Enhancing Financial Decision-Making in Logistics

Process Redesign and Automation Approach for Transport Cost Management

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Enhancing Financial Decision-Making in Logistics: A Process Redesign and Automation Approach for Transport Cost Management

By

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Abstract

Transport costs represent a dominant and volatile share of logistics expenditure, often exceeding one-third of total logistics costs, making their control and transparency a matter of strategic importance. Despite this significance, the verification of transport invoices in outsourced logistics remains highly manual, fragmented, and reliant on individual expertise, leading to processing delays, inconsistent application of contractual terms, and financial risks from overpayment or disputes. This study addresses these challenges by redesigning the transport cost verification process through automation. Adopting a design science methodology within a real-world case from the aviation maintenance sector, the research combines a current-state analysis, a stakeholder-weighted evaluation of alternative automation technologies, and the development of redesigned workflow models. The strategies assessed include Rule-based Automation, Hybrid Structured Automation based on structured data exchange, and AI-powered Intelligent Document Processing (IDP). The results show that IDP offers the highest overall performance, particularly in handling heterogeneous invoice formats, while hybrid automation balances efficiency with partner collaboration, and rule-based systems provide a low-barrier entry point for organizations at earlier stages of digital maturity. These strategies were subsequently integrated into an improved workflow design that embeds standardized validation, strengthens financial control, and reduces reliance on tacit expertise. Conceptually, the study extends cost management research by bridging strategic frameworks with the transactional realities of invoice verification, demonstrating how automation and process redesign can jointly enhance financial decision-making in outsourced logistics.

Keywords: Transport Cost Verification, Logistics Cost Management, Workflow Redesign, Invoice Automation, Intelligent Document Processing (IDP), Outsourced Logistics

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"She believed she could, so she did."

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In the quiet reflection of this moment, every success carries within it the echoes of those who believed long before I did.

"If I have seen further, it is by standing on the shoulders of giants."
– Isaac Newton

Konstantina Mountouri
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List of Abbreviations

ABC	Activity-Based Costing
ADV	Adviesrol (Advisory role)
AI	Artificial Intelligence
API	Application Programming Interface
AWB	Air Waybill
BFSI	Banking, Financial Services, and Insurance
BI	Business Intelligence
BPMN	Business Process Model and Notation
BWM	Best–Worst Method
CV	Computer Vision
DAP	Delivered at Place
DDP	Delivered Duty Paid
DDU	Delivered Duty Unpaid
DSRM	Design Science Research Methodology
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
EXW	Ex Works
FCA	Free Carrier
FS	Fokker Services
GAAP	Generally Accepted Accounting Principles
ICC	International Chamber of Commerce
IDP	Intelligent Document Processing
IQR	Interquartile Range
IT	Information Technology
KP	Kostenplaats (Cost Center)
LA	Lean Accounting
LG	Leidinggever (Manager)

MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision-Making
ML	Machine Learning
MRO	Maintenance, Repair, and Overhaul
NLP	Natural Language Processing
OCR	Optical Character Recognition
PDF	Portable Document Format
Q1	First Quarter (January–March)
Q2	Second Quarter (April–June)
Q4	Fourth Quarter (October–December)
RMA	Return Material Authorization
ROI	Return on Investment
RPA	Robotic Process Automation
T1	External Union Transit document for the movement of non-Union goods within the EU prior to customs clearance
TCO	Total Cost of Ownership
VAT	Value Added Tax

1 Introduction

1.1 Background

In an increasingly global and data-driven economy, organizations rely on efficient logistics and transport operations to remain competitive, while facing growing pressure to improve financial oversight and operational performance. [42] Within this context, the verification of transport-related costs has become a critical yet often overlooked aspect of financial management. Many companies still rely on manual invoice handling and fragmented approval processes, leading to errors, delays, and a lack of cost transparency. [32] As businesses seek greater efficiency and control, the need for automation and structured decision making in transport cost verification is more urgent than ever.

Logistics costs represent a substantial portion of overall business expenses. In developed economies, depending on the industry involved and the method applied, the proportion of company revenue attributed to logistics costs typically tends to be higher than 10 percent. [19] Logistics costs primarily pertain to the expenditures incurred in handling, transportation, and warehousing operations. [55] Among these logistics cost components, transportation consistently represents the largest share. Research indicates that it can account for nearly one-third of total logistics costs. [34] When measured against company revenues, transport costs typically exceed 6 percent, surpassing other logistics-related expenditures such as warehousing, inventory holding, and administrative processing. This dominant share underscores not only the central role that transport plays in shaping overall logistics costs but also the importance of maintaining precise control and visibility over related expenditures. [56]

Yet, despite its importance, transport cost verification remains a manual and error-prone process in many organizations. Companies often rely on fragmented data access, tacit knowledge of experienced staff, and loosely structured approval chains to assess the legitimacy of freight charges. These practices expose businesses to financial leakage, operational delays, and disputes with logistics partners. The challenge is particularly acute in outsourced logistics environments, where shipment execution, invoicing, and contract ownership are distributed across multiple actors, complicating cost validation and allocation.

The growing digitalization of supply chains has introduced new opportunities to address these challenges. Automation technologies such as rule-based engines, hybrid structured data exchanges, and intelligent document processing (IDP) platforms enable faster, more accurate, and auditable handling of freight invoices. However, the practical integration of these technologies into coherent automation-supported workflows remains an emerging area of research and practice.

Against this backdrop, this study investigates how transport cost verification can be redesigned to combine automation with structured business logic. The aim is to support both operational efficiency and financial decision-making through the development of robust, technology-enabled workflows tailored to the realities of outsourced logistics.

1.2 Research Gap

Traditional cost management frameworks such as Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting (LA) offer valuable insights for strategic cost analysis but are not designed to address the transactional complexities of transport invoice verification. These models typically assume stable internal data environments and overlook the cross-organizational dependencies, fragmented data sources, and real-time decision points that characterize outsourced logistics operations.

As a result, there is currently no established framework that systematically supports the verification, allocation, and governance of transport costs in real time within outsourced environments. While the literature acknowledges the importance of transport cost transparency, it lacks practical models that bridge the operational gap between logistics execution, financial reconciliation, and cost accountability. This creates a dual gap: an academic one, where existing models lack operational applicability, and a practical one, where companies remain dependent on manual, error-prone processes.

1.3 Problem Statement

Efficient management of transport costs is a persistent challenge in logistics operations. Many organizations struggle to verify freight charges due to manual invoice processing, unstructured data formats, and misalignment between contractual terms and logistics execution. These issues lead to billing discrepancies, financial inefficiencies, and labor-intensive workflows. The absence of automation and real-time data analysis further limits cost transparency, standardization, and the ability to optimize transport expenditures.

At Fokker Services Group, the case organization of this research, transport invoice verification is currently managed through a fragmented, multi-step workflow involving multiple actors and systems. The process relies heavily on manual data lookups and tacit staff knowledge, making shipment-to-invoice matching unreliable, cost responsibility validation inconsistent, and charge verification largely non-data-driven. Critically, there is no real-time, automated system in place to support the verification process, resulting in a lack of efficiency, transparency, and standardization.

As a result, invoice approvals are often inconsistent, error-prone, and time-consuming. Invoices may be approved blindly, without thorough verification of underlying details such as shipment occurrence, cost allocation, or compliance with contractual rates. This exposes the organization to financial risk and operational inefficiencies, ultimately undermining scalability and control.

1.4 Research Objectives

To address the identified gap in transport cost verification within outsourced logistics environments, this research pursues the following three objectives:

1. **Current-state Diagnosis:** Examine the existing invoice verification workflow at Fokker Services Group to identify structural inefficiencies, manual bottlenecks, and system limitations that hinder process efficiency, consistency, and scalability.
2. **Technology Evaluation:** Assess the potential of three automation strategies, Rule-Based Automation, Hybrid Structured Automation, and Intelligent Document Processing (IDP) platforms, using a structured evaluation framework based on stakeholder-defined criteria: Accuracy, Flexibility, Speed, Scalability, Integration, Partner Dependency, and Cost & Maintenance.
3. **Process Redesign:** Propose future-state workflows supported by automation technologies that embed a shared validation backbone across strategies, enabling standardized, auditable, and automated cost verification and allocation to enhance financial control and decision-making.

1.5 Research Questions

The objective of this research is to contribute to the field of logistics cost management by examining how automation technologies can be integrated into transport cost verification processes. It aims to provide a structured understanding of current inefficiencies and propose redesigned workflows that align operational practices with financial oversight. To guide this investigation, the following main research question is posed:

How can transport cost verification processes be redesigned and supported through automation to improve financial decision-making at Fokker Services Group?

The overarching research question is investigated in relation to the following sub-questions:

1. What are the limitations of existing cost management models in addressing real-time transport invoice verification and decision-making needs?
2. How do current administrative and contract governance practices contribute to inefficiencies in transport cost verification?
3. Which automation technologies can best enhance accuracy and efficiency in transport cost processing?
4. What workflow models can be developed to operationalize automation in transport cost verification?

1.6 Scope

To ensure clarity and relevance, the study defines its scope across organizational, processual, technological, and temporal dimensions, outlined as follows:

- **Organizational Scope:** The empirical analysis focuses on Fokker Services Group and its freight transport invoice verification process. Broader transport procurement activities, contract negotiations, and non-freight invoice types are excluded.
- **Processual Scope:** The study examines the end-to-end freight invoice verification workflow, including invoice intake, verification, approval, ERP booking, and payment execution. The emphasis is placed on the verification stage and the associated decision rules.
- **Technological scope:** The study evaluates and conceptually designs workflows for three automation strategies:
  - ◇ Rule-based automation
  - ◇ Hybrid Structured Automation
  - ◇ Intelligent Document Processing (IDP)

  Pilot implementation, system deployment, and live performance testing are not included. The focus is on conceptual design, comparative evaluation, and anticipated benefits.
- **Temporal Scope:** The study draws on quantitative and qualitative data collected between January 2024 and Q2 2025. Quantitative data includes metrics such as invoice volumes, total transport charges, load distribution across vendors, and time-based performance indicators. These figures reflect operational throughput and efficiency over time. Qualitative data, such as stakeholder interviews and process observations, captures context-specific practices, challenges, and perspectives that were present during this period, providing insight into how freight invoice verification was approached and experienced within the organization.

1.7 Research Structure

This research is organized into seven sections, each addressing a distinct component of the investigation into freight invoice verification and automation.

Section 1 introduces the study by presenting the background, defining the problem statement, and outlining the research objectives, guiding research questions, and scope.

Section 2 reviews relevant literature on logistics cost structures and existing models, including Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting. It critically examines their applicability to transactional-level transport invoice verification and identifies gaps that motivate the need for alternative approaches.

Section 3 outlines the research design, structured around the central research questions. It comprises three key components: a current-state analysis of the invoice verification process, an evaluation framework for assessing automation strategies, and a process redesign approach.

Section 4 provides an overview of the organizational context and the existing freight invoice verification workflow. It outlines the operational environment in which the study is situated and highlights the key challenges that inform the evaluation and redesign efforts.

Section 5 presents the evaluation of automation strategies. It introduces stakeholder-weighted criteria and applies them to assess rule-based, hybrid structured, and IDP models. The section includes a comparative analysis using weighted scoring to determine the relative strengths and limitations of each approach.

Section 6 proposes redesigned workflows aligned with each automation strategy. It synthesizes a shared validation backbone and outlines the expected benefits of automation-supported process redesign.

Section 7 discusses the findings in relation to prior research and explores their implications for both managers and scholars. It also examines considerations for implementation, proposes a strategic pathway for scaling automation, and reflects on the study's limitations and methodological contributions.

Finally, Section 8 concludes the study by summarizing the main insights and offering recommendations for future research.

2 Literature Review

Logistics costs represent a substantial portion of overall business expenses. In developed economies, depending on the industry involved and the method applied, the proportion of company revenue attributed to logistics costs typically tends to be higher than 10 percent. [19] Additional studies corroborate this finding, further emphasizing the considerable share of logistics costs in company revenue. [53]

Despite their strategic significance, there is no universally accepted definition of logistics costs, and interpretations vary considerably. [3] Generally, logistics costs refer to the expenses associated with various activities aimed at structuring, planning, directing, managing and controlling the movement of goods, energy and information. In more detail, logistics costs primarily pertain to the expenditures incurred in handling, transportation, and warehousing operations. [55] Depending on how logistics operations are structured within an organization, logistics costs may also cover related activities such as inventory management, administrative processing, packaging, and other indirect or overhead costs. [38]

Among these logistics cost components, transportation consistently represents the largest share. Research indicates that it can account for nearly one-third of total logistics costs. [34] When measured against company revenues, transport costs typically exceed 6 percent, surpassing other logistics-related expenditures such as warehousing, inventory holding, and administrative processing. This dominant share underscores not only the central role that transport plays in shaping overall logistics costs but also the importance of maintaining precise control and visibility over related expenditures. [56]

Expanding upon this idea, an alternative conceptualization of logistics costs emphasizes the identification of various cost components tied to customer service operations for specific products, along with the structured tracking, evaluation, and documentation of all related expenditures stemming from engagements with suppliers and end consumers. [4] However, in practice, due to fragmented responsibilities across departments within a company, logistics costs are often misaligned with overarching business objectives. This organizational decentralization complicates efforts to trace logistics expenditures back to specific customer demands or operational decisions, ultimately making logistics cost management less effective. [54]

To address these limitations, a thorough understanding of the logistics activities carried out within an enterprise, including the transformation and flow of materials, information, and financial resources, is essential to accurately identify, classify, and manage the associated logistics costs. This knowledge forms the foundation for cost allocation across specific operations and enables more effective control within the logistics system. [52]

Taken together, these observations highlight the need for effective management of logistics costs to optimize a company's operational efficiency. Organizations that fail to recognize the strategic importance of cost reduction in logistics often lack a comprehensive understanding of its implications for overall performance and profitability, which is essential for the company's competitiveness and growth potential. [67] [38]

Logistics cost management refers to the systematic approach of identifying, evaluating and managing expenses associated with logistics activities. It involves making strategic decisions while focusing on optimizing costs based on internal as well as external information to maintain profitability while ensuring service excellence. [33] In the pursuit of financial transparency and operational efficiency, various established cost models have been widely implemented in logistics and supply chain management. These theoretical models offer structured approaches to analyzing, managing, and optimizing logistics costs, helping businesses enhance profitability while maintaining service quality. By leveraging these frameworks, organizations can gain deeper insights into cost drivers, identify areas for improvement, and make informed strategic decisions to achieve long-term sustainability.

Among these, the Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting models are frequently cited in academic and industry literature. Each model provides a structured approach to understanding and managing logistics expenses. However, their applicability and effectiveness in verifying transport costs, particularly in outsourced environments, remain limited. The following section offers a detailed examination of these models, their core characteristics, and their limitations in addressing the specific requirements of transport cost verification.

2.1 Total Cost of Ownership

Total Cost of Ownership (TCO), as described by Ellram (1995), serves as both a purchasing strategy and an evaluative framework designed to assess the actual cost associated with acquiring a specific good or service from a given supplier. Specifically, TCO refers to a complete evaluation of all expenses related to acquiring, utilizing, and maintaining a product or service over its full lifecycle. Beyond the initial purchase price, TCO accounts for factors such as order processing, supplier assessment, transportation, receiving, quality check, rejection, replacement, operational downtime, and disposal expenses. [18] Hence, this framework considers both direct and indirect logistics expenses to provide a comprehensive cost analysis that supports long-term decision-making. [30]

TCO offers a holistic view of costs, enabling better supplier evaluation, performance measurement, and benchmarking over time. Additionally, it serves as a consistent tool for comparing suppliers and clarifying performance expectations, ensuring businesses make informed procurement choices. By identifying cost-saving opportunities, organizations can prevent unexpected expenses during product ownership and improve operational efficiency. TCO also supports long-term planning and strategic procurement, fostering smarter decision-making and sustainable cost management. It enhances internal understanding of cost drivers, strengthening communication and encouraging continuous improvement within organizations. Ultimately, TCO promotes a shift from a price-centric view to a total-cost perspective, encouraging businesses to prioritize long-term value over short-term savings for more strategic purchasing decisions. [17]

Despite its advantages, TCO comes with several limitations that can hinder its practical application. One of the key difficulties is the data-intensive nature of TCO analysis, as accurately gathering and tracking all relevant costs, especially post-use or indirect expenses, can be complex. This challenge is especially pronounced in organizations lacking activity-based costing systems or advanced data infrastructure, making it difficult to assess long-term costs with precision. Moreover, TCO's wide scope can be overwhelming for firms without the appropriate analytical tools or expertise, leading to oversimplification or incomplete analyses. [59] The absence of standardized methodologies leads to variations in models across different firms and industries, makes benchmarking inconsistent and limits comparability. [20] Effective implementation demands significant cross-functional coordination, which may be difficult to achieve in siloed organizations. Cultural resistance may also impede adoption, particularly in firms accustomed to focusing on short-term price reductions rather than long-term value.

While traditionally applied in procurement, TCO has also evolved into a broader methodology for managing resources throughout the entire logistics process. In this context, it allows organizations to evaluate a wider spectrum of costs, including direct logistics expenses such as transportation, warehousing, and inventory holding, as well as indirect and hidden costs like administrative overhead, equipment maintenance, product quality management, risk mitigation, and compliance fees. This extension of the model allows companies to better understand the full financial implications of their logistics operations. Such comprehensive models offer greater cost visibility and help companies identify inefficiencies, assess supplier performance, and align logistics spending with business goals. [2]

Despite its strategic value, TCO presents notable limitations when applied to transport cost verification, especially in companies outsourcing logistics services. More critically, TCO is inherently retrospective and strategic in nature, aiming to support procurement or investment decisions rather than real-time operational processes. It lacks the operational depth to reconcile daily billing details with agreed terms, such as negotiated freight rates, surcharges, customs fees, or shipment tracking information. Secondly, TCO requires a high degree of data centralization and cost traceability, which is often impractical in real-world settings where logistics data is fragmented across third-party systems. Furthermore, TCO frameworks are typically static, offering limited adaptability to fluctuating transport rates, variable surcharge structures, or dynamic service-level agreements. As a result, TCO is ill-suited for environments that demand agile, transactional-level verification, and monitoring of transport expenditures.

2.2 Activity-Based Costing

Activity-Based Costing (ABC) is a cost accounting methodology developed by Cooper and Kaplan in the late 1980s, designed for complex manufacturing and service environments to improve cost allocation. [66] The model involves identifying resource-consuming activities, determining the cost drivers associated with those activities, distributing overhead costs accordingly, and linking these activities to performance metrics for accurate cost allocation. [26] ABC was introduced to address the shortcomings of traditional costing systems by implementing a two-step allocation process. In the first phase, indirect costs are assigned to cost centers according to activities instead of departments. In the second phase, ABC establishes cause-effect relationships using a broader range of cost drivers, both volume-based and non-volume-based, as opposed to the more arbitrary cost distribution used in traditional systems. [16]

The implementation of ABC enhances transparency and traceability in logistics cost management by pinpointing the specific activities that consume resources. It facilitates a more precise and logical allocation of indirect costs across departments, products, and customer segments, shifting the focus from output volume to the underlying processes driving expenditures. As a result, firms gain deeper insights into cost behavior, improving the reliability of product and service cost estimation, particularly in environments with complex operations or high overhead intensity. [27] Moreover, the availability of cost driver data and transaction volumes strengthens managerial decision-making, enabling forward-looking financial planning and more strategic resource allocation. Beyond cost estimation, ABC supports key strategic initiatives such as customer profitability analysis, outsourcing evaluation, pricing decisions, and continuous improvement. By uncovering inefficiencies and non-value-adding activities, it empowers firms to refine operations and enhance competitiveness. Additionally, ABC serves as a valuable tool for performance measurement across business units and functions, linking resource usage to managerial responsibility and encouraging accountability in financial management. [9]

ABC holds considerable potential for enhancing cost management, but its effectiveness can be constrained in practice by the financial and administrative burden associated with its implementation. Establishing an ABC system typically requires considerable investment in setup, consultancy support, and IT (Information Technology) infrastructure. It also places significant demands on internal personnel to collect, structure, and maintain detailed activity-level data. Compared to traditional costing methods, ABC is often more time-consuming and administratively intensive. [50] Additionally, a key challenge lies in identifying and maintaining appropriate cost drivers. Misapplied or poorly defined drivers can distort cost attribution, undermining the reliability of the output. Furthermore, while ABC enhances visibility into cost structures, it does not fully capture unpredictable or irregular costs, limiting its ability to provide complete cost certainty. The model also tends to prioritize operational cost efficiency, sometimes at the expense of a broader, systems-oriented view of organizational performance. [46] Lastly, ABC is not inherently compatible with standard financial reporting frameworks such as GAAP (Generally Accepted Accounting Principles), which may require dual reporting structures, creating further complexity and potential inconsistencies in external comparisons. [27]

While initially developed for manufacturing operations, ABC has since been adopted across various business functions, including logistics. Unlike traditional costing methods, which often rely on arbitrary or averaged allocations, ABC enables the identification of cost drivers at the activity level, including transport planning, warehousing, inventory management, and order processing, and assigns costs based on actual resource consumption. This approach provides greater transparency in evaluating the profitability of logistics services and supports both operational and strategic decisions, such as outsourcing underperforming functions or redesigning inefficient service chains. By integrating performance metrics such as handling volume or operation time, ABC allows logistics managers to trace costs to individual profit objects, including shipments, service contracts, or customer accounts. With its ability to refine cost allocation and improve process transparency, ABC plays a critical role in optimizing logistics operations and strengthening supply chain performance. [7]

In the context of transport cost verification, ABC also presents several operational limitations. While it is well-suited for analyzing internal activities, its application becomes more complex when logistics services are outsourced. [14] External carriers often do not provide the granular activity-level data required to effectively define and update cost drivers. Without access to detailed information on how costs are incurred, such as customs processing, last-mile handling, or exception-based charges, the accuracy of ABC outputs is significantly compromised. Additionally, ABC's structure is better suited for periodic review and internal benchmarking, rather than frequent, transactional-level reconciliation of freight invoices. Its implementation assumes a relatively stable process environment, which contrasts with the variability found in logistics networks involving fluctuating routes, surcharges, and service conditions. Consequently, while ABC can support high-level cost control and process transparency, it lacks the agility and specificity needed for routine invoice validation and exception handling in third-party logistics arrangements.

2.3 Lean Accounting

Lean Accounting (LA) is a cost management methodology developed in the 1990s as a response to the inadequacies of traditional cost accounting systems in lean production environments. Originating alongside the rise of lean manufacturing and the Toyota Production System, LA aims to align financial reporting and decision-making with the core principles of lean thinking, namely waste elimination, continuous improvement, and a strong focus on customer value. [11] Rather than relying on complex cost allocations or unit-based costing, LA emphasizes value stream analysis, real-time performance metrics, and simplified financial reports. Its primary objective is to provide relevant and timely information to operational teams, thereby enhancing cross-functional collaboration and supporting lean transformation efforts. Unlike conventional accounting approaches that often generate detailed but delayed or non-operationally useful reports, LA fosters visual and straightforward reporting structures that enable faster, more informed decisions at all organizational levels. [23]

Among its main advantages, LA offers a more accessible and comprehensible approach to cost management by simplifying financial reports and focusing on actual flows of value. It eliminates arbitrary overhead allocations and redirects attention to the profitability of value streams rather than individual products or departments. This value-stream-centric perspective allows companies to assess the financial performance of complete processes, encouraging a more integrated view of operations. [36] Additionally, LA enhances real-time visibility through tools such as box scores, which combine financial, operational, and capacity data. [10] These simplified metrics help operational staff understand financial implications without requiring accounting expertise, facilitating lean-driven decision-making. The model also supports continuous improvement efforts by highlighting areas of inefficiency and enabling direct feedback loops between performance outcomes and financial data. [62]

Despite these strengths, LA is not without limitations. A primary concern is its reduced focus on detailed cost tracking and variance analysis, which are core features of traditional accounting systems. By aggregating costs at the value stream level and moving away from individual product-level costing, LA may compromise cost precision and hinder granular financial analysis. [39] Furthermore, it lacks a standardized implementation framework. Unlike traditional accounting systems guided by well-established principles, it does not follow a universally accepted methodology, often leaving companies to interpret and apply lean principles independently. [22] Its emphasis on short-term efficiency can also undermine long-term financial sustainability, especially when it assumes that most operational expenses remain fixed. This approach can lead to decisions that favor immediate gains over future growth, reflecting principles of agency theory. Given these issues, many experts suggest that LA is most effective when used in conjunction with more traditional or analytical costing approaches. In complex organizational environments, a hybrid model that blends lean principles with conventional accounting or data-driven costing techniques may be necessary to ensure both operational clarity and strategic agility. [8]

In logistics settings, LA is applied by first identifying end-to-end value streams, such as the full cycle from order receipt to final delivery, to uncover both value-adding and wasteful activities. Conventional financial reports are simplified, replaced by visual tools such as box scores that monitor real-time indicators such as delivery lead times, inventory turnover, and handling efficiency. Non-value-adding activities such as delays, excess handling, or overproduction are identified using lean tools such as process walks and spaghetti diagrams. Costs are tracked directly by value stream instead of being broadly allocated, providing clearer insights into financial performance and pinpointing areas for improvement across entire operational flows. This approach empowers logistics teams to make data-informed decisions in daily operations meetings, without needing to wait for monthly accounting closures, thereby aligning financial insight with lean responsiveness. [37]

Its focus on internal flow and value stream performance does not support detailed reconciliation of freight charges or verification of compliance with negotiated rates, surcharges, or accessorial fees. By simplifying financial reporting and aggregating costs, LA lacks the granularity needed to match invoiced amounts with service terms on a shipment level. This becomes particularly problematic when third-party carriers manage transport and critical data is housed in external systems. Moreover, LA assumes cost transparency within the organization, making it difficult to trace or validate costs generated outside it. [22] As a result, while LA contributes to internal process optimization and waste reduction, it does not offer the transactional depth or data integration capacity required for rigorous, real-time transport cost verification in outsourced logistics networks.

2.4 Limitations of Cost Management Models

The preceding review has examined three influential cost accounting models: Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting (LA), each offering unique lenses for understanding and managing logistics costs. These models have contributed to more informed sourcing decisions, better resource allocation, and improved internal cost transparency. However, their focus areas diverge significantly when applied to the specific challenge of transport cost verification, particularly in outsourced logistics environments.

To make this divergence more explicit, Table 2 compares the models across four critical dimensions: theoretical foundation, technical structure, organizational use, and use-case alignment.

As shown below, none of the three models offers a fully adequate solution for verifying outsourced transport invoices in dynamic logistics settings. TCO provides a valuable strategic overview, but it lacks transactional visibility. ABC offers detailed cost traceability but requires granular 3PL activity data, which is often unavailable or unstructured. LA supports internal efficiency and visibility but does not extend to external validation or multi-party reconciliation.

Dimension	Total Cost of Ownership (TCO)	Activity-Based Costing (ABC)	Lean Accounting (LA)
A. Theoretical Foundation			
Conceptual Focus	Lifecycle ownership cost	Activity-based cost traceability	Lean/value-stream efficiency
Strengths	Holistic, strategic, cross-supplier comparison	Precise, detailed cost tracking	Real-time visibility; operational simplicity
Weaknesses	Retrospective; not transactional; high data demand	Challenging in outsourced settings; data-intensive	Aggregated view; lacks shipment-level detail; inward-facing
B. Technical Structure			
Granularity of Cost Detail	Low (total lifecycle level)	High (activity-level)	Medium (value-stream level)
Data Requirements	High	Very high	Moderate
C. Organizational Use			
Organizational Context Best Suited	Cross-functional procurement / strategic sourcing environments	Data-rich, analytically mature functions; cost engineering	Organizations pursuing lean transformation / value-stream management
Application Frequency in Logistics	High	Medium	Low
Timeframe of Application	Strategic	Strategic / Tactical	Tactical / Operational
D. Use-Case Alignment			
Applicability to Outsourced Transport Invoice Verification	**Low** – strategic cost lens, lacks line-item reconciliation	**Conditional** – possible where granular 3PL activity data is available and mapped	**Low** – internal flow orientation; no external charge validation

Table 2: Comparison of Costing Methods Across Key Dimensions

Taken together, this reveals a clear research and practice gap:

There is no existing cost management framework specifically designed to handle the operational, transactional, and cross-organizational complexities of transport cost verification in outsourced logistics environments.

To address this, the current study proposes a process redesign supported by automation technologies. Instead of relying on static costing models alone, it explores how digital solutions such as intelligent document processing, data integration tools, and rule-based validation engines can enhance financial control, reduce verification lead time, and strengthen decision-making at both operational and strategic levels.

This approach builds on the insights of traditional models but moves beyond their limitations, aiming to deliver a scalable, real-time solution that reflects the actual conditions of outsourced logistics. In doing so, it contributes to both the academic conversation and practical improvement of transport cost management.

3 Methodology

To capture the nature of this challenge, the research begins by situating it within a real-world setting. The complexities of invoice verification cannot be understood in the abstract, detached from the realities where they take place. They must be examined within an organizational setting, where fragmented systems, human decisions, and contractual arrangements converge. On these grounds, the study focuses on Fokker Services Group. The company illustrates the challenges outlined in the research gap while at the same time offering access to operational data and stakeholders that make an in-depth empirical investigation possible. This makes Fokker Services Group a particularly suitable case through which to investigate how process redesign supported by automation technologies can address the identified gap.

Building on this case context, the study adopts a structured methodological approach that combines empirical analysis, evaluation, and process redesign. Rather than approaching the problem from a purely conceptual standpoint, this research embraces a design-oriented methodology. It begins by uncovering inefficiencies within the current workflow, proceeds to a structured evaluation of alternative automation strategies, and culminates in the development of future-state workflows that are enhanced through the integration of digital technologies. This staged approach ensures that the proposed solution is both theoretically grounded and practically implementable within the realities of outsourced logistics.

This section outlines the methodology employed to address the primary research question. Table 3 provides an overview of the sub-questions and the corresponding methods utilized. Further details on these methods are elaborated in the subsequent subsections.

How can transport cost verification processes be redesigned and supported through automation to improve financial decision-making in logistics operations?

Sub-questions	**Methods**
1. What are the limitations of existing cost management models in addressing real-time transport invoice verification and decision-making needs?	Literature review; Framework analysis
2. How do current administrative and contract governance practices contribute to inefficiencies in transport cost verification?	Interviews; Document analysis; Data analysis; Process mapping
3. Which automation technologies can best enhance accuracy and efficiency in transport cost processing?	Qualitative analysis; Quantitative assessment; MCDA (BWM); Stakeholder Survey; Evaluation matrix
4. What workflow models can be developed to operationalize automation in transport cost verification?	Process redesign (DSRM-guided); Workflow modeling (BPMN-inspired); Stakeholder Validation Sessions; Shared Backbone Extraction

Table 3: Sub-questions and associated methods

3.1 Current State Analysis: Process Design and Operational Metrics

This study adopts a mixed-methods approach, integrating qualitative and quantitative techniques to explore and evaluate the current state of transport cost verification at Fokker Services Group. The methodological design was guided by the need to both map operational practices in a structured manner and empirically assess inefficiencies in the company's invoice handling process. By combining stakeholder insights with transactional data, the study aims to generate a comprehensive understanding of the verification workflow and its underlying bottlenecks, serving as a foundation for subsequent process redesign and automation evaluation.

3.1.1 Qualitative Process Mapping

The initial phase of the analysis focused on building an in-depth understanding of the operational workflow through qualitative investigation. Semi-structured interviews and process walkthroughs were conducted with key stakeholders from Finance, Procurement, and, most extensively, Warehouse Operations. These discussions provided detailed insights into how transport invoices are currently processed, including the systems utilized, the actors responsible at each stage, and the sequence of steps involved. Through iterative feedback and validation sessions, informal practices or workarounds that have developed over time were also revealed.

To contextualize how these invoices arise, an additional line of inquiry was dedicated to examining shipment structures, which give rise to transport-related charges. Through stakeholder input and documentation review, the core logistics flows were mapped to capture all relevant shipment scenarios. These were then structured into a visual model distinguishing between inbound and outbound movements, with branching paths illustrating the various triggers and subprocesses under each flow. This diagram helped connect logistical events with cost attribution responsibilities and provided a clearer picture of how transport invoices originate.

Building on these insights, the invoice verification process itself was modeled using a swimlane diagram to represent the "as-is" workflow. Swimlane diagrams were selected as the modeling technique due to their clarity in assigning process responsibilities and depicting interdepartmental handoffs.

In essence, a swimlane diagram is a visual tool used in process mapping that organizes the steps of a process into distinct parallel lanes, with each lane representing a specific entity, department, or system involved in the workflow. This structure clarifies responsibilities and shows how tasks progress between different contributors, making complex processes easier to understand and manage. Commonly used in areas such as business process modeling, requirements engineering, and workflow analysis, swimlane diagrams enhance communication, reduce ambiguity, and support validation by visually representing roles and interactions. Moreover, they are particularly effective in highlighting handoffs, dependencies, and potential bottlenecks that can be difficult to discern in textual descriptions. [65] [6]

The swimlane mapping enabled systematic documentation of verification checkpoints, such as invoice ownership determination, reference number validation, and charge approval, and provided the conceptual structure to identify inefficiencies. The model also facilitated stakeholder validation, ensuring that the diagram accurately reflected real-world practices.

3.1.2 Quantitative Data Analysis

To complement the qualitative findings, a quantitative analysis was performed using invoice transaction data provided by the Finance Department. The dataset, extracted from the company's accounts payable platform, covered the period from January 2024 through the second quarter of 2025. This time frame was selected to capture a full calendar year of activity along with the most recent operational data available, allowing for a comprehensive and up-to-date view of invoice processing trends.

The data set included all freight-related invoices and initially comprised a total of 2,213 line items. As a preliminary step, the data was analyzed based on invoice status to gain insight into the current state of invoice processing and to uncover potential inefficiencies or systemic delays. Invoices were classified intro three statuses: "Active", "Recorded", and "Canceled". Active invoices referred to those still pending approval within the system. Recorded invoices were those booked into the ERP system, although not necessarily paid at the time of analysis. Given the 18-month scope of the dataset, it was reasonable to assume that a large proportion of these were ultimately paid, despite the absence of explicit payment status in the data. Canceled invoices consisted primarily of credit notes manually booked, along with a smaller portion of invoices that had also been manually booked and subsequently settled or paid using credit notes.

A total of 14 canceled entries were excluded from further analysis after close investigation revealed that most were voided invoices unrelated to Fokker S.G. The remaining entries were either voided upon shipping request, booked under the wrong vendor code and later reactivated, or otherwise administratively canceled. As a result, a refined data set of 2,199 invoice lines was used as the analytical baseline.

The analysis was carried out in several stages. Initially, descriptive statistics were applied to assess the volume and temporal frequency of incoming invoices. This evaluation was based on the Accounting Date, which reflects the date each invoice was received in the accounts payable system. Daily, weekly, and monthly data were visualized using box plots to illustrate the distribution of values and summarize key statistical measures, including minimums, maximums, and averages.

