DRIVEN COMPARATIVE ASSESSMENT**
Andrea Tick, Ferenc Katona, András Keszthelyi,
Isidora Milošević, Anđelka Stojanović, Danijela Pantović, Réka Saáry............................ 468

**ASSESSING THE RELATIVE IMPORTANCE OF PRODUCT ATTRIBUTE DIMENSIONS IN TECHNICAL PRODUCTS: A RANKING APPROACH AMONG GENERATION Z CONSUMERS**
Adrijana Jevtić Tomić, Suzana Đukić, Goran Milovanović .............................................. 481

**UNDERSTANDING THE NATURE OF SOCIAL MEDIA CUSTOMER COMPLAINT BEHAVIOUR IN KENYA'S STAR-RATED HOTELS**
Njuguna Muthoni, Kofi Dadzie, Hellen Otieno................................................................. 490

**VARIATION OF THE MONTH EFFECT IN CENTRAL AND EASTERN EUROPE STOCK MARKETS**
Rasa Norvaisiene , Jurgita Stankeviciene........................................................................... 502

**KEY FACTORS OF LONG-TERM VIABILITY IN BUSINESS SYSTEMS FROM A LIFE-CYCLE PERSPECTIVE**
Sara Kremsar, Eva Krhač Andrašec, Tomaž Kern ......................................................... 512

**TECHNOLOGY AND DIGITAL TRANSFORMATION IN INSURANCE: A COMPARATION ANALYSIS WITH EVIDENCE FROM KOSOVO**
Kaltrina Bajraktari, Klime Poposki, Irina Joldeska, Bashkim Cerkini............................... 522

**DEVIATIONS FROM THE ENVIRONMENTAL KUZNETS CURVE AND COUNTRY CLUSTERS WITH SIMILAR GDP-$CO_2$ EMISSION PATTERNS**
Ermina Ćosović, Ivan Mihajlović, Mirjana Misita ......................................................... 535

**IMPLEMENTATION OF RISK MANAGEMENT IN PROJECT-ORIENTED ORGANIZATIONS: CHALLENGES AND PERSPECTIVES IN THE MODERN BUSINESS ENVIRONMENT**
Jelena Ružić, Marija Panić.............................................................................................. 544

**PRIORITIZING DEVELOPMENT STRATEGIES FOR A PASSENGER VEHICLE IMPORTER AND WHOLESALER IN THE SERBIAN AUTOMOTIVE MARKET**
Darko Stanojević, Predrag Đorđević , Anđelka Stojanović, Ljubica Knežević ............ 557

**COMPARATIVE ANALYSIS OF BALKAN COUNTRIES ACCORDING TO DIGITAL TECHNOLOGY USAGE IN BUSINESS: AN INTEGRATED MCDM APPROACH**
Aleksandra Fedajev, Sanela Arsić, Ivana Božić Miljković ........................................... 572

**IMPLEMENTATION OF AI IN VEHICLE REPAIR PROCESSES AS A KEY FACTOR OF CIRCULAR ECONOMY AND TECHNO-ECONOMIC EFFICIENCY IN TRAFFIC SAFETY**
Mirjana Dejanović, Jelena Ružić, Nenad Milijić .......................................................... 589

**A COMPARATIVE ANALYSIS OF ENVIRONMENTAL AWARENESS AND BEHAVIOR AMONG GENERATION Z IN SERBIA AND THE CZECH REPUBLIC**
Marija Panić, Milica Veličković, Aleksandra Fedajev,
Danijela Voza, Sanela Arsić, Dušan Mladenović …………………………………… 602

**THE ROLE OF KNOWLEDGE MANAGEMENT IN THE CREATIVE INDUSTRY: ITS IMPACT ON INNOVATION AND CSR**
Sanela Golubović Corcione, Milica Veličković,
Aleksandra Fedajev, Ivan Jovanović ............................................................................ 615

**BENCHMARKING OF RAILWAY SUPPLY CHAIN PERFORMANCE: THE ROLE OF ORGANIZATIONAL CULTURE**
Vesna Spasojević Brkić, Branislav Tomić, Iva Savić, Martina Perišić Jokić................. 629

**ARTIFICIAL INTELLIGENCE IN THE EVALUATION OF PROJECTS FUNDED THROUGH COHESION POLICY: BETWEEN EFFICIENCY AND PRACTICAL LIMITATIONS**
Hojda Sebastian-Norbert.................................................................................................. 642

**CIVILIAN POWER AND MEN ON UNIFORM: A DESCRIPTIVE ANALYSIS OF WIKE AND YERIMA**
Ehichoya Godday Imonie, Omeahon Henry Oigiangbe................................................. 652

**SERVICE LEVEL MANAGEMENT STRATEGY IN WIRELESS COMMUNICATIONS**
Jovan Zlatanovic.............................................................................................................. 662

**THE INFLUENCE OF PLANNED LIFESPAN TRIGGERS ON LEADER EFFECTIVENESS IN TOP MANAGEMENT OF LISTED COMPANIES IN NAIROBI SECURITIES EXCHANGE**
Paul Kasimu, Hellen Otieno, Fred Walumbwa, Vincent Ogutu.................................... 672

**TOWARDS TRANSCENDING FRAGMENTED PERSPECTIVES ON MACHIAVELLIAN LEADERSHIP IN ORGANIZATIONAL CONTEXTS: AN ADO-TCM–BASED SYSTEMATIC REVIEW**
Hind El Asraoui, Anas Hamzane, Samira Touate, Asmae Houmid Bennani................. 682

**MARITIME GOVERNANCE AND THE BLUE ECONOMY: BETWEEN STRATEGIC AMBITIONS AND IMPLEMENTATION CONSTRAINTS (A SYSTEMATIC REVIEW OF LITERATURE)**
Rajae Janati Idrissi, Youssef Pheniqi............................................................................. 693

**THE ROLE OF STRATEGIC MANAGEMENT IN THE GOVERNANCE OF OIL RESOURCES AND GEOPOLITICAL RISK IN THE MIDDLE EAST**
Anita Babić ...................................................................................................................... 706

**THE IMPACT OF FINANCIAL TECHNOLOGIES AND DIGITAL INNOVATIONS ON THE MODERNIZATION OF GEORGIA'S BANKING SECTOR**
Bichiko Kakabadze, Nana Shonia, Irine Kopaliani.............................................................. 711

