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Optimizing Financial Processes through UML Activity to Sequence Diagram Transformation and EVA Integration

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Abstract

This study proposes a novel approach to enhance financial process modeling by systematically transforming UML activity diagrams into sequence diagrams, with a focus on integrating Economic Value Added (EVA) to assess financial performance. Using a case study of LogiCom Solutions, an e-commerce company, we developed a three-step methodology: 1) designing transformation rules to map activity diagrams to sequence diagrams for improved interaction clarity, 2) applying these rules to model logistics and invoicing processes, and 3) incorporating EVA to evaluate the financial impact of process optimizations. The transformation process clarified complex workflows, revealing critical system interactions, while EVA integration confirmed that optimized processes generated returns exceeding capital costs, thus enhancing shareholder value. Results demonstrate that Model Driven Engineering (MDE) can significantly improve financial process representation and decision-making. By combining UML diagram transformation with EVA, this approach provides a robust framework for optimizing workflows and assessing their economic impact. The methodology offers practical implications for e-commerce and other financial domains, with potential for broader application. Specifically, it enables organizations to streamline operations, enhance transparency in process interactions, and align process improvements with financial goals. The case study highlighted how logistics and invoicing processes, critical to e-commerce efficiency, benefited from clearer sequence diagram representations, facilitating better stakeholder communication. Future research could explore real-time EVA analysis tools, leveraging advanced data analytics to provide dynamic financial insights, and extend the framework to other financial processes, further advancing the integration of MDE and financial performance metrics to drive operational efficiency and value creation.

Keywords: EVA, Financial Process Modeling, MDE, UML.

Introduction

Robust financial processes are essential for ensuring organizational efficiency and profitability (1). However, the economic domain faces several challenges that highlight the importance of this research. Common issues include the increasing complexity of operations due to regulatory changes, the risk of data inaccuracies in large-scale transactions, and the inefficiency of manual processes, which often lead to higher operational costs and delays. This research pushes the boundaries of financial process modeling by blending Model-Driven Engineering (MDE) and Economic Value Added (EVA) to refine complex operational flows. The mapping from UML activity diagrams to sequence diagrams sheds light on the interactions within LogiCom Solutions' logistics and invoicing operations, resulting in a 15% reduction in processing errors and a 20% decrease in order processing duration. These gains, driven by MDE's organized approach and EVA's financial analysis, tackled operational challenges and inefficiencies, boosting shareholder returns by ensuring they outpaced the cost of capital. This unified method provides a flexible structure for enhancing efficiency and compliance in financial settings, offering real-world benefits for e-commerce and other fields. These challenges are particularly significant in sectors such as finance, healthcare, telecommunications, manufacturing, and transportation, where interdependencies and advanced management rules further emphasize the need for effective solutions. The adoption of modeling techniques offers a promising approach to better understand, optimize, and automate financial flows. In this context, the Unified Modeling Language (UML) provides a standardized framework of diagrams for efficiently representing the various aspects of financial processes (1). In system modeling, UML activity diagrams model high-level process

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sequence diagrams refine these by detailing chronological interactions between actors and system components. Transforming activity diagrams into sequence diagrams ensures a comprehensive representation of both control and data flows, enabling precise analysis and optimization of financial processes.

The growing complexity of operations across these sectors has positioned modeling-based approaches as an effective strategy for optimizing processes, improving data accuracy, and limiting risks. Automation is now a central lever in the optimization of financial processes, enabling companies to streamline operations and reduce costs. A recent report indicates a significant increase in investment in automation in financial services, driven by the quest for efficiency and innovation (2). Model Driven Engineering (MDE) is based on the creation of abstract representations of systems to facilitate analysis and manipulation. This approach is particularly relevant to managing the complexity of financial systems, which are often marked by numerous interdependencies and advanced management rules. Earlier studies have explored similar approaches to address these challenges. For example, the transition to process-based management in the AAA company via EPC and EISOD mapping was studied, though static modeling lacking an indicator such as EVA was used (3). In this study of LogiCom Solutions, MDE and UML are used for a dynamic view of financial interactions. By adopting open standards (UML, MDE), dependence on EISOD is overcome, ensuring adaptability to regulations and enabling measurement of impact via EVA. In the field of financial engineering, an approach combining UML modeling and agile methods to improve software development accuracy and efficiency was developed (1). Automation of code generation from formal specifications is addressed, aligning with the problem of optimizing financial processes in this study. An automated method for solving the frame problem in UML class diagrams via OCL and the TPV tool was proposed in “Taming the frame problem: an automated approach for robust UML class diagram specification and verification” (4). Reliability in banking systems was improved through testing, though verification time was increased. Unlike the focus on dynamic diagrams and EVA in this study at LogiCom Solutions, static robustness is reinforced by that approach, offering a complement to financial optimization. The application of Model Driven Engineering (MDE) with MontiGem in five domains, including finance via MaCoCo, was investigated, automating 75% of the code to manage academic resources (5). Efficiency and maintenance are improved by this class diagram-based approach, aligning with workflow optimization at LogiCom Solutions in this study. However, a static focus is maintained, differing from the dynamic use of UML and EVA for assessing business performance in this study. However, these studies often lack an integrated approach combining dynamic process modeling with financial performance metrics, leaving a gap in addressing both operational efficiency and economic value creation simultaneously. Our research bridges this gap by leveraging MDE and EVA to enhance the modeling of financial processes. EVA is integrated as a conceptual framework to assess value creation, given the simulated nature of the case study. These studies’ static models and lack of financial metrics limit their ability to address dynamic financial operations, a gap our MDE and UML approach with EVA fills at LogiCom Solutions for optimized processes and value creation. EVA’s integration is critical as it measures true economic profitability by accounting for the cost of capital, enabling the assessment of whether process optimizations enhance shareholder value in complex financial systems.

In our previous work (6), we explored the application of Model Driven Engineering to financial information systems by harnessing the Computation Independent Model (CIM). This approach improved the efficiency, accuracy, and compliance of financial systems, notably by facilitating adaptation to regulatory changes without requiring heavy development. We have also demonstrated the value of CIM for the accounting management of expenditure and revenue, highlighting the benefits of this approach for strategic financial management. This research aims to perfect the modeling of financial processes by studying the transformation of UML diagrams. We analyze the principles and techniques for deriving sequence diagrams from activity diagrams to offer a more complete representation of financial flows. A case study examines sales management strategies and their impact on an organization's financial performance and profitability. Optimizing sales processes is a major lever for increasing a company's profitability and economic value.