Box plots, also known as box-and-whisker plots, are powerful exploratory data visualization tools that succinctly represent the distributional characteristics of a univariate dataset. Each plot displays the interquartile range (IQR) as a rectangular "box", with the median indicated by a central line. Extending from the box are "whiskers" that typically reach to the minimum and maximum values within 1.5 times the IQR from the quartiles. Observations beyond these limits are flagged as individual outliers. By encapsulating key descriptive statistics, such as central tendency, dispersion, skewness, and outliers, they offer a compact, assumption-free graphical summary ideal for comparative analyses across groups. [41] This method was selected for its clarity in highlighting fluctuations in invoice load and identifying patterns or anomalies that might otherwise remain hidden in raw tabular summaries.

In parallel, quarterly aggregates of both invoice count and net value provided further insight into workload trends across the six-quarter period. In addition to understanding volume, the analysis also sought to identify which vendors contributed most significantly to the invoice workload. The data set was therefore grouped by vendor to calculate the total net invoice value and invoice count per vendor, allowing for the identification of high-impact vendors who generate either a large share of the company's transport costs or a disproportionately high number of individual invoice submissions. These insights provided further evidence of workload concentration and possible areas for targeted automation.

To further assess the efficiency of invoice handling, three time-based performance metrics were introduced. First, the *Invoice Transmission Gap* was calculated as the number of days between the Invoice Date and the Accounting Date, reflecting the delay between when an invoice is issued and when it is registered in the accounts payable system. This metric highlights potential inefficiencies in initial document intake, such as administrative delays or limited visibility into upstream invoice flows.

Second, the *Payment Window* was defined as the number of days between the Accounting Date and the Due Date. This interval indicates the internal lead time available for processing and approval before payment becomes due. Negative values reflect invoices received ahead of their due date, offering greater flexibility, while positive values indicate overdue receipt, which can create payment bottlenecks and strain supplier relationships. A focused analysis was conducted on a subset of 113 invoices with positive payment window values, i.e., those received after their due date, to provide further insight into delays and assess internal responsiveness under time-constrained conditions.

The third metric, *Payment Lead Time*, measured the duration between the Accounting Date and the actual Payment Date, capturing the time taken to execute payment after the invoice is registered. Since payment date information was not available in the original accounts payable dataset, it was extracted from the company's ERP system. Of the 2,199 invoices, 275 were unpaid at the time of analysis or represented credit notes and thus excluded from this metric. The remaining paid invoices served as the basis for calculating descriptive statistics and trends associated with payment execution behavior. Like the temporal intake metrics, these time-based performance indicators were visualized using box plots to facilitate comparative analysis and clearly highlight distributional trends and outliers.

To synthesize these findings and provide a more granular understanding of end-to-end process efficiency, a focused timeline analysis was conducted. The goal of this analysis was to visualize the entire life cycle of individual invoices, from initial issuance by the logistics provider to final payment execution by the Finance Department. Since *Flow Completion Date*, indicating internal approval, was not available in the original dataset, a sample of 43 invoices was manually selected and cross-referenced with the ERP system. After filtering for completeness to ensure that all necessary timestamps were present, a final sample of 33 fully processed invoices was retained for analysis.

For each of these invoices, three key process intervals were measured to capture the distinct stages of the invoice life cycle. The first interval, *Invoice Transmission Gap*, was consistent with the earlier definition and measured the number of days between the invoice issuance date and the date it was entered into the accounts payable system. The second interval, *Internal Processing Time*, measured the time elapsed between the Accounting Date and the completion of internal approval workflows, marked by the Flow Completion Date. This stage represents the period during which the invoice is reviewed, validated, and approved for payment within the organization. The third and final interval, *Payment Execution Time*, captured the number of days between the Flow Completion Date and the actual Payment Date recorded in the ERP system. This duration reflects the time taken to execute the financial transaction after internal approvals have been finalized.

These intervals were visualized using a sequential timeline chart, which displayed the duration and sequencing of each stage across the sample. This format provided a clear view of intra-process variability and enabled the identification of stages that contributed most significantly to overall delay. By decomposing the lifecycle into discrete, measurable components, the analysis delivered actionable insights into the internal pacing of operations and highlighted specific phases in which automation or procedural standardization could have the greatest impact.

3.2 Evaluation of Potential Automation Approaches

Building on the detailed documentation of the current-state workflow and the systematic identification of process inefficiencies, the subsequent phase of the study shifted toward the exploration of automation strategies that could underpin a redesigned verification process.

Scholarly literature identifies several recurring characteristics that make certain business processes particularly suitable for automation. Processes governed by clear and consistent rules lend themselves well to automation, since they can be replicated with predictable outcomes. Stable and mature workflows, with limited expected change, further enhance suitability by reducing the risk of frequent reconfiguration. Another critical factor is the presence of structured and digital inputs, which allow systems to process data consistently, whereas unstructured or paper-based inputs introduce greater error potential. Processes characterized by high transaction volumes are particularly attractive, as automation delivers substantial efficiency gains when repetitive tasks are performed at scale. Suitability also increases when processes are relatively simple, as greater complexity tends to raise implementation and maintenance costs. In addition, workflows that require interactions across multiple IT systems are often strong candidates, since automation can act as a bridging layer between otherwise disconnected platforms. Finally, repetitive tasks requiring extensive human input are especially prone to fatigue-related errors, making them prime candidates for automation. [12]

Invoice verification closely reflects the characteristics commonly associated with processes suitable for automation. It is governed by well-defined, rule-based logic, relies on digital documentation that is often structured or semi-structured, and is executed at high volumes within logistics operations. Furthermore, the process spans multiple system interactions, such as connecting financial, procurement, and warehouse records, while requiring substantial manual input that is both resource-intensive and error-prone. Owing to these attributes, invoice verification has been widely examined in both academic and practitioner literature as a natural application area for automation.

In this light, automation emerged as a logical pathway for transforming the verification workflow. The objective was not only to address the specific bottlenecks observed, but also to propose a workflow that ensures operational efficiency, transparency, and resilience while reducing reliance on manual, error-prone, and time-intensive activities. In doing so, the analysis sought to identify solutions that safeguard process integrity and provide a scalable foundation for sustained performance improvement.

In alignment with these goals, the study proceeded to evaluate three candidate automation strategies capable of enabling the redesigned workflow: *Rule-Based Automation, Intelligent Document Processing, and Hybrid Structured Automation.*

Rule-Based Automation was selected as a foundational approach due to its established role as one of the earliest and most widely adopted forms of process automation. By encoding predefined logic into deterministic workflows, this method provides a baseline against which more advanced solutions can be compared.

Intelligent Document Processing (IDP) was included due to its prominence in academic research and industry adoption as a leading technology for automating document-centric workflows. Leveraging artificial intelligence and machine learning capabilities, IDP represents a more flexible and adaptive alternative capable of handling diverse and unstructured document formats.

Hybrid Structured Automation was introduced as a targeted solution combining structured data exchange from digitally mature vendors with rule-based validation logic. This approach emerged from the observation that a significant proportion of invoices originate from vendors with the capability to provide standardized electronic data, allowing direct integration with validation rules to streamline processing. While narrower in scope, this option offers potential efficiency gains in contexts with a high concentration of business volume among a limited set of technologically capable partners. This strategy, not yet explicitly described in academic sources, is introduced here as a novel configuration, distinguished by its explicit integration of structured vendor data with rule-based validation logic, and derived from practical observations of real-world workflows.

While the evaluation was grounded in the context of the case organization, the approaches were considered in a generalizable manner, enabling broader applicability to other settings where transport invoice verification is a critical operational process.

For each of the three approaches, a concise description was developed to define their core functionality, operational scope, and typical use cases. The evaluation framework was then designed to compare these solutions against a consistent set of seven criteria. The selection of these criteria was informed by three complementary sources:

1. **Literature review** – *Key advantages, limitations, and evaluation factors commonly discussed in academic research and industry publications on automation technologies.*
2. **Empirical process observations** – *Specific bottlenecks, inefficiencies, and structural constraints identified during the current-state analysis of the invoice verification workflow.*

3. **Stakeholder perspectives** – *Operational priorities and performance expectations gathered from interviews with representatives from Finance, Procurement, Warehouse Operations, and Continuous Improvement.*

These criteria reflect a balance between operational requirements, technological capabilities, and organizational priorities. They were established to ensure that each automation approach was assessed in a consistent and comparable manner, capturing both technical performance factors and practical implementation considerations. Each criterion was defined with a clear operational meaning to guide qualitative scoring, as summarized in Table 4.

Criterion	Description
Accuracy	Precision of data extraction for key invoice fields.
Flexibility	Ability to process varied invoice formats and layouts.
Speed	Time required to extract and validate invoice data.
Integration	Compatibility with existing enterprise systems and workflows.
Scalability	Capacity to handle increased document volumes without performance degradation.
Partner Dependency	Extent to which successful operation depends on vendor collaboration.
Cost & Maintenance	Licensing, infrastructure, and ongoing upkeep requirements.

Table 4: Evaluation Criteria and Operational Definitions for Automation Strategies

The evaluation was conducted qualitatively, as implementation-based performance measurement was beyond the scope of the study timeline. Evidence was drawn from vendor white papers, product specifications, and peer-reviewed literature. In addition, domain knowledge from stakeholder discussions was incorporated. For each criterion, strengths, limitations, and context-specific considerations were documented and synthesized into a comparative table. The table used symbolic markers to indicate positive attributes, potential drawbacks, or areas requiring caution.

These qualitative assessments were operationalized as numerical scores on a 1- 9 scale, with 1 representing the weakest alignment with a given criterion, 9 representing the strongest, and intermediate values capturing proportional gradations in observed or expected performance. To account for the relative importance of each criterion, weighting factors were determined using the Best–Worst Method (BWM).

BWM is a structured decision-making technique designed to determine the relative importance of multiple criteria or alternatives. The method involves choosing two criteria to serve as reference points: the one deemed most important (Best) and the one considered least important (Worst). The decision-maker then conducts two sets of pairwise comparisons: first between the Best criterion and all others, and second between all criteria and the Worst. These comparisons form the basis for a mathematical optimization model that derives a set of criterion weights, aiming to minimize inconsistency in the judgments. By anchoring the evaluation to two opposing reference points, BWM reduces cognitive biases, particularly anchoring bias, and enhances the reliability and validity of the resulting weights. [49]

To incorporate stakeholder perspectives, representatives from Finance, Procurement, Warehouse Operations, and Continuous Improvement participated in a BWM survey. The survey was implemented using the Solver Linear BWM Excel tool, which was customized to fit the specific evaluation context of this study. [48] [47] The tool enabled the calculation of optimal criterion weights based on the input provided by each stakeholder group.

Participants identified their most and least important criteria and completed pairwise comparisons in line with the BWM methodology. The resulting individual weight sets were reviewed for potential outliers and assessed using consistency ratios, which indicate how coherent the pairwise judgments are. The Solver Linear BWM tool automatically calculated these ratios and compared them against predefined thresholds based on the number of criteria and comparison values.

Since no notable inconsistencies or significant deviations were observed among the decision-makers, the average weight for each criterion was computed to represent a consolidated perspective across stakeholder groups. Aggregation techniques such as the arithmetic or geometric mean are commonly used in multi-criteria decision-making to combine the individual preferences of multiple decision-makers into a unified set of weights. Although these methods exhibit sensitivity to outliers and can sometimes obscure individual nuances, the high level of consistency in responses across participants in this case justifies their use. The absence of extreme values or conflicting judgments further reinforces the reliability of the averaged results as a meaningful reflection of collective preferences.

These aggregated weights were then applied to the criterion scores assigned to each automation approach, allowing for the computation of a weighted overall performance score and facilitating a comparative ranking of the evaluated alternatives.

3.3 Structured Workflow Redesign

The development of the proposed future-state workflows is based on a structured process redesign methodology aimed at translating the findings from the current state inefficiency analysis (Section 4) and the evaluation of automation strategies (Section 5) into actionable "to-be" workflows. These workflows are intended to guide implementation by aligning technological capabilities with organizational needs. The methodology was guided by principles from the Design Science Research Methodology (DSRM) and comprises four complementary steps: problem framing and requirement derivation, benchmarking of automation strategies, process mapping and workflow design, and comparative synthesis with shared backbone extraction.

Problem Framing and Requirement Derivation

The starting point for the redesign was the set of inefficiencies identified in the current invoice verification process, such as fragmented data access, lack of systematic checks, and reliance on tacit advisor knowledge. These inefficiencies were consolidated into design requirements, which emphasized automation of routine checks, integration of contractual logic (e.g., Incoterms and tariffs), and reduction of manual workload. In parallel, the stakeholder priorities captured in the weighting exercise (Section 5), particularly accuracy, flexibility, and transparency, were translated into guiding design principles for the new workflows.

Benchmarking of Automation Strategies

The automation strategies evaluated in Section 5, namely Rule-Based Automation, Hybrid Structured Automation, and AI-powered IDP platforms, served as the foundation for workflow development. These strategies were selected through literature review, market analysis, and internal consultations, each reflecting distinct assumptions about data availability, technological maturity, and stakeholder involvement. Their inclusion ensured that the redesign addressed both incremental improvements and more advanced, future-oriented solutions.

Process Mapping and Workflow Design

For each strategy, a detailed workflow was developed using BPMN-inspired (Business Process Model and Notation) swimlane diagrams. These models integrated system-driven steps (e.g., OCR, data parsing, validation rules) with human interventions (e.g., exception handling, approvals) to ensure completeness and operational realism. The workflows were iteratively refined through feedback sessions with logistics advisors and finance staff to validate assumptions, confirm feasibility, and align with organizational practices. Flowcharts included in the appendices support transparency and reproducibility of design choices.

Comparative Synthesis and Shared Backbone Extraction

Following the individual workflow designs, a comparative synthesis was conducted to identify the unique strengths, limitations, and dependencies of each approach. This analysis enabled the extraction of a shared validation backbone comprising a universal set of rules, including shipment matching, cost responsibility, and tariff validation, which underpins all automation strategies. This backbone ensures that the redesigned workflows are not tool-specific but grounded in consistent, auditable business logic.

Through this methodology, the process redesign integrates empirical insights from the case study, theoretical perspectives from automation literature, and stakeholder-driven priorities. The resulting workflows serve both as practical blueprints for implementation and as analytical artifacts that demonstrate how automation-supported redesign can enable standardized and transparent transport cost allocation.

4 Case Organization

With the methodological groundwork laid in Section 3, this section turns to the empirical setting of the case organization. The objective is to establish a detailed understanding of the operational context in which freight invoices are generated, verified, and managed, providing the basis for the evaluation of automation strategies in the following chapter.

To begin, Section 4.1 provides an overview of the organization and its logistics environment. Section 4.2 explores core aspects of shipment operations, including shipment structures, identification practices, cost allocation mechanisms, and customs documentation. Section 4.3 then outlines the current workflow for transport cost verification, which forms the basis for the subsequent diagnosis of inefficiencies in Section 4.4. Section 4.5 provides a quantitative overview of the invoice lifecycle, complementing the qualitative findings with empirical evidence. Finally, Section 4.6 synthesizes the systemic challenges that emerge throughout the process.

Taken together, these sections offer a structured account of the current-state process, highlighting both operational practices and their shortcomings. This diagnostic perspective directly informs the comparative evaluation of automation strategies presented in Section 5.

4.1 Organizational Profile

Within the scope of this research, Fokker Services Group serves as a case organization for analysis. This investigation seeks to evaluate existing practices, identify potential inefficiencies, and explore opportunities for improvement within the company's approach to cost validation in transportation operations.

Fokker Services Group, hereafter referred to as 'Fokker S.G.', is an independent aviation specialist with a legacy of over a century in aerospace innovation and support. With operational reach across five global locations, the company supports more than 1,500 aircraft spanning all major fleet segments, including business, commercial, and defense aviation. It serves a diverse clientele of operators, Original Equipment Manufacturers (OEMs), Maintenance, Repair, and Overhaul (MRO) providers, lessors, and government entities, offering customized aftermarket solutions tailored to complex operational needs.

Fokker S.G.'s integrated capabilities cover the entire value chain, from design and production to maintenance, repair, and airworthiness management. This integrated structure enables the company to deliver comprehensive single-source support that ensures aircraft availability, reliability, and compliance.

Within this operational ecosystem, logistics plays a critical enabling role in supporting Fokker S.G.'s high-reliability, time-sensitive service offerings. The timely and accurate movement of parts is essential to minimizing aircraft downtime and maintaining global service continuity. These transport activities give rise to a continuous stream of cost-bearing events, which, in turn demand structured processes for verification, accountability, and financial control.

4.2 Foundational Elements of the Shipment Process

4.2.1 Shipment structures

In order to better understand how transport-related costs emerge, it is essential to examine the logistical activities that trigger and structure outbound and inbound movements. Although Fokker S.G. is not a logistics provider, it relies heavily on regular and time-sensitive transport operations to support its global activities. To fulfill its logistical needs, the company outsources transportation to a diverse range of external service providers, including global express couriers, freight forwarders, regional carriers, and manual transport partners. This outsourcing model allows Fokker S.G. to maintain flexibility and scalability across its logistics network while ensuring service continuity.

However, this reliance on third-party logistics providers also generates a high volume of transport-related charges that must be monitored and validated. Each shipment arranged through these external parties becomes a potential cost-bearing event, making it critical to have structured processes in place for accurate tracking and financial reconciliation.

At Fokker S.G., these transport activities are organized into two principal logistics flows, as depicted in Figure 1. Import refers to inbound shipments, while Export covers outbound shipments. Each flow is associated with distinct operational triggers and use cases. These flows not only reflect the company's core service model, but also form the foundation upon which transport-related invoices are generated, processed, and ultimately verified.

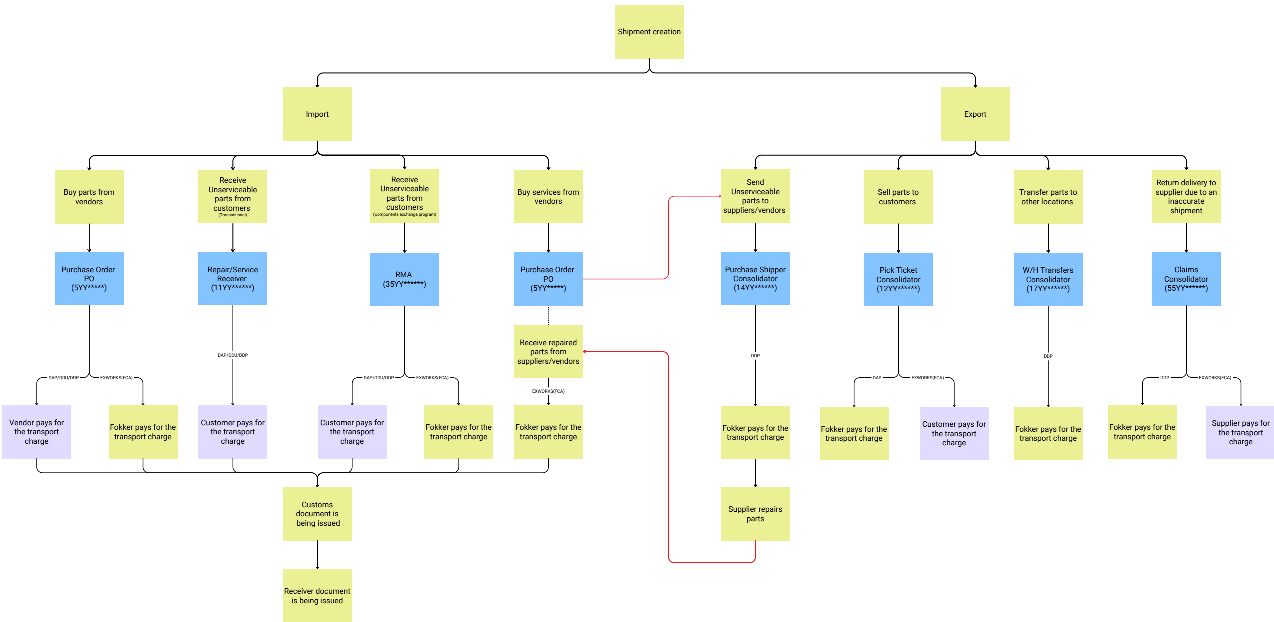

Figure 1: Shipment structures

Import Flow: Inbound Shipments

Fokker S.G.'s inbound logistics activities, collectively referred to as the Import Flow, encompass a diverse set of operational triggers that result in the receipt of goods and components at one of the company's global facilities. These inbound shipments support critical functions such as inventory replenishment, repair operations, and service fulfillment. The Import Flow is built around four distinct streams:

- **Procurement from Vendors:** New parts or components are ordered from external suppliers through purchase orders. Upon arrival, these items are received into stock and subsequently used for internal operations or customer service delivery.
- **Customer Repair Requests:** Customers send unserviceable components to Fokker S.G. for inspection, maintenance, or overhaul. These inbound movements are part of transactional repair agreements and are essential to the company's MRO services.

- **Component Exchange Program:** Through this program, customers are supplied with ready-to-install parts from Fokker S.G.'s inventory. In exchange, they return the used unserviceable components, which become part of the inbound flow and are later routed for repair or refurbishment.
- **Returns from External Repair Vendors:** In such cases, Fokker S.G. acts as the recipient of parts that were previously outsourced for repair or calibration. Once received, these parts are either returned to inventory or shipped onward to fulfill specific customer requests.

Export Flow: Outbound Shipments

Fokker S.G.'s outbound logistics activities, termed together as the Export Flow, comprise a range of operational processes that involve the dispatch of goods from the company's global facilities to customers, suppliers, and external service providers. These outbound shipments are fundamental to fulfilling customer orders, supporting repair cycles, and managing supplier relationships. The Export Flow follows a similar four-stream structure as its inbound counterpart:

- **Dispatch to External Repair Vendors:** Components that are either owned by Fokker S.G. or returned by customers are shipped to specialized third-party vendors for repair, calibration, or testing. Once serviced, these parts are returned through the inbound flow and re-enter the supply chain.
- **Shipment of Customer Orders:** Serviceable components, tools, or consumables are shipped to customers as part of sales transactions or service agreements. These shipments may include both routine inventory orders and urgent dispatches to minimize customer aircraft downtime.
- **Internal Warehouse transfers:** In some cases, parts, materials, or tools are transferred between Fokker S.G.'s various global facilities to rebalance inventory, respond to demand spikes, or support local operations. Although not customer-facing, these shipments still incur transport costs that are processed through the same verification channels.
- **Returns to vendors:** In cases of incorrect, incomplete, or defective deliveries, Fokker S.G. initiates return shipments to the original vendor. These outbound flows fall under claims or quality assurance processes and are logged as separate cost events requiring appropriate documentation and verification.

4.2.2 Shipment Identification

Each shipment initiated within the flows described above is assigned a specific internal reference number by Fokker S.G. These identifiers are not randomly generated but follow a structured and purposeful logic that corresponds to the shipment's operational category, whether it is related to procurement, customer repair, inventory transfer, or outsourced service coordination.

To maintain consistency across processes, each reference number begins with a predefined prefix that reflects the nature of the transaction, followed by a sequence of digits that includes a coded representation of the year. This logic allows users to immediately recognize the type and timing of a shipment based on its identifier. Each complete reference generally consists of a fixed number of digits, either eight or ten, ensuring consistency and uniqueness within the system.

This systematic formatting enhances traceability within the company's ERP and logistics platforms, making it easier to locate, classify, and reconcile shipments throughout their lifecycle. By embedding operational and temporal information directly into the reference structure, Fokker S.G. aims to strengthen internal alignment across departments and improves the efficiency and reliability of downstream processes, particularly in cost verification and invoice reconciliation.

4.2.3 Transport Cost Allocation

Responsibility for transport costs at Fokker S.G. is primarily determined by contractual arrangements established with its business partners, including customers and suppliers. These arrangements are typically governed by Incoterms, a set of internationally recognized rules developed by the International Chamber of Commerce (ICC). Short for *International Commercial Terms*, Incoterms define the division of responsibilities, costs, and risks between buyers and sellers involved in the movement of goods, both in international and domestic trade. Each Incoterm specifies who is responsible for key elements of the delivery process, including freight charges, insurance, customs clearance, and the point at which risk transfers from seller to buyer. Expressed as standardized three-letter abbreviations (e.g., DAP, EXW, DDP), they serve as a globally accepted shorthand to outline supply chain obligations in a legally enforceable manner. [15]

It is important to note that all Incoterm designations, as illustrated in Figure 1, are interpreted from the perspective of the shipper, meaning the party who initiates the shipment. This may be Fokker S.G. or its business partner, depending on the transaction. Viewing Incoterms from this perspective is essential for understanding how responsibilities and cost ownership are assigned throughout the logistics chain. Based on this interpretation, transport cost responsibilities across the company's various shipment flows are summarized as follows:

- **Procurement from Vendors:** In procurement cases, responsibility for the transport charge depends on the agreed Incoterm. If the vendor ships under terms such as Delivered Duty Paid (DDP), Delivered at Place (DAP), or Delivered Duty Unpaid (DDU), they assume the transport costs. Conversely, if the vendor ships under Ex Works (EXW) or Free Carrier (FCA) terms, Fokker S.G. bears the transport costs.
- **Customer Repair Requests:** For these repair flows the transport charge is generally covered by the customer. This is most commonly arranged under DDP/DAP/DDU terms, aligning with the principle that the sender, in this case the customer, is responsible for delivery to Fokker S.G.'s facility.
- **Component Exchange Program:** In the standard arrangement, customers return used components at their own expense under DDP/DAP/DDU terms. However, in select contractual agreements, Fokker S.G. assumes transport responsibility. In these cases, customers ship parts under Ex Works conditions, with Fokker S.G. covering the shipping costs.
- **Dispatch to External Repair Vendors:** This represents another area where Fokker S.G. typically assumes the full transport cost. These outbound shipments are carried out under DDP terms, with the company acting as the shipper and covering all logistics expenses related to delivering components to third-party specialists for external servicing.
- **Returns from External Repair Vendors:** Complementing the outbound flow, the return of serviced components also follows a cost structure where Fokker S.G. is responsible for transport. These inbound shipments are generally conducted under Ex Works terms. In effect, Fokker S.G. bears the cost for both legs of the repair logistics cycle.
- **Shipment of Customer Orders:** The responsibility for transport once again depends on the Incoterm specified in the sales agreement. Under DAP terms, Fokker S.G. pays for transport to the customer. If the agreement specifies Ex Works, the customer arranges and pays for the collection and delivery from Fokker S.G.'s facility.

- **Internal Warehouse transfers:** Although not customer-facing, these transfers generate cost-bearing events. In such cases, Fokker S.G. always covers the transport costs, typically under DDP arrangements, as it manages the shipment internally across its own network.
- **Returns to vendors:** In these instances, transport cost responsibility varies depending on the nature of the claim. If the return is initiated by Fokker S.G., the company typically pays under DDP terms. However, if the responsibility lies with the supplier, the return is made under Ex Works or FCA terms, placing the transport obligation on the vendor.

4.2.4 Customs and Receiving Documentation

Regardless of the shipment flow, all inbound parts received at Fokker S.G. facilities follow a standardized documentation sequence. Each inbound shipment is first registered through a customs document, followed by the issuance of a receiver document. This two-step process ensures compliance with customs regulations and enables accurate tracking of goods received across the company's operations.

An important distinction exists in the case of RMA (Return Material Authorization) flows, which are part of the Component Exchange Program. Unlike other inbound cases where receiver documents are generated after customs documentation, RMA shipments are linked to preexisting receiver references. Once the part is returned by the customer and a customs document is created, it is matched to the existing RMA reference, updating the documentation accordingly.

In all inbound scenarios, including RMA and non-RMA flows, the Air Waybill (AWB) number or tracking reference is consistently recorded in the customs document. This makes the customs document the primary data entry for inbound shipment tracking in the company's ERP system. For verification purposes, such as matching a freight invoice with a physical shipment, the customs database serves as the leading table of reference.

Conversely, for outbound shipments, validation is typically linked to either pick ticket references (used for direct sales) or consolidator references (used for batch shipments). These outbound identifiers form the corresponding documentation trail necessary for verifying transport charges initiated by Fokker S.G.

4.3 Current Workflow for Transport Cost Verification

Following the completion of a shipment, the next critical step in Fokker S.G.'s logistics operations is the receipt and verification of the corresponding invoice. This section outlines the internal procedure Fokker S.G. follows to assess, validate, and approve invoices from logistics service providers.

The current process for transport invoice verification at Fokker S.G. is characterized by a sequential, multi-actor workflow, engaging both administrative and operational roles. The process is designed to ensure that the incoming invoices from logistics service providers are accurately assessed, validated, and approved before payment is released.

To better understand how this workflow unfolds, the process is visually represented in a swimlane diagram, shown in Figure 2, which illustrates the interactions between internal departments and external stakeholders.

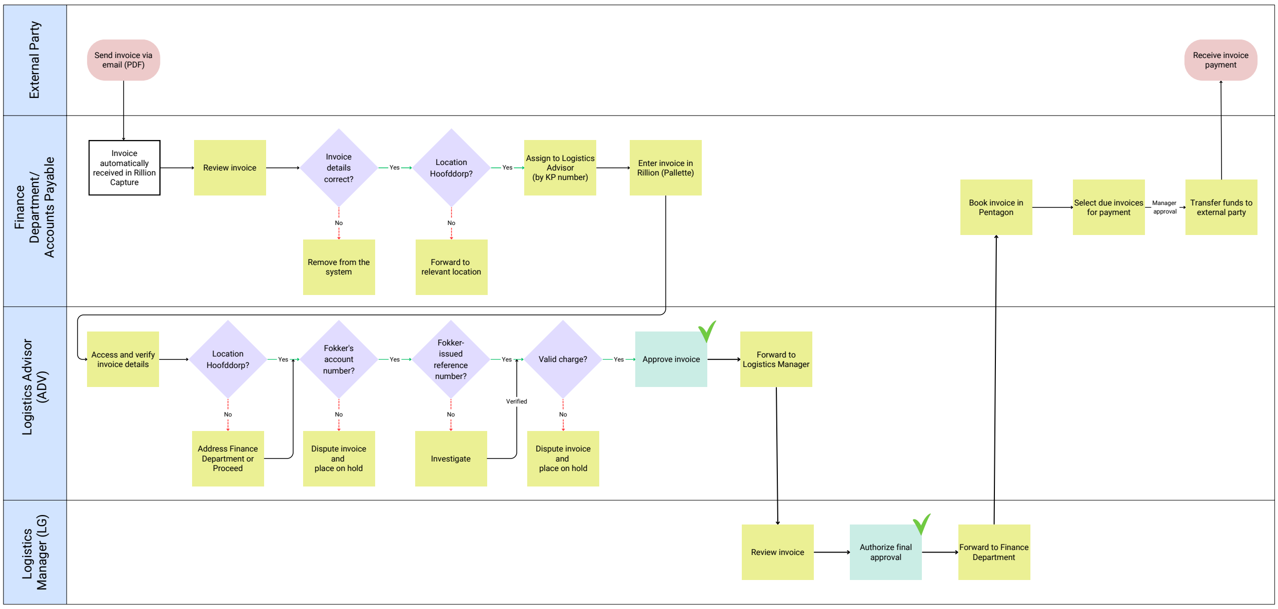

Figure 2: Current Workflow for Transport Cost Verification

At the core of this process, as reflected in the lanes of the diagram, there are four primary actors involved in the current invoice verification process:

- **External Party:** This refers to the logistics service providers (e.g., freight forwarders, carriers) who initiate the process by submitting invoices, typically in PDF (Portable Document Format), to a centralized intake point. Their role is to ensure that billing is issued in accordance with contractual agreements and service deliveries.
- **Finance Department (Accounts Payable):** This unit is responsible for managing the initial intake and administrative handling of incoming invoices. They classify and route the invoices through the appropriate workflow, ensure proper documentation, and oversee the final payment execution upon approval.
- **Logistics Advisor (ADV):** Representing the logistics function, this role focuses on validating the content of each invoice against operational records. Responsibilities include checking shipment details, verifying charge legitimacy, and identifying any discrepancies or exceptions that may require clarification or further investigation.
- **Logistics Manager (LG):** Acting as the final checkpoint in the approval chain, this actor is tasked with reviewing the invoice assessments and ensuring their accuracy and completeness. Upon their approval, the invoice is cleared for financial processing and payment.

Within this collaborative framework, each actor plays a distinct role in the overall workflow. The External Party initiates the process by emailing a freight invoice, typically in PDF format, to a designated intake address. Each operational site or location within the company has its own unique invoice submission email, ensuring that invoices are directed to the correct administrative flow.

Once received, the invoice is automatically ingested into Rillion, a cloud-based accounts payable automation platform. The platform was previously known as Palette. Rillion plays a central role in streamlining and automating the invoice management process, encompassing data capture, approvals, and payment execution. Using optical character recognition (OCR) and intelligent data extraction, the platform scans the PDF to detect and pre-fill key invoice fields, including invoice number, date, vendor name, billing address, VAT (Value Added Tax) and total amounts. By automating this initial capture and routing process, Rillion reduces manual data entry, speeds up invoice cycle times, and enables real-time tracking across departments.

After Rillion has completed the digital capture, the workflow transitions to manual verification. At this point, the Finance Department begins by reviewing the automatically extracted invoice fields to ensure structural completeness and correctness. This includes verifying that key elements, such as the invoice number, date, vendor name, reference codes, and total amount, are present and accurately captured by the Rillion system during the OCR-based intake. If any of this core information is missing or appears inaccurate, the invoice is removed from the system to prevent incorrect processing.

Invoices that pass this validation check are then assessed to determine whether they pertain to the Hoofddorp logistics site. This is a critical sorting decision, as Fokker S.G. operates across multiple locations, each with distinct administrative routing requirements. If the invoice is not associated with Hoofddorp, it is digitally forwarded to the relevant site for localized processing.

If the invoice is relevant to Hoofddorp operations, the Finance team assigns it to the appropriate cost center using an internal “KP number” (short for *Kostenplaats* in Dutch), a departmental or staff-specific reference code. In the case of freight-related invoices, they are further routed to the responsible Logistics Advisor for operational follow-up.

At this stage, the Logistics Advisor accesses the invoice in Rillion and performs a detailed verification. This review includes the following sequence of checks:

- **Location verification:** The first check confirms whether the invoice is correctly routed to the Hoofddorp site. If it has been misassigned, either fully or partially, the advisor may escalate it back to Finance for reassignment. However, in cases where only a minor portion pertains to another location, the advisor may proceed with verification to avoid unnecessary delays.
- **Account number check:** The advisor then reviews the customer account number listed on the invoice to confirm that it corresponds to a valid Fokker S.G. account. If the number is incorrect or unrecognized, the invoice is placed on hold and disputed.
- **Reference number validation:** A key component of the review is checking for the presence and validity of Fokker-issued internal references, such as purchase order numbers, pick ticket identifiers, or consolidator references. These identifiers follow a recognizable logic and structure and are examined alongside the shipper and recipient details for verification. If a reference number is missing, malformed, or not immediately recognizable, the advisor pauses the process for further investigation, which may involve consulting internal shipment records or reviewing information in the external party’s online portal.
- **Charge assessment:** The advisor assesses the legitimacy of the charges listed on the invoice. This step focuses on ensuring that charges appear reasonable and correspond to routine, recurring services. Standard invoices are typically approved quickly, while those with unusually high costs or unclear justifications prompt a closer review. If charges appear inflated or cannot be reconciled with operational expectations, the invoice is disputed and placed on hold for further clarification.