**OCCUPATIONAL SAFETY CHALLENGES IN SERBIA: A LONGITUDINAL ANALYSIS OF INJURY TRENDS AND FORECASTS (2015–2027)**
Nenad Milijić, Aleksandra Radić, Ivan Jovanović................................................................ 720

**CROSS-COUNTRY DIFFERENCES IN GREEN PURCHASING BEHAVIOUR AMONG GENERATION Z: EVIDENCE FROM SERBIA AND THE CZECH REPUBLIC**
Aleksandra Fedajev, Dušan Mladenović, Sanela Arsić,
Danijela Voza, Milica Veličković, Marija Panić.................................................................. 730

**GOVERNANCE AND ECONOMIC INEQUALITY AMONG INDEPENDENT PROFESSIONALS: A COMPARATIVE ANALYSIS OF EDUCATION AND CULTURE SECTORS**
Patricija Jankovič, Sašo Murtič ........................................................................................... 745

**HUMAN CAPITAL AT THE HELM OF INDUSTRY 5.0: THE IMPACT OF EXECUTIVE DEVELOPMENT PROGRAMMES ON SENIOR MANAGERIAL CAPABILITIES IN INDIAN MANUFACTURING**
Sutaarson Murugesh, A K Sheik Manzoor............................................................................. 754

**AGILITY MATURITY MODELS FOR ASSESSING CURRENT AND ACHIEVABLE LEVELS OF STRATEGIC AGILITY**
Katarína Marcineková, Andrea Janáková Sujová.................................................................. 763

**THE ROLE OF EUROPEAN FUNDING IN ACADEMIC SPIN-OFF CREATION: A TRIPLE HELIX PERSPECTIVE FROM A RESEARCH INSTITUTE**
Andra Elena Diaconescu, Lavinia-Maria Iloie…………………………………………... 773

**A PROPOSED THEORETICAL FRAMEWORK FOR THE ADOPTION OF CONTEMPORARY CSR TRENDS IN MALAWI'S TELECOM INDUSTRY**
Wongani Calvin Kaunda, Vusumzi Msuthwana, Siyabonga Sirayi……………………….. 783

**ADAPTATION STRATEGIES FOR GLOBAL ECONOMIC MODELS IN PERIODS OF INSTABILITY**
Geanina – Ioana Blaj ……………………………………………………………………….. 793

**THE IMPACT OF MANAGEMENT COMPETENCIES ON BUSINESS DEVELOPMENT IN THE BALTIC REGION**
Monta Anšica, Una Libkovska …………………………………………………………….. 802

**BIODIVERSITY CONSERVATION IN BROD-POSAVINA COUNTY AND ITS ROLE IN REGIONAL ECONOMIC DEVELOPMENT**
Anica Vukašinović, Ivana Miklošević ……………………………………………………….. 812

**PUBLIC DEBT MANAGEMENT: SEIGNIORAGE MODEL VERSUS DOMAR MODEL**
Dmitrijs Smirnovs ……………………………………………………………………… 821

**FACTORIAL EXPERIMENTAL DESIGN AND SIX SIGMA AS TOOLS FOR PROCESS IMROVEMENT IN HEALTHCARE**
Teodora Filipovska, Sara Srebrenkoska,
Aleksandra Risteska-Kamcheski, Vineta Srebrenkoska ……………………………. 831

**DECISION-MAKING MODELS BASED ON OPTIMIZATION AND DIFFERENTIAL EQUATIONS**
Aleksandra Risteska-Kamceski, Sara Srebrenkoska, Dejan Krstev ………………… 839

**OPTIMAL MATERIAL SELECTION FOR 3D PRINTING (PLA) USING MULTI-CRITERIA DECISION ANALYSIS**
Dejan Krstev, Sara Srebrenkoska, Aleksandra Risteska-Kamcesk …………………. 848

**EMOTIONAL LEADERSHIP COMPETENCIES VS. ARTIFICIAL ITELIGENCE IN EDUCATIONAL INSTITUTIONS**
Stefani Jovcheska, Zorica Siljanovska, Silvana Jovcheska …………………………. 858

**SUSTAINABLE MANAGEMENT OF CARBON EMISSION REDUCTION IN AN INDUSTRIAL COMPANY: A CASE STUDY**
Aouad Razika, Belhour Samira, Chaib Rachid …………………………………….... 867

**STRATEGIC DRIVERS OF DIGITAL ENTREPRENEURSHIP: A COMPARATIVE STUDY OF INDIA, CROATIA, GERMANY, AND SLOVENIA**
Ivana Miklošević, Nikhil Bhardwaj, Nalinee Chauhan ……………………………... 877

**CAPITALISM AND LABOR EXPLOITATION: THE ROLE OF ACCOUNTING IN THE MARITIME LABORERS' MARKET**
Ehtesham Abbasi, Amr Kablema, Ansam Selloum,
Alaa El Alami El Hassani, Kashif Beg ……………………………………………......... 886

**A GOVERNANCE-EMBEDDED DECISION-SUPPORT FRAMEWORK FOR SUSTAINABLE PROJECT PORTFOLIO SELECTION IN THE WESTERN BALKANS**
Nikola Jovanović, Aca Jovanović, Ivana Berić ……………………………………... 900

**ARTIFICIAL INTELLIGENCE ENABLED DECISION MAKING IN CONSTRUCTION PROJECT MANAGEMENT ACROSS ORGANISATIONAL HIERARCHICAL LEVELS AND PROJECT LIFECYCLE STAGES**
Pride Ndlovu ……………………………………………………………………… 908

# INTERNATIONAL MAY CONFERENCE ON

# STRATEGIC MANAGEMENT

Volume XXII, Issue (1) (2026) 444-456

International May Conference on Strategic Management

DOI: 10.5937/IMCSM26444C

Research Article

# FROM URBAN MINING TO DIGITAL PRODUCT PASSPORTS: A STRATEGIC MANAGEMENT PERSPECTIVE ON END-OF-LIFE BATTERIES IN EUROPE

**Mario Carrassi[1], Stefania Massari[2*], Marcello Ruberti[2]**

*[1] Università degli studi di Bari Aldo Moro, Dipartimento di Economia e Finanza, Bari, Italy*
*[2]University of Salento, Department of Economic Sciences, Italy*

**Abstract**: The rapid growth in demand for automotive batteries in Europe, linked to the ongoing and profound global political and economic crisis, is increasingly placing pressure on the supply chains of strategic raw materials. This has obvious repercussions on the volumes of end-of-life batteries and their potential use as important sources of secondary critical resources. Urban mining has therefore emerged as a strategic pillar of the circular economy, particularly for lithium, cobalt, and nickel recovery. At the same time, the European Union is introducing Digital Product Passport (DPP) approach, with batteries representing the first major product group for which a passport becomes legally required. This work develops a strategic management perspective on the role of DPPs in end-of-life battery systems in Europe. Indeed, going beyond the consideration of DPPs as simple and mere regulatory compliance tools, this paper places them within a more complex management framework capable of significantly optimizing the traceability, coordination, and valorization of strategic secondary resources from spent batteries along the entire circular value chain, linking passport-enabled information flows with more accurate end-of-life routing, stronger critical raw material recovery, improved compliance, and improved circular supply security.