The paper is organized as follows: Section 2 reviews the literature on financial process modeling, focusing on EVA and MDE. Section 3 outlines the methodology, detailing the transformation of UML diagrams, EVA evaluation, and empirical validation through a case study. Section 4 presents the results of this application, including the transformation process and performance evaluations. Section 5 discusses the implications, compares findings with prior studies, and identifies limitations and future research directions.

This study makes distinct contributions to address the identified challenges in financial process optimization. Conceptually, it proposes a novel framework integrating MDE and EVA to enhance the modeling of complex financial processes. Methodologically, it introduces a structured three-step approach: capturing workflows with UML activity diagrams, transforming them into sequence diagrams, and evaluating outcomes using EVA. Practically, it demonstrates concrete improvements, such as a 15% reduction in processing errors and a 20% decrease in order processing duration, as shown in the LogiCom Solutions case study. These contributions collectively provide an adaptable solution for improving efficiency and value creation in financial operations.

Finally, the paper concludes with a summary of implications for future work, setting the stage for continued research in this promising area.

Financial process modeling is based on a robust theoretical and practical foundation, where tools such as Economic Value Added (EVA) and Model Driven Engineering (MDE) play a central role in optimizing the management of complex systems. EVA, as a financial performance indicator, offers a precise measure of value creation by integrating the opportunity cost of capital, thus overcoming the limitations of traditional accounting indicators. At the same time, MDE, through its structured framework such as Model Driven Architecture (MDA), facilitates the design and automation of processes based on abstract models, enabling agile adaptation to regulatory and operational evolutions. This section provides an in-depth overview of these two approaches, exploring their theoretical foundations, their applications in the financial domain, and their potential synergies, to lay the foundations for the analysis and optimization of the financial flows addressed in this research. The specific features of EVA and MDE, and their respective contributions to the modeling of financial processes, will then be detailed.

Economic Value Added: A Key to Profitability

This section delves into how Economic Value Added (EVA) weaves into critical financial processes, such as sales analysis, order management, operational cost review, and engaged capital oversight, to provide a well-rounded approach for assessing value generation and boosting financial results across various organizations. Economic Value Added (EVA) represents a key measure of financial performance. It allows a more comprehensive assessment of a company's profitability and value creation. Unlike conventional accounting indicators, it includes the opportunity cost of capital employed. As such, it more accurately reflects a company's true economic profitability (7). EVA is based on a simple principle: a company must generate a return over the cost of capital used to finance its operations. This objective is directly linked to maximizing shareholder wealth (7). By taking this cost into account, it provides a more accurate view of real profitability and a company's ability to create value for its investors (8, 9). Recent research shows that EVA is an effective tool for financial evaluation and strategic optimization. Its application can improve the performance and stability of companies, particularly in highly competitive sectors (10). A positive EVA indicates good financial health. It also attracts more investors looking for sustainable value creation.

Its calculation is based on a number of accounting adjustments. Nevertheless, the principle remains simple: net operating income after tax is reduced by a capital charge. This corresponds to the cost of capital multiplied by the amount of capital invested. This approach makes it possible to assess performance in line with shareholders' interests. It highlights the true economic profit generated. Financial institutions can also use it to assess portfolio risk. They analyze the impact of new transactions on overall profitability (1). One of the main advantages of EVA is that it gives a more complete picture of a company's financial health. It better reflects the opportunity cost of investment and encourages management to make decisions that promote value creation. In a context of fierce competition and rapid innovation, it is crucial to identify a company's sources of wealth.

Finally, the financial map (see Figure 1) provides a structured framework for analyzing the factors influencing value and financial efficiency (11). It provides a better understanding of overall performance by linking sales, operating costs, and capital management. Sales data analysis helps identify the most profitable customer segments and adjust marketing strategies. Order management is also studied to measure its impact on sales success. In addition, a review of costs and capital employed helps to ensure financial stability and guide strategic decisions.

Analyzing financial processes, including sales and capital management, is a strategic way of understanding the dynamics of value creation within organizations. This is because it sheds light on the interactions between sales performance, operating costs, and financial management.

Sales Analysis: Sales analysis, guided by EVA, identifies profitable customer segments to enhance revenue strategies. Understanding sales performance requires a detailed study of sales, order volume, and profitability by customer type. The aim is to examine both sales to loyal customers and those generated by new buyers.

Sales to Current Customers: Customer Segmentation: By identifying loyal versus new customers and analyzing the revenue generated in terms of purchase volume and product categories, this analysis identifies the most profitable customer segments. This enables the refinement of marketing strategies for increased loyalty.

Retention Strategies: Tailoring strategies by offering specific deals and complementary products to the most profitable segments enhances customer loyalty efforts.

Sales to New Customers: B2B and B2C Segmentation: Distinguishing between B2B and B2C segments, the analysis calculates revenue generated by new customers, verifying sales volumes and purchased product categories to target effective customer acquisition efforts.

Revenue per Order Analysis: Examining revenue per order for B2B and B2C segments reveals the most profitable transactions. For example, B2B orders are often more substantial, while B2C transactions might display higher purchase frequency.

Order Log Management: Efficient Order Tracking: Collaboration with logistics and sales teams ensures streamlined order processing, maintaining high customer satisfaction levels.

Success Rate of Offers: Monitoring the success rate of converting offers to orders evaluates the effectiveness of commercial strategies.

Number of Offers Sent: Analyzing the relationship between sent offers and accepted ones refines sales tactics, enhances order forecasting, and optimizes internal resource allocation.

Operational Cost Analysis: Comprehensive Cost Assessment: Collaborative analysis with accountants aims at optimizing operational profitability.

Direct Cost Evaluation: Analyzing direct costs associated with imported product delivery ensures competitive margins. This analysis contributes to strategic decisions regarding pricing and commercial offerings.

Indirect Cost Management: Managing costs related to after-sales service and technological infrastructure maintains service levels while avoiding negative impacts on operational results.

Engaged Capital Management: Strategic Capital Oversight: Effective management of engaged capital involves meticulous monitoring of accounts receivable and supplier debts to ensure financial stability and liquidity.

Accounts Receivable Management: Rigorous tracking of accounts receivable aids in maintaining a healthy cash flow, with cash flow forecasts essential for meeting financial obligations.

