

Bucharest University of Economic Studies - Faculty of Cybernetics, Statistics and Economic Informatics
Economic Informatics Doctoral School



Structured Process Modeling and Machine Learning for Intelligent Digital Ecosystems

- Habilitation Thesis Summary -

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Bucharest

2026

Abstract

This habilitation thesis, titled **Structured Process Modeling and Machine Learning for Intelligent Digital Ecosystems**, consolidates the main scientific and academic outcomes achieved by Assoc. Prof. Anca Ioana Andreescu after completing the PhD in 2009 and outlines a coherent direction for further development. In **Section I**, the thesis advances a unifying premise according to which sustainable digital transformation in high-stakes socio-technical environments rests on a dual foundation of formally modeled processes that ensure traceability, separation of roles and auditability together with intelligent algorithms that support prediction, adaptation and optimization under uncertainty. This premise is supported through implementable architectures, simulation-based evaluation and reproducible analytical workflows spanning digital governance, local electricity markets, banking analytics, Anti-Money Laundering (AML) compliance and climate research intelligence.

The methodological bridge is established in Chapter 1, *"Introduction"*, and consolidated in Chapter 2, *"State of the art"*, where Business Process Modeling (BPM), Unified Modeling Language (UML), blockchain execution and applied machine learning (ML) are positioned as complementary instruments rather than isolated techniques. Building on these foundations, Chapter 3, *"A conceptual architecture for blockchain-based electronic voting"*, develops a permissioned design tailored to university elections, formalized through multi-view UML artifacts and an explicit staged lifecycle. By separating responsibilities across layers and roles and by protecting identifiers through cryptographic mechanisms, the architecture supports verifiable inclusion and auditable evidence trails while keeping ballot secrecy central. The contribution emphasizes operational governance, where modeling choices constrain execution so that correctness can be checked without enabling surveillance.

Economic impact is examined in Chapter 4, *"Blockchain solutions for settlement mechanisms in local electricity markets"*, through two blockchain-based settlement mechanisms, Global Balancing Settlement and Splitting Settlement, embedded as smart-contract procedures. Benchmarked against the classical Pairwise Settlement approach across fourteen simulation scenarios in a residential community with locally tradable electricity, the proposed mechanisms demonstrate consistent incentive improvements, with higher seller revenues and lower buyer payments under realistic deviation patterns. The results reinforce a key insight that blockchain infrastructure becomes economically meaningful only when the underlying market processes are precisely specified, executable and systematically tested.

Applied decision support in the financial sector is consolidated in Chapter 5, *"Machine learning models. Practical applications"*. For customer retention, calibrated churn models based on Random Forest and Light Gradient-Boosting Machine improve probability reliability and support actionable targeting while SHAP analysis provides transparent explanations of key drivers. For AML, the thesis develops an end-to-end detection pipeline combining SQL-analytics feature engineering, TF-IDF transformation for text fields and CTGAN oversampling to mitigate extreme class imbalance, with performance evaluated under alternative probability thresholds aligned with compliance trade-offs. Across the reported configurations, recall reaches very high levels while maintaining strong discriminative performance, supporting rare-event detection without compromising the auditability of analytical steps.

The same emphasis on reproducible workflows extends to research intelligence in Chapter 6, *"Data analysis from an academic perspective on the role of ML in climate change"*. A bibliometric and text-mining study of 7,521 open-access publications from the Web of Science over 2004 to 2024 characterizes growth dynamics, collaboration patterns and thematic structure through knowledge

graphs, clustering and topic modeling, offering a replicable framework for understanding the evolution of the intersection between ML and climate change research. The synthesis is completed in Chapter 7, "*Conclusions*", which articulates cross-domain lessons around measurable performance improvements and governance enhancement through structured modeling and intelligent analytics.

Beyond the research consolidation, **Section II** presents the career development plan and connects the scientific trajectory to curriculum design, student mentoring, academic service and technology transfer into teaching, including sustained integration of SQL, Python and SAS in reproducible project work alongside the long-term academic collaboration with SAS initiated in 2010.

Section III provides the bibliographic foundation supporting the concepts, methods and evaluation practices used throughout the thesis. Overall, the thesis articulates a coherent research identity centered on building intelligent digital ecosystems where modeling discipline enables accountability and auditability while blockchain execution and ML deliver adaptability and demonstrable impact across multiple application domains.