**Keywords**: urban mining, digital product passport (DPP), battery passport, end-of-life batteries, circular economy.

* *Corresponding author: stefania.massari@unisalento.it*

Mario Carrassi, ORCID: 0000-0002-2111-4459
Stefania Massari, ORCID: 0000-0002-3806-4363
Marcello Ruberti, ORCID: 0000-0002-0764-3303

## 1. INTRODUCTION

The European Union's (EU) profound strategic shift, also linked to the rapid transition to sustainable electrified mobility and low-carbon energy systems that are rapidly transforming batteries into one of Europe's most strategically important industrial products, is not simply a matter of technological innovation or growing market demand, but above all a question of the strategic security of critical resources, industrial competitiveness, and proper and effective governance of the circular value chain. According to the International Energy Agency (IEA), demand for electric vehicle batteries reached roughly 1 TWh in 2024 and, under stated policy scenarios, is expected to rise beyond 3 TWh by 2030. This projection leaves little room for doubt: in the next few years, pressure on the supply of critical raw materials for batteries is likely to intensify sharply. At the same time, the European Commission (EC) has made it clear that batteries need to become sustainable across their full life cycle, from raw material extraction to collection, repurposing, and recycling. Nevertheless, the European Court of Auditors (ECA) has also issued a warning that the EU continues to encounter significant challenges in ensuring secure access to the critical raw materials necessary for the energy transition (European Commission, 2024a; International Energy Agency, 2025; European Court of Auditors, 2026).

In numerous aspects, the battery sector at present mirrors a more extensive European challenge. Batteries are key components in the transition towards decarbonisation, energy storage and industrial modernisation. At the same time, however, they remain heavily dependent on materials such as lithium, cobalt and nickel, whose supply chains continue to be subject to factors such as geopolitical concentration, market volatility, environmental constraints and strategic competition between major powers. As a result of this situation, the EU has gradually refocused its strategic objectives, moving from a simple policy of proper waste management to a more comprehensive management framework integrating life-cycle regulation, an industrial policy aimed at recycling, and increasingly ambitious circular economy objectives. This is clearly demonstrated by Regulation (EU) 2023/1542 on batteries and battery waste, which aims not only to regulate the end-of-life phase but, above all, to strengthen sustainability, safety, labelling, collection, and treatment along the entire battery value chain, while supporting the growth of a competitive and sustainable European battery industry (European Parliament and Council of the European Union, 2023; European Commission, 2024a).

In this context, the concept of urban mining takes on relevance, proposing a completely different way of conceiving cities, production and consumption systems, and waste flows: not as simple final disposal facilities for useless and problematic materials, but often as important and valuable secondary reservoirs of resources that have critical economic and strategic value. Eurostat reports that in 2023, approximately 231,000 tonnes of portable batteries and accumulators were placed on the EU market, while approximately 117,000 tonnes were collected as recyclable waste. Compared to the average sales volume of the previous three years, this equates to a collection rate of approximately 49%. Overall, these data suggest two things. On the one hand, the EU is gradually building a significant urban battery stock, which can be interpreted as a growing basis for recovery and recovery strategies. On the other, a still large share of the potential value embedded in this stock continues to be only partially captured, leaving significant room for improvement along the collection and recycling chains. Recent research on the battery sector in the EU also indicates that circularity outcomes are limited by factors such as fragmented infrastructure, uneven collection performance, inconsistent end-of-life governance and uncertainty regarding the implementation of key policy requirements (Eurostat, 2024; Rizos & Urban, 2024a).

A key obstacle lies in the quality, availability, and accessibility of product information throughout the battery's life cycle. End-of-life battery systems are characterized by multiple stakeholders, fragmented ownership histories, changing technical states, and heterogeneous treatment options, all of which complicate decisions regarding reuse, repurposing, dismantling, and recycling. Recent literature on Digital Product Passports (DPPs) shows that circularity depends not only on physical recovery processes but also on the existence of high-quality, interoperable, and stakeholder-relevant data. Jensen et al. (2023) demonstrate that DPPs fundamentally aim to support decision-making throughout the product lifecycle by making critical data available to various stakeholders. Pohlmann et al. (2025) show that stakeholders in the electric vehicle battery sector attach great importance to sustainability and circularity-related information, while identifying persistent gaps in the availability and accessibility of information. In other words, the European battery circularity challenge is not just a catch-up challenge; it is also a challenge in terms of information governance (Jensen et al., 2023; Rizos & Urban, 2024a; Pohlmann et al., 2025).

It is in this context that DPP acquires strategic relevance. As part of the new Ecodesign Regulation and the revised EU battery regulatory framework, the battery DPP is emerging as one of the most ambitious information infrastructures ever introduced to support the circular economy. The EC describes DPP as a digital identity card that will store and make accessible data on a product's sustainability performance, recyclability, and environmental impact throughout its life cycle. In the battery sector, Regulation (EU) 2023/1542 establishes that, from February 18, 2027, every battery for light vehicles (light means of transport, LMT), every industrial battery with a capacity greater than 2 kWh, and every battery for electric vehicles placed on the market must be accompanied by a battery passport (European Parliament and Council of the European Union, 2023; European Commission, 2024b; European Parliament and Council of the European Union, 2024).