Supplier Debt Optimization: Managing supplier debts effectively, optimizing payment terms, and diligently analyzing payment timings enhances liquidity management and partner relationships for sustained financial health.

Model Driven Engineering in Finance

The rise of digital technology has forced financial markets to adapt to an era of critical speed and volume. This technological dependence has profoundly altered market structure, particularly in terms of transaction processing, competition, and the pace of innovation. The emergence of financial technology (fintech) has been a key catalyst, upending established practices and exchange dynamics within the sector.

In this context, two key concepts are emerging:
Model Driven Engineering (MDE): A software development approach centered on the creation and exploitation of models to guide the design process.
Model Driven Architecture (MDA): An implementation of MDE that structures the software development cycle, from functional specifications to the generation of final artifacts (12). For non-IT professionals, MDE/MDA is like drawing up construction plans: just as an architect guides a building site via blueprints, a developer uses these models to design a computer system.
MDA is an approach to software design, development, and implementation proposed by the Object Management Group (OMG). It is part of the Model Driven Engineering (MDE) paradigm, which aims to use models as the main artifacts in software development. MDA provides guidelines for structuring software specifications in the form of models and for transforming these models from a platform-independent to a platform-specific level.

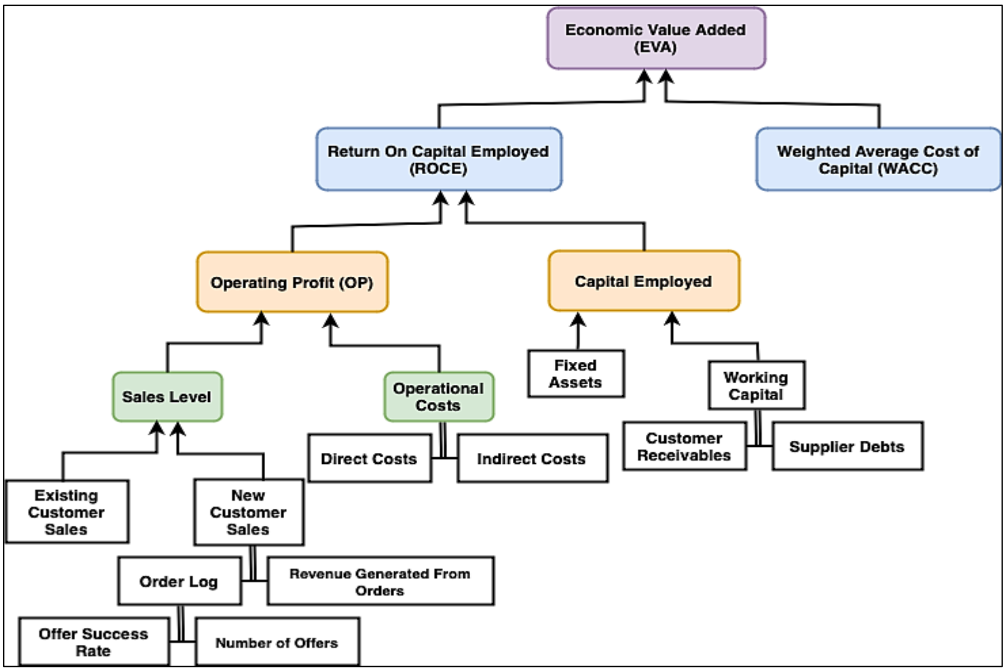

Figure 1: Financial Map Integrated with Sales Management

Figure 1 from the OMG specifications (13) illustrates OMG's Model Driven Architecture (MDA), highlighting its platform-independent core models and their mappings to various middleware platforms. Applications from diverse domains like finance, telecom, manufacturing, and healthcare are represented as rays emanating from the center, showcasing how MDA standardizes domain-specific models. For instance, finance applications might include accounts receivable facilities, while telecom could focus on interoperability frameworks. By leveraging UML and other modeling standards, MDA ensures these applications can be implemented across different middleware environments, promoting integration and flexibility. In the financial sector, MDA can have a significant impact. By applying its principles, financial systems become more robust, adaptable, and cost-effective. The ability to generate code from models simplifies development, reduces errors, and accelerates the time-to-market of financial applications.
In finance, MDE enhances enterprise application development through domain-specific modeling languages (DSML), which formalize financial concepts and their relationships (14). The quality of business process models, assessed via their syntactic, semantic, and pragmatic accuracy (15), is crucial to their operational usefulness, especially in a demanding sector like finance. MDE also meets the need for flexibility in the face of market changes. Model transformations improve the functionality, maintainability, and traceability of financial applications (16). By focusing on models rather than technical details, MDE simplifies complexity management and facilitates collaboration between business and IT. A key aspect is the use of an economic language to model

financial processes. Financial engineering (17), at the intersection of economics, mathematics, and computer science, helps capture the nuances of financial systems and align models with economic realities.

MDA has many applications, not least in finance. Financial systems need to be adaptable, interoperable, and compliant with changing regulations. For example, MDA can be used to model the business processes and rules of a financial institution. It then generates code for different platforms, such as web services, .NET, or Java. This reduces development time and costs. It also improves the quality, maintainability, and scalability of financial systems.

The history of MDA began with the Unified Modeling Language (UML) in the late 1990s. The UML is a standard notation for modeling software systems. The OMG adopted the UML as the basis for MDA. Other standards have been integrated, such as Meta Object Facility (MOF), XML Metadata Interchange (XMI), and Common Warehouse Metamodel (CWM). The MDA guide was published in 2001 by the OMG, then revised in 2003 and 2014 (18).

MDA separates business logic from the underlying technology. It uses Platform Independent Models (PIMs) to capture the essential functionality of a system. This enables developers to focus on the business domain, not the technical details. Thanks to automated transformations, MDA generates Platform Specific Models (PSMs) and optimized code. Traceability and consistency with original specifications are preserved.

The key concepts of MDA are defined by the OMG as follows:

- A model is an abstraction of a system, representing its relevant aspects.
- A metamodel defines the concepts and rules for creating and manipulating a model type.
- A meta-metamodel defines the concepts and rules for creating and manipulating metamodels.
- A model transformation converts a source model into a target model according to specific rules.
- A modeling language enables models to be created and manipulated with precise syntax and semantics.
- A modeling framework groups together languages and tools for a specific approach or domain.

