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Optimization and Automation of an industrial process with Robotic Process Automation

Case study: GEAT -Batna

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Abstract:

This project explores Robotic Process Automation (RPA) implementation at General Electric Algeria Turbines (GEAT) to optimize processes and enhance efficiency. Using Business Process Management (BPM) and Process Mining, tasks were identified for automation. UiPath was used to develop RPA bots, resulting in improved cycle times, error reduction, and cost savings. The study confirms RPA's strategic benefits and future potential."

Keywords: Business process optimization, Process-Mining, RPA.

Sommaire:

Ce projet explore la mise en œuvre de l'automatisation des processus robotiques (RPA) chez General Electric Algérie Turbines (GEAT) pour optimiser les processus et améliorer l'efficacité. Grâce à la gestion des processus métiers (BPM) et au Process Mining, les tâches à automatiser ont été identifiées. UiPath a été utilisé pour développer des robots RPA, ce qui a permis d'améliorer les temps de cycle, de réduire les erreurs et de réaliser des économies. L'étude confirme les avantages stratégiques et le potentiel futur de la RPA.

Keywords: Optimisation des processus métiers, Process-Mining, RPA.

ملخص:

يستكشف هذا المشروع تنفيذ أتمتة العمليات الروبوتية (RPA) في جينيرال ألكتريك للتوربينات الجزائر (GEAT) لتحسين العمليات وتعزيز الكفاءة. باستخدام إدارة العمليات التجارية (BPM) والتنقيب في العمليات vu، تم تحديد المهام للأتمتة. تم استخدام (UiPath) لتطوير روبوتات (RPA)، مما أدى إلى تحسين أوقات الدورات وتقليل الأخطاء وتوفير التكاليف. وتؤكد الدراسة الفوائد الاستراتيجية لتقنية (RPA) وإمكاناتها المستقبلية.

كلمات مفتاحية: تحسين العمليات التجارية، التنقيب في العمليات ، أتمتة العمليات الروبوتية

Dedication

This work is dedicated to our beloved family members, friends, and professors, whose unwavering support and guidance have been instrumental in our journey to graduation. To our parents, whose unconditional love, encouragement, and sacrifices have always inspired us to strive for excellence. Your belief in us has been our greatest motivation. To our siblings, who have been our confidants and cheerleaders. Your support and understanding have been invaluable throughout this journey. To our friends, who have stood by us through thick and thin. Your companionship and encouragement have made this journey more enjoyable and fulfilling. To our professors and mentors, whose wisdom and guidance have shaped our academic journey. Your dedication to our education and your willingness to share your knowledge have been crucial to our success. Thank you all for being a part of this journey and for helping us achieve this milestone.

Thanks

We would like to express our deepest gratitude to our advisor, Professor Ghomari, for her continuous support and invaluable guidance throughout our final year project. Her expertise and dedication have been instrumental in our success. We also extend our heartfelt thanks to Nabil, Djamel,Taha, Rahma and the entirety of GEAT team for their unwavering support during our final internship. Your assistance and encouragement have been crucial to the completion of our work. Additionally, we are grateful to all the other professors who have guided us throughout our educational journey. Your wisdom and teachings have profoundly shaped our academic and personal growth. A special thanks to our parents for their unwavering support, love, and encouragement. Your belief in us has been the foundation of our achievements. Thank you all for your contributions and support.

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Table Of Abbreviations

RPA Robotic Process Automation
BPM Business Process Management
PM Process Mining
VSM Value Stream Mapping
BPA Business Process Automation
DPL Detail Packing List
MO Manufacturing Order
PO Purchase Order
MSD Materials Shipped Directly
ROI Return on Investment
ORE Overall Resource Effectiveness
KPI Key Performance Indicators
IT Information Technology
SAP Systems, Applications, and Products in Data Processing
GEAT General Electric Algeria Turbines
CDC Cahier de Charge (Specification Sheet)
QC Quality Control
SQE Supplier Quality Engineer
AA Automation Anywhere
SRs Software Robots
PLOST Prioritized List Of Suitable Tasks
GEAT General Electric Algeria Turbines
ECRS Eliminate Combine Rearrange Simplify
WFM Workflow Management
BPO Business Process Optimization
5W1H Who?, What?, Where?, When?, Why?, and How
CA Conventional Auotmation
API Application Programming Interface
UI User Interface
UAT User Acceptance Testing
VAE Variational Autoencoder
Bi-LSTM Bidirectional Long Short-Term Memory
SDFA State-Based Deterministic Finite Automaton
S,M,A,R,T Specific, Measurable, Attainable, Realistic, Timely
BPMN Business Process Management and Notation
TG Gas Turbine
TV Steam Turbine (Turbine à Vapeur)
FQ Quality Files (Fiche Qualité)
DA Demande d'Achat (Procurement Order)
OIS Operational Information Systems.
MBOM Manufacturing Bill Of Materials
MP Primary Matter (Matiere Premiere)
ERP Enterprise Ressource Planning
SQE Supplier Quality Engineer
NVA Non Value Added
NNVA Necessary Non Value Added

CT Cycle Time
LT Lead Time
MLI Model List Item
USD United States Dollars
VBO Visual Business Object
IDE Integrated Development Enivronment

General Introduction

In today's competitive business landscape, organizations are focused on enhancing efficiency and reducing costs by integrating BPM (Business Process Management) and process optimization. BPM orchestrates complex operations and aligns them with business strategies, which is crucial for quick adaptation to regulatory changes and market conditions. At the same time, process optimization streamlines operations to maximize resource use and improve output quality. Together, they significantly reduce operational costs and enhance product and service quality. Lean Management and RPA (Robotic Process Automation) are complementary, which drive continuous improvement and automate routine tasks, respectively. Lean Management techniques promote resource optimization, and RPA frees up human resources for more strategic tasks, thus minimizing errors and improving compliance.

Process Mining further enhances organizational efficiency by providing critical insights into the actual workings of business processes through event log analysis. This technology identifies bottlenecks, deviations, and inefficiencies, offering a data-driven basis for informed decision-making and supporting compliance through detailed audit trails. By effectively utilizing these strategies and tools—BPM, process optimization, Lean Management, RPA, and Process Mining—businesses can create a robust framework that allows them to thrive by becoming more responsive, agile, and efficient, thereby navigating the challenges of an ever-evolving global market.

GEAT (General Electric Algeria Turbines), a significant energy sector firm in Algeria that adopts a continuous improvement approach, faces the problem of having mundane tasks within its processes, leading to errors and rework and inefficient human resource allocation. This thesis addresses that issue by leveraging Robotic Process Automation (RPA) to optimize mundane tasks, targeting significant improvements in execution time, cost, and accuracy. Conducted within this major firm, the research showcases the broad applicability of the findings and methodologies employed. The demonstrated success and versatility suggest that the strategies developed could also significantly benefit smaller companies and non-profit organizations, extending the potential impact of this study beyond large corporate settings.

All over our case study, we leveraged various tools, frameworks, and methodologies to successfully create a bot to streamline our processes. To address the specific needs of our project, we crafted a unique framework from a thorough literature review. We derived many aspects from several established frameworks. Notably, we adapted elements from the PLOST framework[29], "A Framework to implement process mining and RPA in organizations" [24], "A framework for implementing robotic process automation projects" [27], and the "UiPath Academy framework" [60]. This tailored approach allowed us to navigate the challenges associated with data availability, time constraints, and resource limitations, ensuring that our framework was well- suited to the specific conditions and expertise available, effectively aligning with the established literature while addressing our unique project needs.

Throughout the phases and steps of the project, we used various lean management principles and tools to identify and eliminate waste and redesign the process before automating it, such as Value stream mapping and 5W1H combined with the ECRS method. As for modeling and simulation, we used the Signavio BPMN and Activity Diagrams.

The implications of this research extend beyond the immediate operational enhancements. The host company, representing stakeholders deeply invested in the outcomes of this study, experienced firsthand the transformative impact of RPA by reducing execution time and freeing up human resources. This case study not only underscores the practical benefits of process automation but also contributes to the broader discourse on the efficacy of RPA in streamlining operational workflows across various organizational types and sizes.

Our thesis is structured into two comprehensive chapters:

Chapter 1—Bibliographic Study: This chapter provides a foundational overview of Business Process Management (BPM), Process Optimization, Lean Management, Process mining, and RPA. It explores the theoretical underpinnings and practical applications of these tools and methods, setting the stage for their use in optimizing business processes. This section is essential for understanding the concepts we later implemented to enhance operational efficiencies in our practical scenario.

Chapter 2 - Case Study: This chapter offers an extensive analysis of the case study conducted at GEAT, where we applied Robotic Process Automation (RPA) to streamline a significant business process. We detail our systematic approach—from initial data collection and process analysis to the strategic formulation and implementation of RPA solutions. Key phases include the design and development of the automation bot, rigorous testing phases, and final deployment within the company's operational framework. Furthermore, the chapter evaluates the impact of these interventions, highlighting the enhanced process efficiencies, reduced execution times, and cost savings. Through performance metrics and economic analysis, we demonstrate the tangible benefits achieved and discuss the broader applicability of these methods to similar organizational contexts.

Chapter 1: Bibliographic Studies

This bibliographic study explores Business Process Management (BPM) and Robotic Process Automation (RPA), essential technologies that drive efficiency and strategic growth in modern businesses. BPM involves designing and controlling automated and non-automated processes to align with organizational goals, while RPA uses software robots to automate routine, repetitive tasks. This study examines their integration, impacts, and roles within digital transformation initiatives across various sectors.

This study aims to provide insights into the operational, strategic, and economic implications of BPM and RPA by reviewing academic literature, industry reports, and case studies. It will identify success factors, challenges, and best practices, offering valuable perspectives for scholars, practitioners, and policymakers on leveraging these technologies for organizational advancement.

1.1 Business Process Management

Business Process Management (BPM) is a systematic approach to making an organization's workflows more effective, efficient, and capable of adapting to an ever-changing environment. A business process is an activity or set of activities designed to accomplish a specific organizational goal. BPM is not a one-time task but an ongoing activity involving persistent process re-evaluation and optimization [65] BPM combines principles, techniques, methods, and tools from operations management and industrial engineering with the capabilities offered by modern information technology. This amalgamation aims to model, deploy, execute, and continually optimize various processes to align them optimally with an organization's performance objectives. It can be seen as an evolution of Workflow Management Systems (WFM) from the 1990s. According to [65], BPM's primary goal isn't necessarily to enhance how individual tasks are performed but rather to minimize execution times, cut costs, speed up returns on investment, enhance quality, reduce errors, make processes more adaptable, and gain a competitive edge through innovation.