However, reducing the battery passport to a mere compliance tool would be analytically insufficient. From a management perspective, the DPP should be understood as a capacity-building mechanism capable of improving visibility, coordination, value retention and resilience throughout the entire circular battery value chain. According to Langley et al. (2023), the role of DPPs should be redefined as that of coordination mechanisms within the context of a smart circular economy. Recent research has expanded on this perspective by demonstrating that DPPs can facilitate the creation of sustainable value across organisational boundaries. However, the effectiveness of these benefits depends on design choices, governance arrangements and the quality of implementation (Langley et al., 2023; Rizos & Urban, 2024b; Christensen et al., 2025; Gieß & Möller, 2025; Losa & Torjesen, 2025; Soavi et al., 2026).

Consequently, the existing literature is making significant progress; however, a clear research gap persists. Existing studies have examined DPPs in terms of data requirements, technological design, stakeholder expectations and implementation challenges, whilst studies on battery circularity have focused more on barriers to recycling, end-of-life logistics, cost implications and policy constraints. Even less developed is a perspective that explicitly interprets the DPP as a strategic framework for end-of-life battery management in Europe and links the potential of urban recycling to circular competitive advantage. This article fills this gap by arguing that urban regeneration provides the resource base, whilst DPP provides the management architecture necessary to convert this resource base into a more visible, governable and resilient system for the recovery of secondary raw materials (Jensen et al., 2023; Lopes & Barata, 2024; Rizos & Urban, 2024a; Rizos & Urban, 2024b).

## 2. LITERATURE REVIEW

### 2.1. Urban mining and end-of-life batteries in the EU

Urban mining has taken on an increasingly central role in the EU debates on batteries, critical raw materials and circular industrial development, as the EU remains structurally exposed to external dependencies for key battery materials, particularly lithium, cobalt and nickel. The EU is vulnerable because it does not have enough capacity to extract resources from its own land. This is since most of the resources come from one place, there is a risk of political instability, and batteries are becoming more important for mobility, renewable energy systems, and industrial competitiveness (European Commission, 2024a; Husmann et al., 2025; Massari & Ruberti, 2026). Europe's "urban mine" of batteries is quickly developing, albeit not to the requisite amount to guarantee efficient cycle recovery.

In 2022, the EU market recorded approximately 243,000 tonnes of batteries, of which around 111,000 tonnes were collected for recycling, accounting for approximately 46% of the total. The survey also highlighted that Member States have achieved quite varying levels of success regarding the recycling of lithium-ion batteries. Recent Eurostat data indicate that the flow remains substantial and, more importantly, growing. In 2023, approximately 231,000 tonnes of portable batteries and accumulators were placed on the market in the EU, while approximately 117,000 tonnes were collected as waste suitable for recycling. Taken together, these data confirm that the EU is building up a significant stock of secondary resources, although unfortunately at the same time, a non-negligible part of the potential value associated with these flows remains wasted (Eurostat, 2024; Massari & Ruberti, 2026).

A parallel, and no less relevant, theme has been highlighted in the relevant literature. This concerns disparities in collection and recovery outcomes among Member States: countries such as Germany, Denmark, and Finland show superior performance, thanks in part to more widespread infrastructure, more effective extended producer responsibility (EPR) systems, and higher levels of public awareness regarding the importance of environmental protection. In contrast, Italy, Greece, Malta, and Portugal continue to face persistent challenges in terms of collection and recycling. This picture is consistent with recent empirical evidence, which identifies a long list of contributing factors, including fragmented collection systems, insufficient economic incentives, lax enforcement of regulations, infrastructure gaps, and, in some contexts, political instability. All these circumstances are recurring obstacles to circularity in the EU battery sector (Eurostat, 2024; Feng et al., 2024; Rizos & Urban, 2024a; Massari & Ruberti, 2026).

From a strictly technical standpoint, it is almost clear that the end-of-life value of batteries, in terms of secondary raw material content, depends primarily on two conditions: the correct and effective design of recycling systems to maximize recovery objectives, and the technical characteristics of the batteries, which must necessarily be compatible with future recycling treatments. In this regard, substantial differences exist between the two possible recovery approaches: pyrometallurgical and hydrometallurgical. Pyrometallurgical technologies are widely used because they are much more well-tested and are also capable of processing heterogeneous raw materials on a large scale; however, lithium recovery using these methods is often penalized, in part due to losses associated with volatilization. Hydrometallurgy, on the other hand, is typically more selective and offers better recovery rates for lithium and cobalt, but it is also a much more complex technology and highly sensitive to process variations. Recent assessments of electric vehicle battery recycling and robotic disassembly confirm this analysis (Windisch-Kern et al., 2021; Windisch-Kern et al., 2022; Feng et al., 2024; Kaarlela et al., 2024; Woeste et al., 2024; Massari & Ruberti, 2026).

Overall, the literature on urban mining regards it as more than just a method of waste management. It also sees it as a way of safeguarding resources, the environment and the economy. However, both recent empirical studies and review articles agree in concluding that these benefits are still limited by infrastructure bottlenecks, the complexity of treatment processes, regulatory fragmentation and poor coordination among the stakeholders involved. This makes urban mining highly relevant, but not self-sufficient, as a circular strategy for batteries in the EU (Rizos & Urban, 2024a; Husmann et al., 2025; Massari & Ruberti, 2026).

### 2.2. Digital Product Passports and the battery passport

In this constantly evolving political landscape, the DPP has established itself as one of the most important tools for putting circularity into practice in the EU. The battery sector is especially significant because it is the first major EU product family for which a passport obligation has been clearly specified in sectoral legislation. Regulation (EU) 2023/1542 states that, from 18 February 2027, each light means of transport battery, each industrial battery with a capacity greater than 2 kWh, and each electric vehicle battery placed on the market or put into service must have an electronic record, namely a battery passport. The same regulatory framework also makes clear that EU battery policy is intended to cover the entire life cycle of batteries, from sourcing and manufacturing to collection, recycling, repurposing, and recovery (European Parliament and the Council of the European Union, 2023; European Commission, 2024a).

The battery passport is therefore much more than a label. The Regulation specifies that it must contain information relating both to the battery model and to the individual battery, including information resulting from the use of that battery. It must be accessible through a QR code linked to a unique identifier, and the information included must be based on open standards and be machine-readable, searchable, structured, and interoperable. These requirements demonstrate that the battery passport is designed as a dynamic data architecture, rather than a static information tool (European Parliament and the Council of the European Union, 2023).