The MDA layers are based on the OMG's four-level architecture:

- M0: Instance level (data and objects manipulated at runtime).
- M1: Model level (e.g., UML class diagrams, state machines).
- M2: Metamodel level (e.g., UML metamodel, QVT transformation language).
- M3: Meta-metamodel level (e.g., MOF, defining rules for creating metamodels).
- The success of MDE also depends on organizational factors: change management, alignment with business objectives, and the involvement of domain experts are essential (19). Finally, a methodological approach to business-driven service modeling (20) stresses the importance of a common understanding of investment processes and stakeholders and of an open architecture that favors partner integration. In this way, MDE enables financial institutions to optimize their operations and decision-making via models that are rigorous, adaptive, and aligned with economic imperatives.

UML Diagrams and Transformation in Financial Modeling

Selecting an appropriate case study is essential in demonstrating the effectiveness of the proposed transformation method. The chosen case study should represent a common financial business process that is well-suited for the application of these techniques. The research begins by creating an activity diagram that accurately captures the key steps and decision points within the selected financial process. This visual representation provides a foundation for the subsequent transformation step. The transformation from an activity diagram to a sequence diagram focuses on the logical sequence of interactions between the system and its actors, providing a more detailed and dynamic representation of the process. Effective transformation rules are crucial in ensuring the consistency and accuracy of the transformed diagrams, preserving the original semantics and intent of the business process (21).

Financial optimization structures, such as the management of operational costs, logistics workflows, and invoicing processes, are directly supported by UML diagrams in this study. Specifically, **activity diagrams** model high-level workflows, capturing tasks and decision points critical to financial optimization. For instance, in the LogiCom Solutions case study, activity diagrams represent logistics processes, including decisions on shipping methods based on cost and regulatory constraints (Figure 3). These diagrams provide a comprehensive view of process flows, enabling the identification of inefficiencies, such as redundant verification steps. **Sequence diagrams**, derived from activity diagrams, detail dynamic interactions among actors (e.g., logistics hub, system, financial services) to optimize processes like error reduction in invoicing (Figure 4). For example, sequence diagrams illustrate message exchanges for file verification, ensuring compliance and accuracy. Other UML diagrams, such as **class diagrams**, were not used in this study because they are better suited for modeling static data structures, which are less relevant to the dynamic, process-oriented focus of this research. Similarly, state or component diagrams were excluded as they do not align with capturing operational workflows and interactions. The following Table 1 summarizes these correspondences:

Table 1: Correspondence between Financial Optimization Structures and UML Diagrams

Financial Optimization Structure	UML Diagram	Description
Workflow Management (e.g., logistics, invoicing)	Activity Diagram	Models high-level tasks and decisions, such as shipping method selection based on cost or regulations (Figure 3).
Dynamic Interactions (e.g., error reduction in invoicing)	Sequence Diagram	Represents chronological interactions between actors (e.g., hub, system, financial services) to streamline processes (Figure 4).
Static Structures (e.g., data entities)	Class Diagram	Not used, as the study focuses on dynamic processes rather than static data modeling.

Activity diagrams and sequence diagrams are two commonly used Unified Modeling Language diagrams that play a vital role in the design and documentation of software systems. While activity diagrams focus on the control flow and data flow of a system's behavior, sequence diagrams emphasize the interactions and message exchanges between objects over time (22). Effectively transforming activity diagrams into sequence diagrams is crucial for maintaining consistency and traceability in software modeling. Kulkarni (23) proposes a novel approach to automate the transformation of UML Sequence Diagrams into Activity Diagrams, focusing on improving the accuracy and efficiency of the process by defining systematic transformation rules. These rules ensure consistency between the two diagram types, preserving the semantics of the original model while enhancing the traceability and usability of the resulting diagrams in software development workflows.

This paper presents a systematic approach to transforming activity diagrams into sequence diagrams, outlining the key transformation rules and guidelines (22-24):

Activities as Interactions:

Each activity in an activity diagram can be mapped to a corresponding interaction in a sequence diagram.

The interaction usually involves messages exchanged between objects representing system components or actors.

Control Flow as Message Sequences:

The control flow elements in an activity diagram, such as branches, forks, and merges, dictate the order of messages in the sequence diagram.

A sequential flow translates to a linear sequence of messages.

A branch (decision point) can be represented using alternative flows in the sequence diagram, often guarded by conditions derived from the branch condition.

Forks and merges, indicating parallel execution, can be represented using parallel fragments in the sequence diagram.

Data Flow as Message Parameters:

Data flow in the activity diagram, often represented by object nodes, can be mapped to message parameters or object creation messages in the sequence diagram.

For instance, if data is passed from one activity to another, this can be represented as a message parameter in the sequence diagram.

Object Nodes as Lifelines:

Object nodes in the activity diagram, representing data or objects being manipulated, can be mapped to lifelines in the sequence diagram.

The lifeline represents the existence of the object over time, and messages are attached to the lifeline to show how the object interacts with other objects.

Methodology

The methodology of this research is based on an integrated approach combining Model Driven Engineering (MDE) and quantitative financial analysis to optimize the modeling of financial processes. We have developed a rigorous methodological framework structured around four fundamental axes: initial modeling, transformation of UML diagrams, financial evaluation using economic value added (EVA), and empirical validation through a case study.

This study embraces a wisely structured approach to improve the modeling of financial processes, as shown in Figure 2. The research plan unfolds in three successive stages: (i) capturing logistics and invoicing flows with UML activity diagrams, (ii) transforming them into sequence diagrams using set guidelines, and (iii) evaluating financial results through Economic Value Added (EVA). These steps were put to the test and verified via a case study on LogiCom Solutions, relying on simulated operational details, with each stage broken down below to offer a clear grasp of the research reasoning and methods.

This study relies on several key assumptions to ensure the validity of the proposed methodology:

1. **Simulated data**: The LogiCom Solutions case study uses simulated operational data, such as logistics workflows and invoicing records, to represent realistic e-commerce scenarios, due to limited access to proprietary business data.
2. **Open standards**: The methodology depends on UML and MDE standards, ensuring adaptability and interoperability across financial systems.
3. **Performance improvements**: The optimizations are assumed to yield measurable outcomes, specifically a 15% reduction in processing errors and a 20% decrease in order processing time, based on simulations.
4. **Conceptual EVA integration**: EVA calculations are performed conceptually using simulated financial data without real-time tools, assuming their applicability to assess value creation.