If the invoice passes all of these checks, the Logistics Advisor issues the initial approval in Rillion, allowing the invoice to progress to the final review stage. From here, the Logistics Manager (LG) assumes responsibility for conducting a second-level check. This review is more strategic in nature, focusing on confirming the consistency and completeness of the advisor’s assessment. The manager’s role is to provide final sign-off from a supervisory perspective, acting as the last line of control before financial execution. If everything appears in order, the Logistics Manager approves the invoice within Rillion, which triggers the final step in the workflow.

With both operational approvals in place, the invoice returns to the Finance Department for payment execution. In this final stage, the department begins by booking the invoice in Pentagon, Fokker S.G.'s enterprise resource planning (ERP) system. Once recorded, they identify and schedule invoices for payment in accordance with due dates, ensuring timely financial execution and compliance with contractual obligations. Following managerial approval, funds are transferred to the external party. After the payment is completed, the transaction is finalized and logged within the accounting system, effectively closing the verification and settlement process.

As noted earlier, reference numbers that cannot be immediately verified require additional scrutiny, prompting the advisor to conduct an investigative review, as outlined in the flow depicted in Figure 3. This investigative step is essential to determine whether the invoiced service was actually rendered and whether the associated charge is legitimate. In doing so, the Logistics advisor aims to eliminate ambiguities, confirm service delivery, and safeguard against erroneous payments. The verification procedure branches into two distinct paths depending on whether the shipment is inbound or outbound, while also incorporating a series of common verification checks shared across both flows.

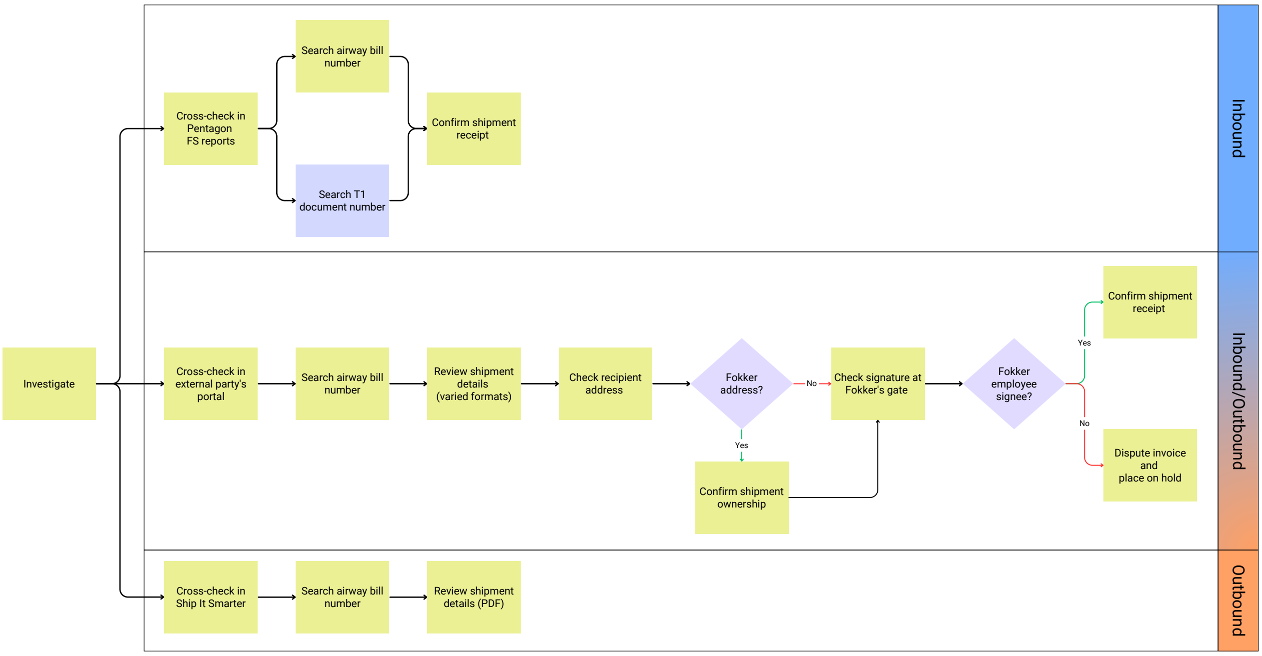

Figure 3: Investigative Review Workflow

To validate inbound shipments, the Logistics advisor first consults FS Reports, a business intelligence tool populated with operational data extracted from Pentagon. These reports are updated twice daily and provide near-real-time visibility into warehouse activities, including receipt confirmations. Within FS Reports, the Logistics advisor can search for the shipment using the air waybill (AWB) number or, where applicable, the T1 transit document. A successful match indicates that the shipment has been received, thereby confirming the invoice's legitimacy. Conversely, if no corresponding entry is found, it typically suggests the shipment was not received. However, in rare cases, the shipment may physically be at the inbound dock but not yet registered in Pentagon, for instance, if there are issues such as an unapproved vendor that prevent the creation of a warehouse receipt. In such exceptions, the advisor may delay the decision until additional documentation or system updates confirm the shipment's receipt.

In cases requiring more thorough validation, such as when FS Reports yield inconclusive or no results, or when charges are unclear or disputed, the Logistics advisor may also consult the external logistics provider's online portal. By inputing the AWB number, the advisor can access detailed shipment records in various formats, including PDFs or Excel files, which typically include tracking updates, recipient information, and proof of delivery. A key part of this review involves checking the delivery address. If it matches a Fokker S.G. facility, this adds credibility to the invoice. If doubts persist, the Logistics advisor may examine the signature recorded at the company's gate. If the signee is confirmed to be a Fokker S.G. employee, the shipment is verified as received. If not, the invoice is placed on hold and formally disputed.

The same verification principle applies to outbound shipments, which the Logistics Advisor can validate using ShipItSmarter, a transport management platform that interfaces with both Pentagon and external logistics providers. For major express couriers, ShipItSmarter provides full tracking functionality by generating and linking AWB numbers to live tracking data. This enables the advisor to review timestamps, delivery status, and shipping routes, mirroring the capabilities available in the carrier's native tracking portal. For smaller forwarders or regional couriers, ShipItSmarter primarily facilitates shipment initiation by relaying transport instructions via email rather than providing full tracking capabilities. In these cases, the tool allows the advisor to confirm that Fokker S.G. has issued proper shipping instructions, although further validation may still require access to the forwarder's own portal or communication with the carrier.

4.4 Emerging Inefficiencies in the Current-State Process

As the current-state analysis unfolds, drawing from both qualitative observations and visual workflow mapping, a more nuanced picture begins to emerge. On the surface, the process for handling freight invoices appears stable, structured, and partially digitized. Yet beneath this operational routine are several inefficiencies that, while not immediately visible, consistently challenge the system's effectiveness.

Crucially, invoice verification remains heavily manual. Logistics advisors are expected to perform multiple checks across documents and systems, often under time pressure, without adequate digital support. In practice, this involves reviewing invoices that follow inconsistent layouts, which vary significantly between vendors. The most demanding cases involve multi-page invoices, often exceeding 60 pages, with each page containing numerous sub-charges tied to individual shipments. On average, the company receives four such invoices every month. While this may seem limited in number, their complexity and length demand a disproportionate amount of time and attention. These documents require meticulous, line-by-line validation, and if this were to be carried out in full detail, it would stretch over several hours per invoice. Under such conditions, comprehensive validation becomes nearly unmanageable. Without structured data formats or automated parsing tools, the verification of these invoices becomes a time-consuming and error-prone task that significantly disrupts workflow and contributes to processing delays.

More fundamentally, advisors have no structured or systematic method to determine whether the company is contractually obligated to pay a given invoice. While checking whether the invoice is addressed to Fokker S.G.'s account number serves as an initial filter, this is not a sufficient safeguard. The account number may be correct, but the transport cost may still fall under the liability of a third party depending on the agreed Incoterms. This aspect is not validated or supported by the current workflow and there is no mechanism in place to confirm who is financially responsible for the transport service in question.

Moreover, even when advisors attempt to verify the legitimacy of individual invoice lines, they often face incomplete or unstructured reference data. Internal shipment identifiers, such as purchase orders or consolidator codes, may be absent, incorrectly formatted, or not recognized by the system, making it difficult or impossible to match an invoice to a corresponding shipment. To bridge this gap, advisors must manually search across multiple disconnected systems, including Pentagon (ERP), FS Reports, ShipItSmarter, and carrier portals. The lack of integration between these platforms means that information must be retrieved and cross-checked manually for each case. This step alone can consume considerable time, turning what should be a straightforward validation into a repetitive and resource-draining task.

This lack of shipment-to-invoice traceability is further exacerbated by the absence of systematic checks on key parameters. Service level, weight, and dimensions cannot be easily validated because this data is not centrally available. While invoices may contain these values, there is no automated comparison against logistics records or rate agreements. Similarly, there is no tool-based support to check if the applied rates comply with the contracted tariff sheets. As a result, rate validation is either skipped or handled based on precedent and approximation.

Instead of structured controls, the process relies on advisors' familiarity with vendor names, account numbers, charge types, and exception patterns. This knowledge is tacit and difficult to transfer, as it is largely built through years of experience. Grasping the rationale behind the validation process typically requires this depth of contextual understanding, making it difficult to replicate without such tenure.

Ultimately, advisors may approve charges blindly without fully verifying the underlying details. They often cannot determine whether the invoice is correctly addressed, whether the shipment actually occurred, or whether the rates applied are accurate. Despite their best efforts and professional diligence, they operate in an environment where critical information is fragmented or inaccessible. Lacking the necessary tools and visibility, they are unable to reliably assess the validity of transport charges. This exposes the organization to financial risk, particularly in complex logistics scenarios where accountability is diffuse.

These issues are not dramatic breakdowns. Rather, they are subtle process frictions that complicate routine tasks, delay decisions, and increase reliance on tacit knowledge. While each issue may seem manageable on its own, together they limit scalability, reduce consistency, and undermine financial control. Table 5 outlines the identified key inefficiencies, linking each to specific elements of the process analysis and explaining why it presents a risk to sustainable and accountable transport cost management.

Inefficiency	Description	Operational Implications	Analytical Link
Manual Intervention in Core Steps	Rillion supports initial intake, but verification steps depend heavily on human actions.	Increased workload, delays, inconsistency, and error risk. Limited scalability and resilience.	*Swimlane diagram Fig. 2:* Multiple hand-offs and decision points require manual judgment without automation support.
Ambiguous Invoice Ownership Criteria	Current controls do not explicitly confirm contractual liability under the applicable Incoterms.	Legal and financial exposure. Risk of paying non-obligated invoices. Undermined compliance and cost accountability.	*Swimlane diagram Fig. 2:* Logistics Advisor's Decision Point 2 ("Fokker's account number") fails to verify liability beyond static identifiers.
Fragmentation of Supporting Data Sources	Validation data is dispersed across internal and external systems, requiring cross-platform searching.	Reduced visibility, slower investigations, increased dependency on tacit knowledge. Impaired decision-making reliability and timeliness.	*Investigative Workflow Fig. 3:* Disconnected tools and reliance on individual initiative to retrieve data.
Subjective Charge Assessment Practices	Charge validation is based on individual experience rather than automated, rule-based validation.	Inconsistency, reduced auditability, and increased error probability. No structured mechanism to enforce rate compliance or contractual terms.	*Swimlane Diagram Fig. 2:* Logistics Advisor's Decision Point 4 ("Valid charge") lacks data-driven support for rate verification.
Absence of Formal Exception Handling Protocol	Non-standard or ambiguous invoices are treated ad hoc, with unclear rules for escalation or resolution.	Process inconsistency and rework, silent acceptance of non-compliant charges, delayed resolution.	*Swimlane Diagram Fig. 2:* No defined path for unresolved or unclear cases. Workflow ends without fallback logic
Rigid and Linear Process Architecture	The verification process is sequential, dependent on role-based approvals, and lacks real-time feedback loops or process integration.	Bottlenecks, limited parallelization or automation, reduced responsiveness, low process adaptability.	*Swimlane diagram Fig. 2 & Investigative Workflow Fig. 3:* Unidirectional flow with no digital connectivity or automated triggers across steps.

Table 5: Key Inefficiencies in the Invoice Verification Process

4.5 Quantitative Overview of the Invoice Lifecycle

To complement the qualitative findings, a quantitative analysis was performed to provide a broader, data-driven perspective on invoice processing activities. As outlined in the methodology, this analysis focused on a refined dataset of 2,199 freight-related invoices sourced from the company's accounts payable platform. These records covered the period from January 2024 through the second quarter of 2025 and collectively represented a total net invoice value of approximately € 4.14 million. The primary objective of this analysis was to identify high-level patterns in workload distribution and assess the efficiency of current invoice processing workflows.

Distribution of Invoice Load by Status

To establish a foundational understanding of the invoice processing landscape, invoices were classified according to their status in Rillion: "Active", "Recorded", and "Canceled". Figure 4 offers a comprehensive breakdown of these statuses, presenting both the number of invoices and their corresponding net values.

"Active" invoices referred to entries that were still pending approval at the time of data extraction, indicating in-progress workflows where financial obligations had yet to be confirmed. Notably, the vast majority of these active invoices originated in 2025, corresponding to invoices that had been recently received but not yet processed. While this recency explains most of the volume, a closer examination revealed several invoices from Q1 2025 that had yet to be resolved, along with three persistent cases dating back to 2024. These long-standing approvals raise concerns about process delays and unresolved exceptions.

"Recorded" invoices comprised the largest share of the dataset, with 1,888 entries totaling approximately €3.83 million. These invoices had been booked into the ERP system, Pentagon, reflecting a more advanced stage in the workflow where financial processing is authorized. Although “Recorded” status does not confirm that payments have been executed, it does suggest that the invoices are ready for payment and likely to have been settled, especially considering the 18-month span of the dataset. This segment of the data underscores the operational scale of the invoice verification effort and reveals a sustained volume of transport-related invoicing across both 2024 and early 2025.

"Canceled" invoices accounted for a minor portion of the dataset and predominantly consisted of credit notes that had been manually booked in the ERP system, along with invoices that were manually entered and subsequently settled using credit notes. This processing method explains the occurrence of negative invoice values within the 2024 data, as these entries reflect credit adjustments rather than new liabilities. The presence of such exceptions underscores the complexity of managing non-standard financial workflows and highlights the need for robust administrative controls.

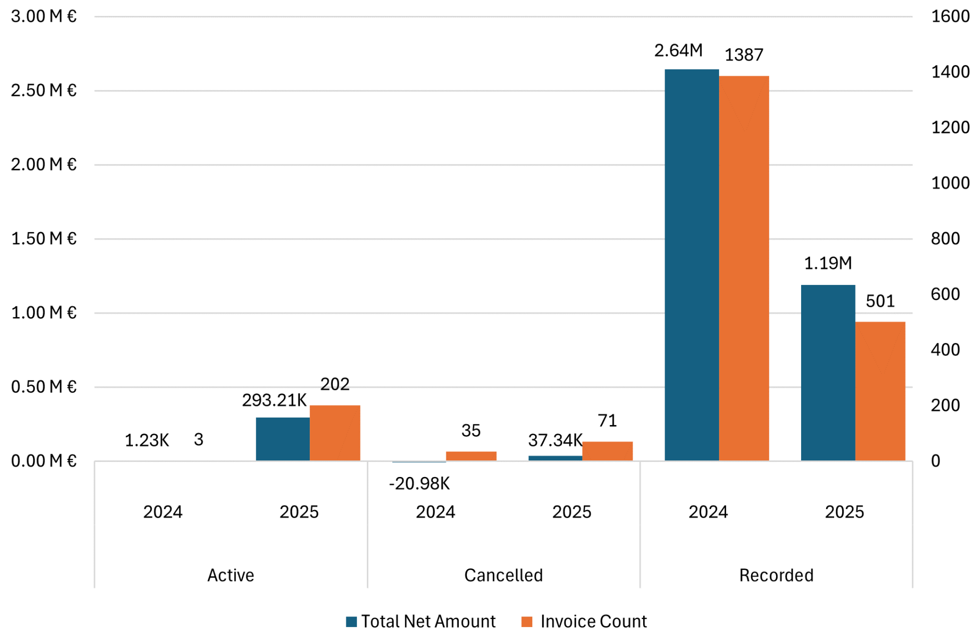

Figure 4: Invoice Summary by Status (2024-Mid 2025)

Invoice Intake Patterns

To further contextualize the operational workload, invoice intake patterns were examined at three temporal resolutions: daily, weekly, and monthly. The results, visualized in Figure 5 through a series of box plots, highlight both the intensity and variability of the volume of incoming invoices.

At the daily level, the company received an average of 6 invoices per day, with intake ranging from as few as 1 to a peak of 28 invoices on the busiest day. The interquartile spread was relatively narrow, indicating a consistent but moderate daily workload under typical conditions.

On a weekly basis, the average intake increased to 28 invoices per week, with the most active week reaching 53 invoices. This level of analysis revealed moderate variability, with most weeks falling within the 25 to 35 range and occasional surges reflecting uneven demand.

On the monthly scale, the company received an average of 122 invoices per month, with totals ranging from 96 to 159 invoices. Compared to daily and weekly patterns, monthly intake showed greater variability, reflecting more substantial shifts in workload from one month to the next.

Overall, these intake trends confirm that Fokker S.G. handles a consistently high volume of transport invoices. Visual analysis reveals regularity in the core processing load, as well as outlier periods where workload spikes may place additional pressure on verification resources.

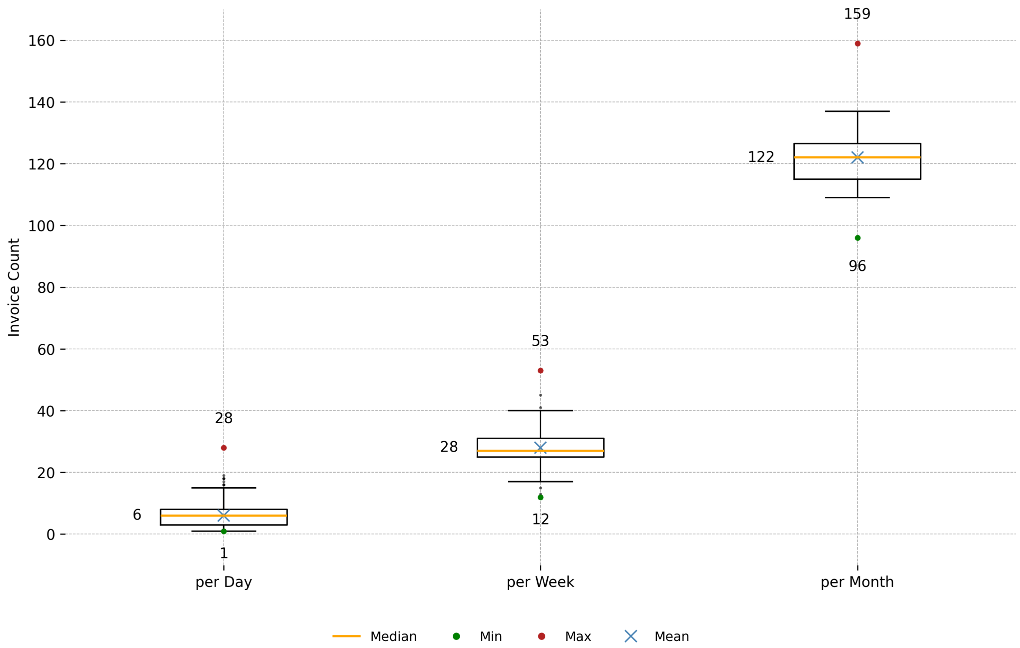

Figure 5: Invoice Intake Patterns (2024-Mid 2025)

To capture broader temporal patterns, invoice volumes and values were aggregated by quarter, as illustrated in Figure 6. The data reveal a generally upward trend in both the number of invoices and their total net value throughout the reporting period. In particular, Q4 2024 marked the highest total net invoice value at approximately € 801K, suggesting a seasonal or operational peak. Although the invoice count remained relatively stable across most quarters, both Q1 and Q2 of 2025 recorded approximately 390 invoices, indicating a modest increase in early 2025. These trends indicate sustained and possibly growing transport activity, reinforcing the need for efficient and scalable invoice processing workflows.

Figure 6: Quarterly Invoice Trends (2024-Mid 2025)

To gain insight into how invoice activity is distributed across transport partners, a vendor-level analysis was conducted, focusing on the top five transport vendors from a pool of 18, as shown in Figure 7. Vendor 1, representing a global express courier, stands out significantly by accounting for the majority of the total net invoice value, approximately € 3.3 million, across 560 invoices. In contrast, Vendor 4, also a major international provider, processed a similar number of invoices at 537, but with a much lower total value of € 174K, indicating a substantially lower average invoice amount. This contrast suggests differences in service types, pricing models, or shipment profiles. The remaining vendors reflect a mix of regional and specialized transport partners, with varying invoice volumes and values.

These findings underscore the operational dominance of global express providers in terms of financial impact and highlight the diversity of the company's transport network. This insight can guide targeted automation efforts by prioritizing high-volume, high-value vendors such as Vendor 1, where optimization would deliver the greatest efficiency gains.

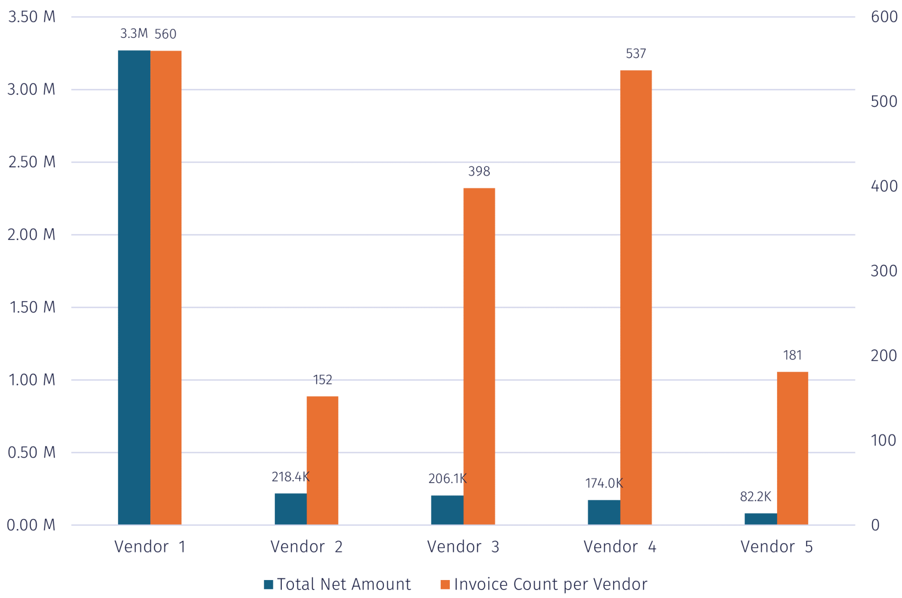

Figure 7: Invoice Activity & Value Distribution Among Key Transport Vendors (2024-Mid2025)

Time-Based Performance Metrics in the Invoicing Lifecycle

To assess the efficiency and timing of invoice processing within Fokker S.G., three key performance metrics were analyzed across the same data set: Invoice Transmission Gap, Payment Window, and Payment Lead Time. These time gaps, previously defined in the methodology, represent distinct stages in the end-to-end invoice life cycle and offer a granular view of operational performance. The performance of each stage is illustrated in Figure 8, where box plots highlight the timing patterns and deviations observed in the data set.

The Invoice Transmission Gap averaged 4 days, indicating that invoices were typically entered into the accounting system shortly after issuance. The box plot for this metric showed a tightly clustered distribution, with the box and whiskers compressed near the lower end of the scale. This suggests that most cases involved short transmission gaps. However, a small number of extreme cases extended up to 264 days, pointing to occasional delays that may stem from exceptional circumstances or administrative bottlenecks.

A similar pattern was observed in the Payment Window, which had an average of –25 days, indicating that invoices were typically entered well before their contractual due dates. This early entry provides a buffer for internal processing and approval. Nonetheless, the wide range, extending up to 234 days, points to inconsistencies in due date alignment, possibly influenced by varying contract terms or supplier practices.

Within this metric, 119 invoices were flagged as overdue cases, where the accounting entry occurred after the due date. These cases had an average delay of 22 days, with some reaching up to 234 days past the deadline. Interestingly, the median delay was notably lower than the average, suggesting that most overdue cases were resolved relatively quickly. All instances were triggered by late accounting entries, highlighting a specific area where process discipline could be strengthened to avoid missed payment windows.

The Payment Lead Time was calculated based on a total of 1,924 invoices, excluding 275 that were either unpaid at the time of analysis or classified as credit notes. The distribution for this metric was noticeably wider than the others, indicating greater variability in processing times. On average, payments were executed 52 days after entry. This broader spread may reflect delays stemming from late accounting entries, extended approval cycles, or administrative lags in finalizing payments. The longest recorded lead time reached 306 days, underscoring the presence of long-tail exceptions that could impact supplier relationships and cash flow predictability.

Overall, the visual and statistical analysis of these metrics indicates a generally stable invoicing process, with most transactions processed in a timely manner. However, the presence of outliers, particularly in overdue cases and payment lead times, indicates that performance could be further improved by enhancing consistency and strengthening process controls.

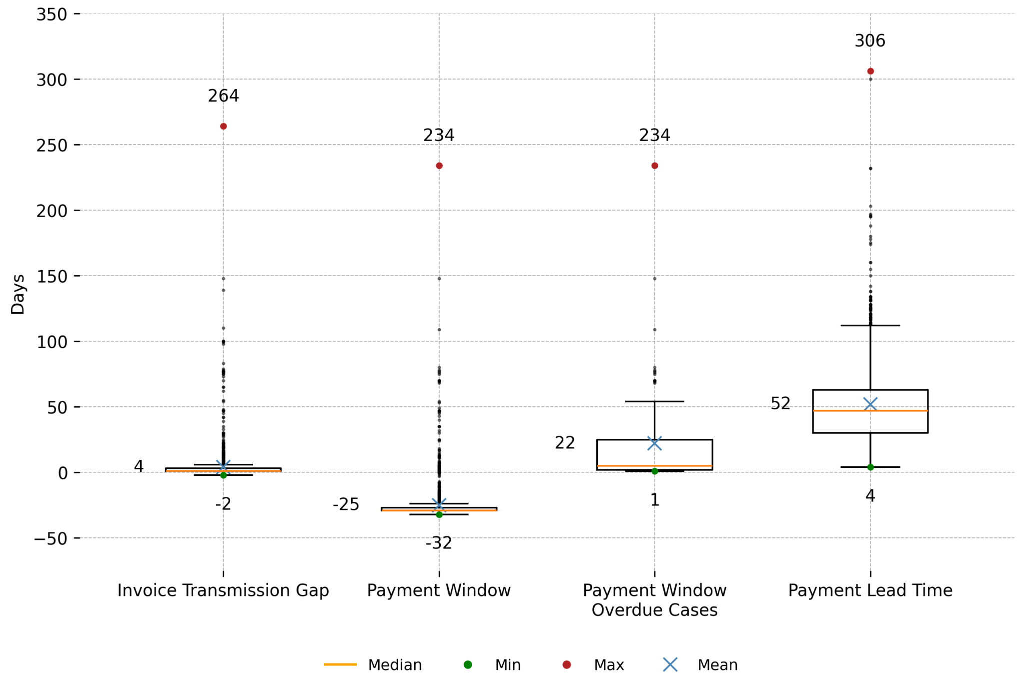

Figure 8: Time-Based Performance Metrics in the Invoicing Lifecycle (2024-Mid 2025)

Timeline Analysis of Invoice Processing Durations

The timeline analysis, based on a sample of 33 fully processed invoices, revealed notable variability in processing durations across the three main stages of the invoice lifecycle: Invoice Transmission Gap, Internal Processing Time, and Payment Execution Time. As shown in Figure 9, each invoice was broken down into these intervals, previously defined in the methodology, to enable a detailed comparison of timing patterns across the end-to-end process.

Across the sample, all three stages exhibited delays to varying degrees. The Invoice Transmission Gap showed the most extreme outliers, with some cases experiencing very long delays between issuance and accounting entry. However, such extreme delays were relatively infrequent. In contrast, Internal Processing Time consistently accounted for a substantial portion of the total cycle time in nearly all cases, suggesting that internal workflows and approval processes are a common source of delay. Payment Execution Time, while still variable, generally showed shorter durations and fewer significant delays compared to the other two stages.

These findings suggest that, while delays can occur at any point in the invoice lifecycle, the internal processing phase tends to contribute most consistently to overall cycle time. This pattern indicates that internal workflows may play a central role in shaping the pace of invoice completion, whereas delays in transmission or payment execution appear more sporadic and case-specific.

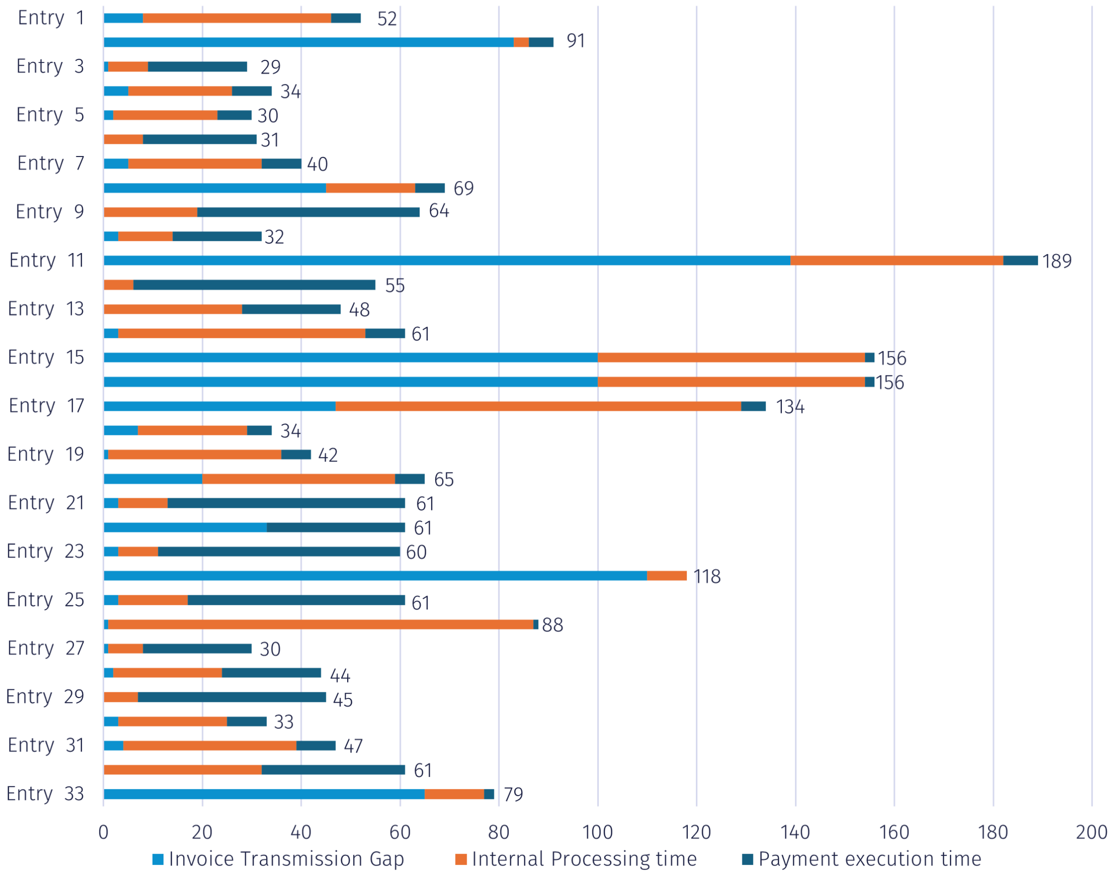

Figure 9: Invoice Lifecycle Timeline

4.6 Systemic Challenges in Transport Cost Verification

The inefficiencies highlighted in the preceding section appear in day-to-day operations, yet they are neither isolated disruptions nor random breakdowns. Instead, they point to more foundational weaknesses embedded in the design and governance of the current transport cost verification process at Fokker S.G. Beneath the surface of a structured and semi-digitized workflow lies a complex set of systemic constraints that hinder accuracy, timeliness, and resource efficiency. These are not merely procedural hiccups, but recurring signals of a process architecture lacking scalability, consistency, and built-in resilience.

Drawing on the results of process mapping, stakeholder interviews, and supporting documentation, this section classifies these constraints into key diagnostic categories. Each reflects a root-level issue that either amplifies operational friction or undermines control in critical stages of the invoice lifecycle.

Manual Processing and Invoice Volume

A core constraint in the current setup is the continued reliance on manual processing within an environment characterized by a high and variable volume of incoming invoices. Fokker S.G. receives a substantial number of freight invoices from various logistics service providers, many of which contain multiple line items and span several pages, with some extending to 60, 75, or even over 110 pages in length. Quantitative analysis confirms the sustained processing demand. Between 2024 and mid-2025, the company received an average of 122 invoices per month, with peak periods reaching up to 159. On the busiest days, intake reached 28 invoices, underscoring the need for scalable solutions.

Despite the use of an accounts payable automation system that supports data capture during initial intake, subsequent validation steps still require significant manual intervention. This heavy dependence on human input makes the process labor-intensive, time-consuming, and prone to human error, particularly under time pressure, during staff absences, or when handling bulk invoice batches. The cumulative effect is a verification process that struggles to scale efficiently, leaving room for both processing delays and financial discrepancies. In a high-volume environment, this manual dependency becomes a structural bottleneck that limits throughput and increases operational risk.

Ambiguity in Invoice Ownership Determination

These operational burdens set the stage for deeper challenges found within each key verification checkpoint, beginning with determining invoice ownership. A fundamental step in invoice processing involves establishing whether the invoice was correctly issued to Fokker S.G. and whether the company is financially responsible. Although the current workflow includes checks on the destination location and account number, these controls are not sufficiently comprehensive. The process currently does not validate whether Fokker S.G. is contractually obligated to pay based on the agreed Incoterms, nor does it verify the role of the supplier or customer involved. This results in missed checks on whether Fokker S.G. was the intended payer, particularly in transactions involving complex third-party logistics arrangements.