However, the overall framework for product passports is still being defined, and the specialist literature clearly shows that many practical aspects are constantly evolving. The EC has described the product passport as a digital identity tool that stores and shares information on a product’s environmental impact, recyclability and sustainability performance throughout its entire life cycle. The JRC’s technological efforts have led to the creation of a formal approach for determining which data should be included in DPPs within the ESPR framework, how such data should be prioritised, and how to address issues such as access rights, governance and the level of detail of the information. This outcome is consistent with the observed evolution of the DPP from a general policy objective to practical implementation (European Commission, 2024b; European Commission, 2025; Chawla et al., 2026).

More recent literature, both academic and policy-oriented, dedicated to battery DPP adds further complexity to this picture. Indeed, Pohlmann et al. (2025) show that actors in the electric vehicle battery supply chain value sustainability and circularity information, but, at the same time, highlight some gaps in data availability and, above all, in their effective accessibility. From a more systemic perspective, Rizos and Urban (2024a, 2024b) argue that effective battery lifecycle circularity in the EU is hampered by still too vague information requirements, some ambiguities in end-of-life responsibilities, and a division of functions among value chain actors that is not always clear or consistent. Losa and Torjesen (2025) acknowledge that battery DPP is presented as a potential enabler of circularity; However, they point out that obstacles remain related to data interoperability, governance mechanisms, and the relationship between recycling and other potentially more profitable circular strategies. Along the same lines, Soavi et al. (2026) discuss how the battery passport intertwines with sustainability goals, digital infrastructures, and industry standards, highlighting the need for technical and organizational alignment that goes beyond the regulatory dimension alone. (Rizos & Urban, 2024a; Rizos & Urban, 2024b; Losa & Torjesen, 2025; Pohlmann et al., 2025; Soavi et al., 2026).

Overall, current evidence does not support the interpretation of the battery passport as a mere regulatory compliance tool: its scope appears broader and depends crucially on data quality, coordination rules between stakeholders, and the ability to be operationally integrated into circularity supply chains. On the contrary, it is becoming increasingly clear that it is an important part of the EU's commitment to transitioning from linear battery value chains to data-driven circular systems. The current literature, however, shows that this transition is not yet fully defined. Issues remain regarding interoperability, certification, governance, data access and implementation costs. These issues will have a significant impact on whether battery passports truly make a difference or function only to a limited extent (Rizos & Urban, 2024b; Chawla et al., 2026; Soavi et al., 2026).

### 2.3. Strategic management and circular end-of-life systems

From a strategic management perspective, end-of-life batteries should no longer be viewed as a simple waste stream. It is more appropriate to interpret them as an area in which producers, recyclers, reuse stakeholders, compliance officers, users, and public authorities can build forms of cooperation aimed at the strategic coordination of resources. This need becomes even more pressing when the availability of materials is limited, information is incomplete or difficult to access, and circularity pathways coexist that compete for priority, cost-effectiveness, and absorption capacity along the supply chain. In this direction, Langley et al. (2023) propose to consider product DPPs as real coordination mechanisms within a smart circular economy; similarly, Gieß and Möller (2025) frame them as elements of a broader value ecosystem, in which different actors, different regulatory requirements and extensive exchanges of multiple information and materials are intimately inter-twined.

This perspective is particularly relevant for end-of-life battery systems, as circular performance is based on a series of strategic choices rather than a single recycling event. Depending on their chemical composition, health status, ownership history, safety conditions and market value, batteries can be reused, repurposed, remanufactured, dismantled or recycled. Jensen et al. (2023) demonstrate that DPPs are closely linked to decisions regarding the product life cycle. Wan and Jiang (2025) highlight the importance of dynamic information flows during the use phase. In the field of batteries, this means that product information can improve transparency regarding the location and status of resources, reduce ambiguity regarding residual value, and optimise the distribution of batteries towards the most appropriate end-of-life pathway (European Parliament and Council of the European Union, 2023; Jensen et al., 2023; Wan & Jiang, 2025).

The literature also helps to understand why battery circularity is so important when it comes to information asymmetry. Batteries that have reached the end of their life cycle cross many organisational boundaries, and stakeholders often lack reliable knowledge about their composition, origin, usage history, treatment alternatives and compliance obligations. In this sense, the passport can help reduce information and operational asymmetries among supply chain actors, facilitate compliance management, and, more generally, lower barriers to interorganizational collaboration. Petrik et al. (2026) describe DPPs as digital artifacts capable of capturing and distributing critical product information beyond the boundaries of individual organizations. However, recent analyses of battery DPP show that actual benefits are not automatic. They essentially depend on data quality, access rights, governance mechanisms, and the ability to integrate this information into both operational processes and strategic decisions (Rizos & Urban, 2024b; Pohlmann et al., 2025; Petrik et al., 2026). From this perspective, battery DPP can be interpreted as an enabling infrastructure, which can be assigned different strategic roles: visibility, coordination, value recovery, and resilience. These are not just technical outcomes, but strategic ones because they influence how companies compete and position themselves along the value chain, their level of regulatory preparedness, the security of "circular" supplies, and, ultimately, the ability of companies and ecosystems to generate value from used batteries in operational and management situations characterized by uncertainty and resource scarcity (Langley et al., 2023; Gieß & Möller, 2025; Petrik et al., 2026).

## 3. DATA AND METHODOLOGY

This study adopts a conceptual research design, informed and supported by empirical evidence. This approach is highly appropriate for the subject of analysis, given that the regulatory and technical framework for DPP is still being consolidated and, more importantly, the available empirical data on the operational effects of battery DPPs in end-of-life management systems are still limited, fragmented, and not always comparable. The most recent available literature virtually unanimously highlights that battery DPP is undergoing a crucial transition from legal and regulatory definition to its actual practical implementation. However, significant issues persist regarding data requirements, access rights, interoperability, governance, reliability and organisational use. In this context, a conceptual paper grounded in authoritative documentary and scientific evidence is methodologically more credible than a forced empirical design based on incomplete or disjointed implementation data (Rizos & Urban, 2024b; Christensen et al., 2025; Wan & Jiang, 2025; Chawla et al., 2026).

The document brings together three types of data. Firstly, it examines EU rules and policies relating to batteries and digital product passports, with a particular focus on Regulation (EU) 2023/1542, Regulation (EU) 2024/1781 and recent methodological work by the Joint Research Centre. Second, it synthesizes secondary evidence from the literature on urban mining, battery circularity, and battery recovery, including the uploaded manuscript that serves as an intellectual starting point for the present study. Third, it develops a conceptual framework that connects battery-passport information functions with strategic outcomes in end-of-life battery systems (European Parliament and the Council of the European Union, 2023, 2024; Chawla et al., 2026; Massari & Ruberti, 2026).