To effectively manage and optimize business processes, it is essential to understand the BPM lifecycle [23], which consists of five phases also depicted in order in figure 1.1:

1. **Design**: In this phase, the current processes are analyzed, and the desired processes are designed. This involves identifying the goals, key performance indicators (KPIs), and resources required for the

2. **Modeling**: The designed processes are then modeled using various tools and techniques to visualize the workflow. This includes simulating different scenarios and evaluating the potential outcomes.

3. **Execution**: Once the processes are modeled, they are implemented using BPM software. This phase involves automating workflows, assigning tasks, and ensuring that the processes are executed as designed.

4. **Monitoring**: After execution, the processes are continuously monitored to ensure they are performing as expected. This involves tracking KPIs, identifying bottlenecks, and collecting data for further analysis.

5. **Optimization**: Based on the insights gained from monitoring, processes are refined and optimized to improve efficiency and effectiveness. This may involve re-designing parts

of the process, implementing new technologies, or adjusting resource allocations.

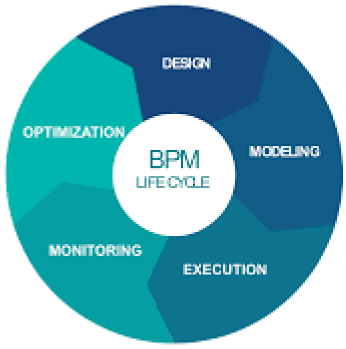

Figure 1.1: BPM Lifecycle [4]

Transitioning from understanding BPM and its lifecycle, the next critical step is Business Process Optimization (BPO). This involves taking the insights gathered from the BPM lifecycle phases and applying various strategies to enhance the overall performance of the processes. BPO aims to streamline operations, reduce waste, and improve the quality and speed of business processes, ultimately leading to increased organizational efficiency and competitiveness.

1.2 Business Process Optimization

Business process optimization (BPO) is a strategic approach to enhance the efficiency and effectiveness of various organizational processes. It involves critically analyzing existing business operations to identify areas for improvement, streamline workflows, and improve overall productivity. The primary goal of BPO is to reduce costs, eliminate inefficiencies, and optimize performance, thereby improving service delivery and customer satisfaction.

1.2.1 Business Process Optimization Using Lean Management

One of the critical methodologies employed in business process optimization is Lean management. Lean focuses on maximizing customer value by minimizing waste and inefficiencies in processes. Originating from the Toyota Production System, it emphasizes continuous improvement (Kaizen), respect for people, and the systematic removal of non-value-added activities (muda). By adopting Lean principles, organizations can create more value with fewer resources, leading to improved operational efficiency and a more decisive competitive advantage. This seamless transition from a broad discussion of BPO to the specific practices of Lean management reflects the natural progression many businesses undertake, moving from general optimization techniques to focused, sustainable management practices that drive long-term success [43].

Lean Management is a crucial aspect of Business Process Optimization (BPO) that focuses on eliminating non-value-adding activities while enhancing the quality of products or services from the customer's perspective. This approach is closely tied to Business Process Management (BPM), aiming to boost organizational efficiency and effectiveness. By removing unnecessary steps and reducing variability, Lean Management enhances efficiency, leading to quicker turnarounds and lower costs, contributing significantly to operational excellence. Additionally, Lean minimizes errors and standardizes processes, ensuring consistent quality improvement. This consistent delivery of quality products or services boosts customer satisfaction and loyalty. Lean also allows organizations to adapt flexibly to customer demands and market conditions. By implementing a pull system, companies can respond swiftly to customer needs while reducing overproduction and inventory costs. Moreover, Lean encourages employee participation at all levels, fostering a culture of continuous improvement. This improves job satisfaction, reduces turnover, and significantly enhances the overall process quality and organizational performance.

Lean management uses many tools in the procedure to achieve its optimization goals, in this project we have used a combination of many tools to identify, quantify and accurately pinpoint wastes and deficiencies in the chosen processes

- **5w1h method combined with ECRS principle**: The 5W1H technique, which stands for What, Why, Where, When, Who, and How, and the ECRS principle (Eliminate, Combine, Rearrange, Simplify) are methodologies used to identify and analyze inefficiencies in processes. Combining 5W1H's comprehensive questioning with ECRS's actionable improvement steps allows for thorough process redesign, enhancing efficiency and reducing waste in production operations [9].
- **VSM**: Value Stream Mapping (VSM) is a lean management tool that provides a visual representation of the flow of materials and information as a product makes its way through the value stream in a manufacturing process. The primary goal of VSM is to identify and eliminate non-value-added activities, thereby enhancing the efficiency of production processes. Academic descriptions emphasize that VSM not only maps the current state of processes but also aids in designing an improved future state. It is characterized by its focus on elements such as lead times, process inefficiencies, and inventory levels, which are critical in optimizing and streamlining operations. Through VSM, organizations are able to see the complete end-to-end system of production and identify systematic waste, ultimately leading to reduced costs, improved product quality, and faster delivery times.

1.2.2 Business Process Optimization Using Automation

Business Process Automation (BPA) refers to using software to automate repetitive and routine tasks that humans traditionally perform. This process involves the partial or total execution of computer functions, allowing businesses to enhance efficiency and accuracy. BPA encompasses various technologies, including workflow management, robotic process automation (RPA), and process mining. Workflow management automates the coordination of business processes, while RPA mimics user interactions with software to execute tasks. Process mining focuses on analyzing and optimizing business processes. The core idea behind BPA is to reduce manual intervention, minimize errors, and streamline operations, leading to improved productivity and cost savings [28].

BPA offers significant benefits by automating routine tasks, freeing up resources for strategic activities which enhance efficiency and reduce errors, improving process quality. It also supports faster decision-making and ensures regulatory compliance through consistent task execution. The integration of AI and machine learning has advanced BPA, enabling more complex tasks to be handled and providing deeper business insights, crucial for maintaining competitiveness in a fast-paced environment.

Key metrics like ROI evaluate the economic value of automation, while cycle and lead times assess speed and efficiency. Overall Resource Effectiveness (ORE) measures productivity, focusing on the utilization of resources, availability, performance, and quality. These indicators collectively provide a thorough understanding of the benefits and productivity enhancements from automation.

1.3 Process Mining

Data mining is a well-known concept that involves extracting valuable information from data for various purposes, such as decision-making and prediction. Process mining, on the other hand, is similar to data mining but specifically focused on managing processes.

Process mining is a research domain that develops innovative methods to gather insights from event logs[3]. It involves applying specialized algorithms to event log data to identify trends, patterns, and details of how a process unfolds[1]. This technique combines data science with process analytics to discover, validate, and enhance workflows, providing organizations with valuable insights to optimize their processes and drive better business outcomes.

1.3.1 Process Mining Techniques

Process mining provides various uses for process improvement using event data stored in today's information systems. These techniques include business process intelligence, activity monitoring, and business process management (BPM). Still, process mining is commonly used for three primary purposes, as the figure 1.6 shows.

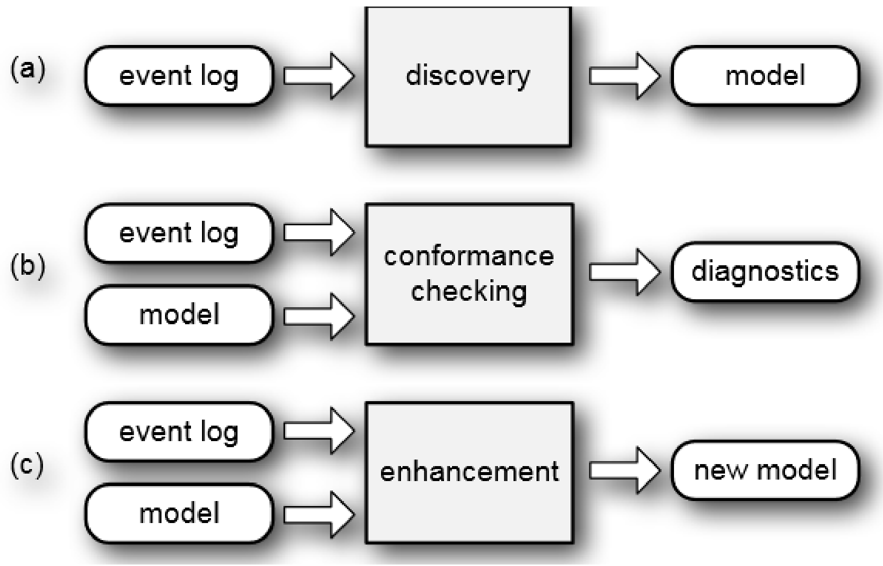

Figure 1.6: PM Purposes [37]

a. Process Discovery: A process mining technique derives process models from event logs devoid of pre-existing information. It is a primary technique within process mining to uncover the actual occurrences by scrutinizing the recorded events in an event log. This method proves especially valuable in elucidating the genuine conduct of a process, distinct from its anticipated or optimal trajectory. Process discovery facilitates organizational comprehension of inefficiencies, bottlenecks, and deviations present within their processes, offering significant insights conducive to process enhancement [61]; there are many algorithms for process discovery, such as the heuristic miner [7]. The evaluation of process model quality encompasses diverse perspectives and employs varied assessment methodologies, as underscored in [19]. One such method involves utilizing model-log metrics, which entails comparing the traces present in the event log and those derived from the mined model. Alternatively, another approach compares a pre-existing model with the model generated through mining, necessitating the presence of an apriori model (referred to as model-model metrics)[19] Conformance Checking: According to the Process Mining Manifesto[61], process mining involves comparing an existing process model with its event log to check for discrepancies or commonalities. This comparison can identify deviations from the expected process behavior using various models and methods such as Token-Based Replay [11] and Alignment-Based[40] Techniques. Recent advances aim to include stochastic elements for deeper analysis like time and cost metrics. However, conformance-checking faces challenges in weakly supervised systems with limited data. A recent study[32] introduces an activity-based Variational Autoencoder (VAE) with a Bidirectional Long Short-Term Memory (Bi-LSTM) architecture, incorporating a Self-Attention mechanism. This method outperforms traditional techniques by better utilizing scarce data for anomaly detection, confirmed by superior precision and recall metrics.

b. Process Enhancement: process enhancement denotes the augmentation or refinement of an extant process model by integrating insights derived from actual process data. This enhancement endeavor seeks to elucidate problematic process pathways, uncover deviations from the expected course, and explain their ramifications on organizational operations. Enriching process models enables enterprises to discern segments ripe for automation, conduct root cause analyses, and initiate process amelioration initiatives. Process enhancement is a pivotal facet of process mining, empowering organizations to refine their operations using empirical data and insights extracted from event logs[3].