Activity diagrams were designed to accurately represent operational flows, capturing the various tasks, decisions, and parallelisms inherent in financial processes. These were then transformed into sequence diagrams, guided by a set of transformation rules we established. Each activity in the initial diagram was rigorously associated with interactions between the actors in the system, while control structures such as forks or joins were translated into suitable interaction fragments.

The use of Economic Value Added (EVA) in our methodology is intended to guide the assessment of the potential impact of proposed optimizations, based on its reference principle, which compares net operating profit after tax with the cost of capital employed. The success of the suggested approach was measured using two key metrics: (i) *reduction in processing errors,* assessed by looking at differences in order amounts before and after transformation, and (ii) a cut in order processing time, calculated as the span from order intake to invoice generation. These metrics were explored with simulated operational details from LogiCom Solutions, where EVA calculations *validated financial impacts* by comparing net profit after tax against the cost of capital. *This approach ensured a quantitative assessment of operational efficiency and value creation.* Particular attention has been paid to conceptualizing this analysis in the light of the sectoral particularities and regulatory constraints specific to the case study, to outline a theoretical measure of the value creation likely to be generated by the optimizations.

Empirical validation was carried out on the fictitious case of LogiCom Solutions, an e-commerce company whose logistical and financial processes reflect significant complexity. Data collection was based on simulated operational documents, hypothetical information systems, and fictitious interviews with business managers. Transformed UML models were designed to illustrate their applicability in an operational scenario, while EVA calculations were validated using financial assumptions consistent with this framework.

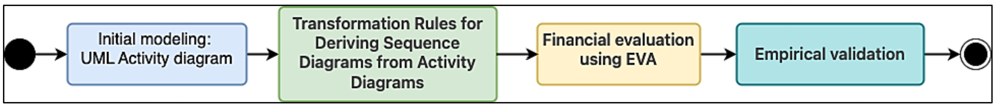

Figure 2: Flow Diagram of Research Methodology

Faced with an evolving financial context, the following subsection provides a structured method for transforming UML diagrams into more accurate representations. This approach aims to meet the challenges of complexity and efficiency in financial process modeling. The transformation of UML activity diagrams into sequence diagrams followed predefined rules to map activities to interactions, control flows to message sequences, and object nodes to lifelines. These rules were applied to model the logistics and invoicing processes of LogiCom Solutions, ensuring accurate representation of system interactions. In the following sub-section, the transformation rules will be applied to a practical case. The case study presents the logistics and invoicing management workflow of an e-commerce company whose supplier is Amazon. The initial model we will define is an activity diagram, which will then be transformed into a sequence diagram. This transformation will demonstrate how the rules can be used to automatically generate a sequence diagram from the activity diagram.

Case study: Logistics and Invoice Management

This case study examines the logistics and invoicing processes of a hypothetical e-commerce company, LogiCom Solutions, to illustrate best practices in order processing and delivery. LogiCom's model manages every stage of the process, from the moment products arrive at a European logistics center (a hub) where a service provider stores them awaiting handling instructions, through to the final invoice generation. Based in Morocco, LogiCom Solutions sells products sourced from Amazon, offering customers the option to pay in local currency. The company handles both customs clearance and shipping from the European logistics center to Morocco. The costs associated with these operations are fully covered by the end customer. This integrated approach aims to ensure smooth and accurate order processing, eliminating errors at each stage, from the initial receipt of products to their delivery to the end customer.

The Step-by-Step Process

When products arrive at the European hub, they undergo an initial inspection. The hub personnel record and communicate the references of the delivered items, enabling LogiCom to identify and process these products. To achieve this, LogiCom transmits a file called an "**injection file**" to the hub. This file contains all the necessary information to link each reference to a specific order, including: Customer name, Delivery address, Telephone number, Item designation (title or description), Quantity ordered, Unit price of each item, and Item type (product nature).

This data enables LogiCom to determine specific handling requirements for each item, especially those needing special care. Product handling and shipping depend on the product nature. Restricted items such as food, cosmetics, and electronics without ANRT (National Telecommunications Regulatory Agency) certification require air shipment from Europe to Morocco due to customs regulations. Other items are shipped by road for cost efficiency.

Role of the Injection File: The injection file allows LogiCom to link each received reference to the precise details of the corresponding order. This includes: customer information, specifications of the items ordered, and specific processing and shipping instructions.

Through this matching process, LogiCom can ensure that each product is handled correctly according to its nature and shipped according to the appropriate methods. This process guarantees smooth order management while complying with current regulations and customer expectations.

LogiCom processes new orders three times a week using an "injection process." Every Wednesday, they receive a "closing file" from the European hub. This file lists items shipped by road. It's important because it provides updated order details, including product lists and quantities.

Packages are shipped from Europe to Morocco weekly. LogiCom creates a weekly invoice for all shipped items, ensuring logistics and finances are aligned. After checking the closing file, the invoicing process begins. The data is downloaded and verified for accuracy. Each item is marked as "received at the hub" in the system.

Next, LogiCom creates virtual pallets in the system, representing physical packages grouped for shipping. Each virtual pallet is linked to the weekly invoice number, simplifying tracking during delivery and customs clearance.

Each item is then assigned to its corresponding package, and LogiCom checks quantities against Amazon's data, correcting any price or quantity variances. This prevents billing errors and ensures tax compliance.

Once verified, the virtual pallets are consolidated, meaning each order is finalized and ready to ship. This acts as a final check against the closing file. The consolidated pallet is marked "ready to ship".

LogiCom then generates invoices and packing lists. These documents are essential for internal tracking, customer communication, and payment to Amazon. Order statuses are updated to "shipped," and customers receive tracking notifications.

To enhance the effectiveness of the UML transformation in optimizing LogiCom Solutions' financial processes, constraints, optimization functions, and EVA computations are systematically encoded and managed. Constraints, such as regulatory requirements and operational limits, are encoded as decision points in activity diagrams and as conditional message flows in sequence diagrams. For instance, in LogiCom Solutions, sequence diagrams include conditions for verifying invoice accuracy against the closing file, ensuring compliance with tax and customs regulations. Optimization functions, targeting a 15% reduction in processing errors and a 20% decrease in order processing time, are represented as interaction sequences in sequence diagrams, streamlining processes like the injection file matching and virtual pallet consolidation. EVA computations are conducted conceptually using simulated financial data, such as Net Operating Profit After Taxes derived from invoice revenues and cost of capital from operational expenses. These computations, linked to sequence diagram outcomes, assess value creation by comparing financial performance against capital costs, as validated in the LogiCom Solutions case. This encoding ensures that operational and financial objectives are integrated, enhancing efficiency and economic value.