While it is technically feasible to automate basic controls, such as rerouting invoices not linked to the company's location or rejecting those with unrecognized account numbers, the deeper verification of party roles and agreed Incoterms remains unsupported by the current tools. The operational impact of this gap is reflected in the data. Among the "Active" invoices pending approval at the time of extraction, several date back to early 2025, with three originating from 2024. This pattern contrasts with the average transmission gap of just four days, suggesting that delays may be less about entry timing and more about unresolved ownership and upstream validation challenges. These systemic gaps force advisors to rely on manual escalation, internal emails, or legacy agreements, introducing inconsistency and room for error.

Fragmented and Inaccessible Reference Data

Even after provisional confirmation of invoice ownership, the validation of reference numbers, which are critical to matching shipments with the corresponding invoice lines, is often impeded by fragmented data and insufficient system integration. In many cases, invoices lack valid or recognizable internally assigned reference numbers, such as purchase orders, consolidator references, or pick tickets. These identifiers may be missing, improperly formatted, or entirely unrecognized. To make matters more challenging, advisors cannot directly confirm whether a shipment occurred or matches Fokker S.G.'s records.

To verify the legitimacy of these invoice lines, logistics advisors must manually search across several disconnected systems, including the ERP platform (Pentagon), FS Reports, ShipItSmarter, and external carrier portals. These searches are typically conducted using alternative identifiers, such as the air waybill (AWB) number or, in some cases, the T1 document number. This fragmented environment results in non-standardized procedures, inconsistent interpretation of data, and substantial delays in resolving mismatches. Moreover, the lack of integration across systems, combined with inconsistent formats of supporting documents, such as PDFs or Excel sheets, further increases the risk of oversight and reduces process efficiency. The absence of a unified data source not only slows down verification but also undermines the reliability of financial control mechanisms.

These qualitative insights are reinforced by the quantitative analysis. In the timeline analysis of the invoice sample, Internal Processing Time consistently accounted for a substantial portion of the total invoice cycle in nearly all cases. This pattern suggests that delays are introduced more frequently during internal validation and approval than at earlier or later stages in the process. Additionally, the Payment Lead Time, averaging 52 days and reaching up to 306 days in some outlier cases, may underscore the operational strain introduced by fragmented reference data, manual verification steps, and the absence of streamlined validation mechanisms.

Subjective and Experience-Based Charge Assessment

Once reference numbers are traced and verified, the focus shifts to assessing the legitimacy of charges. In the absence of structured rules, this process leans heavily on subjective interpretation. As such, it largely depends on the individual experience of logistics advisors, with charges approved based on whether they appear "reasonable" or "recognizable," rather than by referencing standardized pricing rules or defined thresholds.

In practice, invoices listing multiple shipments are scanned for familiar shipper-recipient combinations, recurring patterns, or historically acceptable values. Only unusually high charges are subject to closer scrutiny, while smaller amounts are often approved by default. However, there is currently no automated or systematic way to verify whether the applied rate accurately reflects shipment characteristics, such as weight, dimensions, service level, and zone structure, or complies with contractual discounts and rate agreements.

This reliance on intuition and precedent, while pragmatic in high-volume environments, introduces inconsistency and exposes the company to risks of overpayment, billing errors, or missed opportunities for dispute and recovery. Without a data-driven validation mechanism, financial accuracy remains dependent on individual judgment rather than institutional safeguards.

Lack of Structured Exception Handling

While most invoices follow routine verification paths, those that deviate due to missing data or unclear terms reveal a deeper weakness in the process, namely the absence of structured exception handling protocols. These cases are handled on an ad hoc basis, with each advisor pursuing their own approach based on experience, availability of tools, or perceived urgency. This results in non-repeatable decision-making and inconsistent outcomes, which are difficult to audit or optimize.

Without a defined flow for handling exceptions, such as disputes over Incoterms, account mismatches, or unclear references, advisors rely heavily on manual communication to resolve issues. This slows down the process and limits the ability to scale verification practices across the organization. Moreover, the lack of escalation logic or documentation standards prevents the organization from learning from recurring exceptions or identifying systemic root causes.

Structural Risks Embedded in the Flow

Beyond case-by-case inconsistencies, the overall process architecture reinforces these challenges, relying on linear approvals and limited system connectivity. From a process design perspective, the current workflow appears logical when represented in a swimlane diagram. However, it is structured around a sequential human-driven approval chain, where invoices must be reviewed by multiple stakeholders before payment is authorized. This design makes the process vulnerable to bottlenecks when any one party is unavailable, overloaded, or constrained by limited system visibility.

Given the high volume of invoices and the complexity of certain documents, even well-trained personnel may overlook exceptions or make mistakes under pressure. The lack of parallel processing or system-driven escalation mechanisms means that the process cannot adapt dynamically to workload fluctuations or exception cases. In light of this, the process is not inherently flawed but lacks the safeguards and automation needed to ensure reliable, repeatable outcomes at scale.

Together, these diagnostic findings suggest that the current transport cost verification process is constrained not by the absence of effort but by the absence of system-level support. Manual effort and experience can mask inefficiencies, but they cannot sustainably resolve them. Addressing these structural limitations is essential for improving financial accuracy, operational resilience, and long-term scalability.

5 Evaluation of Automation Strategies

Building on the insights from the current-state assessment in Section 4, this section evaluates the automation strategies identified as potential enablers of the redesigned transport invoice verification process. The analysis is organized into three sequential components. In Section 5.1.1, the focus is on outlining the fundamental concepts, operational scope, and relevance of each automation approach within the context of transport invoice verification. Section 5.2, examines their strengths, limitations, and contextual fit against the predefined evaluation criteria, synthesizing findings from the literature, stakeholders' insights, and process observations. Finally, Section 5.3, applies a weighted multi-criteria decision-making framework to translate qualitative judgments into numerical performance scores, enabling a data-driven comparison and overall ranking of the candidate strategies. Together, these stages provide both a detailed understanding and an evidence-based comparison of the available automation options.

5.1 Overview of Candidate Strategies

To support the redesigned workflow for transport invoice verification, this study identified and evaluated three distinct automation strategies, each offering unique strengths and operational characteristics. The selected approaches were chosen to reflect a spectrum of technological maturity and applicability. Together, they provide a comprehensive foundation for assessing automation potential, ranging from deterministic logic-based systems to AI-driven document handling and integrated data exchange models. Each strategy is outlined below, providing the basis for a comparative assessment of their suitability within the case context, as discussed in Sections 5.2 and 5.3.

5.1.1 Rule-Based Automation

Rule-based automation refers to a class of systems that apply predefined logic and structured workflows to perform repetitive tasks in a consistent and deterministic manner. These systems encode domain knowledge into a series of if-then statements grounded in Boolean operations, enabling information extraction or decision making based on fixed, explicitly defined conditions. Often considered a foundational form of artificial intelligence, sometimes called symbolic AI or expert systems, rule-based approaches aim to replicate human reasoning within narrowly defined problem areas. Rather than storing knowledge as static truths, they operationalize it through dynamic rules that dictate actions or inferences depending on the context. [13] [43]

Rule-based automation solutions play a vital role across a range of industries, including Banking, Financial Services, and Insurance (BFSI), healthcare administration, telecommunications, manufacturing, and shared services. [25] These systems are widely used to enforce business rules, validate structured inputs, and drive consistent decision-making across high-volume, repeatable processes. Their primary strength lies in environments where data inputs follow standardized formats and predictable schemas, allowing them to operate with exceptional speed and reliability. By automating routine tasks with minimal human intervention, these systems enhance workflow efficiency, support consistent document processing, and deliver dependable performance in structured operational settings. [60]

Within the scope of transport invoice verification, rule-based automation offers a structured and transparent solution for handling standardized, recurring validation tasks. These systems are particularly effective when invoice formats follow consistent templates, enabling the application of predefined business logic to streamline document processing and support accurate decision-making. Their appeal lies in their stability, ease of implementation, and low infrastructure requirements, making them especially suitable for organizations seeking predictable results without the complexity or cost of AI-based solutions. By reinforcing process consistency and reducing manual workload, rule-based automation supports scalable, audit-ready operations in structured logistics environments.

In practice, rule-based automation operates through a structured pipeline that begins with a defined trigger, such as the receipt of a new invoice file or an email containing an invoice attachment. These systems work best with digital invoice files in standardized formats, such as PDF, XML, or Excel. Rather than relying on probabilistic models, rule-based solutions apply a fixed set of predefined logic rules to parse, validate, and interpret the document content. The processing logic is explicitly encoded through conditional statements that enforce consistency with business rules and contractual criteria. Document validation tasks are executed in a deterministic manner, ensuring predictable and auditable outcomes when input formats are stable. Although these systems do not adapt to changing formats, their reliability and transparency make them well-suited to environments where invoice structures are controlled. Once validation is complete, the extracted and verified data are passed on to downstream systems, such as ERP or financial management platforms, for further processing or archival.

5.1.2 Hybrid Structured Automation

Hybrid Structured Automation refers to a blended approach that combines structured data exchange from vendors that have the digital maturity to deliver machine-readable invoice files with internal rule-based validation mechanisms. These systems are typically offered by large logistics providers or financial service platforms as part of their digital customer interface, allowing clients to consolidate invoice access, download billing data, manage multiple accounts, and initiate payment or dispute processes in one unified environment. Where supported, structured invoice files are obtained directly from service providers via web-based portals, often alongside other formats such as PDF. Rather than relying solely on document parsing technologies or fully integrated data exchange interfaces like EDI, this model leverages semi-structured data delivery (e.g., CSV, XML, or Excel) and applies deterministic business logic to process and verify invoices in a structured and auditable manner. As presented here, Hybrid Structured Automation is a conceptual model proposed in this study, integrating proven elements from structured data exchange and rule-based automation into a configuration suited to the case organization.

This hybrid approach is particularly well-suited for organizations operating in logistics and supply chain environments, where vendor digital maturity may vary widely. It enables a shift away from PDF-based invoices toward structured file formats, reducing the need for OCR or AI-based parsing. At the same time, it maintains internal control and consistency by applying rule-based validation logic, such as format checks, field matching, and reference lookups. This ensures that invoice data can be reliably processed without requiring full system-to-system integration or intensive AI deployment. In doing so, it acts as a bridge between document-based processing and fully integrated EDI systems, offering a practical solution in environments where vendors are not yet EDI-ready but can still produce consistent and downloadable digital outputs.

As it pertains to transport invoice verification, hybrid structured automation serves as a transitional solution by offering structured data access from external providers and enabling companies to process and validate that data internally using rule-based logic. By shifting the data extraction burden upstream, these systems reduce manual effort and improve the consistency of inputs, while still retaining flexibility in how the information is handled once received. This approach enables a more modular and adaptive architecture, where downstream validation workflows can evolve independently of upstream document formatting.

Conceptually, hybrid structured automation begins with the retrieval of machine-readable invoice files from a vendor's digital platform, typically via secure login to a web portal or through automated scheduled downloads.

These files, commonly in CSV, XML, or Excel format, are ingested directly into the organization's processing environment, bypassing the need for OCR or layout parsing. Once received, the data is subjected to predefined rule-based validation checks, such as verifying mandatory fields, matching shipment and reference numbers, and confirming agreed rates or charge codes. Validation is performed deterministically, ensuring consistent and auditable outcomes when vendor data is stable and reliable. Following successful validation, the structured data is transferred to downstream systems such as ERP or financial management platforms for posting, payment scheduling, or archival, while flagged discrepancies are routed to human operators for resolution.

5.1.3 Intelligent Document Processing

Intelligent Document Processing (IDP) platforms are advanced systems that leverage artificial intelligence technologies to automatically extract, classify, and convert data from unstructured or semi-structured documents into structured, actionable information. Such systems typically incorporate technologies such as Machine Learning (ML), Natural Language Processing (NLP), Computer Vision (CV), Optical Character Recognition (OCR), and Robotic Process Automation (RPA). These platforms are capable of processing a wide range of document formats, including PDFs, scanned images, and text files. By automating repetitive tasks and minimizing manual errors, they help organizations streamline document processing workflows, enhance operational efficiency, and boost overall productivity.

IDP solutions are gaining significant traction across various industries, including Banking, Financial Services, and Insurance (BFSI), government, healthcare and life sciences, retail and e-commerce, manufacturing, and notably transportation and logistics, where they streamline document-intensive workflows, enhance compliance, and accelerate operational processes. The surge in demand for automation, particularly within the SaaS sector, is a key driver of the global expansion of the IDP market. As organizations increasingly seek scalable, cloud-based solutions to manage growing volumes of data, IDP platforms represent a critical shift toward intelligent automation in document-heavy environments, offering substantial cost savings, improved accuracy, and more efficient resource allocation. [29][44] [63] [5]

In the context of transport invoice verification, IDP platforms can be positioned as a middle-ground solution between rule-based automation and full data integration through APIs (Application Programming Interface) or EDI (Electronic Data Interchange). They offer the ability to handle high volumes of vendor invoices in varying formats, extract relevant data fields, and trigger verification workflows based on the extracted content. Some commercially available IDP platforms also provide out-of-the-box invoice models or connectors for ERP systems, further streamlining integration into the company's existing process landscape.

Functionally, the process begins with document ingestion, which involves either scanning physical documents or uploading digital files. Once ingested, OCR technology is applied to convert images or PDFs into machine-readable text, enabling further processing and analysis. Next, NLP and machine learning algorithms extract relevant information, classify document types, and validate data accuracy, often incorporating human-in-the-loop review for exceptions or corrections. This approach shifts the verification process from a document-centric model to a data-centric one, while still preserving a degree of flexibility for unstructured documents. The processed data are then integrated into downstream business systems for further action or storage. IDP systems are adaptable, learning from user feedback to continuously improve accuracy and handle evolving document formats, making them essential for organizations dealing with high volumes of paperwork and regulatory requirements. [35]

5.2 Comparative Qualitative Analysis

With the candidate strategies defined, the next step was to critically assess their practical value. This section presents a comparative evaluation grounded in a structured framework of seven criteria, as defined in the Methodolody (Section 3) and summarized in Table 4, each selected to reflect the intersection of technological capability, operational need, and organizational priority. Drawing from academic literature, real-world process observations, and stakeholder insights, the analysis highlights how each approach performs under the specific demands of the case context. The goal is not only to identify strengths and limitations, but also to understand how well each strategy aligns with the realities of implementation. The comparison proceeds criterion by criterion, offering a nuanced view of the strengths, limitations, and contextual fit of each strategy, with the results consolidated in Table 6.

Accuracy

Traditional rule-based systems perform best in controlled environments where invoice formats are standardized and well-defined. In such cases, logic-based validation and extraction rules can deliver high accuracy for documents that follow consistent and predictable structures. However, when formats deviate from expectations, such as when a vendor modifies the layout or introduces a new charge type, the automation may fail or yield incomplete results. [51]

On the other hand, IDP platforms provide moderate to high accuracy depending on several factors, such as the quality of the input documents, the sophistication of the underlying AI models, and the maturity of the solution. While modern IDP tools leverage machine learning to improve layout recognition and data extraction, initial performance may vary, especially for noisy, scanned, or poorly structured invoices. In such cases, human oversight remains essential, particularly during the system's learning phase, to guide corrections and help the model improve over time. [64] Moreover, recent findings suggest that if training data are heavily skewed toward a few common layouts, model performance may decline when processing invoices from less frequent suppliers. This highlights the need for balanced and representative training datasets to ensure consistent accuracy across all invoice types. [31] Overall, empirical evidence suggests that IDP systems consistently outperform traditional rule-based approaches in terms of accuracy. According to a study, IDP achieved approximately 98% accuracy in key field extraction, significantly higher than the 85% observed for traditional systems. [1]

Conceptually, Hybrid Structured Automation is expected to deliver high accuracy when processing invoices from vendors that provide stable, machine-readable formats such as CSV, XML, or Excel. By bypassing OCR and unstructured document parsing, it avoids common errors related to layout recognition and text extraction. Its embedded rule-based validation layer systematically flags issues such as missing mandatory fields, mismatched reference numbers, or invalid rates. While accuracy may match that of rule-based automation under controlled data conditions, it remains dependent on the quality and consistency of vendor-supplied files. When upstream data integrity is maintained, performance can approach near-perfect levels. However, inconsistencies in vendor output or formatting may directly affect results.

Flexibility

Rule-based automation is inherently less flexible, as it relies on predefined logic tailored to specific document formats. These systems are often brittle when faced with layout changes, ambiguous inputs, or unexpected data structures. Even minor variations in labeling or positioning can require manual rule adjustments, limiting their adaptability in dynamic environments with diverse invoice formats. [43]

In contrast, one of the defining strengths of IDP platforms is their ability to manage the wide variability of invoice formats encountered across vendors. Unlike traditional rule-based systems that depend on rigid templates, modern IDP solutions employ layout-agnostic models capable of interpreting and extracting data from a broad spectrum of document structures. This adaptability is especially valuable in logistics, where invoice designs often differ in layout, language, and file type. By leveraging technologies such as NLP, OCR, and transformer-based models, these systems can generalize across formats and continuously evolve, learning from new inputs without requiring manual reconfiguration. This flexibility not only minimizes human intervention but also ensures robustness in dynamic, high-volume environments where invoice templates frequently change. [58]

Hybrid Structured Automation offers moderate flexibility, positioned between the rigidity of rule-based automation and the adaptability of Intelligent Document Processing (IDP). Its reliance on structured file formats insulates it from most layout changes, though it remains dependent on vendors maintaining consistent data schemas. Minor structural adjustments can be accommodated through modest updates to validation rules, while significant schema changes require coordinated vendor alignment. Although it cannot interpret arbitrary unstructured formats, its ability to process multiple structured types, such as CSV, XML, and Excel, provides greater adaptability than traditional rule-based PDF processing.

Speed

AI-powered IDP platforms offer a substantial performance advantage over traditional manual workflows. Experimental studies have shown that these systems can extract and validate key invoice data significantly faster than human operators, reducing the need for manual review and accelerating throughput. [64] In fact, some implementations report up to 80% reduction in processing time compared to fully manual methods. [44]

Meanwhile, rule-based automation offers relatively fast execution within its defined scope, but its speed advantage is often undermined by its fragility. These systems perform well when the input format aligns perfectly with predefined rules, but any deviation can trigger manual fallback or troubleshooting, leading to delays. Compared to IDP systems, rule-based automation demonstrates significantly lower efficiency. A comparative study found that while rule-based systems processed documents in approximately 15 minutes each, AI-driven IDP solutions completed the same tasks in just 18 seconds, representing a 98% improvement in processing speed. [1]

Hybrid Structured Automation is expected to achieve consistently high processing speeds due to its reliance on pre-structured input files that require minimal preprocessing. Without the computational overhead of OCR or AI inference, ingestion and validation can be performed rapidly, often limited only by file retrieval and downstream posting to ERP or finance systems. For vendors with stable, machine-readable outputs, end-to-end processing could be nearly instantaneous from download to posting, with delays occurring only when validation flags trigger manual review.

Integration

Rule-based automation systems often face integration challenges due to their origins as self-contained components. Many were designed to manage both decision logic and interface-level tasks within a single environment, which limits their adaptability in modern, interconnected systems. This architecture makes it difficult to link rule logic with external data sources or enterprise applications without additional effort. To address these limitations, newer integration models treat rule engines as modular decision-making units embedded within broader systems. These setups often rely on callbacks, service-based communication, or model-driven design to bridge the gap between rule logic and operational workflows. However, achieving seamless integration still frequently requires custom development, middleware, or formalized design frameworks to ensure interoperability and maintainability. [40]

Similarly, integration complexities are a notable concern with IDP platforms. While many solutions support API connectors and export formats compatible with ERP and document management systems, integration is often limited to downstream data transfer after document processing, rather than enabling real-time, bi-directional interaction. [35] These challenges are especially pronounced during the deployment of IDP platforms in conjunction with legacy systems, where adapting existing workflows and maintaining operational continuity can be complex. To overcome these hurdles, organizations benefit from a strategic, phased implementation approach, often leveraging standardized APIs, RPA frameworks, or Business Intelligence (BI) tools. [64] Additionally, organizational culture and leadership play a critical role, as openness to innovation and clearly defined use cases significantly influence integration success. [29]

Hybrid Structured Automation presents moderate integration requirements. On the input side, structured files are retrieved from vendor portals or via scheduled downloads, requiring only secure authentication and, optionally, automated retrieval scripts. On the output side, validated datasets can be mapped directly into ERP systems in standardized formats, often with minimal transformation effort. This approach reduces complexity compared to EDI or API-based integrations, while still enabling clean interoperability. Unlike IDP, which focuses on post-extraction integration, Hybrid Structured Automation delivers ready-to-use structured data, potentially shortening the integration pipeline.

Scalability

Scalability is central to the value of modern IDP solutions. These platforms are built to handle increasing document volumes and vendor diversity with ease. As they process more data, their extraction models improve through continuous learning, boosting accuracy and adaptability. Cloud-based deployments enable dynamic scaling during volume spikes, while human input is limited to edge cases. [24] However, scalability should be considered early in the design process, as organizations that overlook future growth often face system bottlenecks when document volumes increase. When strategically deployed, IDP is ideal for expanding across business units, locations, or partners with minimal retraining and reduced manual effort. [44]

Conversely, rule-based systems scale poorly in complex or dynamic environments. As the number of document types and vendors increases, maintaining and updating rule sets becomes increasingly burdensome. While rule engines can process high volumes, they struggle to adapt to unstructured data and evolving formats. This often results in inefficiencies, errors, and compliance risks. Despite ongoing digitization, rule-based automation alone cannot scale effectively. As operational demands grow, the exponential increase in rules needed to manage diverse scenarios makes these systems difficult to maintain and prone to bottlenecks. [43] [44]

For Hybrid Structured Automation, scalability is heavily dependent on the vendor's digital maturity. When the majority of invoices come from partners that provide structured files, scaling is straightforward. New vendors typically only need an initial mapping of their file formats to fit into the validation pipeline. However, in ecosystems with many suppliers still relying on unstructured formats, additional channels, such as IDP, would be needed to process those documents, reducing the efficiency of scaling. Within its applicable scope, scaling is rapid and low-cost, but it cannot cover a fully heterogeneous vendor base without supplemental solutions.

Partner Dependency

Rule-based automation has low initial partner dependency, as it functions without requiring vendors to modify their behavior or systems. However, it depends on stable and predictable document formats, and uncoordinated changes by vendors can disrupt processing. As automation scales, collaboration with external partners becomes more important to align IT systems, workflows, and communication protocols. Early involvement can lead to cost savings and process improvements, making partner engagement a strategic factor in long-term success. [21]

Additionally, IDP platforms exhibit even lower partner dependency. They are designed to handle documents as-is, regardless of structure, format, or file type, without requiring logistics providers or other external partners to standardize inputs or upgrade their systems. [63] This high degree of flexibility makes IDP especially effective in environments with vendors at varying levels of digital maturity. While collaboration may enhance outcomes, it is not essential for successful deployment, positioning IDP as a robust solution for heterogeneous and evolving partner ecosystems.

Hybrid Structured Automation has higher partner dependency than both rule-based automation and IDP. It relies on vendors providing structured invoice files in consistent, machine-readable formats, requiring prior alignment on file specifications and delivery methods. While this dependency demands more initial coordination, it shifts much of the data preparation burden upstream, reducing internal processing complexity. In cases where there is a concentrated vendor base and strong commercial leverage, partner dependency may be a manageable and even beneficial factor in ensuring long-term data quality.

Cost & Maintenance

Rule-based automation entails financial considerations that go beyond initial acquisition, including infrastructure, implementation, and maintenance. Initial costs typically include software licensing, setup, and consulting. Licensing varies by vendor, deployment model, and license type, with annual expenses ranging from relatively low figures to amounts that can exceed several hundred thousand dollars. Setup and consulting fees may add tens of thousands more, depending on process complexity. Infrastructure costs vary by deployment model. Cloud-based solutions offer lower upfront investment and flexible pricing, while on-premises setups demand higher initial costs but allow greater control. Hybrid approaches combine both, adding integration complexity. Overall, infrastructure expenses typically fall between $10,000 and $150,000. Implementation involves designing, connecting systems, validating functionality, and launching the automation solution, with costs typically ranging from $50,000 to $500,000 depending on scale and complexity. Maintenance involves recurring tasks such as applying system updates, resolving technical issues, monitoring performance, and providing ongoing support. These expenses are influenced by system complexity and service agreements, and can amount to approximately 20% of original investment annually. [61] [57]

AI-powered IDP platforms often entail considerable upfront and ongoing costs, especially for enterprise-scale deployments, with pricing influenced by company size and operational complexity. Entry-level solutions typically come with a base licensing fee ranging from $35,000 to $100,000 annually for large organizations, with additional costs for implementation and training that can increase the initial investment by 10 to 20 percent. However, in complex enterprise scenarios, these costs can be significantly higher, for instance, $400,000 for implementation on top of a $100,000 solution license. Beyond upfront licensing fees, key cost drivers include invoice volume, feature complexity, system integration challenges, and the type of deployment, whether cloud-based or on-premises. [44] Further expenses may also result from migrating data, customizing workflows, and maintaining ongoing support services. [28] To manage costs, businesses often opt for phased rollouts, cloud deployment, or cost-sharing models. Some platforms also offer pay-as-you-go pricing, which provides flexibility based on actual usage. Over time, reduced manual effort and improved efficiency can help offset the initial investment. [45] Furthermore, maintaining these platforms requires ongoing model updates, data quality management, and adjustments to accommodate changing document formats and business needs. Continuous learning and feedback integration are essential to sustain high accuracy and automation performance. [64]

For Hybrid Structured Automation, cost structures are expected to be moderate, sitting between rule-based automation and IDP. Upfront costs primarily involve the configuration of retrieval mechanisms, the mapping of vendor file formats, and the implementation of validation rules. Maintenance focuses on updating rules when vendor schemas change, as well as monitoring data quality, without the ongoing expenses of retraining AI models or managing OCR pipelines. While partner coordination for schema adjustments can introduce additional effort, stable vendor outputs can keep long-term costs relatively low. For organizations with a concentrated vendor base, this approach could yield a favorable balance between investment and efficiency gains over time.

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	✓ High accuracy in standardized, predictable formats ✓ Reaches approximately 85% accuracy in key field extraction ⚠ Accuracy drops when formats deviate or new elements are introduced	✓ Moderate to high accuracy depending on input quality, model sophistication, and training data ✓ Achieves approximately 98% accuracy in key field extraction ⚠ May struggle with noisy or uncommon layouts without sufficient training data	✓ High accuracy with structured formats (CSV, XML, Excel) ✓ Near-perfect accuracy with consistent upstream data ⚠ Dependent on vendor data quality and consistency
Flexibility	✗ Rigid and template-dependent ✗ Requires manual rule updates for even minor layout changes ✗ Poor adaptability in dynamic environments	✓ Highly flexible and layout-agnostic ✓ Adapts to diverse invoice formats using AI/ML, NLP, OCR, and transformer models ✓ Learns from new inputs without manual reconfiguration	⚠ Moderate flexibility ✓ Insulated from layout changes due to structured input ⚠ Requires vendor schema consistency
Speed	⚠ Fast within defined scope ✗ Fragile – errors or deviations cause delays ✗ Takes approximately 15 minutes per document	✓ Significantly faster than manual and rule-based methods ✓ Up to 80% reduction in processing time compared to manual ✓ Completes tasks in approximately 18 seconds per document	✓ Very fast due to structured input ⚠ Delays only when validation flags trigger manual review ✓ Near-instantaneous for stable vendor files
Integration	⚠ Challenging due to stand alone design ✓ Newer models support modular integration via callbacks or service-based design ⚠ Requires custom development or middleware to connect with external systems	⚠ Complex when working with legacy systems ⚠ Often limited to post-processing data transfer ✓ Strategic use of APIs, RPA, and BI tools improves integration success ✓ Organizational readiness and leadership are key enablers	✓ Moderate integration effort ✓ Structured files retrieved via secure scripts or portals ✓ Validated data maps directly into ERP ✓ Simpler than EDI/API
Scalability	⚠ Scales poorly in dynamic environments ✗ Rule maintenance becomes burdensome with vendor diversity ✗ Susceptible to bottlenecks as rule complexity grows	✓ Designed for scalable growth across data and operations ✓ Efficiently handles increasing complexity and volume ⚠ Requires thoughtful design upfront to avoid future performance bottlenecks	✗ Depends on vendor digital maturity ✓ Easy to scale with structured data; minimal setup for new vendors ⚠ Needs IDP for unstructured formats to scale across heterogeneous ecosystems
Partner Dependency	⚠ Low initial dependency on partners ✗ Vulnerable to uncoordinated vendor changes ⚠ Requires increasing collaboration as scale grows ✓ Early partner involvement improves outcomes	✓ Very low dependency on partner systems ✓ Handles documents "as-is" without requiring standardization ✓ Effective in heterogeneous vendor ecosystems ⚠ Collaboration can enhance results but is not essential	✗ High dependency on vendor cooperation ⚠ Requires structured file delivery and schema alignment ✓ Best suited for concentrated vendor bases with strong commercial leverage
Cost & Maintenance	⚠ Moderate to High cost ⚠ Licensing, Setup & consulting, Infrastructure, implementation ✗ Manual rule updates, System upgrades & monitoring, Technical support, $\sim$ 20% annual upkeep	✗ High cost (higher upfront and scaling cost); Volume-based pricing options ⚠ Licensing, Training & Customization, Integration & Deployment ⚠ Model retraining, Data quality management, Feedback integration, Format adaptation & support	⚠ Moderate cost ⚠ Setup includes retrieval, mapping, validation rules; no OCR/AI retraining needed ⚠ Maintenance tied to vendor schema changes and ongoing data quality monitoring

Table 6: Qualitative Comparison of Candidate Strategies Across Evaluation Criteria

5.3 Quantitative Assessment and Ranking

To complement the qualitative comparison presented in the previous section, the three candidate strategies were further evaluated using a structured quantitative framework. In this step, the insights derived from the qualitative analysis were systematically converted into numerical performance indicators across the same set of evaluation criteria, enabling a more transparent and reproducible comparison. Recognizing that the evaluation criteria vary in importance, these initial scores were subsequently combined with weighting factors derived through the Best–Worst Method (BWM), as detailed in Section 3.2. By incorporating stakeholder-derived preferences into the weighting process, the assessment reflects not only technical performance but also organizational priorities. The resulting weighted decision matrix provides a rigorous basis for comparing the three strategies and identifying their relative suitability.

5.3.1 Initial Strategy Evaluation Matrix

The qualitative assessments from Section 5.2 were systematically translated into numerical scores to enable structured comparison across the three strategies. Each criterion was rated on a 1–9 scale, where higher values reflect stronger alignment with the underlying evaluation dimension. The translation followed a structured rule set. Descriptors of strong performance, such as *high accuracy*, *near-instantaneous processing*, or *validated data maps*, were placed in the upper range (7–8). Moderate or conditional statements, including *dependent on vendor maturity*, *moderate flexibility*, or *fast within defined scope*, were positioned in the mid-range (4–6). Weak or fragile attributes, such as *rigid and template-dependent*, *scales poorly*, or *manual updates required*, were assigned to the lower range (2–3). The translation was initially developed in the study and then reviewed with organizational stakeholders, who confirmed that the numerical values were consistent with both the qualitative evidence and organizational realities. This ensured that the assigned values remained anchored in empirical findings and conceptual reasoning, rather than arbitrary judgment.

The scale represents a continuum, where 9 corresponds to near-perfect alignment with a criterion and 1 reflects very weak performance, with intermediate values capturing proportional gradations between these extremes. Importantly, the assigned scores reflect both the intrinsic performance of each strategy and their relative positioning against the other alternatives. In some cases, a mid-range value may not signify outright weakness but rather indicate lower comparative performance when benchmarked against stronger options.

Table 7 presents the resulting unweighted performance scores for the three candidate strategies. To avoid implying absolute optimality, the maximum score in this study was deliberately capped at 8. This cautious scoring approach acknowledges that even the strongest-performing strategies have limitations and remain subject to future technological advancements. By leaving headroom at the top of the scale, the evaluation maintains realism and credibility, emphasizing that the scores represent relative strengths within the current context rather than definitive end-points.

In assigning scores, each criterion was evaluated based on both the level of performance demonstrated by each strategy and the strategic desirability of that performance from the organization's perspective. Most criteria were scored directly, meaning that higher levels of performance corresponded to higher scores. However, for the criteria Partner Dependency and Cost & Maintenance, the evaluation was conducted inversely. In these cases, lower levels of the attribute were considered more desirable, and therefore received higher scores. This scoring approach ensures consistency across all criteria, such that higher scores uniformly reflect more favorable strategic outcomes.

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	6	8	7
Flexibility	3	8	6
Speed	4	8	7
Integration	4	6	7
Scalability	3	8	6
Partner Dependency	6	7	4
Cost & Maintenance	6	5	7

Table 7: Initial Scoring Matrix - Raw Numerical Scores

Within this framework, the matrix highlights several important dynamics. AI-powered IDP platforms consistently achieve the highest scores across flexibility, speed, and scalability, reflecting their strong ability to handle heterogeneous and dynamic environments. Rule-based automation, in contrast, demonstrates strong performance only under controlled conditions, with marked weaknesses in adaptability and long-term scalability. The proposed Hybrid Structured Automation occupies a middle ground. It achieves very high scores in accuracy and speed under structured data conditions, but its dependency on vendor maturity limits its flexibility and scalability in more diverse ecosystems.

Taken together, the initial scoring matrix illustrates that while IDP emerges as the strongest candidate in raw performance terms, Hybrid Structured Automation offers a targeted balance of efficiency and accuracy in contexts where structured data is reliably supplied. Rule-based automation, by contrast, demonstrates limited applicability beyond controlled environments.

This scoring matrix provides a systematic foundation for the weighted aggregation step. By applying the criterion weights derived through the BWM process, the analysis moves beyond raw performance values to reveal how each strategy aligns with organizational priorities, enabling a transparent and structured comparative ranking.

5.3.2 Stakeholder Weighting of Evaluation Criteria

While the unweighted scores highlight differences in performance, they implicitly assume that all evaluation criteria carry equal importance. In reality, organizational stakeholders assign different levels of priority to aspects such as accuracy, scalability, or cost efficiency, depending on their functional roles and strategic concerns. To capture these perspectives, weighting factors were derived using the Best–Worst Method (BWM), as outlined in Section 3.2.