1.3.2 Process Mining Algorithms

Research has shown that the most prominent algorithms in process discovery depend on features of event logs and process characteristics [45]. Discovery algorithms in process mining encounter significant challenges when applied to real-world event logs, particularly those arising from unstructured processes. These challenges include noise, duplicate tasks, hidden tasks, non-free choice constructs, and loops, as identified in [64]. The inherent complexity and variability of real-world processes[41] contribute to these issues and impact the performance of discovery algorithms. Consequently, the effectiveness of such algorithms is contingent upon the specific characteristics of the event log and the underlying process it represents.

a. Alpha Algorithm: The Alpha Algorithm is a process mining technique used to discover workflow nets from event logs. It differentiates between sequential and parallel activities by identifying start and end activities, direct successions, and parallel operations. The resulting Petri net models the process, aiding in the visualization of workflow, bottleneck identification, and efficiency enhancement[2].

b. Heuristics Miner: The Heuristics Miner focuses on the control-flow aspect of processes by analyzing the sequence of events. It constructs a dependency graph to explore activity relationships and captures complex structures and long-distance dependencies. This approach helps optimize operations and provides deep insights into process dynamics[8].

c. Genetic Process Mining: This approach uses a genetic algorithm for process optimization in various sectors by mimicking natural selection. It evolves a solution population through selection, crossover, and mutation, effectively handling noisy or incomplete data and modeling complex relationships within processes[39].

d. Fuzzy miner: Developed by Sarno, Sinaga, and Sungkono, the Fuzzy Miner uses fuzzy logic to manage the uncertainty in dynamic business environments. It builds fuzzy models to detect deviations and anomalies in standard operations, identifying potentially fraudulent patterns by adapting to the data's fuzziness [52].

1.3.3 Process Mining Assessment Metrics

Evaluating process discovery methodologies is crucial for assessing the effectiveness and applicability of process models generated from event logs. This chapter discusses the primary dimensions and specific metrics used to evaluate these methodologies, focusing on accuracy and comprehensibility, and introduces additional metrics that have gained prominence in recent research.

a. Accuracy and Comprehensibility: process discovery methodologies are evaluated along two main dimensions: accuracy and comprehensibility [64].

   Accuracy refers to the degree to which a process discovery technique accurately reflects the behavior recorded in an event log. It challenges the balance between overgeneralization, which can omit critical details, and excessive granularity, which may introduce noise and irrelevant elements into the model [3].

   Comprehensibility involves the understandability of the discovered process models, emphasizing their ease of interpretation and simplicity. This metric assesses the ability of stakeholders to effectively grasp and utilize the process models in practical scenarios
   [3]

b. Conformance Checking Metrics: conformance checking is integral to validating the accuracy of process models against actual event logs. Developing a State-Based Deterministic Finite Automaton (SDFA) is a noteworthy method wherein the SDFA is constructed iteratively from an event log. Initially starting with a single state, this automaton expands by adding new states and transitions as it encounters new events in the log, thus forming a probabilistic model through normalized transition probabilities [33].

c. Precision and Recall: precision and recall are critical metrics derived from information retrieval and classification. They evaluate the specificity and completeness of the elements within a discovered model, respectively. Precision measures the proportion of accurately identified elements within the model, reflecting its specificity and exclusion of irrelevant details. Recall assesses the extent to which a model captures all relevant process elements, indicating its comprehensiveness. Balancing these metrics is crucial as overemphasis on one can detrimentally affect the utility of the process model[32]..

d. Additional Key Metrics: recent studies have highlighted several other metrics that are essential for a holistic evaluation of process models:

- Fitness: assesses how well a model can reproduce the behavior seen in the event log using various methods, such as token-based replay or behavioral alignment [22].
- Generalization: Measures the model's ability to predict unseen instances, ensuring it is not overfitted to the training data [14].
- Simplicity: Evaluates the model's ease of understanding based on its structure and complexity [14].
- Overall Accuracy: Encompasses various aspects of model quality, including precision, recall, fitness, and generalization, to provide a comprehensive evaluation of its effectiveness [66].

The selection of appropriate metrics (see Table 1.2) depends on the specific goals and context of the process mining project. Considerations include the model's purpose, the complexity of the process, the stability of the process environment, and the quality of the event log. Through careful metric selection, researchers and practitioners can derive significant insights into the capabilities and limitations of discovered process models, thereby enhancing their practical applications in organizational contexts.

Table 1.2: Model Evaluation Metrics and Their Usage

Parameter	**Focus**	**Usage**
Precision	Accuracy of positive predictions	Conformance checking, filtering evaluation, algorithm comparison
Recall	Completeness in capturing positive cases	Conformance checking, filtering evaluation, algorithm comparison
Fitness	Fit to the observed data	Overall model evaluation, model selection
Generalization	Ability to handle unseen data	Overall model evaluation, model selection
Accuracy	Ease of understanding	Overall model evaluation, model selection, communication
Simplicity	Overall correctness and reliability	Overall model evaluation, model selection

1.3.4 Process Mining Benefits And Challenges

Process mining is an innovative analytical approach that leverages data mining techniques to analyze business processes. It has gained substantial attention due to its ability to provide detailed, data-driven insights and its applicability across various industries, including healthcare [6] banking, finance[35], and production industries and production industries [30]

Process mining reliably extracts useful data from event logs of various systems due to its objective, data-driven approach, minimizing biases and errors (see Fig. 1.7). It is versatile, aiding in conformance checking, identifying deviations and bottlenecks, and predicting outcomes of process adjustments. This method enhances transparency and efficiency by offering a detailed view of organizational processes through various visual representations, making complex data easily understandable and promoting a transparent audit trail for continuous improvement.

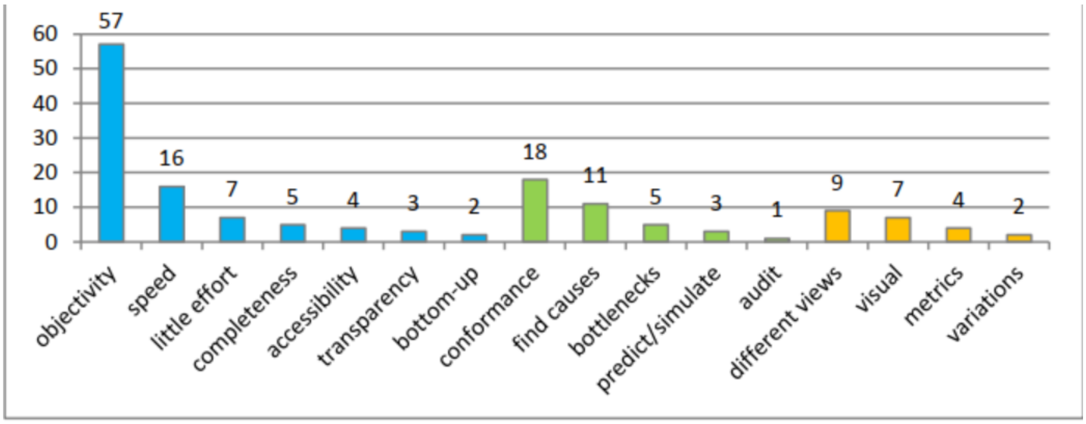

Figure 1.7: Benefits of process mining techniques (42 questions, 94 respondents) (blue: characteristic, green: application, orange: representation), Source: [18]

Strategically, process mining supports decisions that boost productivity by providing insights into process performance and compliance. It even allows for the simulation of changes before actual implementation, helping foresee potential impacts. Its adaptability means it is beneficial across different sectors like healthcare, finance, and manufacturing, enhancing patient flow, fraud detection, and reducing waste, respectively.

However, the adoption of process mining faces challenges (see Fig. 1.8). Accessing and ensuring the quality of the right data is a significant barrier, as poor data quality can lead to inaccurate models, undermining reliability and usefulness. The complexity and usability of process mining tools may deter adoption, especially when benefits are not immediate. Integration costs and the need for technical expertise for incorporating these tools into existing IT systems can be substantial. Moreover, the high costs associated with training and maintenance might be prohibitive for some organizations. Additionally, outputs like complex process models can be difficult to interpret, limiting the actionable insights gained from process mining efforts.

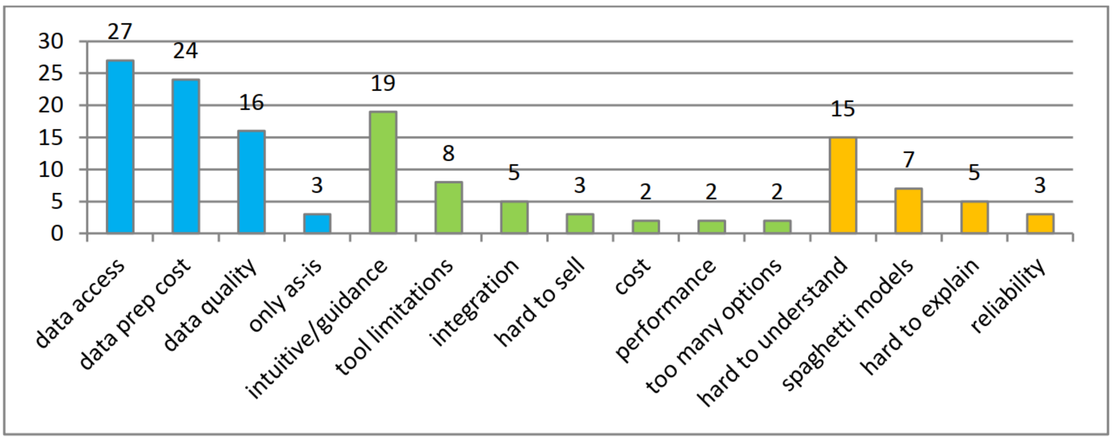

Figure 1.8: Drawbacks of process mining techniques (question 52, 90 respondents) (blue: input, green: techniques, orange: output). Source: [18]

1.3.5 Future Directions In Process Mining

Looking ahead, the future of process mining lies in addressing these challenges while leveraging advancements in technology and methodology:

a. Enhanced Data Management Techniques: Advanced data management techniques will be crucial for improving the accessibility and quality of data. This includes developing more sophisticated data cleaning tools and methodologies to ensure the integrity and completeness of data used in process mining.

b. User-friendly Tools: More intuitive process mining tools that cater to users with varying technical expertise are needed. Simplifying the user interface and providing more explicit guidance on using tools can help make process mining more accessible to a broader audience.

c. Integration Solutions: Developing better integration solutions that reduce the cost and complexity of deploying process mining tools will encourage more organizations to adopt these techniques. This could involve creating more modular and scalable tools that can easily fit into different IT environments.

d. Advanced Analytical Techniques: Future research should also focus on refining analytical techniques to handle complex data and provide more precise, interpretable models. Artificial intelligence and machine learning could play a significant role in developing these advanced techniques.

1.4 Robotic Process Automation (RPA)

Conventional process automation can automate business processes. It involves direct integration with backend systems through APIs or other connectivity means. In general, this needs to be developed and maintained by IT staff who are highly expert in the systems and technologies underneath. Traditional automation, integrated much deeper into system architecture, handles many tasks, such as data processing, system operation, and complex business logic [47].