The analytical procedure follows four sequential steps. First, the study identifies the main end-of-life management bottlenecks affecting battery circularity in the EU, including fragmented information flows, insufficient visibility regarding battery composition and condition, uncertainty over actor responsibilities, limited interoperability, weak reverse-logistics coordination, and incomplete support for higher-value circular strategies such as reuse and repurposing (Rizos & Urban, 2024a, 2024b; Losa & Torjesen, 2025).

Second, the study identifies which passport-enabled information functions are most relevant for addressing these bottlenecks. Here the analysis draws on DPP literature concerning product identification, composition, usage history, maintenance and repair information, compliance data, supply-chain and reverse-logistics information, and lifecycle data updating. Jensen et al. (2023) identify major DPP data clusters linked to reverse supply-chain decision-making, while Wan and Jiang (2025) emphasize that lifecycle information should not remain static but must be capable of being updated during product use. Chawla et al. (2026) contribute a structured methodology for defining and prioritizing DPP data fields in relation to policy objectives and practical feasibility.

Third, these functions are grouped into four broader strategic capability areas: visibility, coordination, value recovery, and resilience. This step is necessary because the purpose of the document is not simply to list possible passport data elements, but to interpret them from a strategic management perspective. Product information is analytically relevant only to the extent that it improves the ability of companies and value chain actors to make better end-of-life decisions, align reverse logistics processes, reduce information asymmetry, and ensure more reliable secondary material flows (Psarommatis et al., 2024; Christensen et al., 2025).

Fourth, the paper derives the expected strategic outcomes from these areas of expertise for end-of-life battery systems in the EU. These outcomes are conceptualized in terms of improved pathways between reuse, recycling, and repurposing; improved quality and reliability of critical raw material recovery; improved compliance and reporting; and increased resilience of circular supply. The outcome does not replace future case studies, interviews, or quantitative validation. Rather, it provides a structured analytical basis for understanding how the battery passport can operate as a strategic mechanism within circular end-of-life battery systems in Europe (Jensen et al., 2023; Wan & Jiang, 2025; Chawla et al., 2026).

## 4. RESULTS AND DISCUSSION

The main outcome of this study is a strategic management framework that views the battery passport not only as a legislative or technical tool for dissemination, but also as a means of enhancing capacity-building within end-of-life battery management systems in Europe. The framework links certain functions of the battery passport to four strategic pillars of capacity: visibility, coordination, value recovery, resilience and circular competitiveness. Furthermore, the analysis highlights how these capabilities can translate into measurable effects on end-of-life management outcomes and, more generally, on further circularity dynamics. This interpretation is consistent with recent contributions on the topic of DPPs, which increasingly interpret product passport systems as enabling tools for orchestrating value chains across different sectors, increasing transparency, and creating circular value, rather than as simple information repositories (Langley et al., 2023; Christensen et al., 2025; Gieß & Möller, 2025).

Visibility is the first pillar of capabilities. In the context of end-of-life battery systems, visibility refers to the ability to make relevant product, material and lifecycle information accessible, structured and usable across stakeholders and stages. Under Regulation (EU) 2023/1542, the battery passport must contain information relating to both the battery model and the individual battery, including information derived from use. In practical terms, this means that the passport can improve visibility regarding the battery's identity, its chemical composition, origin, health status, carbon footprint information and end-of-life status. Greater visibility reduces uncertainty and minimises the risk of inefficient pathways, inappropriate treatment choices and avoidable loss of information along the battery value chain (European Parliament and Council of the European Union, 2023; Pohlmann et al., 2025; Chawla et al., 2026).

Coordination is the second key pillar. The battery passport can serve as a coordination tool between manufacturers, users, collection schemes, re-users, dismantlers, recyclers and public authorities. This role is central to the strategy, as the performance of end-of-life batteries does not depend solely on the effectiveness of recycling technologies. It also depends on the ability of stakeholders to share information, keep it up to date, analyse data and fully understand their roles throughout the value chain. Existing literature suggests that battery DPP could significantly optimize information flows and make recycling and reuse processes more efficient. At the same time, critical issues arise regarding data confidentiality, still insufficient levels of interoperability, and persistent ambiguity in defining responsibilities throughout the various life cycle phases (Langley et al., 2023; Rizos & Urban, 2024b; Christensen et al., 2025).

Another, more strictly managerial, issue concerns the ability to direct batteries toward the most appropriate end-of-life pathway (i.e., reuse, reprocessing, reconditioning, disassembly, or recycling) when, of course, the necessary information is available. This means that it is not enough for a battery to reach a treatment facility, but for it to reach the right facility, at the right time, and with adequate information to support the related technical and operational decisions. Indeed, the chemical composition of batteries, treatment techniques, and national capacity conditions obviously have a direct impact on the effectiveness of critical raw material recovery. Adding to the complexity of the overall EU system, recycling and recovery performance remains markedly uneven across Member States within the EU. A DPP-based system can certainly improve the match between battery characteristics and treatment choices, optimizing the recycling value chain and facilitating the higher-quality recovery of lithium, cobalt, nickel, and other strategically important materials (Rizos & Urban, 2024a; Losa & Torjesen, 2025; Massari & Ruberti, 2026).

Resilience and circular competitiveness constitute the fourth and most strategic pillar of capabilities. If battery passports improve visibility, coordination, and end-of-life value recovery, they can also enhance EU ability to generate more reliable and traceable flows of secondary raw materials. This is important because EU battery policy is explicitly linked not only to sustainability, but also to competitiveness, the clean energy transition, and reducing dependence on external resources. The resilience effect manifests itself when improved end-of-life governance generates more predictable, better documented, and more reliable flows of secondary raw materials. Such flows can strengthen circular procurement, support compliance with future recycled content requirements, and improve the position of European companies in an increasingly stringent regulatory and supply chain environment (European Parliament and Council of the European Union, 2023; European Commission, 2024a; Rizos & Urban, 2024b; Soavi et al., 2026).