Representatives from the case organization participated in the process by identifying their most and least important criteria and providing pairwise comparisons. Individual weights were calculated for each participant, reviewed for consistency, and subsequently aggregated into a consolidated set of criterion weights. This

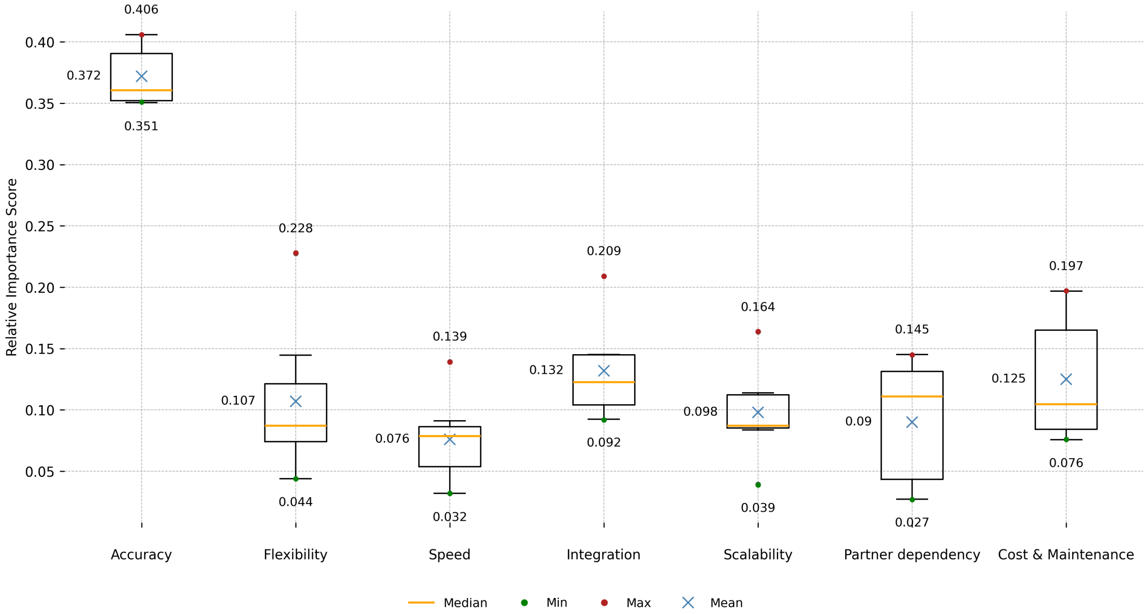

Figure 10: Stakeholder Prioritization of Evaluation Criteria

unified weighting scheme ensures that the quantitative assessment reflects both the diversity of stakeholder perspectives and a coherent organizational viewpoint, thereby providing a more realistic foundation for the weighted evaluation in the following step.

To complement the consolidated weighting scheme, the distribution of stakeholder-assigned weights was visualized using boxplots shown in Figure 10. This visual representation highlights the central tendencies through the mean and median values and illustrates the extent of variation among participants for each evaluation criterion. It provides insight into which aspects were consistently prioritized and where stakeholder opinions differed more significantly.

The results reveal that Accuracy carries the highest importance by a considerable margin, with mean values clustering around 0.37 and minimal variation across stakeholders. This consensus underscores the centrality of accuracy in freight invoice verification and reflects the organization's strong emphasis on ensuring correctness in financial reconciliation, where even minor errors can lead to disproportionate downstream impacts.

A second tier of criteria includes Flexibility and Integration, both of which were consistently rated as less critical, with average scores below 0.15. Flexibility displayed some divergence, with most stakeholders assigning limited importance while one emphasized it more strongly. Integration, in contrast, received relatively more consistent ratings across stakeholders, with one notably higher score standing out. This suggests a shared view that system compatibility is important, albeit typically considered less critical than accuracy.

A similar pattern emerges for Speed and Scalability, which also occupy the lower end of the weighting spectrum. Speed displayed greater variation across stakeholders, suggesting differing views on the value of rapid processing, even though it is generally not considered a critical criterion. Scalability, on the other hand, showed less dispersion, indicating more consistent stakeholder opinions. While its average weight remains low, the narrower spread suggests a shared view that future growth and workload variability are relevant but not urgent concerns.

Finally, Partner Dependency and Cost & Maintenance showed some of the widest spreads in stakeholder opinions. For certain participants, minimizing the reliance on external vendors and keeping long-term operational expenses under control were seen as important priorities. For others, these considerations were considered secondary to functional performance and accuracy, reflecting the differing vantage points of finance, procurement, and operations roles within the organization.

Taken together, the distribution of weights highlights Accuracy as the uncontested priority, consistently rated highest by all stakeholders with minimal variation. Its dominant position in the weighting results reinforces its role as the primary driver of automation quality. In contrast, the remaining criteria represent differentiated but secondary concerns, with no clear hierarchy among them. The variation in stakeholder preferences across the remaining criteria suggests that these aspects involve trade-offs between adaptability, efficiency, and sustainability, and are interpreted differently depending on functional roles. This lack of uniformity underscores the importance of incorporating diverse perspectives into the evaluation, while reinforcing that accuracy remains the central benchmark for automation success.

To consolidate these diverse perspectives into a coherent evaluation framework, the individual weight sets were aggregated using the arithmetic mean. This approach ensured that no single stakeholder view disproportionately influenced the outcome while preserving the overall distribution of opinions. The resulting unified set of weights provides a representative organizational perspective, which is applied in the next step to compute the weighted performance scores for the alternative strategies. These average weights are summarized in Table 8, which presents the relative importance assigned to each evaluation criterion.

Criterion	Average Weight
Accuracy	0.372
Flexibility	0.107
Speed	0.076
Integration	0.132
Scalability	0.098
Partner Dependency	0.090
Cost & Maintenance	0.125

Table 8: Average Weights of Evaluation Criteria

As shown above, the consolidated weights confirm that Accuracy is by far the most influential criterion, with an average weight of 0.372, underscoring its primacy in the evaluation. Integration, Cost & Maintenance, and Flexibility form a mid-tier of considerations, while Speed, Scalability, and Partner Dependency were assigned comparatively lower importance. This distribution highlights the unequal contribution of criteria to the assessment, reinforcing the importance of incorporating stakeholder priorities into the weighted analysis.

Collectively, these average weights offer a synthesized reflection of organizational priorities. In the subsequent step, they are applied to the raw performance scores to derive weighted outcomes, enabling a more representative comparison of the candidate strategies.

5.3.3 Final Strategy Evaluation Matrix

With both the unweighted performance scores and stakeholder-derived criterion weights established, the analysis proceeds to integrate these elements into a weighted decision matrix. This step ensures that the evaluation reflects not only the technical merits of each strategy but also the relative importance of the criteria as prioritized by stakeholders. The weighted scores were calculated by multiplying each strategy's raw score for a given criterion, as detailed in Table 7, by the corresponding average weight provided in Table 8. The resulting products were then summed across all criteria to yield an overall weighted score for each strategy. This approach allows the analysis to move beyond raw performance values and incorporate organizational priorities into the ranking of alternatives.

The final weighted evaluation matrix is presented in Table 9, along with the aggregated scores that inform the ranking of the three candidate strategies.

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	2.231	2.974	2.603
Flexibility	0.321	0.857	0.643
Speed	0.303	0.606	0.531
Integration	0.527	0.791	0.922
Scalability	0.294	0.783	0.587
Partner Dependency	0.543	0.633	0.362
Cost & Maintenance	0.751	0.626	0.876
Total Weighted Score	**4.970**	**7.271**	**6.524**

Table 9: Final Weighted Evaluation Matrix

The weighted analysis offers a structured and transparent ranking of the three automation strategies, incorporating both their raw performance and the relative importance of each evaluation criterion as defined by organizational stakeholders.

AI-powered IDP Platforms achieved the highest overall score, 7.27, standing out as the most favorable option. This strong result is primarily driven by excellent performance in Accuracy, scoring 2.97, and Flexibility, scoring 0.86. These scores indicate that IDP Platforms not only deliver on the organization's top priority, ensuring precise data reconciliation, but also meet the demand for adaptability to varied invoice formats and layouts, a consideration that held moderate weight in stakeholder evaluations. The strategy also shows strong performance in Integration, scoring 0.79, reflecting its ability to align well with system compatibility requirements that were emphasized by stakeholders, even though it slightly trails the Hybrid approach in this area. Furthermore, even in low-weighted dimensions such as Speed, where it scores 0.61, IDP Platforms maintain competitive results, reinforcing their robustness across both critical and supporting evaluation criteria. In contrast, they score the lowest in Cost & Maintenance, at 0.63, showing limited alignment with stakeholder expectations in this important area. This breadth of consistently strong results, despite a few limitations, explains their clear lead in the ranking.

Hybrid Structured Automation ranked second with a total weighted score of 6.52. Its profile is characterized by relative balance across criteria, excelling particularly in Integration with a score of 0.92 and in Cost & Maintenance with a score of 0.88, areas where it outperforms both other strategies. These strengths align with stakeholder concerns about system compatibility and long-term operating costs, which were highlighted as moderately important in the weighting exercise. However, the Hybrid approach falls short in Partner Dependency, where it scores 0.36, the lowest of all strategies. This reflects the reliance on vendor maturity and collaboration that stakeholders viewed as a potential risk. Despite these weaknesses, the strong technical and cost-related performance of the strategy positions it as a credible alternative in scenarios where structured data is readily available and vendor dependency risks can be managed.

Rule-Based Automation, with a total score of 4.97, falls clearly behind the other two alternatives. Its relative strengths appear in Partner Dependency with a score of 0.54 and in Cost & Maintenance with a score of 0.75, indicating that it remains an attractive option for minimizing vendor reliance and maintaining predictable long-term costs. However, it performs poorly on highly weighted criteria such as Accuracy, where it scores 2.23, and Flexibility, where it scores 0.32. These shortcomings directly conflict with the priorities emphasized by stakeholders, who consistently rated accuracy as critical and flexibility as an increasingly important enabler in diverse, digitalized workflows. The strategy's limited scalability, with a score of 0.29, and modest integration capability, with a score of 0.53, further underscore its lack of fit as a forward-looking solution. Nonetheless, its strengths in cost control and independence from external vendors may still make it a viable choice in niche or tightly controlled environments.

Overall, the analysis demonstrates a clear hierarchy among the evaluated automation strategies. AI-powered IDP Platforms emerge as the strongest candidate, offering the most consistent alignment with both performance requirements and stakeholder priorities. Hybrid Structured Automation provides a balanced, though narrower, fit and remains a viable alternative, particularly in contexts where integration capabilities and cost efficiency are paramount. By contrast, Rule-Based Automation lags behind, with strengths concentrated in areas of lower strategic importance, making it more suitable for stable or transitional environments rather than as a long-term solution for freight invoice verification.

6 Workflow Redesign for Invoice Verification

The proposed workflow redesign is conceived as a structured framework to enhance the transport cost verification process and enable transparent, standardized cost allocation. Its purpose extends beyond technical efficiency: it provides a governance-oriented redesign that embeds automation into process logic while retaining human oversight where judgment is essential.

The workflow redesign builds directly on the insights from the earlier stages of this study. The current-state assessment (Section 4.4) revealed inefficiencies such as heavy reliance on manual input, fragmented system interactions, and inconsistencies in documentation handling. Stakeholder weighting of evaluation criteria (Section 5.3.2) emphasized accuracy as the primary organizational priority, while also recognizing the relevance of cost efficiency, integration, and scalability. The comparative evaluation of candidate automation strategies (Section 5.3.3) identified AI-powered IDP Platforms as the most favorable solution overall, with Hybrid Structured Automation offering a viable alternative under certain conditions.

Positioned within this context, the redesigned workflows provide a blueprint for operationalizing these findings. They define how invoice verification should be structured under different automation strategies, clarifies the logic guiding task execution, and ensures that decision-making is both systematic and traceable. In this way, the redesigned workflows act not merely as technical models but as enablers of organizational priorities, aligning technological capabilities with the broader goals of efficiency, transparency, and resilience in transport cost management.

Against this backdrop, the following section presents the workflow redesign for invoice verification, translating the conceptual framework into actionable process models. Section 6.1 introduces three proposed workflow models, each aligned with one of the evaluated automation strategies: Rule-Based Automation, AI-driven IDP, and Hybrid Structured Automation. These workflows detail the initiation, data extraction, and validation logic, and are visualized using swimlane diagrams to illustrate the to-be process. Complementing these models, Section 6.1.4 outlines a shared post-validation workflow applicable across all automation strategies, covering exception handling, manual review, and payment processing. Section 6.2 offers a comparative synthesis of the proposed workflows, highlighting their respective strengths, limitations, and implementation considerations. Building on this, Section 6.3 introduces the concept of a shared validation backbone, emphasizing the modular and reusable nature of rule logic across different automation configurations. Finally, Section 6.4 concludes with a summary of the expected benefits of automation-supported process redesign, including improved transparency, reduced financial risk, and enhanced scalability.

6.1 Proposed Workflow Models for Invoice Automation

To articulate the design of a structured approach to freight invoice verification, this section introduces a series of workflow models that translate the automation strategies evaluated in Section 5 into practical process configurations. Each model corresponds to a distinct strategy, namely Rule-Based Automation, Hybrid Structured Automation, and AI-driven IDP Platforms, and is accompanied by a detailed explanation of its initiation logic, data extraction mechanisms, and validation procedures.

The workflows are visualized using swimlane diagrams to illustrate the redesigned to-be processes and clarify the division of responsibilities across systems and roles. While each strategy presents specific advantages and implementation considerations, they share a common structural foundation that supports systematic and traceable decision-making. To ensure consistency in subsequent processing steps, a shared post-validation workflow is also introduced and discussed, encompassing exception handling, manual review, and payment processing across all three models. Collectively, these workflows form the operational core of the redesign, establishing a foundation for scalable, transparent, and resilient invoice verification.

6.1.1 Rule-based Automation

The proposed workflow for Rule-based Automation in invoice verification represents a structured and logic-driven approach to invoice verification by embedding predefined business rules into the process. These rules are configured within a cloud-based automation tool that enables users to design workflows between applications and services, supporting low-code or no-code development. The system operates through step-by-step execution based on conditional logic, following an "if-then" structure. Each rule defines a specific condition and the corresponding action to be triggered when that condition is met, allowing the process to respond dynamically to different invoice scenarios.

At its core, the system begins by matching shipments to the corresponding invoices, ensuring alignment between logistical records and financial documentation. This is followed by a series of conditional checks that determine cost responsibility, validate charges, and flag any deviations for manual review.

This approach is particularly well-suited to environments where invoice formats and business logic are stable and predictable, such as in freight and logistics operations governed by contractual terms and standardized documentation.

Workflow Initiation and Data Extraction

The workflow begins when an external party submits a freight invoice via email, typically in PDF format. Upon receipt, the system automatically initiates the verification process through an email trigger mechanism. Once the invoice is ingested, the system performs an initial check to determine whether the email contains an attachment. If an attachment is present, the invoice is routed for automated processing without requiring manual intervention.

The invoice is then processed using an AI Builder tool, which extracts key data points from the document. These typically include shipment details, such as Air Waybill (AWB) number, Origin and Destination, Shipment Date, Weight, Service Type, Incoterms and Invoiced Amounts. An AI Builder tool refers to a low-code or no-code automation component that uses artificial intelligence to identify and extract structured data from documents, enabling integration with business workflows. Although this extraction method is less flexible than advanced IDP systems, it is sufficiently robust for handling structured invoice formats, which are commonly used in freight operations.

Following data extraction, the system retrieves additional contextual information from internal sources to support the upcoming validation logic. Shipment details are retrieved from the organization’s ERP system to ensure that relevant logistical records are available for reference. In cases where Incoterms are not explicitly stated on the invoice, they are retrieved from internal documentation such as sales agreements, purchase orders, or contracts. Similarly, tariff rates are retrieved from contractual agreements with external logistics providers. To enable automated access, these contracts must be transformed into a machine-readable format that allows the system to filter rates by service type, zone, and weight range. As a final preparatory step before initiating the rule-based validation logic, the system calculates the expected charge for each shipment by applying the appropriate rate logic.

This initial phase significantly reduces reliance on manual monitoring and ensures timely and structured initiation of the invoice verification process. It also establishes a structured data foundation for the subsequent rule-based validation steps, enabling consistent, accurate and efficient processing of incoming invoices.

Rule-Based Validation Logic

Once all relevant data has been extracted and retrieved, the system performs a series of conditional checks based on predefined business rules. These checks are designed to validate the accuracy and appropriateness of invoice data in relation to contractual obligations and expected cost structures.

The first and foundational rule involves verifying whether the shipment referenced in the invoice corresponds to a recorded shipment in the organization's internal systems. This is primarily done by checking the Air Waybill (AWB) number, along with key shipment attributes such as origin, destination, weight, and shipment date. This initial validation step is essential to confirm that a shipment has indeed taken place and that it matches internal records. Establishing this alignment between logistical and financial documentation ensures that only legitimate and traceable invoices proceed to further validation, reducing the risk of processing errors or duplicate charges.

Once shipment matching is confirmed, the system evaluates cost responsibility based on the shipment direction, whether inbound or outbound, and the applicable Incoterm. Only valid combinations of these two parameters proceed to the next step in the validation process. For instance, an inbound shipment under EXW indicates that the buyer is contractually responsible for freight charges, whereas an outbound shipment under DAP/DDU/DDP assigns that responsibility to the seller. This rule ensures that invoiced charges reflect the correct allocation of transport costs as defined by contractual terms, thereby maintaining consistency with agreed responsibilities.

The final core validation rule involves verifying whether the invoiced amount aligns with the expected charge calculated earlier in the process. This step is essential for ensuring financial accuracy and contractual compliance, and serves as a safeguard against billing errors or deviations from agreed pricing terms.

Each invoice proceeds through this sequence of validation rules in strict order. The system advances to the next rule only if the current check is successfully passed. Invoices that satisfy all three conditions are automatically approved and routed for further processing. This streamlines approval pathways by minimizing bottlenecks and administrative workload, allowing routine invoices to be handled efficiently without manual intervention. However, if any rule fails, such as a mismatch in AWB details or a discrepancy between expected and invoiced amounts, the validation logic is interrupted and the invoice is flagged for manual review. This ensures that exceptions are handled appropriately without disrupting the automated flow. A dual approval mechanism is then activated, involving finance staff and logistics advisors, and, where necessary, escalation to logistics managers. This layered approach maintains oversight and accountability while ensuring that flagged invoices are resolved in a controlled and traceable manner.

The proposed workflow is presented in Figure 11, which illustrates the redesigned process based on the rule-based system. This figure provides a concise overview of the automation logic, highlighting the main decision flow used to determine whether an invoice proceeds automatically or requires manual intervention. For a more granular view of the underlying logic, Appendix A, Figure A.1 presents a detailed version of the workflow, outlining each verification step, including shipment matching, cost responsibility checks, charge validation, and exception handling.

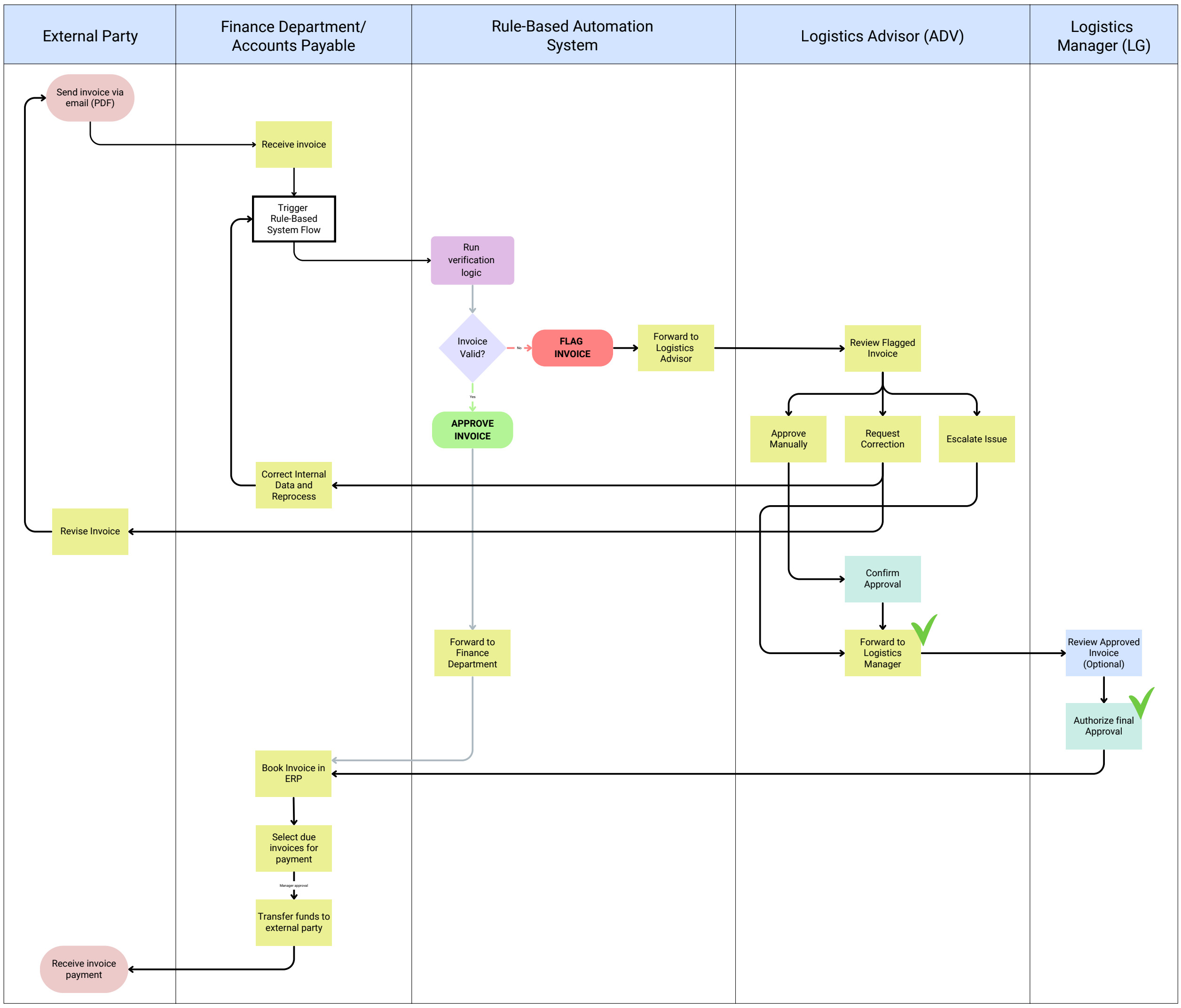

Figure 11: Proposed rule-based workflow for invoice verification (to-be process).

6.1.2 Hybrid Structured Automation

The proposed workflow for Hybrid Structured Automation builds upon the logic-driven principles of rule-based automation but introduces a significant advancement: the integration of structured, machine-readable data at the point of entry. This enhancement addresses a key limitation of traditional rule-based systems, which rely heavily on document parsing, by requiring external parties to submit invoice data in standardized formats such as CSV, XML, or Excel through a dedicated portal.

By receiving clean, structured data directly from the source, the system bypasses the need for OCR or PDF extraction, reducing error rates and improving processing speed. Once ingested, this data is routed through a rule-based validation engine, where predefined business rules are applied to assess cost responsibility, verify charges, and detect anomalies. The hybrid model retains the conditional logic of the rule-based approach but benefits from higher data quality and interoperability.

This workflow is particularly suited for environments where collaboration with external vendors or logistics partners is feasible, and where data exchange standards can be enforced. It enables a more scalable and resilient automation framework, capable of adapting to diverse invoice formats while maintaining consistency in validation logic.

Workflow Initiation and Data Extraction

Similarly to Rule-based Automation, the workflow is initiated when an external party submits a freight invoice via email, typically in PDF format. In parallel, structured and machine-readable data, such as CSV, XML, or Excel, is made available through their portal to support automated processing. While the structured data is used to drive automation, PDF submission remains important for two main purposes. It serves as an archival record, given its legally recognized and immutable format, and provides a reference for manual review in cases where invoices are flagged during the validation process.

Upon receiving the structured data, the system automatically initiates the verification process through a trigger mechanism. This trigger can be immediate or based on conditions such as elapsed time or a threshold number of pending invoices. Once the invoice data is ingested and loaded, the system proceeds to parse the contents. This step is essential to extract and map usable fields, such as AWB number, origin, destination, weight, date, service type, Incoterms, and invoiced amounts, while filtering out any irrelevant or extraneous data that may be included by the external party. Ideally, the structure and content of the submitted data can be aligned with the requirements of the organization through collaboration with the external party, ensuring that only relevant fields are provided and formatted appropriately.

Once parsing is complete, the workflow retrieves supplementary information to support validation. AWB details are pulled from the organization's ERP system to verify shipment status and logistical records. Cost responsibility is determined by retrieving the relevant Incoterm, while tariff rates are accessed from contractual agreements with logistics providers. These contracts, maintained in a machine-readable database, are filtered by service type, weight range, and zone. As in the rule-based model, the system then calculates the expected charge by applying rate logic to the shipment details.

This preparatory stage ensures a high degree of consistency and reliability, as invoices are received in structured form and validated against machine-readable contract data. It reduces the error-prone reliance on parsing unstructured inputs and provides a more standardized foundation for rule-based validation.

Rule-based Validation Logic

Following data ingestion and contextual enrichment, the workflow proceeds through the same validation sequence described in the rule-based system, as outlined in Section 6.1.1. Invoices are first matched against AWB records, followed by verification of cost responsibility based on shipment direction and Incoterms. Finally, they are validated against expected charges derived from contractual tariff agreements. Invoices that pass all checks are approved automatically, while any deviations trigger a flag for manual review and dual-approval procedures.

This workflow effectively combines the structured input advantages of IDP-like systems with the simplicity and transparency of rule-based validation. By shifting the responsibility for data standardization upstream to external partners, the hybrid model reduces complexity within the system itself while ensuring that internal verification steps remain robust, traceable, and auditable.

The hybrid workflow is illustrated in Figure 12, which presents the redesigned process integrating structured data inputs with rule-based validation logic. This figure offers a high-level view of the automation sequence, emphasizing the decision point that determines whether an invoice is processed automatically or flagged for manual intervention. For a more detailed breakdown of the hybrid logic, Appendix B, Figure B.1 provides an expanded version of the workflow. It outlines each stage of the process, beginning with the ingestion of structured data and contextual enrichment, followed by the subsequent validation rules and decision points. This visual representation demonstrates how the hybrid model leverages upstream data standardization to simplify system-side processing, while maintaining the transparency and auditability of rule-based validation.

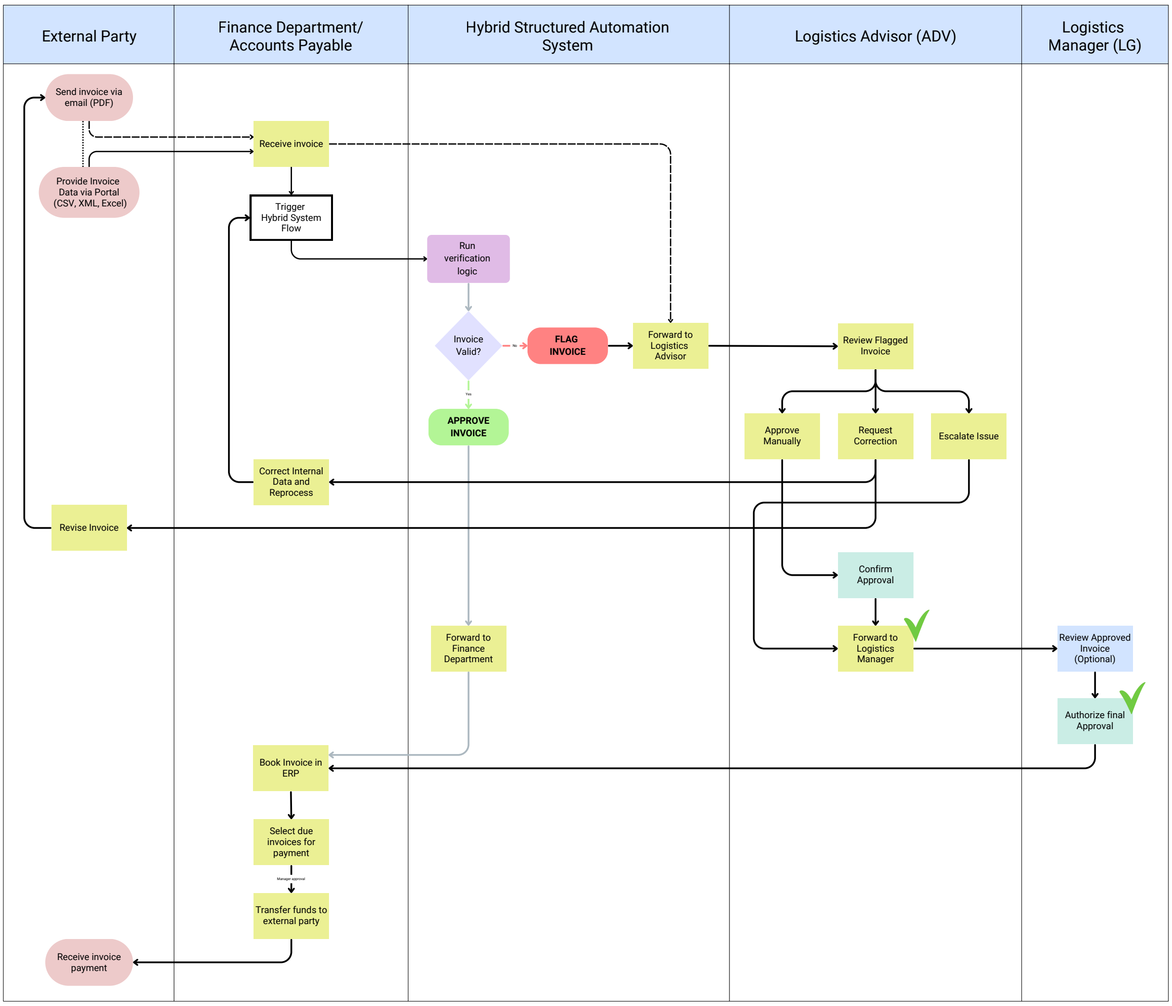

Figure 12: Proposed hybrid workflow for invoice verification (to-be process).

6.1.3 Intelligent Document Processing

The proposed workflow for AI-powered IDP platforms represents a data-driven approach to invoice verification that leverages machine learning and natural language processing to handle heterogeneous invoice formats. Unlike rule-based or hybrid setups, which rely on predefined structures or standardized machine-readable inputs, the IDP system is designed to extract, classify, and validate information directly from semi-structured or unstructured documents.

The process begins with the automatic ingestion of invoice documents into the IDP platform, where OCR and AI-based field classification techniques are applied to identify key data points. These extracted fields are then routed through a validation engine that applies business rules to assess accuracy, detect anomalies, and flag exceptions for manual review.

This approach is particularly suited to environments where invoice formats vary widely across carriers, and where standardization of input formats is not feasible. By enabling flexible data extraction and scalable validation, the IDP workflow enhances automation capabilities in complex, document-heavy processes while maintaining alignment with core business logic.

Workflow Initiation and Data Extraction

As in the other automation models, the verification process begins when a freight invoice, typically in PDF format, is received via email and automatically ingested by the IDP platform. This triggers a sequence of automated steps designed to extract and validate invoice data without manual intervention.

The system first applies OCR to convert the visual content of the invoice, such as scanned text and tables, into machine-readable characters. This step transforms the raw image into a structured text layer that can be further analyzed. Next, AI-based field classification models are applied to this text layer. These models use a combination of NLP, layout analysis, and contextual pattern recognition to identify and extract key fields such as the AWB number, shipment origin and destination, service type, weight, Incoterms, and invoiced amounts. Rather than relying on fixed templates, the classifiers are trained on diverse invoice samples and use probabilistic scoring to determine the most likely field matches. For instance, the system can identify an AWB number by detecting a numeric string near relevant keywords, even if its position varies across documents. Similarly, it infers fields such as weight using contextual clues such as nearby terms or units like “kg” or “lbs”.

Following extraction, the invoice data is standardized and enriched through integration with internal systems. The IDP platform accesses supplementary information via secure API connections or middleware integrations. AWB details are retrieved from the ERP system to verify shipment status and logistics records. Missing or ambiguous Incoterms are supplemented using data from purchase orders or contractual agreements. In parallel, tariff rates are pulled from structured contract databases, filtered by service type, weight range, and zone. These data sources are queried dynamically using the extracted invoice fields as lookup keys. The result is a harmonized dataset that combines external invoice data with internal business logic, forming the foundation for rule-based validation and exception handling.

This initial stage lays the groundwork for structured validation. While the extraction process is AI-driven, the subsequent verification still relies on rule-based logic, ensuring consistency, accuracy, and scalability across varying invoice formats.

Validation Logic

Following data extraction and enrichment, the workflow proceeds through the same core validation sequence described in Section 6.1.1. Invoices are first matched against AWB records to confirm shipment status and logistical consistency. Next, cost responsibility is verified based on shipment direction and Incoterm rules. Finally, invoiced amounts are validated against expected charges derived from contractual tariff agreements. Invoices that pass all checks are automatically approved, while exceptions are flagged for manual review and dual-approval procedures.

In the IDP workflow, these validation steps are supported by AI-driven extraction and intelligent matching techniques. Confidence scoring is used to rank potential matches between invoice data and reference records, such as AWB entries or tariff tables. Each match is assigned a confidence level, and predefined thresholds determine whether the invoice is processed automatically or routed for manual review. This mechanism allows the system to handle variability in invoice formats and data quality without compromising accuracy or traceability.

Unlike the hybrid model, which depends on structured inputs, and rule-based systems that require consistent formatting, the IDP workflow handles variability internally through AI-driven extraction and matching. This makes it more adaptable and scalable across diverse invoice formats, while still ensuring reliable and auditable validation.

The IDP workflow is depicted in Figure 13, which outlines the redesigned process integrating AI-driven document understanding and rule-based validation. It offers a broad overview of how OCR captures key data and machine learning models classify fields, followed by decision points that guide the approval flow. This visual structure emphasizes how the IDP model handles variability in input formats internally, ensuring robust and scalable processing without relying on upstream data standardization. A deeper look at the validation logic is provided in Appendix C, which contains separate diagrams for AWB matching (Figure C.1), Incoterm-based cost responsibility (Figure C.2), and charge validation (Figure C.3). These diagrams map out the internal decision processes and are designed to be reusable across different automation models, including rule-based and hybrid.