1.4.1 RPA Definition And Lifecycle

Another growing approach to process automation that uses software robots to mimic human tasks is called Robotic Process Automation (RPA). RPA automates repetitive tasks or workflows previously performed manually, streamlining business processes through technology and software [26] [38]. According to Dr. Choi et al., RPA is a category of software tools that automates repetitive tasks involving structured data, rules, and user interface interactions. The primary objective of RPA is to minimize human effort in labor-intensive processes, thereby increasing the speed and efficiency of high-volume transactional tasks [17].

While RPA focuses on automating individual steps within a process, workflow automation seeks to streamline the entire process's coordination. This involves automatically assigning work to employees and directing process instances based on predefined business rules (Table 1.1)

Table 1.1: A comparison between Conventional Automation and RPA according to criteria determined by [46]

Criteria	Conventional Automation	RPA
IT infrastructure adjustments	Necessary	Unnecessary
Human behavior emulation	Incapable	Capable
Coding knowledge	Necessary	Recommended but not necessary
Customization flexibility	High	Low
Speed	Fast	Relatively to CA, it is slow, but still much faster than manual

According to [17], RPA can be divided into three components (see Fig. 1.2):

- Robots: Virtual software bots that perform mundane, repetitive tasks instead of human resources. They can be "attended" type bots, which work alongside their human counterparts, or "unattended" bots, which work independently and require little to no human involvement.
- Orchestrator: an RPA orchestrator is a management server that schedules, monitors, manages, and audits robots. It is used in the development, testing, and production [31]. As a highly scalable platform that connects the studio to the robots, the orchestrator also bridges the development environment (studio) and the robots, enabling efficient and centralized control of automated processes.
- Studio: The RPA studio is a user-friendly, intuitive tool for designing and automating robotic processes. It also allows users to create and automate robot workflows.

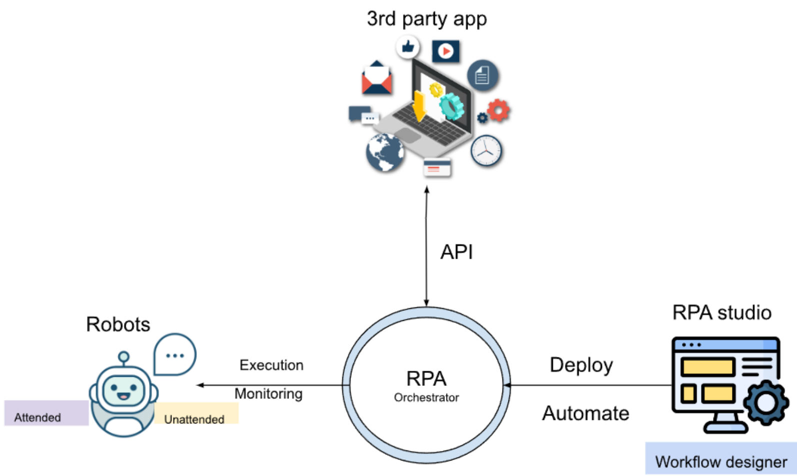

Figure 1.2: RPA components according to [16]

Implementing Robotic Process Automation (RPA) involves a structured six-phase lifecycle (see Fig. 1.3). The process starts with the Discovery Phase, where suitable processes for automation are identified. The Analysis Phase then assesses the feasibility of automating these processes.

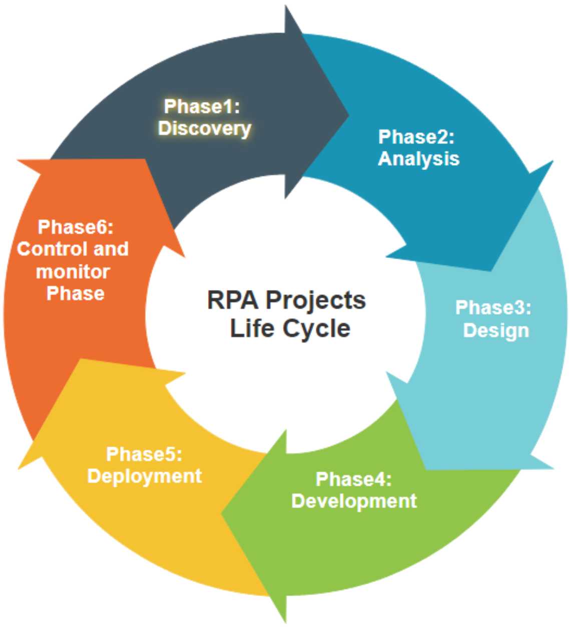

Figure 1.3: RPA Project Lifecycle

The specifications for the automated processes are outlined in the design phase. The Development Phase transforms these designs into actionable components. The Deployment Phase follows, where robots are executed in operational environments. Control and Monitoring oversee the robots' performance, while the Evaluation Phase evaluates their effectiveness, facilitating continuous improvement [46].

1.4.2 RPA Tools

In [31], Amira Khan conducted a comparative study on the three most common RPA tools: Ui Path, Automation Anywhere, and BluePrism. Other tools include Windows Power Automate, Taskt, RoboCorp, and many more (for more details on RPA tools, see appendix). She specified that tools can have two types of architectures. It is either a client-server architecture, meaning that every node can be a client or a server. Or a web-based orchestrator that links automated tasks to create a unified workflow; a web-based architecture can be like the .Net Framework. We will now conduct a comparative study on some popular RPA tools: UiPath, Automation Anywhere, Blue Prism, and TASKT, a popular open-source solution. We will briefly overview each tool, its components, and its advantages and disadvantages. Then, we shall compare these tools according to some criteria in Table 3 (see Appendix A).

1.4.3 The RPA Implementation Frameworks:

Implementing robotic Process Automation (RPA) necessitates a well-defined framework, as the complexity of these projects demands structured guidance to ensure efficacy and Flexibility. Some of these frameworks are based on process mining.

1.4.3.1 Process mining-based RPA frameworks Using process mining-based framework for an RPA project: Unlike conventional frameworks, a PM-based framework makes less room for guesswork and depends directly on data logs generated by process behavior, thus giving a better understanding of the process and detecting RPA opportunities in a better way. Moreover, it helps during and after the implementation of the RPA bot (as described in the previous section). In what follows, we describe some frameworks that rely on process mining to implement RPA in organizations.

a. PLOST framework: The "Prioritized List Of Suitable Tasks" (PLOST) framework, developed by Hilde Jongling [29], employs eight steps, starting with establishing an automation strategy that prioritizes business values and assesses risks. It involves collecting processes through semi-structured interviews, evaluating them against six criteria, and analyzing them using process mining tools to assess criteria like Cycle Time and Case Frequency. The final step is creating a prioritized list of tasks for RPA automation, integrating strategy and detailed analysis (see Fig. 1.4). Although the framework effectively guides the identification of repeatable tasks for automation, it originally lacked considerations for ROI during the process selection phase and was deemed incomplete for IT-related processes, leading to the addition of sub-steps for process critique and redesign, and enhanced data collection for increased accuracy in process mining.

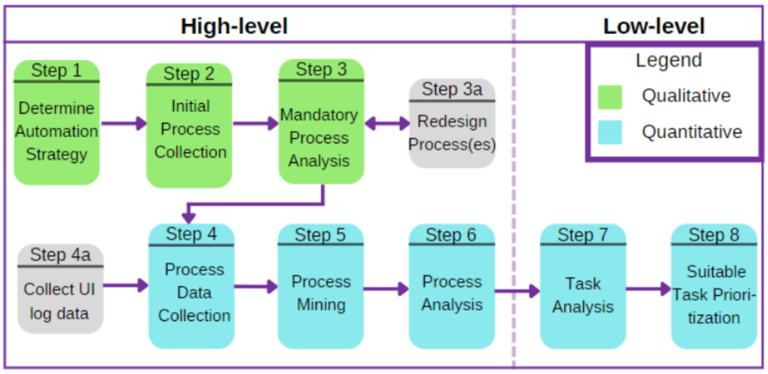

Figure 1.4: The PLOST + framework

b. A framework for implementing Process mining and RPA in Organizations:

In 2023, research [24] introduced a framework leveraging process mining (PM) to evaluate the suitability of tasks for automation and facilitate RPA implementation in organizations. This framework employs process mining techniques to uncover automation opportunities by analyzing event logs to detect automatable routines, identify patterns, and pinpoint bottlenecks and inefficiencies, which helps organizations pinpoint processes that could benefit significantly from RPA. Additionally, it assesses the feasibility of automating these processes through insights on execution frequency, process variants, and exceptions, thus aiding decision-making on whether a process is apt for automation. Moreover, the framework enhances process understanding and improvement by revealing hidden variations, deviations, and inefficiencies, which is essential for optimizing processes prior to RPA implementation. After RPA deployment, it supports continuous monitoring to track the performance of automated processes, comparing actual outcomes against expected models to detect deviations or errors, ensuring the accuracy, consistency, and efficiency of automation. This framework not only identifies and assesses automation opportunities but also maintains efficiency in RPA-implemented processes. However, it might not fully address the scale of RPA solutions and the cultural and change management necessary for successful adoption.

1.4.3.2 Frameworks that do not primarily rely on process mining Frameworks based on something other than process mining require domain expertise and might depend on much guesswork, which, as a result, may lead to a wrong task choice and the failure of the RPA project as a whole. They are necessary in enterprises that need better-structured data.

a. A framework for implementing robotic process automation projects: A paper [27] outlines a comprehensive, adaptable RPA framework structured into four phases: Initialization, Implementation, Scaling, and Rollout. The framework begins with identifying potential automation areas, followed by selecting suitable processes and RPA tools, and testing these through pilot projects. Scaling involves expanding automation across more processes and setting up a Center of Excellence to manage RPA operations. The framework aligns RPA projects with business goals and emphasizes sustainable operation and maintenance. Enhancements could include using process mining and workshops for better process selection and prioritization.

b. A UiPath Academy proposed framework:The UiPath Academy framework [60] details the RPA implementation process and assigns roles and deliverables for each stage, shown in Fig 1.5 It begins with project evaluation during the discovery phase, followed by process analysis where automation potential is assessed. Solution design and development phases include creating and testing modules based on design documents. User acceptance testing (UAT) ensures all scenarios are covered before final signoff. The deployment phase involves monitoring and troubleshooting the bots in operation. While this framework effectively outlines BOT development, it lacks in process selection and identifying automation opportunities.