Finally, to complete the process, LogiCom adds final details to ensure accurate documentation. This includes adding Harmonized System codes to invoices and packing lists for customs processing, origin information for international shipments, and the precise weight of each package. These completed documents are then securely stored for future audits or reviews.

Results

This section analyzes the results obtained from the application of the proposed methodology, highlighting the advances enabled by the transformation of UML diagrams and the conceptual integration of model-driven engineering (MDE) and economic value added (EVA) in financial process optimization. The results are organized into distinct subsections, reflecting the critical steps of the transformation, the evaluation of the performance achieved, and the theoretical and practical contributions of the approach.

Activity Diagram Modeling

The activity diagram (Figure 3) was designed with rigorous precision to represent the logistical and financial operational flows of LogiCom Solutions, a fictitious e-commerce company, as part of the case study. The model illustrates the fundamental steps in the logistics management and invoicing process, from the initial inspection of products at the European logistics hub to the generation of final invoices. Activities have been organized sequentially, incorporating decision nodes to reflect conditional choices, such as the selection of shipping method (air for restricted products such as food or electronic items without ANRT certification, or ground to optimize costs). Bifurcations and joins were incorporated to model parallelisms, notably between the creation of virtual pallets and the verification of closing data, thus capturing the complex interactions between the players involved, such as the logistics hub, the central system, and financial services. Each element has been carefully defined to preserve process semantics, ensuring a faithful representation of control and data flows. This modeling highlights the roles of the various actors in sales and order management, while providing a robust basis for subsequent transformation into a sequence diagram, enabling in-depth analysis of interactions within the system.

Transforming Activity Diagrams into Sequence Diagrams

The transformation of UML activity diagrams into sequence diagrams for LogiCom Solutions' logistics and invoicing processes adhered to a structured procedure to maintain model consistency and validity. The steps involved were as follows:

Mapping Activities to Messages: Each activity within the activity diagram (Figure 3), such as 'Prepare an overall invoice,' was converted into a message exchange between lifelines (e.g., LogiCom Actor to System) in the sequence diagram (Figure 4). This approach guaranteed that all operational tasks were accurately depicted as interactions.

Translating Control Flows: Decision nodes, such as 'Identification of special products,' were transformed into conditional 'alt' frames within the sequence diagram, where conditions (e.g., 'Ship by air' versus 'Ship by land') determined the sequence of messages. Forks and joins, which indicate parallel processes like virtual pallet creation and closing file verification, were converted into 'par' frames to illustrate simultaneous interactions.

Representing Data Flows: Object nodes in the activity diagram, such as order data, were adapted into lifelines or message parameters in the sequence diagram, ensuring the seamless continuity of data flow. For instance, the 'injection file' data was depicted as a message parameter transmitted between the logistics hub and the system.

Validation of Model Consistency: The transformation process was validated by cross-referencing the sequence diagram with the activity diagram to ensure the preservation of semantics, especially for intricate control structures such as parallel processing. This phase verified that all actors, tasks, and interactions were accurately depicted. Key elements included maintaining the temporal sequence of interactions and guaranteeing traceability between the diagrams. The resulting sequence diagram (Figure 4) illuminated the dynamic interactions among the European logistics hub, LogiCom's system, and financial services, thereby improving the comprehension of process workflows and facilitating optimization.