The proposed framework can be summarised as follows: Functions of the ‘Battery Passport’ → Strategic capabilities → End-of-life outcomes → Competitive effects of circularity. Within this framework, the functions of the ‘Battery Passport’ include identity, classification, composition, origin, health data, usage history and end-of-life information. These functions enable the development of strategic capabilities, namely visibility, coordination, value recovery and resilience. Those capabilities affect end-of-life outcomes, including better routing, improved sorting and treatment matching, higher compliance quality, lower informational losses, and stronger support for reuse, repurposing, and recycling decisions. Finally, these outcomes contribute to circular competitive effects such as stronger supply security, better circular performance, and improved positioning under EU regulatory change (European Parliament and the Council of the European Union, 2023; Langley et al., 2023; Chawla et al., 2026).

The discussion should not be overly optimistic. The emerging evidence repeatedly shows that the success of the battery passport will depend on unresolved strategic and organizational challenges. The most important barriers include data confidentiality, uneven digital maturity across firms, weak interoperability, lack of clarity about access rights, and uncertainty over responsibilities at different end-of-life stages. The strategic value of the battery passport therefore does not lie in data existence alone, but in the organizational and inter-organizational ability to govern access, interoperability, and actionability of those data across end-of-life battery systems (Rizos & Urban, 2024b; Losa & Torjesen, 2025; Pohlmann et al., 2025; Chawla et al., 2026).

*Table 1.* The DPP as a strategic tool in end-of-life battery systems management

| Passport function | Strategic capability | End-of-life managerial effect | Expected circular outcome |
|---|---|---|---|
| Battery identity and classification | Visibility | Better sorting and routing | Lower losses, better compliance |
| Composition and material information | Value recovery | Better treatment matching | Higher CRM recovery |
| State of health and use history | Coordination | Better reuse/repurpose decisions | Longer value retention |
| Actor and chain information | Coordination | Smoother handoffs | More integrated reverse logistics |
| Verified recovery and recycled-content data | Resilience | Better reintegration planning | Stronger secondary supply security |

## 5. CONCLUSION

This paper has argued that urban mining and DPP should not be treated as separate policy or managerial domains in the EU battery sector. Instead, they should be seen as two complementary pillars of the same circular strategy. Urban mining provides a resource base by highlighting the growing strategic value inherent in end-of-life batteries, particularly as secondary sources of lithium, cobalt, nickel and other critical raw materials. The document shows that the flow of battery waste in the EU already represents a significant recovery opportunity, but also that the effective realisation of this value remains limited by uneven national performance, infrastructure shortcomings, technological constraints and fragmented governance of the end-of-life phase. In this sense, urban mining explains why end-of-life batteries matter strategically, but not by itself how their value can be consistently captured and reintegrated into European industrial systems.

The main conclusion of this study is that digital product passports provide the management framework capable of making end-of-life battery systems more circular, more efficient and strategically more valuable. In particular, the proposed framework has demonstrated that the functions of the battery passport can be interpreted as factors enabling four key strategic capabilities: visibility, coordination, value recovery and resilience. Thanks to these capabilities, the passport can improve the information conditions under which batteries are identified, routed, assessed, reused, dismantled, recycled and reintegrated into secondary material flows. This interpretation is consistent with the legal framework of Regulation (EU) 2023/ 1542 and with recent literature on the DPP, which increasingly views passport systems as enabling mechanisms for life-cycle decision-making, data-driven end-of-life strategies and cross-cutting value chain orchestration, rather than merely as compliance repositories. From this perspective, the battery passport should not be interpreted simply as a new administrative obligation. In the EU, it should be regarded as a strategic tool for circular coordination, the recovery of critical raw materials and industrial resilience. This conclusion is strongly in line with the direction of EU battery policy. The EC explicitly states that EU battery rules aim to make batteries sustainable throughout their entire life cycle, from material sourcing to collection, recycling and reuse, whilst promoting a competitive and sustainable battery industry that supports Europe’s transition to clean energy and greater independence from fuel imports.

At the same time, the document also concludes that the strategic benefits of the battery passport are conditional rather than automatic. Recent implementation-oriented studies repeatedly demonstrate that the effectiveness of the battery passport depends on unresolved issues such as data privacy, uneven digital maturity across companies, poor interoperability, uncertain governance arrangements and a lack of clarity regarding access rights and responsibilities at different stages of the lifecycle. Consequently, the strategic value of the battery passport lies not in the mere existence of data, but in the organisational and inter-organisational capacity to govern the accessibility, interoperability and usability of such data within circular battery systems.

The paper thus contributes to the literature by linking urban mining and DPPs through a strategic management lens. It suggests that the future competitiveness of the EU circular battery systems will depend not only on recycling capacity or regulatory compliance, but also on the ability to transform battery-related data into better end-of-life decisions, stronger coordination of reverse logistics, higher-quality recovery of secondary raw materials, and more reliable circular supply security. Future research should now empirically test this framework through case studies, interviews, pilot implementations and comparative analyses involving actors in the battery value chain and Member States.

## REFERENCES

Chawla, K., Chirvasuta, T., Wolf, M.-A., Wolf, K., Rongen, S., Rurup, R., Gonzalez Torres, M., Naumann, G., & Arcipowska, A. (2026). Methodology for defining data requirements for the Digital Product Passport under the ESPR framework (EUR 40660 EN, JRC145830). Publications Office of the European Union. https://doi.org/10.2760/4511279.

Christensen, A., Stingl, V., Omair, M., & Wæhrens, B. V. (2025). Digital product passport in support of data-driven end-of-use strategies: A systems design perspective. Cleaner Environmental Systems, 19, Article 100354. https://doi.org/10.1016/j.cesys.2025.100354.

European Commission. (2024a). Batteries. Directorate-General for Environment. https://environment.ec.europa.eu/topics/waste-and-recycling/batteries_en.

European Commission. (2024b, November 13). Commission seeks views on the future Digital Product Passport. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/news/commission-seeks-views-future-digital-product-passport-2024-11-13_en.

European Commission. (2025, April 9). Commission launches consultation on the Digital Product Passport. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. https://single-market-economy.ec.europa.eu/news/commission-launches-consultation-digital-product-passport-2025-04-09_en.

European Court of Auditors. (2026). Critical raw materials for the energy transition – Not a rock-solid policy (Special Report No. 04/2026). https://www.eca.europa.eu/en/publications?ref=SR-2026-04.