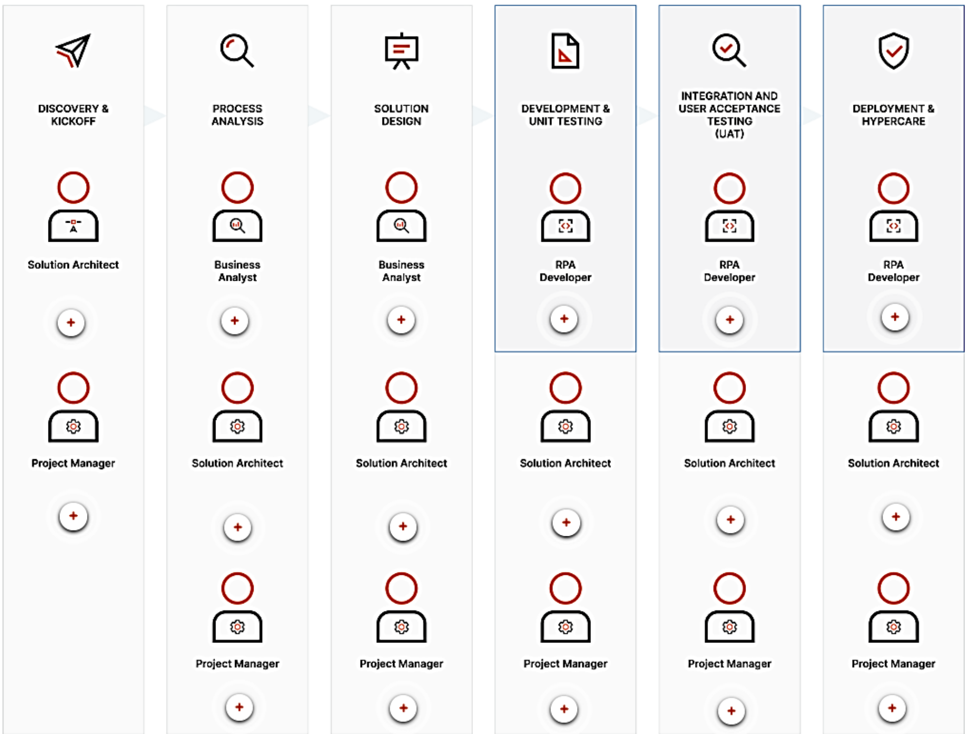

Figure 1.5: Phases of Uipath Framework and stakeholders concerned by each phase

1.4.4 RPA Benefits And Challenges

Robotic Process Automation (RPA) offers significant benefits including rapid efficiency gains and predictable ROI, minimal disruption to existing systems, and 24/7 operational productivity which enhances compliance and reduces human error [56].

RPA also scales well, supporting Lean Six Sigma programs and improving process repeatability [51].

However, RPA faces challenges such as frequent maintenance due to software updates and diminishing utility with the advent of modern systems with better integration capabilities. This technology is often seen as a short-term fix rather than a solution to underlying inefficiencies, and its effectiveness is debated, particularly in modern IT environments where it is less relevant [51],[56]

In essence, while RPA boosts operational efficiency and compliance, it also grapples with issues related to maintenance and ongoing relevance, reflecting the ongoing debate about its long-term value in technology-driven environments.

1.5 Conclusion

Chapter 1 has provided a comprehensive overview of Business Process Management (BPM), process optimization, Lean Management, Process Mining, and Robotic Process Automation (RPA). We have delved into the theoretical foundations, practical applications, and benefits of these methodologies and tools. By understanding these concepts, we have laid a strong foundation for analyzing and enhancing business processes, particularly in the context of our case study at General Electric Algeria Turbines (GEAT).

The integration of BPM, Lean Management, and RPA offers significant potential for improving organizational efficiency, reducing costs, and enhancing overall performance. The insights gained from this chapter will be instrumental as we transition to our case study, where we will explore the practical implementation of these strategies.

With this foundational knowledge in place, we now turn our attention to a practical application. The following chapter will examine a detailed case study at GEAT, where the theories and methods discussed are put into practice. This real-world example will illustrate the process of implementing RPA, the challenges faced, and the significant improvements achieved, providing valuable insights into the practicalities of process automation and optimization.

Chapter 2: Case Study

This chapter presents a detailed case study on implementing a Robotic Process Automation (RPA) solution within a reception structure during our internship. We will explore the stages of the project, from its initiation, analysis, and redefinition of processes to the design and development of RPA bots. The goal is to demonstrate how automation can transform business processes to increase efficiency and reduce costs based on accurate data and precise simulations. This practical case illustrates the application of theories and tools discussed in previous chapters and serves as a reference for evaluating the economic impacts and operational improvements brought about by automation interventions.

2.1 Presentation Of The Internship Hosting Structure

Algeria's energy production relies heavily on fossil fuels, particularly natural gas and oil. Despite having high solar and wind energy potential, renewable sources play a minor role. The government aims to diversify its energy mix, targeting 27% renewable energy in electricity generation by 2030. Key initiatives include large-scale solar and wind projects and exploring hydrogen production from renewable resources to reduce economic dependency on hydrocarbons and enhance energy security[13].

General Electric Algeria Turbines (GEAT) is a joint venture between General Electric (49%) and Sonelgaz (51%), established in 2014 and located in Ain Yagout, Batna. GEAT specializes in the assembly of gas and steam turbines, notably the 9F04 model. It is one of the few facilities worldwide equipped for such production and has around 300 employees. GEAT is an Industry 4.0 company, leveraging advanced technologies like IoT, AI, and big data analytics to enhance production efficiency and reliability.

GEAT products & services include:

A. Turbine Assembly: GEAT assembles gas and steam turbines, including preparation, vertical and horizontal assembly, and final preparations such as painting and packaging.

B. SKID Fabrication: The company fabricates SKIDs, involving operations like cutting, turning, drilling, milling, welding, and assembly, followed by simulation and testing.

C. Control Command Systems: GEAT assembles and tests control command systems, which include building and testing control cabinets.

D. Turbine Repair: Recently, GEAT has expanded its services to include repairing turbine parts, enhancing its service range in the energy sector.

2.2 Project Initiation And Adopted Methodology

Upon our arrival at the host company, we quickly planned an interview with the lean management expert to propose our automation project. We interviewed the lean management expert. We presented our background and explained that our project focused on optimizing processes through robotic process automation (RPA). We then inquired about the state of the company 's processes. The lean expert informed us that the company adopts a continuous improvement principle, continuously monitoring and checking processes against their appropriate performance indicators.

We asked the expert how he and his team determine a scope to start diagnosing waste. He explained that they use three main approaches: Internal Audit, Nonachievement of Objectives, and Continuous Improvement. Internal audits compare internal processes to established norms, highlighting areas where processes may not exist or are performed ad hoc. Non-achievement of Objectives involves setting S.M.A.R.T. goals and identifying waste when these goals still need to be met. Continuous Improvement is a cyclical approach where processes are regularly checked and diagnosed for further waste, even if previous audits and objectives are satisfied. This thorough approach ensures ongoing optimization and efficiency; the lean expert then proposed that we start by gathering data on the processes by planning interviews with employees, which we promptly executed.

We conducted a second interview with the head of the IT department and explained the concept of RPA from an IT standpoint. We demonstrated the benefits of RPA, such as increased efficiency, reduced error rates, and enhanced scalability, as well as its limitations, including the initial cost of implementation and the need for ongoing maintenance. The IT head was very receptive to the idea. He expressed enthusiasm for the potential improvements RPA could bring to the company 's operations. Moreover, he informed us that a similar project was already implemented in his department using Microsoft Power Automate.

Another question we asked was: "For local software improvement projects, how do you go about detecting the problems, and which methods or tools do you use for that?" to which he answered by saying that since the IT team is small, their focus is on delivering solutions that directly address the needs of their internal clients. Rather than investing time in diagnostics to identify software inefficiencies, they prioritize understanding user requirements upfront. They then proceed to propose, develop, and implement tailored solutions. Their ongoing efforts involve maintenance to address any bugs and ensure continuous enhancement. They also prioritize studying the Return on Investment (ROI) post-implementation to ensure that maintenance costs are justified by the benefits gained.

We interviewed employees who expressed frustration with mundane tasks that did not require their expertise. We investigated their workflows and discovered a need for further automation. The workers highlighted that many manual processes remained prone to errors, rework, and inefficiencies despite the initial transition, consuming significant time and presenting opportunities for automation. These tasks were routine and weakened by more valuable human contributions. After a thorough analysis, we pinpointed specific wasteful processes.

We initiated the automation project by tailoring a framework based on four previously mentioned frameworks in section 1.3.3, that is explicitly adapted for this case study.

We primarily relied on the PLOST (and PLOST+) frameworks [29] for most of the process analysis and redesign phase.
We referred to [24] to integrate Process Mining in step 1 (discovery) and [27] to develop a pilot before the interviews (in step 2). This was done to test the feasibility and provide stakeholders with a better understanding of what a workflow automated by an RPA bot looks like.

Furthermore, we combined [29] and the [UiPath Academy framework] [60] for the design and development and additionally the user acceptance testing and deployment phases.

Figure 2.1 illustrates the framework we have tailored based on the four frameworks declared above to satisfy GEAT 's specific requirements.

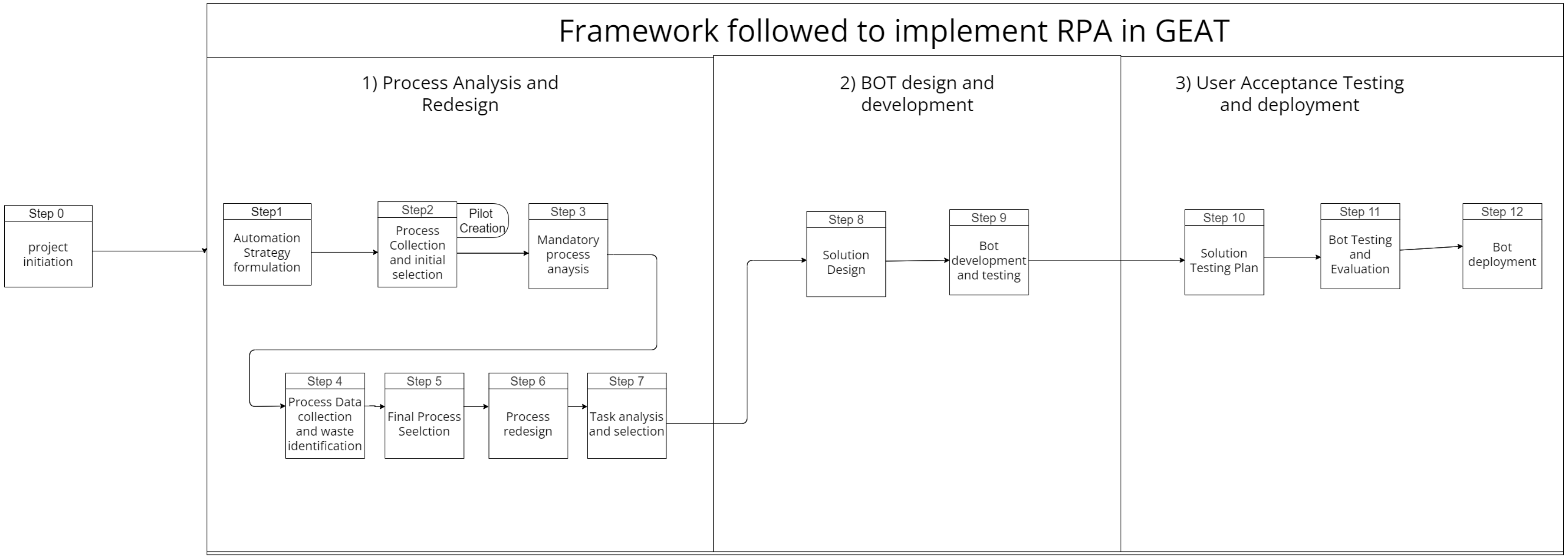

Figure 2.1: The Tailored framework

2.3 Phase1 : Process Analysis And Redesign

This section delves into the systematic approach taken to analyze and redesign processes at GEAT for robotic process automation (RPA) implementation. Starting with an Automation Strategy Formulation, the section outlines the prioritization of desired outcomes like speed, precision, and flexibility based on stakeholder inputs. It continues with the Collection and Initial Selection of Processes, utilizing interviews and BPMN modeling to identify and select potential processes for automation. The section further details the Mandatory Process Analysis to evaluate the suitability of selected processes based on criteria such as digital input and structured data. Subsequent stages include detailed data collection, waste identification, and the final selection of processes to undergo redesign, ensuring that only the most impactful and feasible processes are automated to enhance operational efficiency and accuracy.