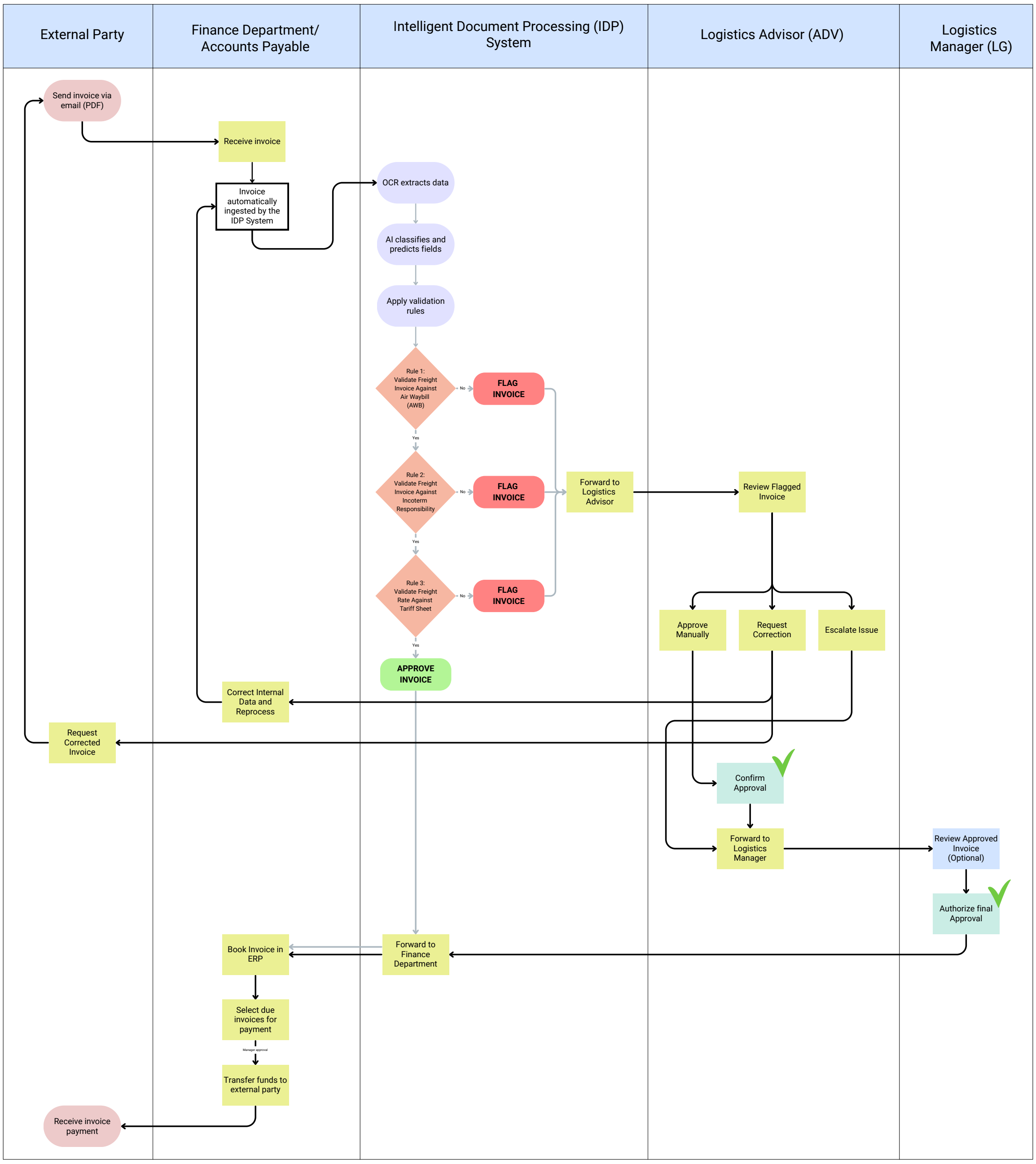

Figure 13: Proposed IDP workflow for invoice verification (to-be process).

6.1.4 Post-Validation Workflow

All three proposed automation strategies, whether Rule-based Automation, AI-driven IDP, or Hybrid Structured Automation, share a common post-validation pathway for handling exceptions and processing approvals. To avoid redundancy and ensure clarity, this section outlines the shared workflow steps for exception handling, manual review, and payment processing independently of the specific automation model. This unified approach ensures consistency in stakeholder responsibilities, escalation procedures, and financial controls across all invoice verification processes. Figure 13 illustrates these shared steps using the IDP workflow as a representative example.

Exception Handling and Manual Review

Invoices that do not pass one or more validation checks are flagged and routed to designated stakeholders for manual intervention. The review process is structured and role-based, ensuring that each exception is appropriately addressed depending on its nature and severity. Typically, flagged invoices are first directed to the Logistics Advisor, who is responsible for reviewing the case and determining whether the invoice can be manually approved. This step is particularly relevant when the automated system is unable to confirm compliance due to missing or ambiguous data.

If the invoice requires correction, it is either forwarded to the Finance Department for internal data adjustments and reprocessing, or returned to the external party with a request to revise and resubmit the invoice. In more complex cases, such as unresolved discrepancies or contractual ambiguities, the Logistics Manager may be involved to provide oversight and escalate the issue as needed.

The invoice is manually approved by the Logistics Advisor, either directly or after the necessary adjustments have been made, ensuring compliance with both internal records and contractual standards. Following this first-level approval, the invoice is forwarded to the Logistics Manager for optional review and final authorization. Once fully approved, the invoice is returned to the Finance Department for subsequent payment processing.

Approval and Payment Processing

Invoices are forwarded to the Finance Department for payment processing through two distinct pathways: either directly after passing all automated validation checks, or following manual review and final authorization by both the Logistics Advisor and the Logistics Manager.

Once approved, invoices are recorded in the ERP system, and payments are scheduled based on their respective due dates. Managerial approval is obtained when required, after which the funds are transferred to the external party. Upon completion, the external party receives the payment, marking the final step in the process. This end-to-end workflow improves efficiency while reinforcing financial control and operational transparency.

6.2 Comparative Synthesis of Proposed Workflows

Looking across the three proposed workflows, it becomes evident that they represent not only varying levels of technological sophistication, but also distinct organizational philosophies and operational requirements. Each approach offers a distinct lens through which invoice verification can be managed, shaped by its underlying logic, data requirements, and stakeholder dependencies. This section examines the strategic implications of each model, focusing on their respective strengths, limitations, and alignment with the realities of dynamic freight environments. To facilitate comparison and highlight the nuances of each approach, Table 10 below presents a structured summary of the key dimensions.

Rule-Based Automation can be viewed as the most internally controlled and logic-driven approach, with its primary strength lying in its simplicity. By embedding contractual rules into a step-by-step validation flow, it ensures transparency and predictability in cost allocation. In environments where invoice formats are stable and contractual structures are well-defined, this approach can deliver efficiency at relatively low cost. Additionally, it demonstrates that automation-supported workflows can be implemented with minimal technological barriers, leveraging tools already available in most enterprise environments. However, this simplicity also represents its main vulnerability. The rule-based system is inherently brittle, relying on the assumption that documents follow predictable structures. In practice, the diversity of carriers, international shipping conditions, and evolving service agreements make this assumption difficult to sustain. As a result, the system would likely generate a high rate of exceptions, undermining its intended efficiency gains. In this sense, rule-based automation reflects a philosophy of strict internal control, but one that may prove too rigid for the realities of dynamic freight environments.

Hybrid Structured Automation represents a different philosophy. Rather than internalizing complexity, it shifts part of the burden upstream to external partners. By requiring vendors to submit structured data in machine-readable formats, this model reduces reliance on document parsing, improves accuracy and speed, enhances interoperability, and ultimately enables cleaner validation downstream. This redistribution of responsibility offers clear advantages. Structured inputs simplify internal workflows and reduce exception handling, making automation more scalable. Yet this improvement is conditional, since its effectiveness depends on the degree of partner compliance and the organization's leverage to enforce such standards. In fragmented or highly diverse carrier networks, this assumption may prove unrealistic, limiting the hybrid model's feasibility. Its philosophy is one of collaboration and co-responsibility, where efficiency gains are achieved not only through technology but through alignment across organizational boundaries. If successfully implemented, it could institutionalize a higher level of standardization and cooperation, creating value that extends beyond invoice verification itself.

AI-powered Intelligent Document Processing (IDP) embodies yet another philosophy that absorbs external variability rather than deflecting it. Instead of constraining input diversity or outsourcing standardization, it accepts variability as the baseline condition and manages it through advanced technology. By applying OCR, NLP, and probabilistic field classification, the IDP model is able to handle heterogeneous invoice formats without requiring uniformity upfront. This makes it, at least in theory, the most adaptable and future-proof model, especially in global freight environments where format diversity is too extensive to regulate through external agreements. Its main strength lies in its robustness and scalability. IDP can maintain consistent performance even when faced with unstructured or unfamiliar inputs, allowing the redesigned process to function effectively in highly heterogeneous ecosystems. This aligns closely with the operational realities of most global transport networks. However, this robustness is achieved at a cost. Implementation requires significant technological investment, ongoing model training, and reliance on specialized vendors. While IDP offers unmatched flexibility, it also increases the organization's dependency on external technology providers and raises the cost of maintaining accuracy over time. Strategically, IDP represents a model of technological centralization. It absorbs complexity internally through AI capabilities rather than managing it through rigid rules or external alignment. Organizations adopting this approach must be prepared to accept a higher degree of technological dependency along with the associated long-term maintenance efforts.

Dimension	Rule-Based Automation	Hybrid Structured Automation	AI-Powered IDP Platforms
Philosophy	Internal control through logic and rules	Shared responsibility through partner alignment	Absorbs external variability through AI capabilities
Input Requirements	Stable formats with predictable structure	Structured, machine-readable data from partners	Unstructured, diverse formats without prior standardization
Strengths	Simplicity, transparency, low cost, minimal technological barriers	Improved accuracy, scalability, cleaner validation, reduced parsing effort	High adaptability, robustness, and scalability in heterogeneous environments
Limitations	Brittle in dynamic contexts, high exception rate	Dependent on vendor compliance and standardization leverage	High implementation cost, vendor dependency, ongoing model training
Technological Dependency	Low	Medium	High
Scalability	Limited in fragmented or evolving environments	Conditional on ecosystem alignment and partner cooperation	High, even in fragmented networks
Strategic Implication	Logic-driven, internally governed	Collaborative, externally aligned	Centralized, AI-driven complexity management
Best Fit For	Stable, well-defined contractual and document environments	Semi-structured ecosystems with enforceable data standards	Highly variable, global freight environments

Table 10: Comparative Summary of Invoice Automation Models

In summary, the three workflows reflect divergent approaches to governing invoice verification. Rule-based automation prioritizes clarity but risks fragility. Hybrid automation leverages external collaboration but depends on enforceable data standards. IDP embraces diversity and promises scalability, but increases reliance on advanced technology. Choosing between them is less about identifying a single “best” solution and more about aligning the workflow design with organizational priorities, partner landscapes, and tolerance for technological dependency.

6.3 Shared Validation Backbone

Despite the differences in technological sophistication and input formats, all three workflows converge on a common validation backbone. Regardless of whether inputs are parsed PDFs, structured CSVs, or AI-extracted fields, the core validation logic remains consistent. Invoices are subject to a uniform sequence of checks that include alignment with shipment records, cost allocation based on Incoterms, and verification of invoiced amounts against contractual tariffs. This backbone provides the essential standardization that has long been missing from the current process, where checks are inconsistent, incomplete, or reliant on tacit expertise.

In the current workflow at Fokker S.G., attempts to validate invoices are often fragmented and insufficient. For instance, responsibility for transport costs is not confirmed in a systematic way based on Incoterms. Instead, advisors rely on heuristics such as whether the invoice was issued to the company’s account number. This approach may serve as a preliminary filter but cannot guarantee correctness, as liability frequently depends on shipment direction and contractual terms. Likewise, shipment matching is currently hampered by missing or poorly structured identifiers, forcing advisors to manually consult multiple disconnected systems. These efforts, while diligent, are not only time-consuming but also lack the consistency and reliability needed for financial control. Finally, charge validation is rarely performed against actual contractual tariffs, but instead relies on precedent or personal judgement. This injects subjectivity into what should be a data-driven decision, creating variability between advisors and eroding auditability.

By contrast, the proposed validation backbone transforms these weak points into structured, rule-based safeguards. Shipment-to-invoice matching becomes a systematic process anchored in AWB and ERP data rather than guesswork across multiple platforms. Cost allocation is validated against shipment direction and Incoterm logic, ensuring that financial responsibility is confirmed rather than assumed. Charges are benchmarked against machine-readable tariff sheets, eliminating reliance on tacit knowledge and ensuring strict compliance with contractual agreements.

What makes this backbone particularly important is its universality. It applies regardless of whether the enabling technology is rule-based, hybrid, or IDP. While the sophistication of data ingestion may vary, the rules governing correctness remain consistent. This ensures that invoice verification no longer depends on the limitations of a chosen system or the personal expertise of individual advisors. Instead, it follows a transparent and standardized pathway. In doing so, it not only addresses long-standing inefficiencies but also establishes a robust foundation for scalability, auditability, and fairness in transport cost allocation.

6.4 Expected Benefits of Automation-Supported Workflow Redesign

The proposed workflow redesign introduces a structured and scalable approach to transport invoice verification, addressing long-standing inefficiencies in the current workflow. By combining a shared validation backbone with flexible implementation pathways such as rule-based, hybrid, or AI-powered IDP, the redesigned workflows offer both operational improvements and strategic value. While each model contributes distinct advantages, the AI-powered IDP strategy emerges as the most promising due to its ability to handle input variability, reduce manual effort, and deliver high accuracy at scale. This section outlines the key benefits across four dimensions: efficiency, accuracy, cost-effectiveness, and governance.

Efficiency Gains and Time Savings

A primary benefit lies in efficiency. By automating initiation, validation, and approvals for routine cases, the workflows reduce the volume of manual interventions and shorten processing cycles considerably. Under the current process, validating a single freight invoice can take anywhere from 15–25 minutes, depending on the availability of shipment references and tariff data. With IDP-enabled workflows, routine invoices that pass validation rules can be approved automatically, reducing processing time to 2–3 minutes per invoice. For an organization processing several thousand invoices annually, comparable to the volume of the case company, this translates into a time saving of 600–700 labor hours per year, freeing up advisors and finance staff for exception handling and higher-value tasks.

Accuracy and Transparency Improvements

Beyond efficiency gains, the redesigned workflows deliver measurable improvements in accuracy and transparency by replacing subjective judgments with structured, rule-based checks. Manual validation today often relies on tacit knowledge and heuristics, resulting in inconsistencies and an estimated error rate of 5–10% in invoice approvals, whether due to overpayment, delayed dispute handling, or overlooked deviations. With IDP's AI-driven field extraction and automated tariff validation, accuracy on routine invoices can realistically reach 98%, reducing the error rate by up to 90%. This significantly cuts financial leakage from overbilling and establishes a transparent, auditable trail that strengthens the organization's position in financial reconciliation and carrier disputes.

Cost and Maintenance Considerations

From a cost and maintenance perspective, the choice of automation pathway can be tailored to the organization's digital maturity. Rule-based and hybrid models typically require lower upfront investment but involve ongoing maintenance of rules, portals, and data standards. IDP systems, by contrast, carry higher licensing costs due to their AI capabilities, but reduce long-term configuration overhead since they learn and adapt to variable invoice formats.

For an organization that already licenses an IDP platform but uses it only for basic OCR, activating advanced AI features and embedding validation rules would involve incremental costs mainly in system configuration, training models, and API integrations. These costs remain modest when compared with the potential benefits. In settings with invoice volumes and freight charges similar to the case company, manual processing costs are estimated at around €70,000 per year. By contrast, IDP-enabled processing reduces this to approximately €10,000, representing an 85% reduction in labor costs due to faster cycle times and lower manual effort. In addition, avoiding errors equivalent to around 2% of total freight charges contributes an estimated €70,000 in savings. Even when factoring in platform costs and periodic model retraining, full IDP activation remains a financially viable solution.

Strategic Value Beyond Efficiency

In addition to measurable gains, the redesigned workflows reshape how cost allocation is governed. By embedding Incoterm logic and rate validation into an auditable system, it eliminates ambiguity and arbitrariness from decision-making. This fosters greater accountability across logistics and finance functions, while also raising expectations for external partners to provide structured and transparent data. Crucially, the modular design ensures flexibility by allowing organizations to begin with a simpler rule-based or hybrid setup and gradually scale into full IDP capabilities as partnerships, budgets, and digital readiness evolve.

Taken together, the redesigned workflows demonstrate more than incremental automation. They represent a fundamental shift in how cost allocation is governed and optimized. By institutionalizing business logic in a consistent and data-driven way, the approach promotes transparency across functions, reduces financial risk, and lays the groundwork for measurable cost savings. Its modular design allows organizations to start with simpler configurations and scale as needed, making it adaptable to varying levels of digital maturity. The combination of operational efficiency, financial impact, and strategic flexibility highlights its transformative potential in logistics.

7 Discussion

7.1 Transferable Insights for Transport Cost Management

While the research is grounded in a single organizational case, the challenges identified such as fragmented data sources, reliance on tacit knowledge, manual invoice checks, and limited automation, are widespread in outsourced logistics environments. They represent structural weaknesses that extend beyond Fokker Services Group and are commonly embedded in how many firms approach transport cost management.

The findings demonstrate that automation in this domain can be approached as a staged progression rather than a single technological leap. Companies can begin by embedding rule-based checks to standardize basic validations, advance toward hybrid approaches where structured data from partners is available, and ultimately leverage AI-enabled solutions such as IDP to manage greater variability at scale. This staged logic does not prescribe a one-size-fits-all solution, but it does offer a transferable pathway adaptable to different levels of digital maturity and ecosystem complexity.

The study highlights mechanisms, such as progressive automation, collaboration with partners, and closer integration of financial and logistics data, that other organizations can draw on to improve transparency, efficiency, and financial control in transport cost management.

7.2 Positioning in Prior Research and Emerging Implications

The present study contributes to academic and managerial discourse that has traditionally treated transport cost management at an aggregate, model-driven level rather than at the granular level of invoice verification. Established frameworks such as Activity-Based Costing (ABC) and Total Cost of Ownership (TCO) have long emphasized the importance of assigning costs to activities or products in a transparent way. These models succeed in providing visibility into cost drivers, facilitating strategic decisions around outsourcing, network design, or supplier evaluation. However, they often assume that the underlying cost data is accurate, verified, and readily available. What this research demonstrates is that this assumption does not hold in outsourced logistics environments. The stage in which costs are first captured, typically through invoices, is burdened with inefficiencies, fragmented data, and dependence on tacit human knowledge.

By explicitly focusing on transport invoice verification, this study extends the scope of cost management research into a domain where financial control is both strategically important and operationally fragile. In contrast to prior work that often regards automation as a marginal improvement in efficiency, the findings here demonstrate that automation can fundamentally reshape how financial accountability is governed. Instead of being reactive, approving invoices post hoc with minimal validation, automation-supported workflows can institutionalize validation logic, making the process proactive, transparent, and auditable. In doing so, this research contributes to the broader literature on supply chain digitalization and real-time decision-making by grounding these concepts in a concrete, operational context.

7.3 Managerial and Research Implications

The managerial implications of these findings are significant. Invoice verification should no longer be regarded as a low-value administrative task, but as a strategic control point that safeguards financial accuracy and transparency. Embedding shipment matching, Incoterm logic, and tariff validation into structured workflows enables organizations to resolve disputes with carriers using objective data, strengthens cross-functional collaboration between finance and logistics, and reduces exposure to financial leakage. Managers should also recognize that automation maturity is not binary but progressive. Rule-based systems offer simplicity and accessibility, hybrid systems leverage partner collaboration, and AI-powered IDP provides scalability in heterogeneous contexts. Choosing a pathway should therefore be based on ecosystem complexity, partner leverage, and digital readiness.

From a research perspective, this study demonstrates how cost management concepts can be operationalized through process redesign and digital automation. The design-science approach, which involves diagnosing inefficiencies, evaluating technology options, and proposing to-be workflows, offers a replicable methodology for similar contexts. By bridging the gap between conceptual models and transactional realities, the study opens avenues for future research on how digital tools can strengthen financial control in other outsourced or data-fragmented environments, extending the academic conversation from aggregate models to operational-level governance.

7.4 Considerations for Implementation

Despite these advantages, the implementation of automation strategies for transport cost verification is not without challenges. A first and often underestimated consideration is data readiness. Automated verification is only as reliable as the quality and accessibility of the underlying data. Shipment identifiers, tariff agreements, and Incoterm details must be stored in structured and machine-readable form to support automated checks. However, in many organizations, these data remain fragmented between multiple systems or inconsistently recorded, limiting the effectiveness of even advanced solutions such as IDP.

A second consideration is organizational change management. The introduction of automation-supported workflows alters the nature of work for logistics advisors and finance staff. Rather than manually reviewing every invoice, their role shifts towards exception handling, data stewardship, and oversight of automated rules. While this reallocation of effort promises efficiency, it also demands new skills, training, and, in some cases, a redefinition of professional responsibilities. Resistance to such changes may slow adoption unless accompanied by clear communication of benefits and adequate support.

Third, an important consideration is ecosystem and economic viability. The feasibility of hybrid approaches depends heavily on the external partner landscape. Structured data submissions from carriers can dramatically reduce complexity, but such arrangements require negotiation and compliance enforcement. In highly fragmented or globally dispersed logistics networks, the leverage to impose such standards may be limited. Finally, the cost-benefit balance of advanced IDP systems must be carefully evaluated. While they offer scalability and adaptability, they also introduce new forms of vendor dependency, licensing costs, and ongoing maintenance obligations. Organizations must ensure that the expected efficiency and accuracy gains are sufficient to justify these investments.

7.5 Pathways for Implementation and Future Replication

One of the strengths of the proposed workflow redesign is its modularity. Instead of being forced to choose between simplicity and sophistication, organizations can adopt a phased and adaptive implementation pathway. In practice, this means that companies can begin with a rule-based configuration, which delivers immediate improvements in transparency, standardization, and efficiency without significant technological or financial investment. This initial step secures early wins by embedding contractual rules into workflows and reducing reliance on tacit knowledge, while at the same time creating organizational familiarity with structured, system-supported validation.

Once a stable baseline has been achieved, organizations may extend the redesign into a hybrid configuration, which shifts part of the responsibility upstream to logistics partners by requiring structured, machine-readable data input. This phase not only improves accuracy and reduces exception handling, but also builds inter-organizational collaboration and enforces higher data standards across the supply chain. Crucially, this step allows companies to leverage their bargaining power to push for greater partner compliance, creating benefits that extend beyond the firm itself and into its ecosystem.

In the final stage, AI-powered Intelligent Document Processing (IDP) can be introduced to absorb residual variability that cannot be standardized or controlled externally. This capability ensures scalability and robustness in complex global networks, where invoice heterogeneity is unavoidable. By adopting IDP at a mature stage of digital readiness, firms can minimize the risks of over-investment, reduce dependency on external vendors during early implementation, and ensure that the organizational competencies and governance mechanisms needed to manage such a system are already in place.

This staged approach offers strategic benefits by aligning technological adoption with organizational readiness, budget cycles, and strategic priorities. It avoids the pitfalls of premature complexity and ensures that the value of automation is realized incrementally, thereby strengthening both managerial buy-in and long-term sustainability. Importantly, even when organizations commit to a specific strategy, implementation does not have to be monolithic. A phased pathway can still be pursued incrementally, allowing organizations to build capabilities over time. This gradual approach minimizes disruption, reduces risk, and allows organizations to adapt and learn before scaling up. From a strategic perspective, the pathway also creates optionality by allowing organizations to retain the ability to halt or recalibrate at each stage, rather than being locked into a single trajectory.

For researchers, this modular framework provides a replicable structure for empirical testing and cross-case comparison. Each stage, whether rule-based, hybrid, or IDP, can be piloted, measured, and benchmarked across industries and organizational settings. Such staged evaluations can reveal not only performance outcomes (e.g. efficiency gains, accuracy improvements, or cost reductions) but also contextual factors such as partner compliance, organizational change management, or the trade-offs between control and dependency. By accumulating findings across diverse cases, scholars can refine theoretical insights on how automation maturity influences cost management performance and governance structures, contributing to the development of a more generalizable body of knowledge on digital process automation in logistics and beyond.

7.6 Limitations and Academic Reflections

The study inevitably carries limitations that shape the scope and interpretation of its contributions. First, the research is situated in a single organizational context: Fokker Services Group. Although the inefficiencies identified, such as fragmented data, reliance on tacit expertise, and lack of systematic validation, frequently arise in outsourced logistics settings, their severity and the feasibility of the proposed solutions may vary considerably across industries, geographies, and governance arrangements. Organizations operating in stable and concentrated supply networks may face fewer barriers to addressing these issues than those embedded in highly fragmented or globally dispersed networks. The findings therefore carry strong analytical generalizability in the sense that they highlight mechanisms and pathways relevant for theory, but they cannot claim statistical generalizability without broader replication across diverse cases.

Second, the proposed workflows are conceptual rather than empirically tested. While efficiency gains, error reductions, and cost savings were estimated based on benchmarks, organizational feedback, and secondary data, these remain projections. Real-world implementation could surface unforeseen complexities such as system integration failures, new types of data inconsistencies, or resistance from end-users who perceive automation as a threat to their roles. Moreover, benefits may be unevenly distributed across functions. While finance departments may experience significant efficiency gains and greater transparency, logistics staff may encounter new forms of workload, such as maintaining master data or monitoring exception rules, while also having to adapt to a more technologically advanced system that requires new skills and alters established routines. Future empirical studies are therefore necessary to validate, refine and quantify the actual impact of automation-supported workflows, not only in aggregate performance terms but also in terms of organizational acceptance and change management.

Third, the study faces an inherent temporal limitation. Technologies such as Intelligent Document Processing evolve at a rapid pace, with model capabilities, licensing models, and integration options changing significantly over relatively short time horizons. The workflows designed here should therefore be understood as a blueprint that captures state-of-the-art capabilities at the time of writing, rather than as prescriptive or timeless solutions. Future adaptations will be required as new functionalities, such as self-learning validation rules, blockchain-based audit trails, or autonomous agent-based workflows, become mainstream.

Despite these limitations, the study offers meaningful academic reflections. First, it demonstrates the value of applying a design science approach in the intersection of logistics and accounting research. Much of the existing literature on logistics cost management remains descriptive or conceptual. By contrast, this study illustrates how prescriptive design artifacts, exemplified by to-be workflows for invoice verification, can bridge the gap between theoretical frameworks and operational realities. This methodological orientation opens the door to more interventionist research that does not stop at diagnosing problems, but also provides structured, testable solutions.

Second, the study highlights the transactional layer of logistics cost management, which has often been overlooked in favor of aggregated cost models or strategic decision frameworks. By focusing on invoice verification, the precise point at which financial and logistical records converge, it calls attention to a domain where small improvements in accuracy or efficiency can have disproportionate strategic effects. This redirection of scholarly attention enriches both logistics and management accounting literature by foregrounding the micro-processes through which financial control is enacted.

Third, the research underscores the importance of integrating digitalization debates into cost management scholarship. While prior studies have often framed automation as a technological breakthrough aimed at reducing administrative overhead and streamlining operations, this study positions it as a governance mechanism that reshapes accountability, transparency, and trust across organizational boundaries. This reframing aligns with broader debates in information systems and supply chain research on digital transformation, while bringing them into closer dialogue with cost verification practices.

Finally, by foregrounding the role of stakeholders through weighting exercises, validation of criteria, and the design of workflows, the study demonstrates how organizational perspectives can be systematically incorporated into design research. This methodological contribution provides a replicable model for future researchers who wish to evaluate automation strategies not only on technical merit, but also on organizational fit, stakeholder priorities, and governance implications.

Taken together, the limitations and reflections suggest that, while the study findings must be applied with caution and contextual sensitivity, they also expand the scholarly agenda. They show that logistics cost management research can move beyond abstract cost models and toward actionable, digitally enabled frameworks that both reflect and shape the realities of practice.

8 Conclusion and Recomendations

8.1 Conclusion

This study set out to explore how financial decision-making in logistics can be enhanced by approaching transport cost management through a systematic redesign and automation lens. The central research question addressed in this study was:

How can transport cost verification processes be redesigned and supported through automation to improve financial decision-making at Fokker Services Group?

The overarching research question was addressed through four sub-questions, which are analyzed in turn in light of this study's findings:

1. ***What are the limitations of existing cost management models in addressing real-time transport invoice verification and decision-making needs?***

   The review of established models such as Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting (LA) highlighted that while these models provide valuable insights at strategic or tactical levels, they fall short when applied to the transactional realities of outsourced logistics. TCO enables organizations to compare suppliers and assess lifecycle costs, but its strategic orientation means it does not extend into the granular verification of individual freight invoices. ABC offers highly detailed cost traceability but presupposes access to structured, activity-level data from logistics providers, an assumption rarely met in outsourced freight environments. LA, in turn, emphasizes internal efficiency and value-stream performance, but its inward-facing perspective does not capture the external, multi-party validation that transport cost verification requires. Together, these shortcomings show that while existing models provide conceptual clarity, they do not address the operational frictions where costs are actually recorded and validated.

   This study demonstrates that existing cost management models are insufficient for contexts where invoice verification is both highly complex and financially material. The gap lies not in the conceptual soundness of frameworks such as TCO, ABC, or Lean Accounting, but in their detachment from real-time data validation. Although they provide strategic clarity and analytical structure, the three models fall short of offering a comprehensive solution for verifying outsourced transport invoices in dynamic logistics settings. The analysis therefore highlights the need to move beyond static costing frameworks and incorporate process redesign and automation. Such an approach does not replace existing models but rather complements them by ensuring that invoice verification generates reliable, auditable, and standardized data. In doing so, it strengthens the foundation on which higher-level cost management frameworks operate, enabling meaningful strategic analysis that is grounded in accurate transactional data.

2. ***How do current administrative and contract governance practices contribute to inefficiencies in transport cost verification?***

   The process analysis shows that Fokker's administrative and governance practices contribute directly to inefficiencies in transport cost verification. Invoice validation remains heavily manual, with logistics advisors spending 15–25 minutes per invoice cross-checking data across multiple systems. The burden is particularly acute for large multi-page invoices, which cannot be comprehensively verified under current conditions. As a result, advisors often rely on heuristics and plausibility checks rather than systematic rules, introducing inconsistency and limiting scalability.

Contract governance practices further amplify these weaknesses. Incoterm responsibilities are not systematically validated, with advisors instead using proxies such as the account number, which can be misleading. Tariff agreements are stored in unstructured formats, preventing automated benchmarking of invoiced charges against contractual rates. This absence of structured controls means that cost responsibility and rate validation are handled in a reactive, ad hoc manner, dependent on individual expertise rather than institutional safeguards.

Taken together, these practices turn invoice verification into an administrative burden rather than a governance mechanism. The lack of integration, structured validation, and standardized exception handling not only slows down processing but also increases exposure to overpayment and disputes. In this sense, the current system is not simply inefficient but structurally incapable of providing the reliable, auditable data needed for financial decision-making, which highlights the urgency of redesign.

3. ***Which automation technologies can best enhance accuracy and efficiency in transport cost processing?***

   To address the identified inefficiencies, this study evaluated three distinct automation strategies: Rule-based Automation, Hybrid Structured Automation, and AI-powered Intelligent Document Processing (IDP). The evaluation, guided by stakeholder-weighted criteria such as accuracy, flexibility, scalability, integration, and cost, revealed a differentiated performance profile. IDP emerged as the strongest candidate with an overall score of 7.27, driven primarily by its superior accuracy and adaptability in handling heterogeneous invoice formats. Hybrid Structured Automation followed with 6.52, offering notable strengths in integration and cost control but limited by its dependency on partner compliance. Rule-based Automation, with a score of 4.97, proved least aligned with organizational priorities, reflecting its vulnerability in dynamic environments despite its low technological barriers.

   The analysis underscores that no technology represents a one-size-fits-all solution. Instead, automation maturity should be conceptualized as a staged journey rather than a binary choice. Rule-based systems may deliver immediate efficiency gains in stable environments where invoice formats are predictable and contracts clearly defined. Hybrid approaches extend these benefits by shifting the standardization effort upstream, but their feasibility depends heavily on ecosystem leverage and partner cooperation. IDP, while requiring higher investment and ongoing maintenance, provides unmatched scalability and resilience in global logistics contexts where input diversity cannot realistically be controlled.

   Ultimately, the findings emphasize that the choice of automation strategy must balance technical capabilities with organizational realities. Effective adoption is not about selecting the most advanced technology, but about aligning the chosen approach with stakeholder priorities, data readiness, and ecosystem conditions. In this light, IDP represents the most future-proof option, while rule-based and hybrid models remain important stepping stones, enabling organizations to advance their workflow redesign in line with digital maturity and strategic context.

4. ***What workflow models can be developed to operationalize automation in transport cost verification?***

   The final sub-question turned to the design of workflow models for transport cost verification. To address this, three to-be workflows were proposed, each aligned with one of the automation strategies: Rule-based Automation, Hybrid Structured Automation, and Intelligent Document Processing. While these workflows differ in their approach to data ingestion, relying variously on document parsing, structured partner submissions, or AI-driven extraction, they all converge on a common validation backbone. At its core, this backbone operationalizes three systematic checks: shipment-to-invoice matching through AWB records, explicit verification of cost responsibility based on Incoterms, and charge validation against machine-readable tariff sheets. By institutionalizing these rules, the redesigned workflows directly confront the weaknesses of the current process, where checks are fragmented, inconsistent, and heavily reliant on individual experience.

Crucially, the workflows function not merely as technical process models but as a governance mechanism. They embed financial accountability into day-to-day operational processes, creating transparency and reducing dependence on tacit expertise. Instead of invoice approval being contingent on the intuition of individual advisors, the redesigned workflows establish an auditable, rule-based trail that ensures decisions can be explained, defended, and replicated. This enhances cross-functional alignment between logistics and finance, while also strengthening the organization's position in disputes with carriers by grounding decisions in objective, data-driven evidence.

Equally important is the modularity of the workflow design. By offering three pathways, namely rule-based, hybrid, and IDP, it provides flexibility to match organizational readiness, partner dynamics, and budgetary constraints. A firm can begin with rule-based validation to capture early efficiency gains, evolve towards hybrid workflows where partner compliance is feasible, and ultimately scale into IDP capabilities in complex global environments. Importantly, committing to a specific strategy does not require a monolithic implementation. Organizations can still pursue a phased pathway, building capabilities gradually over time. This staged model avoids the risks of over-investment while ensuring that cost verification remains robust, auditable, and strategically aligned. In this way, the workflow models enable not only standardized and transparent cost allocation but also a roadmap for gradual digital maturity, ensuring relevance across diverse organizational contexts.

Taken together, these insights provide a structured answer to the main research question. Transport cost verification can be strengthened by designing standardized workflow models built around a common validation backbone that ensures shipment traceability, contractual cost allocation, and tariff compliance. On top of this backbone, different automation strategies can be layered depending on the organizational and ecosystem context. Rule-based, hybrid, and IDP configurations represent stages along a continuum of automation maturity, rather than mutually exclusive alternatives.

For Fokker Services Group, the findings suggest that a hybrid-to-IDP pathway offers the most strategic fit. In the short term, hybrid automation can enforce structured data submissions from partners, reducing exception handling and improving data quality without requiring disruptive investment. Over time, the organization can scale into Intelligent Document Processing to absorb residual variability across global carriers, ensuring long-term robustness and flexibility.

8.2 Recommendations for Future Research

Future research should place empirical validation at the forefront. While this study has proposed and conceptually evaluated three workflow models for transport cost verification, their real-world performance remains to be tested. Pilot implementations could provide concrete, measurable evidence of time savings, error reductions, and financial impact, complementing the conceptual evaluation presented here. For example, tracking key metrics such as processing cycle time, error detection rates, dispute resolution speed, and payment lead times before and after implementation would allow for more precise ROI calculations. Longitudinal studies would further strengthen the evidence base by showing how the benefits of automation evolve over time, particularly as machine learning models improve through retraining and as staff transition into new oversight and exception-handling roles. Such longitudinal perspectives are essential to move beyond one-off efficiency gains and toward a deeper understanding of how automation contributes to sustained organizational learning and resilience.