European Parliament and the Council of the European Union. (2023). Regulation (EU) 2023/1542 of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC. Official Journal of the European Union, L 191, 1–117. https://eur-lex.europa.eu/eli/reg/2023/1542/oj/eng.

European Parliament and the Council of the European Union. (2024). Regulation (EU) 2024/1781 of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and

Regulation (EU) 2023/1542, and repealing Directive 2009/125/EC. Official Journal of the European Union, L 2024/1781. https://eur-lex.europa.eu/eli/reg/2024/1781/oj/eng

Eurostat. (2024). Waste statistics – recycling of batteries and accumulators. Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_recycling_of_batteries_and_accumulators.

Feng, J., Guo, P., & Xu, G. (2024). Barriers to electric vehicle battery recycling in a circular economy: An interpretive structural modeling. Journal of Cleaner Production, 469, Article 143224. https://doi.org/10.1016/j.jclepro.2024.143224.

Gieß, A., & Möller, F. (2025). Exploring the value ecosystem of digital product passports. Journal of Industrial Ecology, 29(2), 561–573. https://doi.org/10.1111/jiec.13621.

Husmann, J., Beylot, A., Ginster, R., Marie, A., Muller, S., Philippe, A., Monfort, D., Blömeke, S., Spengler, T. S., & Herrmann, C. (2025). Determining the key drivers of the potential secondary battery raw materials supply from the urban mine in the European Union. Resources, Conservation and Recycling, 218, Article 108246. https://doi.org/10.1016/j.resconrec.2025.108246.

International Energy Agency. (2025). Global EV Outlook 2025. IEA. https://www.iea.org/reports/global-ev-outlook-2025.

Jensen, S. F., Kristensen, J. H., Adamsen, S., Christensen, A., & Wæhrens, B. V. (2023). Digital product passports for a circular economy: Data needs for product life cycle decision-making. Sustainable Production and Consumption, 37, 242–255. https://doi.org/10.1016/j.spc.2023.02.021.

Kaarlela, T., Villagrossi, E., Rastegarpanah, A., San-Miguel-Tello, A., & Pitkäaho, T. (2024). Robotised disassembly of electric vehicle batteries: A systematic literature review. Journal of Manufacturing Systems, 74, 901–921. https://doi.org/10.1016/j.jmsy.2024.05.013.

Langley, D. J., Rosca, E., Angelopoulos, M., Kamminga, O., & Hooijer, C. (2023). Orchestrating a smart circular economy: Guiding principles for digital product passports. Journal of Business Research, 169, Article 114259. https://doi.org/10.1016/j.jbusres.2023.114259.

Lopes, C., & Barata, J. (2024). Digital Product Passport: A review and research agenda. Procedia Computer Science, 246, 981–990. https://doi.org/10.1016/j.procs.2024.09.517

Losa, R., & Torjesen, S. (2025). The quest for more circular battery value chains: Implementing the EU digital battery passport and remaining challenges. Cleaner Production Letters, 9, Article 100118. https://doi.org/10.1016/j.clpl.2025.100118.

Massari, S., & Ruberti, M. (2026). Urban mining in Europe: Exploring the recovery potential of critical elements for battery manufacturing. Quality Innovation and Sustainability

Petrik, D., Strobel, G., Schoormann, T., Möller, F., Hoppe-Ludwig, C., & Springer, V. (2026). Digital product passports. Electronic Markets, 36(1), Article 25. https://doi.org/10.1007/s12525-026-00877-0.

Pohlmann, A., Popowicz, M., Schöggl, J.-P., & Baumgartner, R. J. (2025). Digital product passports for electric vehicle batteries: Stakeholder requirements for sustainability and circularity. Cleaner Production Letters, 8, Article 100090. https://doi.org/10.1016/j.clpl.2024.100090.

Proceedings from the 6th International Conference on Quality Innovation and Sustainability (ICQIS), Urbino, Italy, May 21-23, 2025. Conference proceedings. Springer Nature. June 2026 [In Press]. https://link.springer.com/book/9783032196279.

Psarommatis, F., Konstantinidis, F., Azamfirei, V., & May, G. (2024). Identification of the benefits from the use of Digital Product Passport in a value chain and single organizations. IFAC-PapersOnLine, 58(19), 301–306. https://doi.org/10.1016/j.ifacol.2024.09.199.

Rizos, V., & Urban, P. (2024a). Barriers and policy challenges in developing circularity approaches in the EU battery sector: An assessment. Resources, Conservation and Recycling, 209, Article 107800. https://doi.org/10.1016/j.resconrec.2024.107800.

Rizos, V., & Urban, P. (2024b). Implementing the EU digital battery passport: Opportunities and challenges for battery circularity (CEPS In-Depth Analysis No. 2024-05). Centre for European Policy Studies. https://www.ceps.eu/ceps-publications/implementing-the-eu-digital-battery-passport.

Soavi, F., Gregucci, A., Liverani, A., Mojtahedi, S., Petri, E., Mascetti, F., Capodarca, F., & Bel Hadj Jrad, E. (2026). The European Battery Regulation and Digital Battery Passport: Prospects and challenges. Batteries, 12(3), Article 97. https://doi.org/10.3390/batteries12030097.

Wan, P. K. F., & Jiang, S. (2025). Enabling a dynamic information flow in digital product passports during product use phase: A literature review and proposed framework. Sustainable Production and Consumption, 54, 362–374. https://doi.org/10.1016/j.spc.2025.01.014.

Windisch-Kern, S., Gerold, E., Nigl, T., Jandric, A., Altendorfer, M., Rutrecht, B., et al. (2022). Recycling chains for lithium-ion batteries: A critical examination of current challenges, opportunities and process dependencies, Waste Management, 138, 125-139, ISSN 0956-053X. https://doi.org/10.1016/j.wasman.2021.11.038.

Windisch-Kern, S.; Holzer, A.; Ponak, C.; Raupenstrauch, H. (2021). Pyrometallurgical Lithium-Ion-Battery Recycling: Approach to Limiting Lithium Slagging with the InduRed Reactor Concept. Processes, 9, 84. https://doi.org/10.3390/pr9010084.

Woeste, R., Drude, E.S., Vrucak, D., Klockner, K., Rombach, E., Letmathe, P., Friedrich, B. (2024). A techno-economic assessment of two recycling processes for black mass from end-of-life lithium-ion batteries. Applied Energy, 361. https://doi.org/10.1016/j.apenergy.2024.122921.