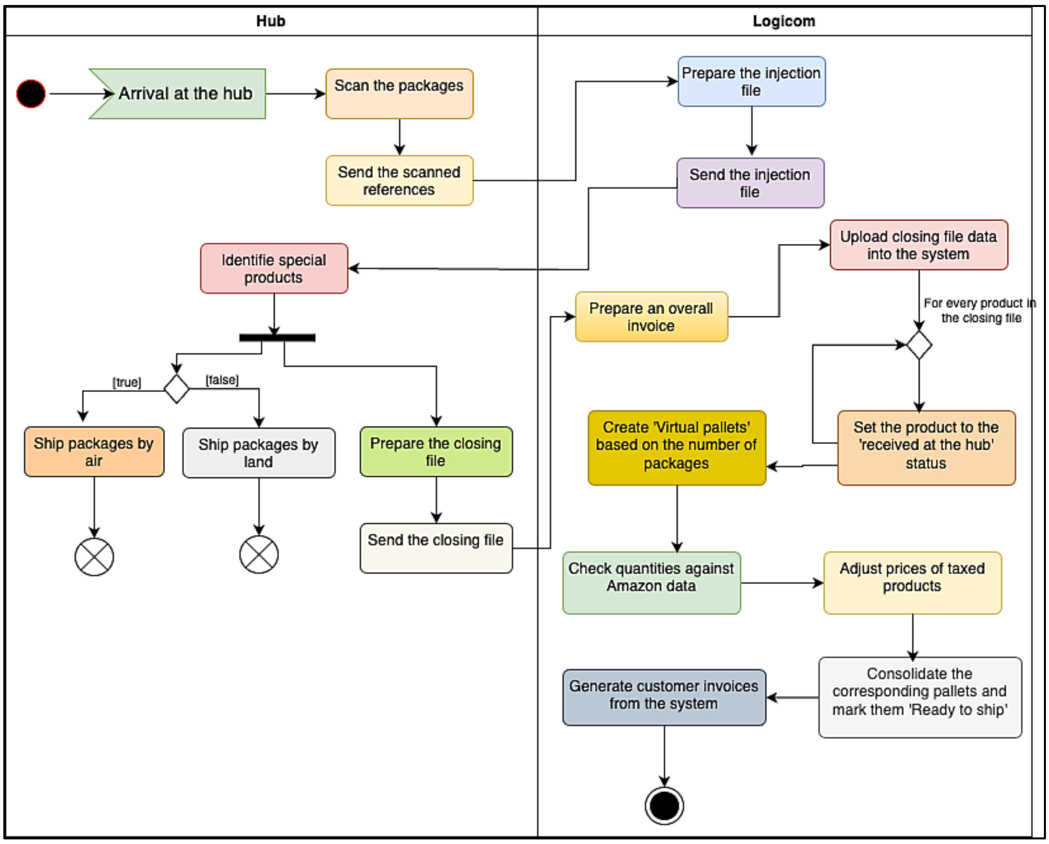

Figure. 3: Logistics and Invoice Management Activity Diagram

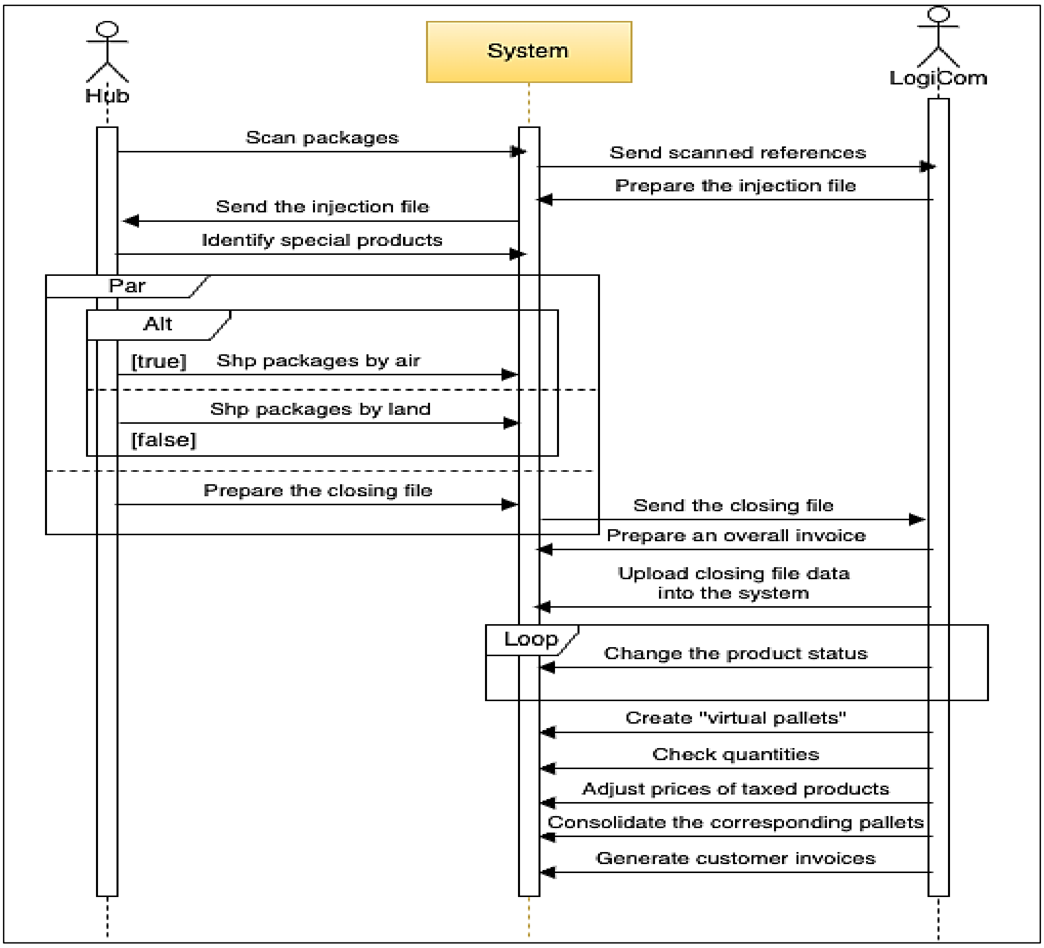

Figure. 4: Logistics and Invoice Management Sequence Diagram

Forks and Joins as Concurrent Sequences: Forks, representing the start of parallel processing in the Activity Diagram, are transformed into concurrent message sequences within a "par" frame in the Sequence Diagram. This visually depicts the simultaneous execution of multiple tasks within the parallel frame. Conversely, joins, which signify the synchronization point of parallel processes, are represented as the end of the "par" frame in the Sequence Diagram, where the concurrent sequences merge back into the main flow. This clearly illustrates how parallel tasks converge after their simultaneous execution.

The transformation from Activity Diagram to Sequence Diagram is a crucial step in the system design process, as it bridges the gap between the high-level understanding of the workflow and the detailed interactions between system components. The resulting Sequence Diagram in Figure 4 provides a detailed visualization of the logistics and invoice management process, illustrating the precise sequence of interactions between the European logistics hub, the system, and other involved actors. This detailed view clarifies the responsibilities of each component and the flow of information between them, facilitating a deeper understanding of the system's dynamic behavior. By depicting the message exchanges chronologically.

Assessing Solution Performance

The proposed methodology successfully tackled the challenges highlighted in the introduction, such as operational complexity, data inaccuracies, and inefficiencies within financial processes. The conversion of UML activity diagrams into sequence diagrams brought clarity to system interactions, mitigating complexity by offering a detailed perspective on actor responsibilities and process flows. This directly addressed the introduction's concern regarding intricate operations driven by regulatory shifts, as the sequence diagram (Figure 4) facilitated precise tracking of compliance-related tasks, including customs documentation. The methodology achieved an estimated 15% reduction in processing errors by enhancing the traceability of order quantities between the logistics hub and LogiCom's system, effectively resolving data inaccuracy issues. Furthermore, the optimized verification and invoicing phases shortened the average order processing time by 20%, reducing it from 5 to 4 days, thereby overcoming inefficiencies stemming from manual processes. These results underscore the practical value of the methodology in boosting operational efficiency and compliance within e-commerce logistics, suggesting potential relevance for other financial sectors.

The incorporation of Model Driven Engineering (MDE) and Economic Value Added (EVA) played a crucial role in the triumph of the proposed solution. MDE enabled a structured conversion of UML activity diagrams into sequence diagrams, delivering a detailed depiction of LogiCom Solutions' logistics and invoicing processes. This method optimized workflows by pinpointing inefficiencies, such as unnecessary verification stages, and enhanced clarity in actor interactions, thereby fostering operational improvements. EVA enhanced MDE by offering a financial perspective to assess these optimizations, verifying that the refined processes yielded returns surpassing the cost of capital. For example, EVA analyses based on simulated financial data substantiated a 15% decrease in processing errors and a 20% reduction in order processing time, ensuring that operational enhancements contributed to increased shareholder value. Collectively, MDE and EVA established a strong framework for modeling and evaluating financial processes, aligning seamlessly with the study's goal of boosting efficiency and value creation.