A second avenue lies in replication across industries and geographies. While the aviation MRO (maintenance, repair, and overhaul) sector provides a complex and illustrative case, its carrier relationships, invoice structures, and governance frameworks are not universal. Applying the modular workflow framework to industries such as retail, automotive, manufacturing, or pharmaceuticals, which are characterized by high invoice volumes and fragmented carrier networks, could refine the understanding of which automation strategies are best suited to particular contexts. For instance, industries with concentrated supplier bases may find hybrid automation easier to implement, while sectors facing highly fragmented or globalized logistics networks may benefit most from Intelligent Document Processing (IDP). Comparative cross-case research would therefore not only test the robustness of the workflow models but also highlight sector-specific adaptations that could inform more generalizable design principles.

Third, future work should examine the behavioral and organizational dimensions of automation adoption. The shift from manual invoice verification to system-supported exception handling represents a profound change in employee roles. How do logistics advisors and finance staff adapt when their expertise is redirected from transactional tasks to data stewardship and exception management? What forms of resistance, adaptation, or even skill redefinition emerge? These questions link logistics automation to broader research on organizational change and digital transformation. Empirical studies on adoption dynamics could provide insight into how best to manage this transition, ensuring that automation enhances rather than undermines professional identity, motivation, and cross-functional collaboration.

In sum, the future research agenda should move decisively beyond conceptual design toward empirical testing, cross-industry replication, and organizational adoption studies. Doing so would not only validate the projected benefits of automation, but would also reveal how these solutions must be adapted across different contexts and embedded into day-to-day practices. Such work would broaden the contribution of this study, advancing academic theory on cost management while also guiding the practical transformation of logistics finance toward greater accuracy, efficiency, and resilience.

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Appendix A: Rule-Based Automation Workflow

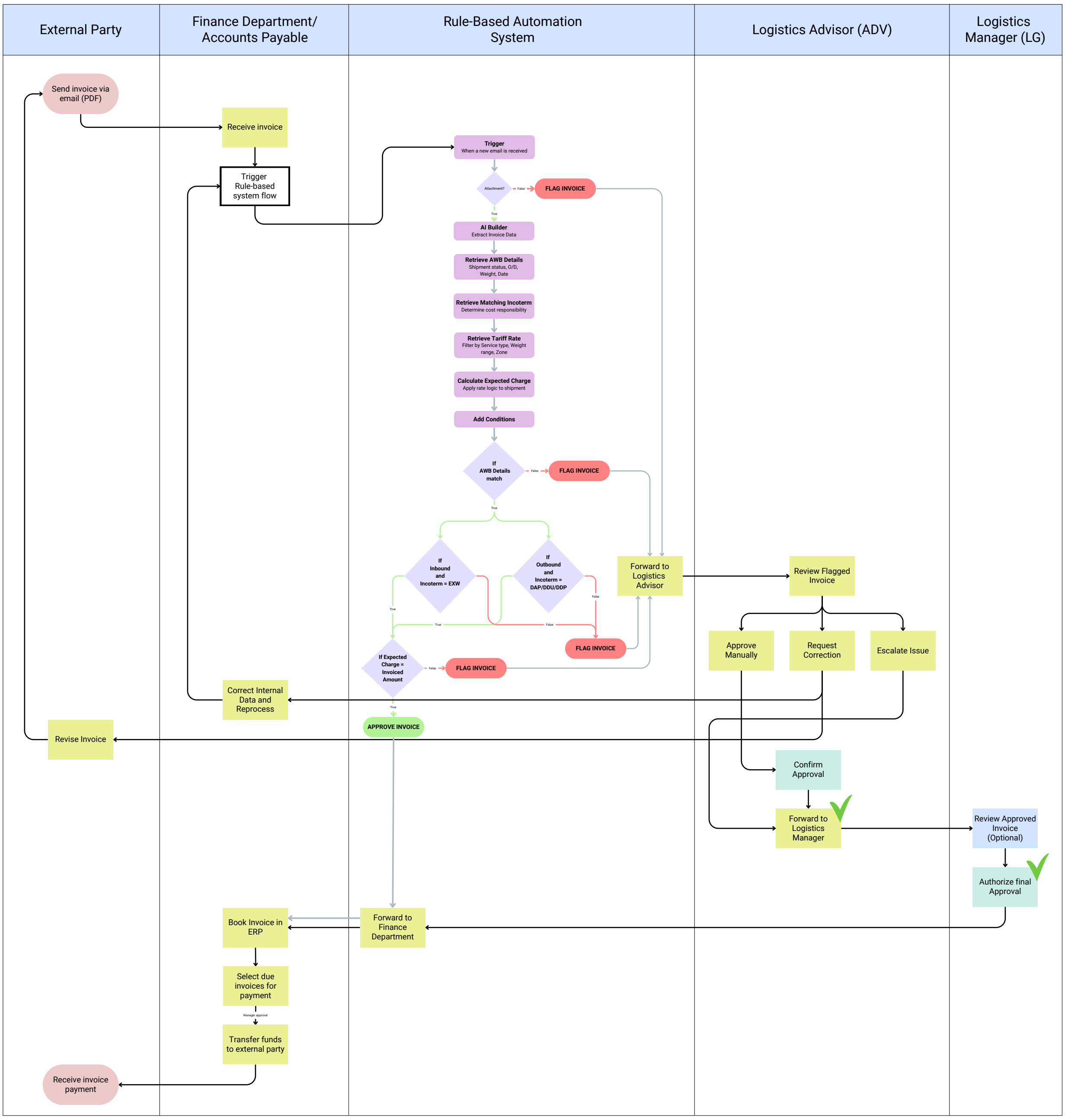

Figure A.1: Detailed rule-based automation workflow for invoice verification (to-be process).

Appendix B: Hybrid Structured Automation Workflow

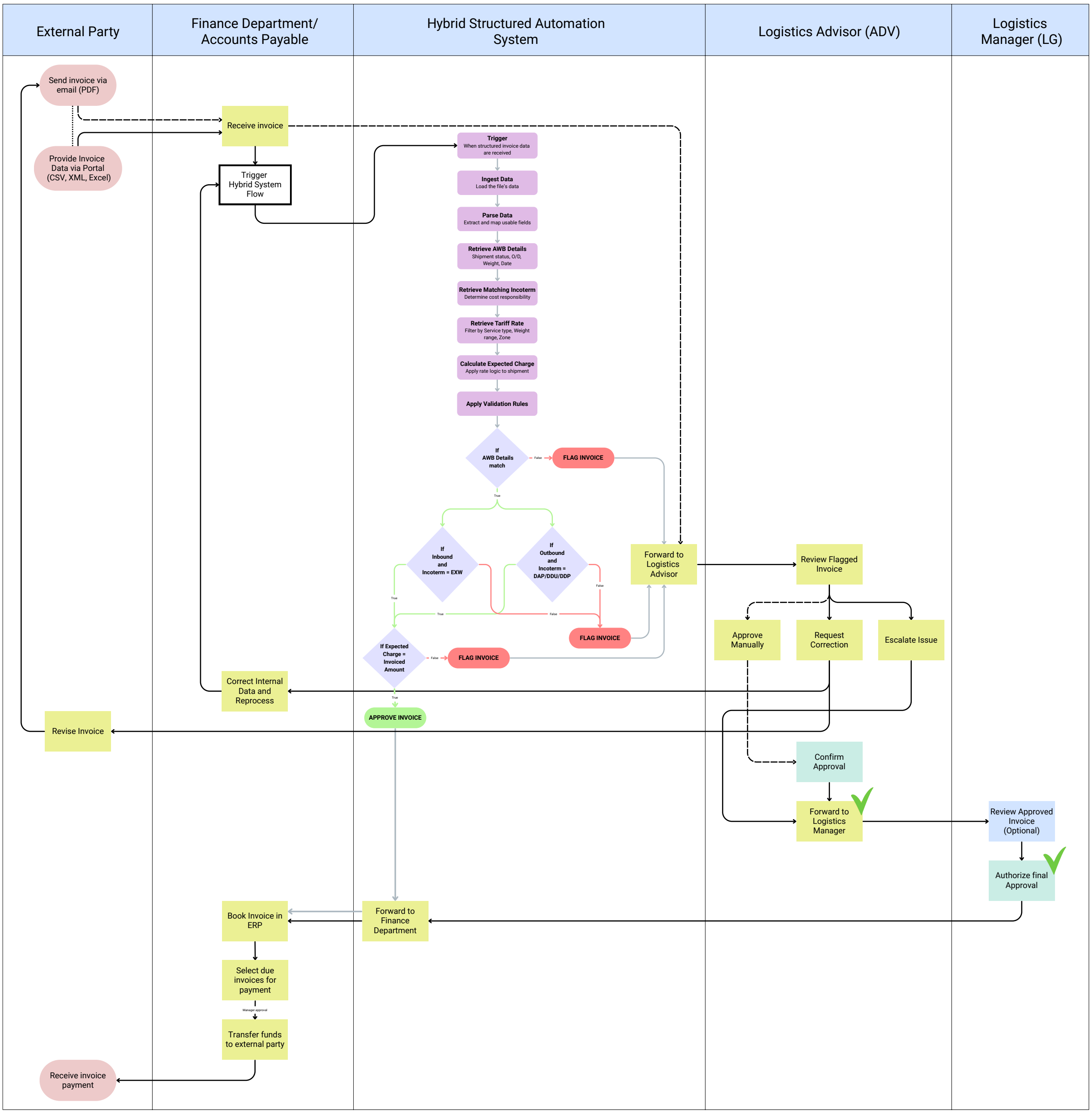

Figure B.1: Detailed hybrid structured automation workflow for invoice verification (to-be process).

Appendix C: Intelligent Document Processing Workflow

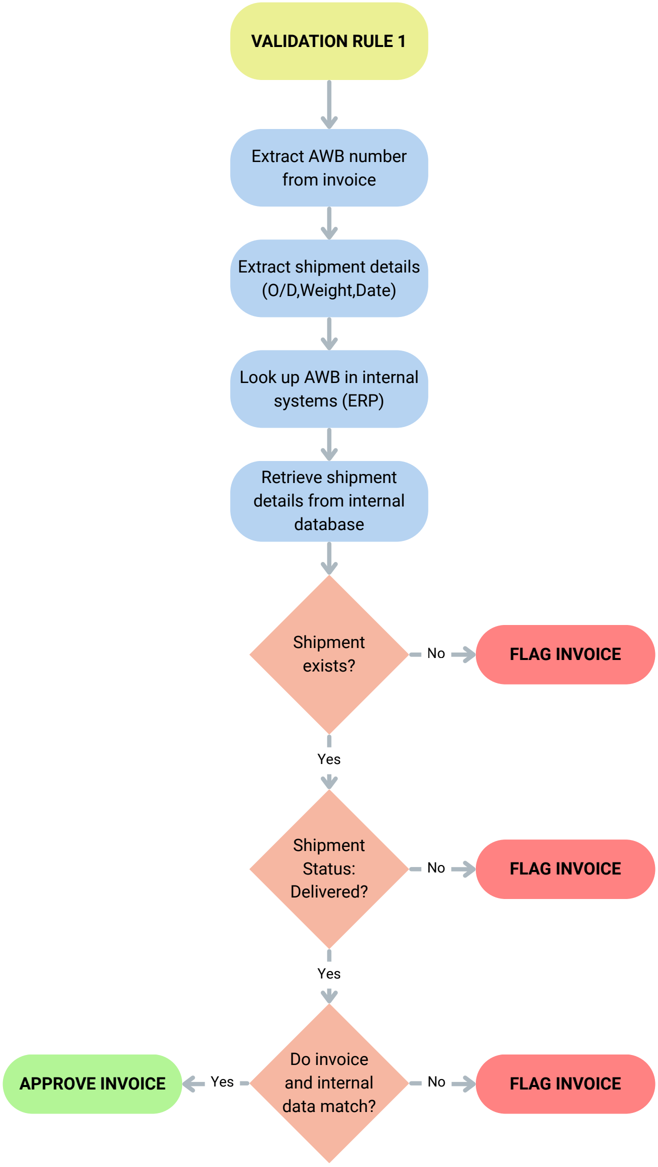

Figure C.1: AWB Matching Validation Logic for Invoice Verification.

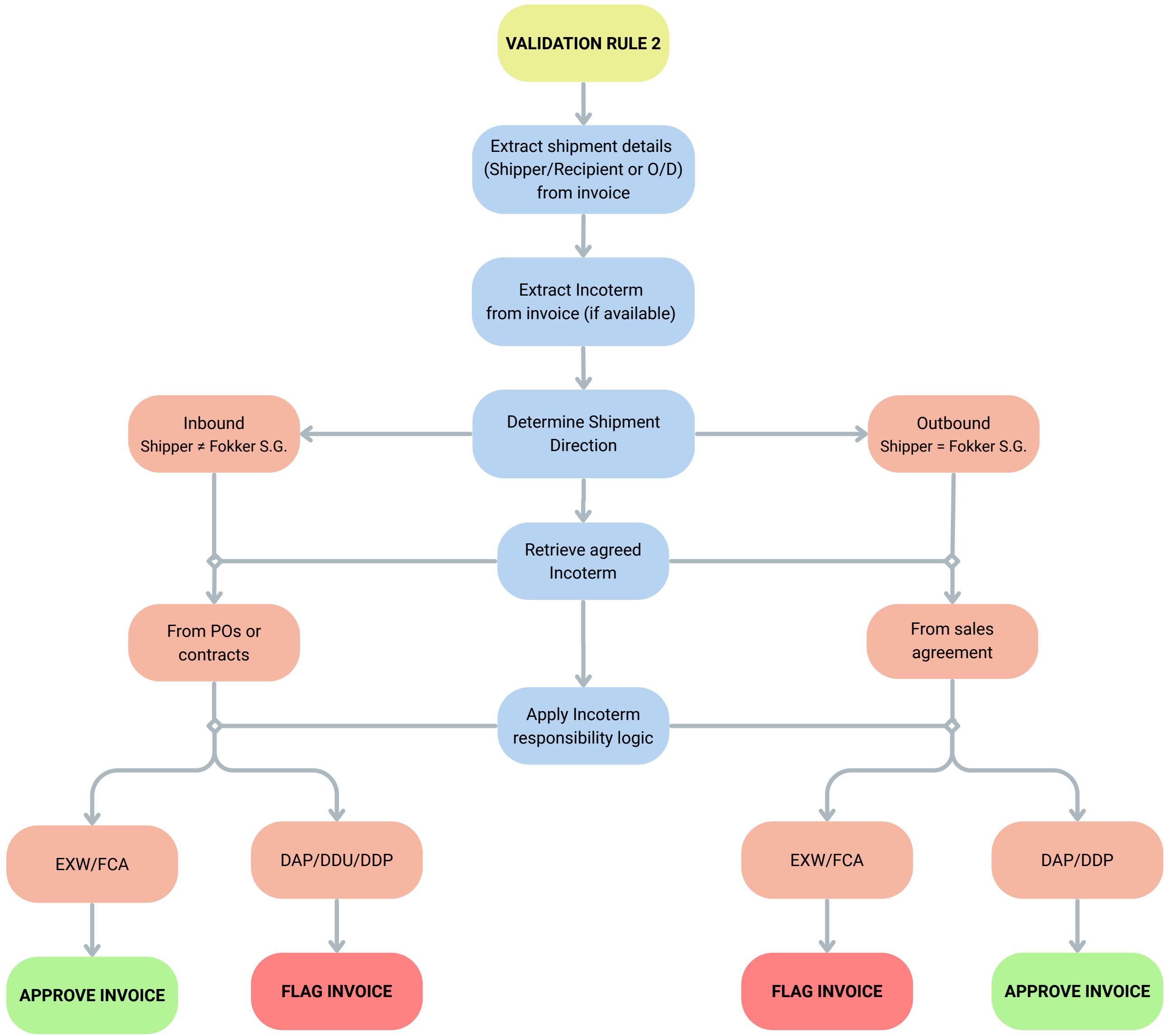

Figure C.2: Incoterm-Based Cost Responsibility Validation Logic for Invoice Verification.

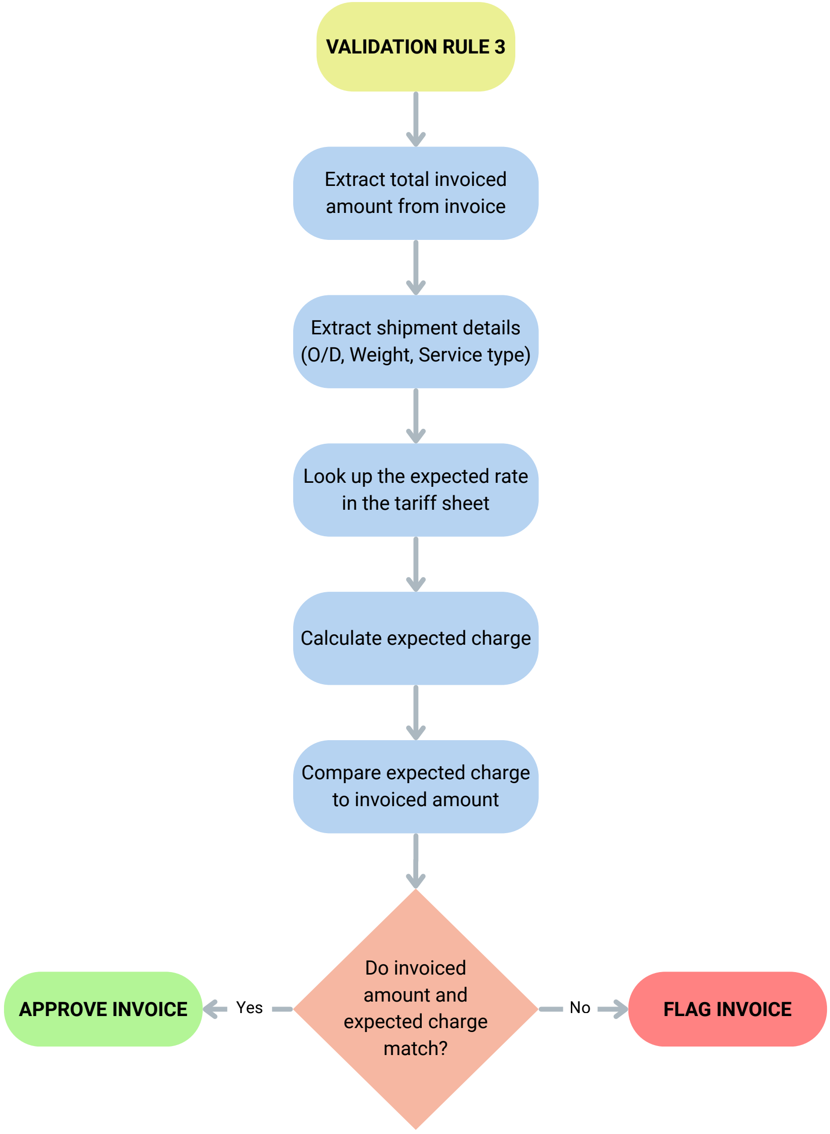

Figure C.3: Tariff-Based Charge Validation Logic for Invoice Verification.

Appendix D: Scientific Paper

Enhancing Financial Decision-Making in Logistics: A Process Redesign and Automation Approach for Transport Cost Management

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Abstract

Transport costs represent a dominant and volatile share of logistics expenditure, often exceeding one-third of total logistics costs, making their control and transparency a matter of strategic importance. Despite this significance, the verification of transport invoices in outsourced logistics remains highly manual, fragmented, and reliant on individual expertise, leading to processing delays, inconsistent application of contractual terms, and financial risks from overpayment or disputes. This study addresses these challenges by redesigning the transport cost verification process through automation. Adopting a design science methodology within a real-world case from the aviation maintenance sector, the research combines a current-state analysis, a stakeholder-weighted evaluation of alternative automation technologies, and the development of redesigned workflow models. The strategies assessed include Rule-based Automation, Hybrid Structured Automation based on structured data exchange, and AI-powered Intelligent Document Processing (IDP). The results show that IDP offers the highest overall performance, particularly in handling heterogeneous invoice formats, while hybrid automation balances efficiency with partner collaboration, and rule-based systems provide a low-barrier entry point for organizations at earlier stages of digital maturity. These strategies were subsequently integrated into an improved workflow design that embeds standardized validation, strengthens financial control, and reduces reliance on tacit expertise. Conceptually, the study extends cost management research by bridging strategic frameworks with the transactional realities of invoice verification, demonstrating how automation and process redesign can jointly enhance financial decision-making in outsourced logistics.

Keywords: Transport Cost Verification, Logistics Cost Management, Workflow Redesign, Invoice Automation, Intelligent Document Processing (IDP), Outsourced Logistics

I. Introduction

In an increasingly global and data-driven economy, organizations rely on efficient logistics and transport operations to remain competitive, while facing growing pressure to improve financial oversight and operational performance. [34] Within this context, the verification of transport-related costs has become a critical yet often overlooked aspect of financial management. Many companies still rely on manual invoice handling and fragmented approval processes, leading to errors, delays, and a lack of cost transparency. [25] As businesses seek greater efficiency and control, the need for automation and structured decision making in transport cost verification is more urgent than ever.

Logistics costs represent a substantial portion of overall business expenses. In developed economies, depending on the industry involved and the method applied, the proportion of company revenue attributed to logistics costs typically tends to be higher than 10 percent. [14] Logistics costs primarily pertain to the expenditures incurred in handling, transportation, and warehousing operations. [45] Among these logistics cost components, transportation consistently represents the largest share. Research indicates that it can account for nearly one-third of total logistics costs. [27] When measured against company revenues, transport costs typically exceed 6 percent, surpassing other logistics-related expenditures such as warehousing, inventory holding, and administrative processing. This dominant share underscores not only the central role that transport plays in shaping overall logistics costs but also the importance of maintaining precise control and visibility over related expenditures. [46]

Yet, despite its importance, transport cost verification remains a manual and error-prone process in many organizations. Companies often rely on fragmented data access, tacit knowledge of experienced staff, and loosely structured approval chains to assess the legitimacy of freight charges. These practices expose businesses to financial leakage, operational delays, and disputes with logistics partners. The challenge is particularly acute in outsourced logistics environments, where shipment execution, invoicing, and contract ownership are distributed across multiple actors, complicating cost validation and allocation.

Traditional cost management frameworks such as Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting (LA) offer valuable insights for strategic cost analysis but are not designed to address the transactional complexities of transport invoice verification. These models typically assume stable internal data environments and overlook the cross-organizational dependencies, fragmented data sources, and real-time decision points that characterize outsourced logistics operations. As a result, there is currently no established framework that systematically supports the verification, allocation, and governance of transport costs in real time within outsourced environments.

The growing digitalization of supply chains has introduced new opportunities to address these challenges. Automation technologies such as Rule-based Automation, Hybrid Structured Automation based on structured data exchange, and AI-powered Intelligent Document Processing (IDP) enable faster, more accurate, and auditable handling of freight invoices. However, the practical integration of these technologies into coherent automation-supported workflows remains an emerging area of research and practice.

This study addresses these gaps by examining how automation technologies can be integrated into transport cost verification processes within a real-world case. Fokker Services Group (FSG), an independent aviation specialist in aerospace innovation and support, serves as the empirical setting of this study, exemplifying the challenges of outsourced logistics where high invoice volumes, complex contractual terms, and fragmented data flows complicate cost verification.

Against this backdrop, the research sets out three objectives. It begins by diagnosing the current state of invoice verification in order to identify structural inefficiencies and bottlenecks. Building on this, the study evaluates the potential of the three automation strategies, namely rule-based, hybrid structured, and IDP, drawing on qualitative evidence structured within a stakeholder-weighted multi-criteria decision-making (MCDM) framework. Finally, it proposes redesigned workflow models that incorporate a shared validation backbone, ensuring standardized, auditable, and automated cost verification that can reinforce financial decision-making. In line with these objectives, the central question posed is:

"How can transport cost verification processes be redesigned and supported through automation to improve financial decision-making?"

The remainder of this article is structured as follows. Section II reviews relevant literature on cost management frameworks in logistics. Section III outlines the methodology, combining a case-based analysis with a design science approach. Section IV presents the current-state analysis at FSG. Section V evaluates the candidate automation strategies and reports the qualitative and quantitative results. Section VI introduces the IDP-based workflow redesign and its expected benefits. Finally, Section VII concludes the study and outlines directions for future research.

II. Literature Review

Logistics costs represent a substantial share of business expenses, often exceeding 10% of company revenues. [14][44] Within this, transportation is consistently the largest component, accounting for nearly one-third of total logistics costs. [27] This prominence highlights the importance of effective logistics cost management, as unmanaged inefficiencies can undermine operational performance, profitability, and long-term competitiveness. [55][31]

At its core, logistics cost management refers to the systematic approach of identifying, evaluating, and managing expenses across logistics activities, while making strategic decisions to optimize costs and balance profitability with service excellence. [26] In pursuit of financial transparency and operational efficiency, various cost models have been widely implemented, with Total Cost of Ownership (TCO), Activity-Based Costing (ABC), and Lean Accounting (LA) most frequently cited in the literature. Each provides a structured approach to managing logistics expenses, but their applicability to transport cost verification, particularly in outsourced environments, remains limited. The following sections briefly reviews these models, their core characteristics, and their limitations for transport cost verification.

A. *Total Cost of Ownership (TCO)*

Total Cost of Ownership (TCO), as described by Ellram (1995), serves as both a purchasing strategy and an evaluative framework to assess the full cost of acquiring a specific good or service from a supplier, as well as using and maintaining it over its lifecycle. In doing so, it extends beyond the purchase price to include logistics, quality, and disposal costs, thereby accounting for both direct and indirect logistics expenses. It supports long-term decision-making by enabling supplier comparison, cost-saving identification, and strategic procurement, and encourages a shift from a price-centric view to a total-cost perspective. [12][13][23]

Despite its advantages, TCO comes with several limitations that can hinder its practical application. One key difficulty is its data-intensive nature, as accurately gathering and tracking all relevant costs, especially post-use or indirect expenses, can be complex, especially in organizations lacking advanced costing systems or data infrastructure. Its wide scope can be overwhelming for firms without the appropriate analytical tools or expertise, leading to oversimplification or incomplete analyses. [48] In addition, the absence of standardized methodologies leads to variations in models across different firms and industries, makes benchmarking inconsistent, and limits comparability. [15] Effective implementation further demands significant cross-functional coordination and may face cultural resistance in organizations focused on short-term price reductions.

More critically, when applied to transport cost verification, TCO is limited, particularly in outsourced settings, as it is inherently retrospective and strategic in nature. It lacks the operational depth to reconcile daily billing details with agreed terms, and further requires a high degree of data centralization and traceability, which is often impractical when logistics data are fragmented across third-party systems. Moreover, its static framework offers limited adaptability to fluctuating freight rates, variable surcharges, or dynamic service-level agreements, making it ill-suited for agile, transactional-level verification, and monitoring of transport expenditures.

B. *Activity-Based Costing (ABC)*

Activity-Based Costing (ABC) is a cost accounting methodology developed by Cooper and Kaplan in the late 1980s, designed for complex manufacturing and service environments to improve cost allocation. [54] This is achieved through a two-step allocation process, in which indirect costs are initially assigned to activities rather than departments and subsequently linked to a broader set of cost drivers through cause-effect relationships, avoiding the arbitrary distributions of traditional systems. [11][20] By focusing on activities, ABC enhances transparency and traceability, enabling more precise cost allocation, deeper insights into cost behavior, and stronger support for managerial decision-making, strategic initiatives, and continuous improvement. [5][21]

However, in practice, ABC's conceptual strengths are offset by notable challenges. Establishing an ABC system typically requires considerable investment in setup, consultancy support, and IT infrastructure, while also placing heavy demands on personnel to collect, structure, and maintain detailed activity-level data. As a result, it is often more time-consuming and administratively intensive than traditional costing methods. [42] These difficulties are compounded by the challenge of identifying and maintaining appropriate cost drivers, as misapplied or poorly defined drivers can distort cost attribution and undermine the reliability of outcomes. Furthermore, ABC does not fully capture irregular or unpredictable costs and may at times prioritize operational efficiency at the expense of a broader, systems-oriented view of organizational performance. [38] Lastly, the model is not inherently compatible with standard financial reporting frameworks such as GAAP(Generally Accepted Accounting Principles), which may require dual reporting structures, creating further complexity and potential inconsistencies in external comparisons. [21]

In the context of transport cost verification, ABC also presents several operational limitations. While it is well-suited for analyzing internal activities, its application becomes more complex when logistics services are outsourced. [10] External carriers often do not provide the granular, activity-level data needed to define and update cost drivers, compromising accuracy in areas such as customs processing, last-mile handling, or exception-based charges. Moreover, ABC is better suited to periodic review and internal benchmarking than to frequent, transactional-level reconciliation of freight invoices. Its reliance on relatively stable process environments contrasts with the variability of logistics networks, making it insufficiently agile or specific for routine invoice validation and exception handling in third-party arrangements.

C. *Lean Accounting (LA)*

Lean Accounting (LA) is a cost management methodology developed in the 1990s as a response to the inadequacies of traditional cost accounting systems in lean production environments. Emerging alongside the Toyota Production System, it aligns financial reporting and decision-making with lean principles such as waste elimination, continuous improvement, and customer value. [7] Instead of relying on complex allocations or unit-based costing, LA emphasizes value stream analysis, real-time performance metrics, and simplified reporting to provide timely and relevant information for decision-making. [18] By eliminating arbitrary overhead allocations and focusing on value streams rather than individual products or departments, it offers a more accessible view of financial performance, enhances operational transparency, and supports continuous improvement. [6][29][50]

Despite these strengths, LA is not without limitations. By aggregating costs at the value stream level and moving away from product-level detail, LA reduces the focus on cost tracking and variance analysis, potentially undermining precision and limiting financial insight. [32] The lack of a standardized framework further complicates implementation, as firms often interpret lean principles differently, leading to inconsistent application. [17] In addition, its emphasis on short-term efficiency can at times undermine long-term sustainability, particularly when operational expenses are assumed to remain fixed. To address these shortcomings, experts often recommend combining LA with conventional or data-driven costing approaches to balance operational clarity with strategic agility. [4]

In logistics applications, LA shifts attention to end-to-end value streams, replacing conventional financial reports with visual tools such as box scores and process maps to track real-time indicators like lead times, turnover, or handling efficiency. [30] While this supports internal process optimization, its simplified reporting and cost aggregation limit its capacity for reconciling freight charges or validating compliance with negotiated rates and surcharges. The model assumes cost transparency within the organization, making it difficult to trace or verify costs generated externally by third-party carriers. [17] As a result, LA is ill-suited for the transactional depth and data integration required for rigorous, real-time transport cost verification in outsourced logistics networks.

The preceding review has examined three influential cost accounting models: TCO, ABC, and LA, each offering unique lenses for understanding and managing logistics costs. Collectively, these models have supported more informed sourcing decisions, improved resource allocation, and enhanced internal cost transparency. Their focus areas, however, diverge significantly when applied to the specific challenge of transport cost verification, particularly in outsourced logistics environments. Crucially, none of the three offers a fully adequate solution for verifying outsourced transport invoices in dynamic logistics settings. TCO provides a valuable strategic overview but lacks transactional visibility, ABC enables detailed cost traceability but depends on granular 3PL (Third-Party Logistics) activity data that is often unavailable or unstructured, and LA enhances internal efficiency but does not extend to external validation or multi-party reconciliation.

Taken together, these limitations reveal a clear research and practice gap: no existing framework adequately addresses the operational, transactional, and cross-organizational complexities of transport cost verification in outsourced logistics environments. To address this, the current study proposes a process redesign supported by automation technologies. This approach builds on the insights of traditional models but moves beyond their limitations, aiming to deliver a scalable, real-time solution that reflects the actual conditions of outsourced logistics.

III. Methodology

To address the research question, the study captures the nature of the challenge by situating it within a real-world setting. The complexities of invoice verification cannot be understood in the abstract, detached from the realities where they take place. They must be examined within an organizational setting, where fragmented systems, human decisions, and contractual arrangements converge. On these grounds, the study focuses on Fokker Services Group (FSG). The company illustrates the challenges outlined in the research gap while at the same time offering access to operational data and stakeholders that make an in-depth empirical investigation possible.

Building on this case context, the study adopts a structured methodological approach that combines empirical analysis, evaluation, and process redesign. Rather than approaching the problem from a purely conceptual standpoint, this research embraces a design-oriented methodology. It begins by uncovering inefficiencies within the current workflow, proceeds to a structured evaluation of alternative automation strategies, and culminates in the development of future-state workflows enhanced through the integration of digital technologies. This staged approach ensures that the proposed solution is both theoretically grounded and practically implementable within the realities of outsourced logistics.

A. *Current-state Analysis*

This study adopts a mixed-methods approach, combining qualitative and quantitative techniques to investigate the current state of transport cost verification at FSG. The design was guided by the need to map operational practices in a structured manner and empirically assess inefficiencies in invoice handling. By integrating stakeholder insights with transactional data, the analysis generates a comprehensive understanding of the verification workflow and its underlying bottlenecks, serving as a foundation for process redesign and automation evaluation.

Qualitative Process Mapping

The initial phase of the analysis focused on building an in-depth understanding of the operational workflow through qualitative investigation. Semi-structured interviews and process walkthroughs were conducted with key stakeholders from Finance, Procurement, and, most extensively, Warehouse Operations. These discussions provided detailed insights into how transport invoices are currently processed, including the systems utilized, the actors responsible at each stage, and the sequence of steps involved. Through iterative feedback and validation sessions, informal practices or workarounds that have developed over time were also revealed.

Building on these insights, the invoice verification process itself was modeled using a swimlane diagram to represent the "as-is" workflow. Swimlane diagrams were selected as the modeling technique due to their clarity in assigning process responsibilities, depicting interdepartmental handoffs, and highlighting dependencies or bottlenecks that are difficult to discern in textual descriptions. [3][53] This mapping enabled systematic documentation of verification checkpoints, such as invoice ownership determination, reference number validation, and charge approval, and provided the conceptual structure to identify inefficiencies.

Quantitative Data Analysis

To complement the qualitative findings, invoice transaction data were analyzed for the period January 2024 through Q2 2025, extracted from the company's accounts payable platform. After excluding voided or irrelevant entries, the refined dataset consisted of 2,199 freight-related invoice lines. Descriptive statistics were applied to examine volumes and temporal trends, while grouping by vendor allowed the identification of carriers contributing the largest shares of invoice value and workload. These insights highlighted workload concentration and suggested opportunities for targeted automation.

To further assess the efficiency of invoice handling, time-based performance metrics were introduced, capturing delays between issuance, registration, approval, and payment. These metrics were then synthesized in a focused timeline analysis designed to visualize the entire life cycle of individual invoices, from initial issuance by the logistics provider to final payment execution. This approach provided a granular view of intra-process variability and highlighted the stages that contributed most significantly to overall delay.