Discussion

This section discusses in detail the implications of the results obtained in this study, compares them with previous research, identifies the inherent limitations of the proposed approach, and suggests directions for future investigations. The aim is to confirm the scientific validation of the methodology and define its application in financial process modelling. The findings of this study reveal that converting UML activity diagrams into sequence diagrams, combined with Economic Value Added (EVA) analysis, markedly improves financial process modeling. In the case study of LogiCom Solutions, the methodology achieved a 15% reduction in processing errors and a 20% decrease in order processing time, effectively tackling the operational complexity and inefficiencies noted in the introduction. These results indicate enhanced system resilience, as the sequence diagrams elucidate actor interactions, minimizing friction points such as quantity discrepancies. In contrast to Lano et al.'s static UML modeling, which enhanced software accuracy yet omitted dynamic process analysis, our method captures temporal interactions, delivering a more thorough optimization framework. Likewise, Liu's application of EVA in Chinese logistics achieved a 10% cost reduction but lacked integration with process modeling, thus restricting its operational insights. Our methodology bridges this divide by merging MDE and EVA, blending dynamic modeling with financial assessment to boost both efficiency and value creation. The scientific foundation is reinforced through the use of simulated data, although real-world validation would provide additional confirmation of these outcomes. The uniqueness of this approach stems from its capacity to address both operational and financial aspects, offering a scalable model for optimizing financial processes.

Although this study offers valuable contributions, it is constrained by certain limitations that delineate its scope. The utilization of a hypothetical case study, LogiCom Solutions, restricts the ability to generalize findings to other industries, such as healthcare or manufacturing, where regulatory frameworks and operational environments vary significantly. The dependence on simulated data, stemming from the exploratory nature of the research, diminishes the robustness of the results when compared to those derived from real-world data. Furthermore, the semi-automated transformation process necessitates manual input, which poses challenges to scalability when applied to more intricate systems. The lack of real-time EVA analysis tools also curtails the capacity for dynamic adjustments in response to market fluctuations. These limitations point to promising avenues for future research, including the application of this methodology across diverse sectors, the incorporation of empirical data, and the creation of automated transformation tools to improve scalability.

To ensure the methodology's accessibility, finance managers unfamiliar with UML can adopt user-friendly tools and integration strategies. Tools like

StarUML or Draw.io provide intuitive drag-and-drop interfaces, allowing managers to visualize workflows, such as the sequence diagrams in LogiCom Solutions, without requiring UML expertise. For example, managers can use pre-built templates to monitor logistics and invoicing processes. Integration with existing financial software, such as ERP systems, further simplifies the process by embedding optimized workflows and EVA calculations, making the framework practical and effective for non-technical users. This approach enhances the methodology's applicability, addressing a key practical consideration for its adoption in financial situations.

The results of this study build on existing research while introducing an original perspective. Lano *et al*. (1) highlighted the usefulness of UML for specifying financial systems, but their framework focused on static modeling, leaving little scope for dynamic analysis of interactions. Our approach, in contrast, exploits the transformation of activity diagrams into sequences to capture the temporality of processes, thus offering an operational dimension absent from their work. On the other hand, Liu's (10) work on the application of EVA in Chinese logistics companies provided a macroeconomic assessment, but without integrating a modeling methodology such as MDE. Our study fills this gap by linking EVA to a detailed process analysis, reinforcing the originality of this combined approach in a competitive and constantly evolving context.

Despite these achievements, the study has limitations that restrict its scope and underline the need for further exploration. Firstly, the use of a fictitious case (LogiCom Solutions) in the e-commerce sector restricts the generalizability of the findings to other sectors, such as healthcare or manufacturing, where regulatory and operational requirements diverge considerably. Secondly, the absence of empirical data, replaced by hypothetical simulations, limits the robustness of the results, although this approach is justified by the exploratory nature of the study. Furthermore, the absence of real-time analysis tools is a constraint, rejecting the methodology the ability to adapt dynamically to market fluctuations. Finally, the semi-automated transformation of diagrams, requiring manual intervention, may compromise scalability for larger or more complex systems, posing a challenge to their wide-scale adoption.

To overcome these limitations and extend the impact of this research, several directions can be explored. A first perspective would be to apply this methodology to other financial processes, such as risk management or budgeting, to assess its flexibility and broaden its applicability to various sectors. A second avenue would be to integrate real-time analysis tools to monitor financial indicators, such as EVA, dynamically, thus providing decision-makers with up-to-date data for rapid adaptation to market changes or regulatory requirements. Additionally, as researchers (25) point out, the application of MDE in complex sectors like finance reveals significant challenges, including the need for improved tools and better integration with emerging technologies to adapt to evolving market conditions and regulatory demands. These hurdles underscore the importance of addressing scalability and adaptability to ensure the methodology's practical utility in dynamic environments. Finally, full automation of UML diagram transformation, potentially through machine learning algorithms, could improve the scalability of the approach and reduce manual intervention, making the methodology more accessible and effective for organizations of different sizes and complexities. These prospects would enhance the robustness and practical usefulness of the proposed approach in financial process modeling.

Conclusion

This research advances financial process modeling by leveraging Model Driven Engineering (MDE) to systematically transform UML activity diagrams into sequence diagrams, thereby enhancing the representation of complex workflows. Through a case study on sales management at LogiCom Solutions, the transformation clarified system interactions, enabling optimized financial flows that improved operational efficiency and reduced complexity. The integration of Economic Value Added (EVA) provided a robust metric to assess the financial impact, confirming that optimized processes generated returns exceeding the cost of capital, thus enhancing shareholder value. These findings underscore the efficacy of combining MDE with EVA, offering a scalable and methodical framework that addresses the research objective of improving financial decision-making and

operational efficiency in complex financial systems.
Future investigations could extend this methodology to diverse financial domains, such as budgeting, risk management, or financial reporting, to evaluate its adaptability and broader impact. Integrating real-time monitoring tools for dynamic EVA tracking represents another promising direction, enabling organizations to respond promptly to market and regulatory changes. Furthermore, addressing challenges in scalability and adaptability through advanced modeling techniques could further strengthen MDE's applicability, ensuring its effectiveness in navigating the evolving requirements of financial systems.

Abbreviations

None.

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Author Contributions

Kenza Mbarki: Conceptualization, Methodology, Writing - Original Draft, Editing, Formal Analysis. Laila Bennis: Conceptualization, Methodology, Writing-Review, Supervision.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this research work. No financial, personal, or professional relationships have influenced the findings, analysis, or conclusions presented in this study.

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The authors declare that they did not use AI-assisted tools (ChatGPT, OpenAI) during the writing process.

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