B. Evaluation of Potential Automation Approaches

Following the current-state analysis, the study turned to the evaluation of automation strategies that could address the identified inefficiencies. Literature consistently highlights characteristics that make processes well-suited for automation, including clear rule-based logic, structured and digital inputs, high transaction volumes, cross-system workflows, and repetitive manual tasks prone to error. [8] Invoice verification aligns strongly with these characteristics, making it a natural candidate for automation.

Three strategies were selected as potential enablers of a redesigned verification process because they capture both established and emerging approaches to automation. Rule-Based Automation was included as a foundational benchmark, as its deterministic workflows based on predefined logic create a clear baseline against which more advanced solutions can be compared. Intelligent Document Processing (IDP) was chosen for its prominence in both research and practice as a leading technology for document-centric workflows, which leverages artificial intelligence and machine learning to flexibly handle heterogeneous and unstructured invoice formats. Finally, Hybrid Structured Automation was introduced as a novel configuration observed in practice, where structured vendor data can be directly integrated with rule-based validation logic to target efficiency in settings with digitally mature partners. While rooted in the case study, the three strategies were considered in a generalizable way, reflecting pathways applicable to outsourced logistics environments more broadly.

To compare the strategies, an evaluation framework was developed around seven criteria: Accuracy, Flexibility, Speed, Integration, Scalability, Partner Dependency, and Cost & Maintenance. The assessment was conducted qualitatively, since implementation-based performance testing was beyond the study timeline. Evidence was drawn from vendor white papers, product specifications and peer-reviewed literature, complemented by domain knowledge from stakeholder discussions. For each criterion, strengths, limitations, and context-specific considerations were documented and synthesized into a comparative table.

The qualitative findings were then operationalized as numerical scores on a 1–9 scale, where higher values indicated stronger alignment with a given criterion. Strong attributes such as high accuracy or rapid processing were assigned to the upper range, moderate or conditional statements to the mid-range, and weaker attributes such as rigidity or poor scalability to the lower range. The scoring scheme was developed within the study and validated with stakeholders to ensure consistency with both qualitative evidence and organizational realities. The assigned scores reflected both the intrinsic performance of each strategy and their relative positioning against the alternatives. While most criteria were scored directly, Partner Dependency and Cost & Maintenance were assessed inversely, with lower levels rated more favorably. Mid-range values did not necessarily indicate weakness, but often reflected comparatively lower performance when benchmarked against stronger options.

To account for the relative importance of each criterion, weighting factors were derived using the Best–Worst Method (BWM). This structured multi-criteria decision-making technique requires decision-makers to identify the most important (Best) and least important (Worst) criteria and rate all other criteria in relation to these two reference points. The resulting pairwise comparisons are processed through an optimization model that calculates consistent weights while reducing cognitive bias. [41]

To capture stakeholder perspectives, a BWM survey was conducted and implemented using a customized Solver Linear BWM tool. [40][39] The inputs produced optimal criterion weights for each participant, which were reviewed for consistency before being aggregated into average weights. Given the high level of agreement across responses, the consolidated results were considered a reliable reflection of collective preferences. These aggregated weights were then applied to the criterion scores assigned to each automation approach, allowing for the computation of a weighted overall performance score and facilitating a comparative ranking of the evaluated alternatives.

C. Structured Workflow Redesign

The final stage of the study focused on translating the findings from the current-state analysis and the evaluation of automation strategies into actionable "to-be" workflows. Following principles of Design Science Research, the process began by consolidating inefficiencies such as fragmented data access and reliance on tacit knowledge into design requirements. These requirements were then benchmarked against the evaluated automation strategies to ensure both incremental and advanced solutions were considered.

For each strategy, BPMN-inspired (Business Process Model and Notation) swimlane diagrams were developed to capture the interaction of automated steps (e.g., data parsing, validation rules) with necessary human interventions (e.g., exception handling, approvals). The models were iteratively refined through feedback sessions to validate feasibility and alignment with organizational practices. In this way, the redesigned workflows integrate empirical insights, automation opportunities, and stakeholder priorities, serving as structured blueprints for the implementation of automation in transport cost verification. Among these, this article highlights the IDP-based workflow redesign, chosen for its superior performance and organizational fit.

IV. Current Workflow for Transport Cost Verification

At Fokker Services Group (FSG), transport-related costs arise directly from outsourced logistics activities. Although not a logistics provider itself, FSG depends on regular and time-sensitive transport operations to support its global activities. To fulfill its logistical needs, the company outsources transportation to a diverse range of external service providers. Each shipment arranged through these external parties becomes a cost-bearing event, with the corresponding invoice requiring structured validation before payment.

Following the completion of a shipment, the process of invoice verification begins. At FSG, this is currently characterized by a sequential, multi-actor workflow engaging both administrative and operational roles. Invoices, typically submitted in PDF format to a centralized intake point, are automatically ingested into Rillion, a cloud-based accounts payable platform. From there, they move through a series of checks performed largely by the Logistics Advisor, as represented in the swimlane diagram in Figure 1. These checks cover routing, reference numbers, and charges, with final approval provided by the Logistics Manager before payment execution in Pentagon, the ERP system.

Despite partial digitization, FSG's invoice verification remains a heavily manual process, challenged by a steady yet high volume of freight invoices, many of which are lengthy, multi-page documents containing numerous line items. Comprehensive validation would require meticulous, line-by-line checks that are nearly unmanageable in practice, forcing staff to prioritize speed over rigor. As a result, many invoices are effectively approved blindly, without full verification of the underlying details.

Beyond the manual nature of the process, there are three additional weaknesses in the current approach. Invoice ownership remains ambiguous, since existing controls do not explicitly confirm contractual liability under the applicable Incoterms. Supporting data is fragmented across disparate internal and external systems, requiring labor-intensive cross-checks that slow validation and compromise reliability. Charge assessment relies on subjective judgment, with approvals often based on individual experience rather than standardized, data-driven mechanisms, leaving decisions inconsistent and difficult to replicate. In addition, exception handling is ad hoc, with non-standard or unclear invoices managed without defined escalation or resolution rules, further eroding consistency and control.

Quantitative analysis reinforced the systemic weaknesses identified qualitatively while also highlighting new patterns in workload and performance. Invoice data pointed to a consistently high but regular processing load, punctuated by outlier periods where workload spikes placed additional pressure on verification resources. A vendor-level breakdown revealed the operational dominance of global express providers, suggesting that automation efforts could deliver the greatest impact if targeted at these high-volume contributors. Time-based performance metrics indicated a generally stable invoicing process, with most transactions handled in a timely manner. However, overdue cases and extended payment lead times revealed inconsistencies that weaken overall reliability. A timeline analysis of the full invoice lifecycle showed that delays may occur at any stage, but the internal processing phase emerged as the most consistent contributor to prolonged cycle times, whereas delays in transmission or payment execution appear more sporadic and case-specific.

Taken together, these issues are not dramatic breakdowns, but subtle frictions that complicate routine tasks, delay decisions, and increase reliance on tacit knowledge. The current process is constrained less by effort than by the absence of system-level support. Manual effort and experience can mask inefficiencies, but they cannot sustainably resolve them. Addressing these structural limitations is essential for improving financial accuracy, operational resilience, and long-term scalability. As stakeholders noted: *"The process is not inherently flawed but lacks the safeguards and automation needed to ensure reliable, repeatable outcomes at scale."*

V. Evaluation of Automation Strategies

Building on the insights from the current-state assessment, this section evaluates the automation strategies identified as potential enablers of the redesigned transport invoice verification process. Three distinct automation strategies were chosen to reflect a spectrum of technological maturity and applicability: Rule-Based Automation, Intelligent Document Processing, Hybrid Structured Automation. Together, they provide a comprehensive foundation for assessing automation potential, ranging from deterministic logic-based systems to AI-driven document handling and integrated data exchange models.

A. Overview of Candidate Strategies

Rule-Based Automation

Rule-based Automation applies predefined logic and structured workflows to perform repetitive tasks in a consistent and deterministic manner. These sys-

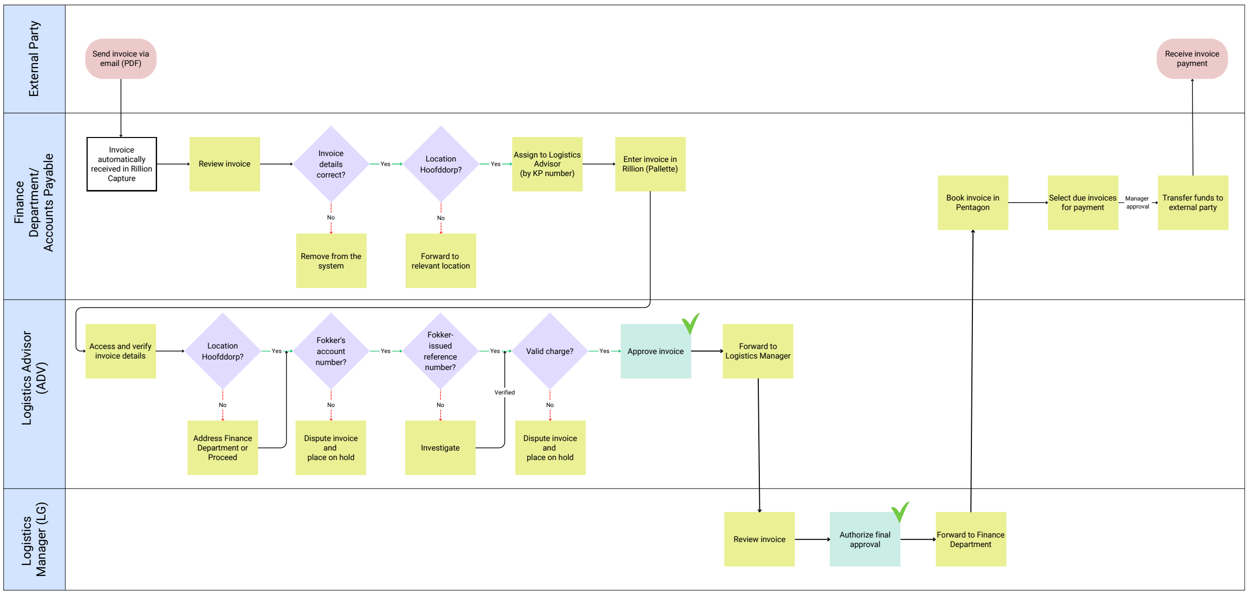

Fig. 1: Current Workflow for Transport Cost Verification ("as-is" process).

tems encode domain knowledge into if-then statements grounded in Boolean operations, enabling information extraction or decision making based on fixed, explicitly defined conditions. Their strength lies in standardized, predictable data environments, where they deliver speed, reliability, and consistent processing with minimal human intervention. [9][35][49]

Intelligent Document Processing

Intelligent Document Processing (IDP) platforms use artificial intelligence technologies such as Machine Learning (ML), Natural Language Processing (NLP), Computer Vision (CV), Optical Character Recognition (OCR), and Robotic Process Automation (RPA) to extract, classify, and convert unstructured or semi-structured documents into structured, actionable data. They are capable of processing a wide range of document formats, including PDFs, scanned images, and text files, automating repetitive tasks and minimizing manual errors. By streamlining document workflows, IDP enhances efficiency, accuracy, and scalability, making it increasingly relevant in logistics and other document-intensive industries. [2][22][36][51]

Hybrid Structured Automation

Hybrid Structured Automation blends structured data exchange from digitally mature with internal rule-based validation. Rather than relying solely on document parsing technologies or fully integrated data exchange interfaces like Electronic Data Interchange (EDI), this model leverages semi-structured data delivery (e.g., CSV, XML, or Excel) and applies deterministic business logic to process and verify invoices in a structured and auditable manner. As a transitional model, it shifts part of the data preparation upstream while maintaining internal control, allowing downstream validation workflows to evolve independently of upstream formatting.

B. *Comparative Qualitative Analysis*

The three automation strategies were assessed against seven criteria, reflecting technological capability, operational need, and organizational fit. While details are consolidated in Table 1, several key patterns stand out.

In terms of Accuracy, Rule-based Automation performs reliably when invoice formats are standardized and well-defined, but struggles when layouts deviate from expectations. [43] IDP platforms demonstrate consistently higher accuracy, supported by machine learning and layout-agnostic models, though quality depends on document inputs and balanced training data. [1][24][52] Hybrid Structured Automation is also capable of high accuracy, provided vendors supply stable, machine-readable files, while errors arise primarily from inconsistencies in upstream data.

For Flexibility and Speed, rule-based systems are inherently rigid, requiring frequent adjustments when formats change. [35] IDP platforms excel in managing diverse layouts and can reduce processing times dramatically, with studies reporting throughput up to 80% and 98% faster than manual and rule-based methods, respectively. [1][36][47][52] Hybrid approaches offer speed comparable to rule-based solutions but retain more adaptability, since structured files bypass OCR and reduce reliance on document parsing.

Regarding Integration and Scalability, rule-based

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	✔ High accuracy in standardized, predictable formats ✔ Reaches approximately 85% accuracy in key field extraction ⚠ Accuracy drops when formats deviate or new elements are introduced	✔ Moderate to high accuracy depending on input quality, model sophistication, and training data ✔ Achieves approximately 98% accuracy in key field extraction ⚠ May struggle with noisy or uncommon layouts without sufficient training data	✔ High accuracy with structured formats (CSV, XML, Excel) ✔ Near-perfect accuracy with consistent upstream data ⚠ Dependent on vendor data quality and consistency
Flexibility	✘ Rigid and template-dependent ✘ Requires manual rule updates for even minor layout changes ✘ Poor adaptability in dynamic environments	✔ Highly flexible and layout-agnostic ✔ Adapts to diverse invoice formats using AI/ML, NLP, OCR, and transformer models ✔ Learns from new inputs without manual reconfiguration	⚠ Moderate flexibility ✔ Insulated from layout changes due to structured input ⚠ Requires vendor schema consistency
Speed	⚠ Fast within defined scope ✘ Fragile – errors or deviations cause delays ✘ Takes approximately 15 minutes per document	✔ Significantly faster than manual and rule-based methods ✔ Up to 80% reduction in processing time compared to manual ✔ Completes tasks in approximately 18 seconds per document	✔ Very fast due to structured input ⚠ Delays only when validation flags trigger manual review ✔ Near-instantaneous for stable vendor files
Integration	⚠ Challenging due to stand alone design ✔ Newer models support modular integration via callbacks or service-based design ⚠ Requires custom development or middleware to connect with external systems	⚠ Complex when working with legacy systems ⚠ Often limited to post-processing data transfer ✔ Strategic use of APIs, RPA, and BI tools improves integration success ✔ Organizational readiness and leadership are key enablers	✔ Moderate integration effort ✔ Structured files retrieved via secure scripts or portals ✔ Validated data maps directly into ERP ✔ Simpler than EDI/API
Scalability	⚠ Scales poorly in dynamic environments ✘ Rule maintenance becomes burdensome with vendor diversity ✘ Susceptible to bottlenecks as rule complexity grows	✔ Designed for scalable growth across data and operations ✔ Efficiently handles increasing complexity and volume ⚠ Requires thoughtful design upfront to avoid future performance bottlenecks	✘ Depends on vendor digital maturity ✔ Easy to scale with structured data; minimal setup for new vendors ⚠ Needs IDP for unstructured formats to scale across heterogeneous ecosystems
Partner Dependency	⚠ Low initial dependency on partners ✘ Vulnerable to uncoordinated vendor changes ⚠ Requires increasing collaboration as scale grows ✔ Early partner involvement improves outcomes	✔ Very low dependency on partner systems ✔ Handles documents "as-is" without requiring standardization ✔ Effective in heterogeneous vendor ecosystems ⚠ Collaboration can enhance results but is not essential	✘ High dependency on vendor cooperation ⚠ Requires structured file delivery and schema alignment ✔ Best suited for concentrated vendor bases with strong commercial leverage
Cost & Maintenance	⚠ Moderate to High cost ⚠ Licensing, Setup & consulting, Infrastructure, implementation ✘ Manual rule updates, System upgrades & monitoring, Technical support, $\sim$ 20% annual upkeep	✘ High cost (higher upfront and scaling cost); Volume-based pricing options ⚠ Licensing, Training & Customization, Integration & Deployment ⚠ Model retraining, Data quality management, Feedback integration, Format adaptation & support	⚠ Moderate cost ⚠ Setup includes retrieval, mapping, validation rules; no OCR/AI retraining needed ⚠ Maintenance tied to vendor schema changes and ongoing data quality monitoring

Table 1: Qualitative Comparison of Candidate Strategies Across Evaluation Criteria.

solutions often prove brittle when interfacing with multi-layered interconnected system environments and scale poorly as vendor diversity grows. [33][35][36] IDP, in contrast, scales effectively in heterogeneous high-volume ecosystems, although integration into legacy systems can be complex. [19][22][28][52][36] Hybrid requires moderate integration, but once vendor schemas are aligned, it scales efficiently and with relatively low overhead.

Finally, in terms of Partner Dependency and Cost, Rule-based Automation demands little vendor alignment but incurs growing maintenance costs as document variability increases. [16] IDP minimizes partner dependency, as it can process documents “as is”, although this advantage comes with high upfront and ongoing costs. [37][51] Hybrid approaches require stronger vendor alignment but typically yield moderate, sustainable cost structures, particularly in ecosystems dominated by a few high-volume partners.

C. *Quantitative Assessment and Ranking*

Initial Strategy Evaluation Matrix

To complement the qualitative comparison, the three automation strategies were systematically scored across the evaluation criteria, with results summarized in Table 2.

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	6	8	7
Flexibility	3	8	6
Speed	4	8	7
Integration	4	6	7
Scalability	3	8	6
Partner Dependency	6	7	4
Cost & Maintenance	6	5	7

Table 2: Initial Scoring Matrix-Raw Numerical Scores.

Within this framework, the matrix highlights several dynamics. IDP platforms achieve the highest scores in flexibility, speed, and scalability, reflecting their strength in heterogeneous and dynamic environments. Rule-Based Automation performs well only under controlled conditions but shows marked weaknesses in adaptability and long-term scalability. Hybrid Structured Automation occupies a middle ground, excelling in accuracy and speed with structured data, though its reliance on vendor maturity limits broader applicability. Accordingly, IDP stands out as the strongest performer, Hybrid offers targeted advantages in stable ecosystems, and Rule-Based Automation remains suited only to narrow, controlled contexts.

Stakeholder Weighting of Evaluation Criteria

While the unweighted scores assume all criteria are equally important, stakeholders assigned different priorities through the Best–Worst Method (BWM), as shown in Figure 2.

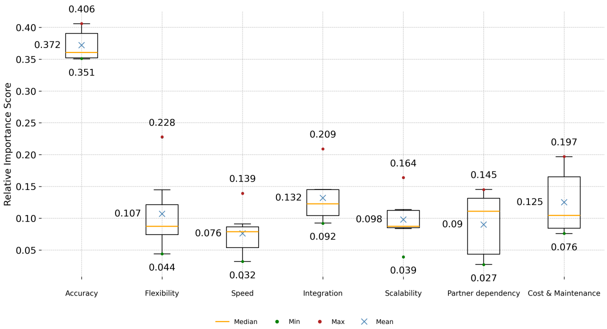

Fig. 2: Stakeholder Prioritization of Evaluation Criteria.

Collectively, the distribution of weights highlights Accuracy as the uncontested priority, consistently rated highest by all stakeholders with minimal variation. In contrast, the remaining criteria represent differentiated but secondary concerns, with no clear hierarchy among them. Flexibility, Integration, Speed, and Scalability were consistently ranked lower, with divergence in stakeholder views particularly evident in the former two. Partner Dependency and Cost & Maintenance displayed the widest spread, reflecting differences between finance, procurement, and operations perspectives. Overall, the results confirm Accuracy as the dominant benchmark, while other criteria represent context-dependent trade-offs.

Final Strategy Evaluation Matrix

To integrate both technical performance and organizational priorities, the unweighted scores were combined with stakeholder-derived criterion weights into a final weighted decision matrix presented in Table 3.

Criterion	Rule-based Automation	AI-powered IDP Platforms	Hybrid Structured Automation
Accuracy	2.231	2.974	2.603
Flexibility	0.321	0.857	0.643
Speed	0.303	0.606	0.531
Integration	0.527	0.791	0.922
Scalability	0.294	0.783	0.587
Partner Dependency	0.543	0.633	0.362
Cost & Maintenance	0.751	0.626	0.876
Total Weighted Score	**4.970**	**7.271**	**6.524**

Table 3: Final Weighted Evaluation Matrix

Overall, the analysis demonstrates a clear hierarchy among the evaluated automation strategies. IDP platforms achieved the highest overall score, driven by superior accuracy and flexibility, confirming their ability to manage diverse formats while addressing the organization's top priority of reliable reconciliation. Hybrid Structured Automation ranked second, offering a balanced profile with notable advantages in integration and cost efficiency, though constrained by vendor dependency. Rule-based Automation trailed significantly, with strengths in partner independence and cost predictability but persistent weaknesses in accuracy, flexibility, and scalability.

In effect, the results position IDP as the strongest candidate, offering the most consistent alignment with both performance requirements and stakeholder priorities. Hybrid Structured Automation provides a balanced, though narrower, fit and remains a viable alternative, particularly in contexts where integration capabilities and cost efficiency are paramount. By contrast, Rule-Based Automation lags behind, with strengths concentrated in areas of lower strategic importance, making it more suitable for stable or transitional environments rather than as a long-term solution for freight invoice verification.

VI. Workflow Redesign

The proposed workflow redesign, based on IDP, is conceived as a structured framework to enhance the transport cost verification process and enable transparent, standardized cost allocation. Its purpose extends beyond technical efficiency: it provides a governance-oriented redesign that embeds automation into process logic while retaining human oversight where judgment is essential. Figure 3 illustrates how the redesigned workflow operationalizes this model, linking data capture, validation, and approval into a transparent end-to-end process.

A. Workflow Initiation and Data Extraction

The redesigned IDP-enabled workflow begins with the automatic ingestion of freight invoices, typically in PDF format, which are processed using OCR to create a machine-readable text layer. AI-based field classification models then extract key data such as air waybill (AWB) number, shipment details, Incoterms, and invoiced amounts. Unlike rule-based or hybrid models, this approach does not depend on fixed templates or structured inputs but instead applies probabilistic scoring and contextual analysis to handle diverse invoice formats.

Once extracted, the invoice data is standardized and enriched through integration with internal systems. The IDP platform accesses supplementary information via secure API connections or middleware integrations. AWB details are retrieved from the ERP system to verify shipment status and logistics records. Missing or ambiguous Incoterms are supplemented using data from purchase orders or contractual agreements. In parallel, tariff rates are pulled from structured contract databases, filtered by service type, weight range, and zone. These data sources are queried dynamically using the extracted invoice fields as lookup keys.

B. Validation Logic

After enrichment, the IDP workflow proceeds through a structured validation sequence. Invoices are first matched against AWB records to verify shipment status and logistical consistency, ensuring that the billed transport corresponds to a legitimate and traceable shipment. Cost responsibility is then checked against shipment direction and the applicable Incoterm, ensuring alignment with contractual obligations. Finally, invoiced amounts are validated against expected charges derived from contractual tariff agreements. These checks are executed sequentially and supported by AI-driven extraction and intelligent matching techniques, where confidence scoring is used to rank potential matches between invoice data and reference records such as AWB entries or tariff tables. Each match is assigned a confidence level, and predefined thresholds determine whether the invoice is processed automatically or routed for manual review.

C. Post-Validation Workflow

Invoices that do not pass one or more validation checks are flagged and routed to designated stakeholders for structured, role-based review. Typically, flagged invoices are first directed to the Logistics Advisor, who reviews the case and determines whether the invoice can be manually approved. If correction is required, it is either forwarded to the Finance Department for internal adjustments and reprocessing, or returned to the external party for revision and resubmission, while more complex cases may be escalated to the Logistics Manager for oversight. The invoice is manually approved by the Logistics Advisor, either directly or after the necessary adjustments have been made, ensuring compliance with both internal records and contractual standards. Following this first-level approval, the invoice is forwarded to the Logistics Manager for optional review and final authorization.

Invoices are forwarded to the Finance Department for payment processing through two distinct pathways: either directly after passing all automated validation checks, or following manual review and final authorization by both the Logistics Advisor and the Logistics Manager. Once approved, invoices are recorded in the ERP system, and payments are scheduled based on their respective due dates. Managerial approval is obtained when required, after which the funds are transferred to the external party. Upon completion, the external party receives the payment, marking the final step in the process. This end-to-end workflow, in turn, enhances efficiency, strengthens financial control, and ensures greater operational transparency.

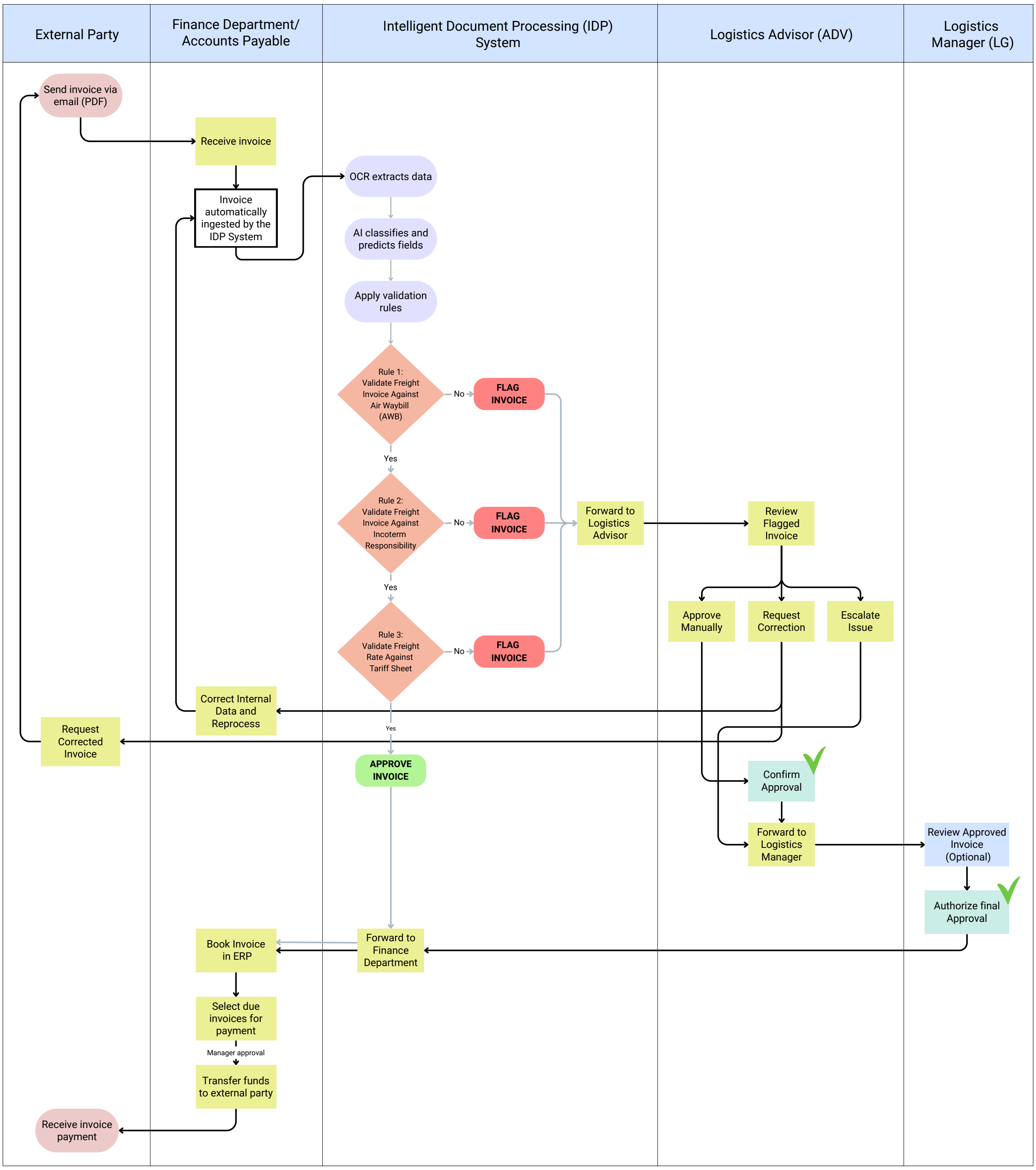

Fig. 3: Proposed IDP-enabled Workflow for Transport Cost Verification ("to-be" process).

D. *Expected Benefits of Automation-Supported Workflow Redesign*

The redesigned workflow, centered on IDP, is projected to deliver improvements in efficiency, accuracy, cost-effectiveness, and governance. Automation can reduce manual interventions and shorten cycle times from 15–25 minutes to 2–3 minutes per invoice. For an organization processing several thousand invoices annually, comparable to the case company, this may equate to savings of 600–700 labor hours per year. Accuracy is expected to reach about 98%, with error rates potentially reduced by up to 90% through AI-driven field extraction and tariff validation, strengthening financial reconciliation and dispute handling. While IDP entails higher licensing fees, it is likely to lower long-term configuration overhead and reduce manual processing costs by roughly 85%, alongside additional savings from avoided billing errors. Beyond these operational gains, the redesign embeds business rules such as Incoterm logic and tariff validation into a verifiable, auditable system, enhancing accountability and partner expectations. Its modular structure enables organizations to begin with simpler configurations and scale into full IDP capabilities, making the approach adaptable to varying levels of digital maturity. Overall, the workflow redesign appears to represent a strategic shift that enhances efficiency and transparency while reducing financial risk and enabling scalable, future-proof invoice verification.

VII. Conclusion and Recommendations

This study set out to explore how financial decision-making in logistics can be enhanced by approaching transport cost management through a systematic redesign and automation lens, using Fokker Services Group as a case. The findings point to a critical gap between established cost management models and the realities of outsourced freight operations. Frameworks such as TCO, ABC, and LA provide valuable strategic and analytical insights, yet they remain detached from the transactional layer where invoices are recorded and validated. At FSG, invoice validation was found to be fragmented, heavily manual and reliant on tacit expertise, turning what should be a governance mechanism into an administrative burden and exposing the organization to errors, overpayment and disputes. In this sense, the current system is not simply inefficient but structurally incapable of providing the reliable, auditable data needed for financial decision-making, underscoring the urgency of redesign.

To address these challenges, three automation strategies were evaluated: Rule-Based Automation, Hybrid Structured Automation, and AI-powered Intelligent Document Processing (IDP). Guided by stakeholder-weighted evaluation criteria, the analysis revealed IDP as the most promising option due to its superior accuracy, adaptability, and scalability. Hybrid performed moderately well, offering strengths in integration and cost efficiency, while rule-based approaches trailed behind, reflecting rigidity in dynamic contexts despite their low entry barriers. The evaluation underscores that no technology is a one-size-fits-all solution: adoption must balance technical capabilities with organizational realities. In this light, IDP represents the most future-proof option, while hybrid and rule-based models remain valuable stepping stones that allow organizations to advance automation in line with their digital maturity and strategic context.

The proposed IDP-enabled workflow integrates AI-driven extraction with a rule-based validation backbone to ensure shipment traceability, contractual cost allocation, and tariff compliance. The benefits over manual processing are clear. Invoice handling time can be reduced from 15–25 minutes to 2–3 minutes, which can yield annual savings of 600–700 labor hours in an organization processing several thousand invoices. Accuracy can reach 98%, reducing error rates by up to 90%, while processing costs fall by roughly 85%, with further savings generated from avoided billing discrepancies. Beyond technical efficiency, this design embeds accountability into daily operations, reinforcing financial control and organizational oversight.

A key strength of the framework is its modularity. Organizations can pursue a phased pathway, beginning with rule-based workflows to secure early wins, advancing to hybrid approaches where structured partner data is feasible, and ultimately scaling into IDP to manage residual variability in global networks. This flexibility aligns adoption with organizational readiness and budget cycles, ensuring that automation benefits are realized incrementally while avoiding premature complexity. For FSG, a hybrid-to-IDP trajectory offers the best balance between near-term improvements and long-term robustness.

However, successful implementation depends on several critical prerequisites. A first and often underestimated factor is data readiness, since automated verification is only as reliable as the quality and accessibility of the underlying data. Shipment identifiers, tariffs, and Incoterms must be structured and machine-readable, a condition many organizations have yet to achieve. Change management also plays a decisive role, as staff shift from routine validation to exception handling, requiring new skills and potentially facing resistance without clear communication and training. Ecosystem dynamics add further complexity, as hybrid solutions depend on carriers providing structured data, an arrangement that is difficult to enforce in fragmented or global networks. Finally, IDP brings new costs and vendor dependencies that must be carefully weighed against the expected efficiency and accuracy gains.

The study nonetheless carries limitations. Its findings are based on a single organizational context and remain conceptual rather than empirically tested. While efficiency gains and cost savings were projected, real-world implementation may surface new challenges such as integration complexity, uneven benefit distribution across functions, or resistance to role changes. Furthermore, technologies like IDP evolve rapidly, meaning that the workflow presented here should be understood as a blueprint rather than a prescriptive end-state.

Despite these caveats, the study contributes to both practice and scholarship. It demonstrates how systematic workflow redesign, grounded in automation, can transform invoice verification from a transactional burden into a governance mechanism that enables accuracy, transparency, and cost control.

Building on this foundation, future research should move decisively beyond conceptual design toward empirical validation. Pilot implementations could generate measurable evidence of efficiency gains, error reductions, and financial impacts by tracking key performance indicators such as cycle times, error detection rates, dispute resolution speed, and payment lead times before and after adoption. Longitudinal studies would add further value by revealing how benefits evolve over time as machine learning models improve and as staff adapt to new oversight and exception-handling roles.

A second priority lies in cross-industry and cross-geography replication. While the aviation MRO sector provided a complex and illustrative case, its carrier structures and governance frameworks are not universal. Applying the modular workflow framework to sectors such as retail, automotive, or pharmaceuticals could clarify which automation strategies align best with particular network configurations, whether these involve concentrated supplier bases that suit hybrid automation or fragmented and global networks where IDP may deliver greater value. Comparative research of this kind would strengthen generalizability and inform sector-specific adaptations.

Finally, future work should examine the behavioral and organizational dynamics of automation adoption. The transition from manual verification to exception-based oversight entails a redefinition of staff roles, skills, and responsibilities. Studying how logistics advisors and finance staff navigate this shift, including patterns of resistance, adaptation, or role evolution, would enrich understanding of how automation can be embedded sustainably into organizational routines without undermining professional identity or collaboration.

In sum, such empirical, comparative, and organizational research would not only validate the projected benefits of automation but also ensure that redesigned workflows are sustainable, adaptable, and firmly embedded in day-to-day practice.

Ultimately, this study underscores that while the proposed IDP-enabled workflow is not a universal solution, it provides a scalable blueprint for bridging the gap between strategic cost models and transactional realities. In doing so, it reframes invoice verification as a transparent and auditable process that strengthens financial decision-making and resilience.

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