2.3.1 Automation Strategy Formulation

We performed initial quick surveys with some stakeholders, asking them to rank the desired outcomes from automation. We asked each stakeholder to distribute 100 points on the desired outcomes. The possible options were Speed, precision, and Flexibility.

Moreover, we asked them if they wanted to automate a process with a high-risk level (critical process) or a lower-risk level (a noncritical process). The desired outcomes of each stakeholder are summarized in table 2.1.

Table 2.1: Automation strategy determination outcome

Desired outcome	S1	S2	S3	S4	Total
Speed	30	25	30	40	125
Precision and accuracy	50	50	50	50	200
Flexibility	20	25	20	10	75
Total	100	100	100	100	400
Risk level	low				

Overall, precision and accuracy were universally prioritized, with a moderate emphasis on speed and a divided view on freeing up human resources. Moreover, stakeholders wished for a low-risk project.

These results will later help us in primary process collection and task selection.

2.3.2 Process Collection and Initial Selection:

In accordance with the PLOST Framework, the integration of process mining for process discovery and analysis could significantly enhance the identification of suitable processes and tasks for automation. However, the database at the host company lacked the necessary event log and additional information for comprehensive analysis and insight extraction.

To demonstrate the potential of process mining, we created a dummy event log that mirrored the activities in process 11, as shown in Table 2.2. We selected the software Disco for its simplicity and demo version that accommodates up to 100 instances. The resulting direct-follow diagrams generated by the Disco software using the dummy event log are presented in Appendix E10.

For this step, we conducted interviews with stakeholders at GEAT to gather the initial processes for the framework. The PLOST framework outlines how to conduct interviews and what questions to ask. Please refer to APPENDIX B for details on the questions prepared for the interviews and the answers provided by stakeholders for each process. The semi-structured interviews involved various experts from GEAT, specifically those involved in the sourcing and supply process. The complete BPMN process models for sourcing and supply at GEAT are provided in APPENDIX B, and the interviews were conducted during a temporary production halt in preparation for the Repair project. The identification and roles of the different interviewees are detailed in Table , chosen for their expertise and experience in the processes.

Midway through the interviews, we noticed that many stakeholders struggled to understand the concept of RPA. To address this issue [27] suggested creating a pilot Bot to help the interviewees better understand RPA ac a concept, which we included as part of the process collection and initial selection step in our taylored framework illustrated in figure 2.1. Thus, we created a pilot that extracts data from an e-mail(see APPENDIX D1)..

Table 2.2 shows details of each process collected by which stakeholder from what department:

Table 2.2: Collected processes per Role and per Department

Department	Role	Identified Process	Process Code
TG-TV and Repair	Lead Method engineer	Technical evaluation of offers	P1
	Repair shop supervisor (temporary methods engineer)	Filling the Procurement demand (DA)	P2
	Quality Management System	3-FQ (verify quality documents' status on DMS)	P3
IT	IT systems manager	4-IT helpdesk	P4
		5-System monitoring	P5
Finance	Financial analysis	6-Checking OIS and imputation conformity	P6
		7-Data gathering for analysis	P7
	Accountable	8-Matching MBOM to inventory materials (MP & subcomponents)	P8
		9-analyse charge par rapport chiffre d'affaires	P9
Logistics	Logistics engineer	10-Merchandize reception	P10
		11-DPL treatment	P11
Quality	Quality Management System	3-FQ	P3
	Quality Control	12-supplier requirements documents treatment	P12
	Supplier Quality Engineer	13-Creation of quality information sheet	P13
		14-Reception of supplier documents	P14

After the initial process collection, we modeled all the processes using BPMN models. We confirmed each model with the concerned stakeholders. After the confirmation, we conducted a preliminary screening to eliminate processes that were unsuitable for automation. This included processes with very low frequency, those for which better automation methods than RPA existed, or those already automated. See Table 2.3

Table 2.3: Initial process collection

Process	Pass to the next step?	Reason for abolishment
P1	No	Domain knowledge required excessively
P2	Yes	/
P3	Yes	/
P4	Yes	/
P5	Yes	/
P6	No	Verification is secondary in this process
P7	No	Already automated
P8	No	Very low frequency (done each quarter)
P9	No	Very low frequency
P10	Yes	/
P11	Yes	/
P12	Yes	/
P13	Yes	/
P14	Yes	/

2.3.3 Mandatory Process Analysis

The processes that passed through the initial selection can now be subjugated to mandatory criteria, which are digital input, structured data, few variations, repetitive, rule based and mature. See Table 2.4 :

Table 2.4: Mandatory process analysis

Criteria\Proces	P2	P3	P4	P5	P10	P11	P12	P13
Digital input	yes	yes	yes	yes	no	yes	yes	yes
Structured data	yes	yes	yes	yes	no	yes	no	yes
Few variations	no	no	no	yes	yes	yes	yes	yes
Repetitive	yes	yes	yes	yes	no	yes	yes	no
Rule Based	yes	yes	yes	yes	yes	yes	yes	yes
Stable (Mature)	yes	yes	no	yes	yes	yes	yes	yes

Table 2.4 indicates that the suitable processes for automation are P5, P11, and P12. Although process P12 does not meet the "Structured Data" criterion, it could still be automated by integrating AI to structure the data. We modeled these processes (see Figures 2.2, 2.3 and 2.4) to analyze them and select at most one process for automation.

2.3.4 Process Data Collection And Waste Identification

We chose Academic Signavio to model our processes. Signavio is a leading software suite for business process management (BPM). It offers robust BPMN capabilities, a user-friendly interface, real-time collaboration, and comprehensive analytics. Signavio ensures standardized, clear, and consistent process representations, enhancing understanding and efficiency in business operations. Its integration with other tools and Flexibility make it ideal for various organizational needs.

Data Collection means (qualitative and quantitative: data mining and interviews):

Primary process collection was done using interviews, the results of the questions and results of Interviews can be found in the Appendix B. Process Mining was also used (as per step 1 of A framework for implementing Process mining and RPA in Organizations). We modeled the primarily selected processes and got them validated by the concerned stakeholders before going to the next step.

Process P11 : Reception DPL :

This is a sub-process of the supply process (refer to Appendix B, "Compare DPL to MO "). It occurs before "Merchandise Reception " when the supplier (in this case, General Electric) sends a group of files called DPL (Detail Packing List), which contains a list of the shipped materials per case. These files are then consolidated into one and compared to the MO (Ordre de Fabrication/Manufacturing Order) to identify any excess or missing quantities sent by the supplier. The production department is notified of any discrepancies. Subsequently, the quantities in the DPL are compared to those in the PO (Purchase Order) and vice versa to detect inconsistencies between the received and ordered quantities. Finally, after the comparison, the Logistics team verifies items that do not have an MO code, which is considered MSDS (Materials Shipped Directly), meaning they do not need to go through the production process and are sent directly to the client. The team also creates new GEAT templates to send DPLs to their clients. We have modeled the process using BPMN (see Figure 2.2).

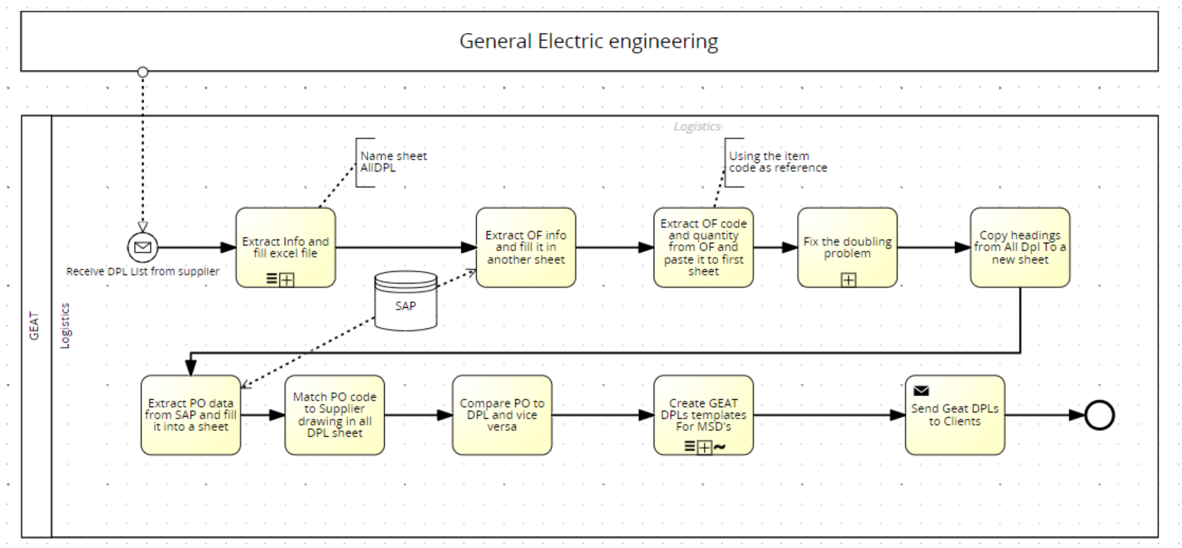

Figure 2.2: BPMN model for the process “Reception DPL process”

All the sub-processes of this process were modeled Using BPMN and details on each sub process can be found in Appendix E:

Process P5: System Monitoring

This process is a support process of the enterprise and does not interfere directly with the company's activities. At 15:30 daily, the IT engineer initiates a comprehensive IT systems check, verifying hardware components, server storage, RAM, CPU usage, network connectivity, and application health. Disk health, CPU status, disk usage, memory usage, and network interfaces) are checked. Critical service statuses and log files are analyzed. A report is generated, and notifications are sent if issues are detected, ensuring optimal system performance and prompt resolution. See figure 2.3

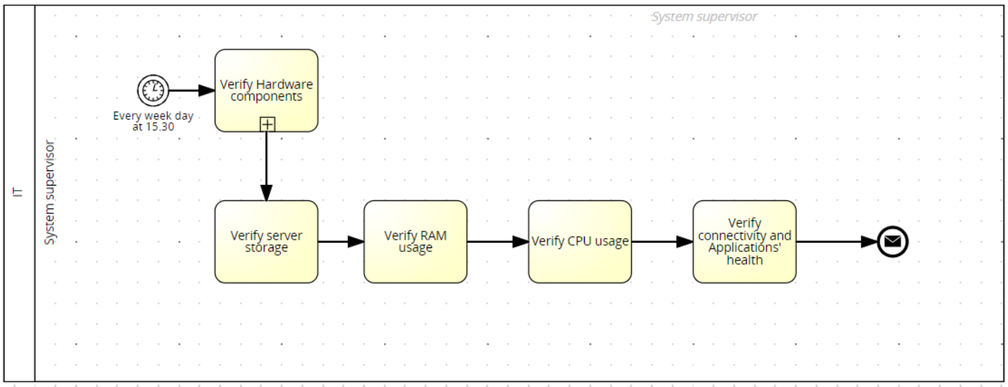

Figure 2.3: BPMN model for the process "System Monitoring"

The sub Processes for this process can be found in Appendix E

Process P12: Supplier requirements documents treatment

P12 is a subprocess of the Sourcing Process. It involves the Supplier Quality Engineer (SQE) receiving documents that prove the supplier's conformance to quality requirements via email, placing them in the "P" folder (a shared folder), and sending an email with the document path while notifying the Quality control (QC). The QC team then receives the file path, retrieves the article code from the Purchase Order (PO) located in the ERP SAP system, QC team specifies an Excel file containing criteria for each supplier and then matches the required criteria with the satisfied criteria, and writes a small report in the Excel file indicating whether the documentation is conforming or not, finally the SQE verifies the report sent by QC if the report is positive; the process ends, else a notice is sent to the supplier, and SQE waits for the supplier to send documents again, after which the process loops from the first activity. See figure 2.4

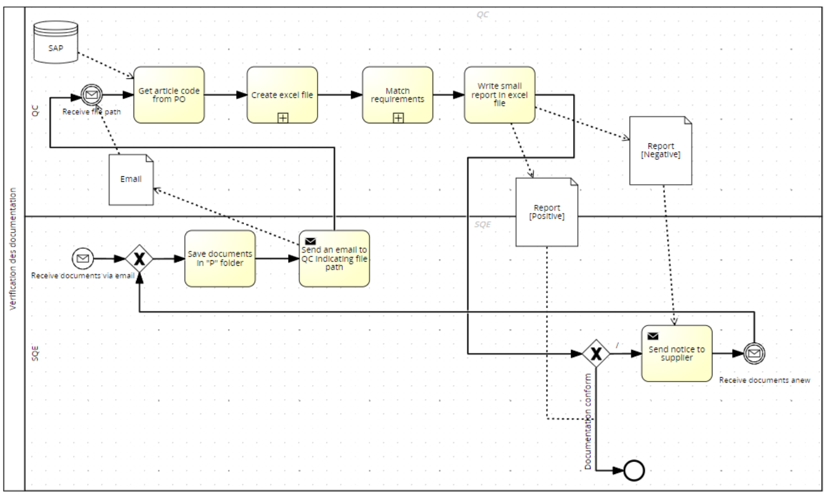

Figure 2.4: BPMN model for the process "supplier requirements documents treatment"

Next, we estimated the **overall time for process execution** and carried out a **waste analysis of the selected processes**. We have used the seven Muda method to identify the waste in the three candidate processes so that it will help us more in choosing the process that will benefit more from automation and fix other problems through process redesign see Table 2.5

- P5: This process's total cycle time is 15 minutes (daily); we obtained this information by asking the stakeholders directly involved in this process.
- P11: this process's total cycle time is 4 to 5 hours to treat 100 DPLs (an average of 3 min per DPL). However, due to rework and the logistics team's many other tasks, this process has an average lead time of 15 days. We got this information from interviewing individuals from the logistics team and holding a stopwatch to find the time to treat a DPL.
- P12: this process is realized per project; it has a lead time of around 20 to 30 days; after we discussed it with stakeholders, namely Supplier Quality Engineer and Quality Control, they informed us that they work on this process in parallel with other methods. And that it takes on an average of 20% of their day. So for 22 working days (a month without including weekends) for 8 hours of work a day, the cycle time of this process is calculated as follows: (22 days * 8 hours/day) *0.20= 35.2 hours/month

Table 2.5: Process waste identification using seven muda

Waste\Process	P5	P11	P12
Transportation	/	/	/
Inventory	/	Incomplete Files waiting to be treated between activities.	Unverified supplier documentation is taking space in the "P" folder and is waiting to be verified.
Motion	/	/	/
Waiting	/	Tasks of this process have to be halted each day as the logistics team has many other responsibilities. Production has to wait for logistics to confirm DPLs	We are waiting for SQE to put the required documents in the directory and notify QC.
Over Processing	/	Complicated, well-defined steps lead to accessing the same document multiple times. Steps like "Copy headings" are considered overprocessing as it can all be done in one step.	Unstandardized templates received from suppliers will lead to more time needed to process said documents.
Overproduction	/	/	/
Defects	/	Mistakes happen a lot when manipulating data manually, leading to rework.	Mistakes tend to occur so that verification can be repeated.
Skills	Monitoring the IT systems does not require the skills IT members possess.	Most of the work in this process includes copying and pasting mundane/straightforward activities, thus wasting the logistics team's skills and time.	QC has the technical skills required to identify nonconformities in received products; his skill is wasted on a simple, time-consuming task.

Process P11 includes treating DPL files if the supplier is GE. However, the logistics team ensures that if the automation provides good results for the GE example, they will force a DPL template on their suppliers to automate the process for any supplier.

2.3.5 Final Process Selection:

Stakeholders emphasized that they wanted this project to target low-risk, non-strategic processes. Among the three methods, P5 has the lowest risk level, followed by P11 and P12. The risk level ranking was determined based on recommendations from each stakeholder and the involvement/impact of each process on the enterprise's current activities.

Process P5 is independent of the main activities (even though it is still a mandatory process), so testing automation on this process would not affect the enterprise. Although process P11 involves the main activities, it includes internal analysis where mistakes can be corrected quickly, thus not leading to severe consequences. It will be generalized later if automation shows promising results. However, process P12 is critical, as mistakes would lead to significant time penalties and harsh legal consequences.

This ranking, along with Table 8, helped us select a single process that will benefit more from an automation project.

In the PLOST framework, it is assumed that data for this criteria is collected from process mining. However, due to the partner organization's unorganized database, we primarily relied on interviews and observations to determine the values of each criterion. Cycle and lead time were previously calculated, and case frequency was determined during interviews. Process length was derived from the models, and the automation rate and the estimation of human error proneness were based on user estimates. A detailed explanation of the criteria used can be found in Appendix F,

Table 2.6 compares the three processes based on the given criteria; the green-colored cases are the most favored for automation, followed by orange and then red for least favored. Three points are attributed to green, two to orange, and one to red.

Table 2.6: Process Analysis (Final Process selection)

Criteria\Processes	**P5**	**P11**	**P12**
Lead time	20 min	15 days	22 days
Cycle Time min/day	15 min/day	66 min/day	96 min/day
Case Frequency	360/year	22/year	22/year
Length # of tasks	7	19	12
Automation Rate	20%	0	0
Human Error Prone	0%	30%	20%

The total points were calculated to determine the best process for automation, as shown in Table 2.7.

Table 2.7: Process ranking by points attributed to each criterion

Criteria\Processes	**P5**	**P11**	**P12**
Lead time	1	2	3
Cycle Time (min)	1	2	3
Case Frequency	3	2	2
Length # of tasks	3	1	2
Automation Rate	1	3	3
Human Error Prone	1	3	2
Total of points	10	13	15

Process P12 has the most points, followed by process P11 and finally P5. However, as stakeholders indicated the desire to automate a low-risk process, we could not go on with process P12 and chose the next best option, which is P11 and ensures a higher success rate.

2.3.6 Process Redesign

Process P11 has significant waste and requires redesign. First, we conducted a Value Stream Mapping (VSM) with the assistance of the GEAT Lean expert to pinpoint exact areas with types of waste, non-value-added (NVA), and necessary non-value-added (NNVA) activities. Then, we redesigned the process using the Lean method ECRS (Eliminate, Combine, Rearrange, Simplify) to minimize waste.

a. VSM of the process before redesign:

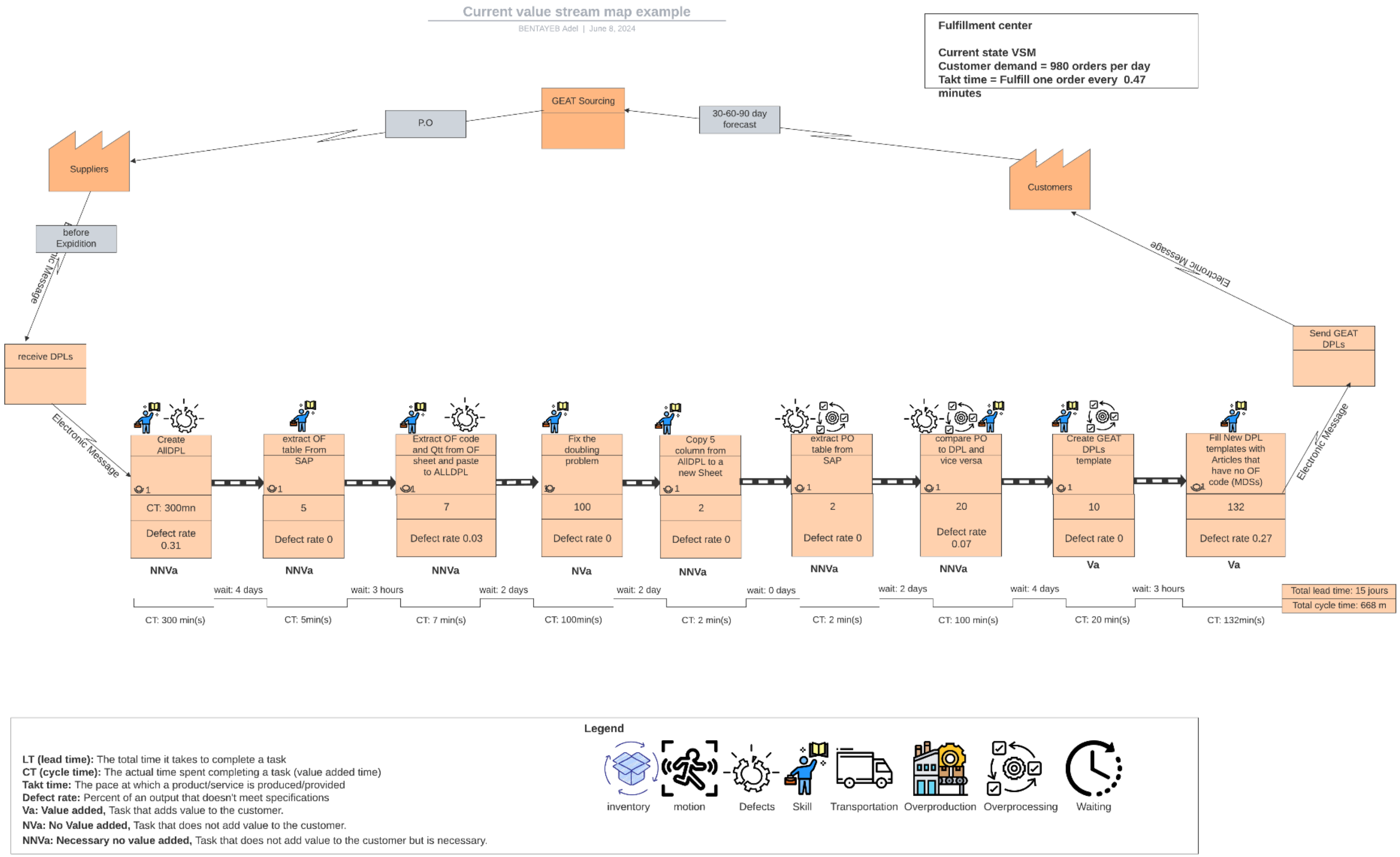

Figure 2.1: Current state VSM of P11

The current state value stream map (VSM) diagram represents the process flow from suppliers to customers in a fulfillment center, focusing on the creation and handling of DPLs (Delivery Performance Logs). Each process step includes critical metrics such as cycle time (CT), defect rate, and whether the activity adds value (VA), no value (NVA), or necessarily no value (NNVA). The lead time (LT) and wait times between steps are also depicted. The map highlights inefficiencies like high defect rates, long waiting periods, and significant non-value-added activities. This detailed visualization of the current process helps identify bottlenecks and areas for improvement, aiming to streamline operations, reduce defects, and increase overall efficiency in fulfilling customer orders. The total lead time is 15 hours, and the total cycle time is 668 minutes, which indicates substantial room for process optimization. See figure 2.5

b. Redesigning the process using the ECRS principle:

We used the 5W1H method to analyze the identified waste in the process. By asking "Why," we identified redundant steps that did not add value. The "What" aspect highlighted activities prone to overprocessing, such as excessive data entry. "Where" focused on the locations of bottlenecks. "When" emphasized timing issues, noting delays from waiting for confirmation. "Who" identified that highly skilled logistics personnel were often engaged in mundane tasks. Finally, "How" revealed the convoluted nature of current procedures, necessitating repeated document handling and inefficient workflow steps. This comprehensive analysis laid the groundwork for targeted improvements.

After examining various aspects of waste in Process P11, we applied the ECRS principle to propose improvements. This involved automating manual tasks to reduce pending documents and rearranging the workflow to prioritize automated activities, thereby minimizing inventory and waiting times. Overprocessing was addressed by simplifying and combining tasks, such as creating GEAT DPLs and integrating the "copy headings" step. Defects were reduced by automating data handling and streamlining user tasks. Lastly, mundane tasks were automated to allow the logistics team to focus on more complex activities, enhancing efficiency and better utilizing their skills. See Table 2.8, Each column is filled with dots indicating where the specific aspect of 5WIH and ECRS is relevant to the suggested improvements for each waste category. This structured approach helps in systematically analyzing and implementing process improvements.

Elimination in ECRS was mostly used to replace manual tasks with automatic tasks that the RPA bot would perform.

Process P11 after redesign:

The number of tasks in the redesigned process was lowered from 19 to 14 (including tasks in sub-processes), of which 11 are candidates for automation; for security reasons, the three remaining manual activities could not be considered for automation. The redesigned process is illustrated in the BPMN model in Figure 2.6.

Table 2.8: Implementation of 5W1H Technique and ECRS Principle

Waste	Why	What	Where	When	Who	How	Improvement	E	C	R	S
Inventory	•	•		•			Automate manual tasks that generate pending documents and rearrange them so that they will be the first ones to be performed	•		•	
Waiting				•			Rearranging activities so that automated activities will be the first to be executed, followed by manual activities realized by users, thus finishing all the process at once and reducing waiting times			•	
Over Processing						•	Automate and simplify “Create GEAT DPL” into well-defined simple steps, as well as combine "copy headings" with “Match Po code to Supplier Drawing” and “Compare Po to DPL”	•	•		•
Defects					•	•	Automate manual handling of data and simplify data handling tasks performed by users	•			•
Skills					•	•	Automating simple tasks that require no domain knowledge	•			

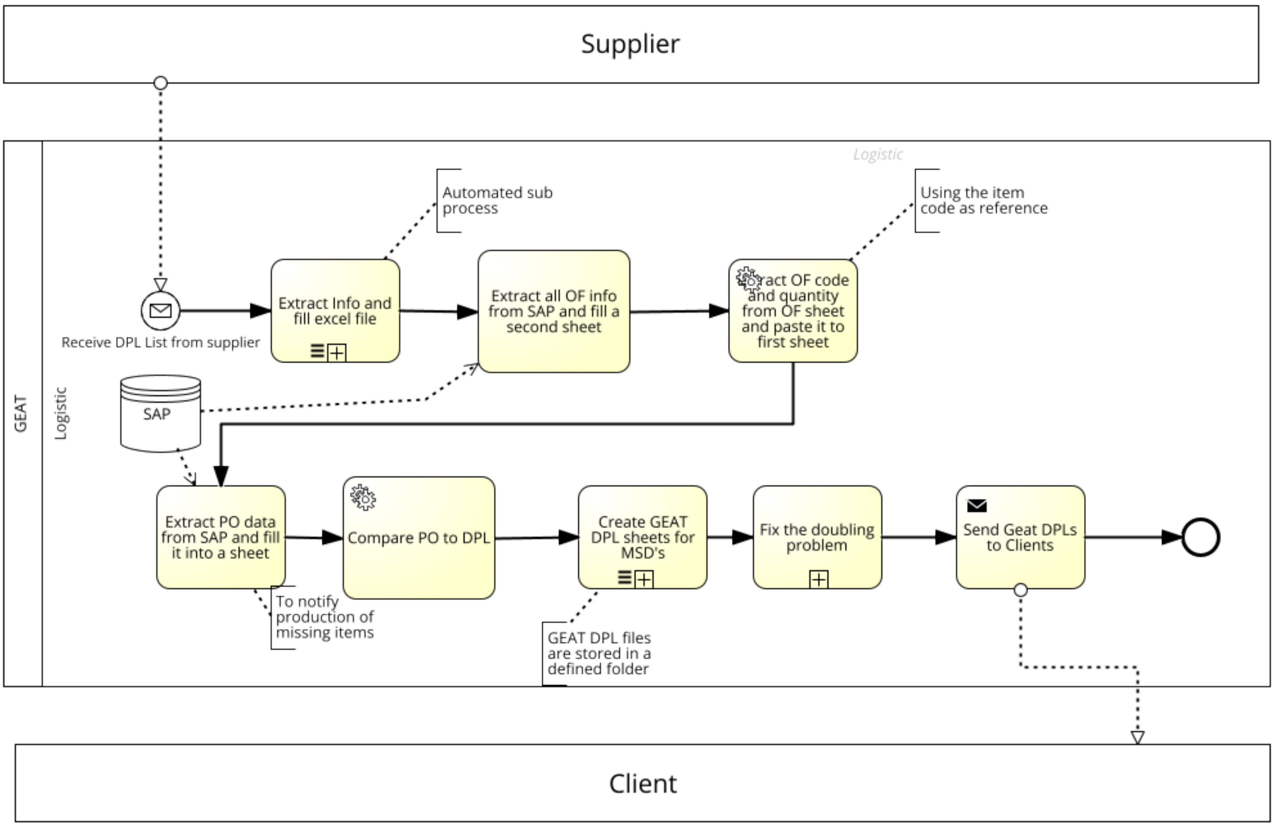

Figure 2.6: process P11 after redesign

The sub-processes of the new process were redesigned, please refer to Appendix E for the new subprocesses of P11 :

2.3.7 Task Analysis and Selection:

We have run the 11 candidate tasks of the redesigned process through the following criteria to determine which tasks are more suitable for automation :

Table 2.9 shows each task title and its attributed code; the tasks are ordered by their succession in the redesigned process :

Table 2.9: Candidate tasks codes

Task name	Task code	SubProcess code
Download the DPL file from email/ access through the directory	T1	Sp1
Extract relevant information from each file.	T2	
Fill information in the target Excel file	T3	
Extract the MO code and quantity from the MO sheet and paste it onto the first sheet.	T4	
Compare PO to DPL	T5	
Get a list of case numbers of MSD's	T6	Sp2
Verify if the case number is in the MSD list	T7	
Copy All data and save it under the GEAT template	T8	
Filter MO sheet by supplier drawing	T9	Sp3
Verify if there is more than one MO quantity	T10	
Delete one of the quantities and even the number with the DPL quantity.	T11	

We have analyzed the candidate tasks using a list of criteria explained in Appendix F in Table 2.10 to determine the prioritized tasks for automation :

Table 2.10: Task analysis

Criteria \Tasks	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Activity frequency	14	100	100	100	1	1	78	78	1	30	30
Duration (min)	3	149	149	5	20	2	100	100	3	50	47
Automation rate	0	0	0	0	0	0	0	0	0	0	0
Human Prone Error	31%	31%	31%	3%	7%	27%	27%	27%	0%	0%	0%

Points will now be attributed to each criterion (by task) as explained in Appendix G; Table 2.11 shows the attribution of points :

Table 2.11: Point attribution for each task

Criteria \Tasks	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Activity frequency	8	11	11	11	7	7	10	10	7	9	9
Duration (min)	5	11	11	6	7	4	10	10	5	9	8
Automation rate	11	11	11	11	11	11	11	11	11	11	11
Human Prone Error	11	11	11	8	9	10	10	10	7	7	7

As explained in Appendix G, criteria were multiplied by desired outcome values to get the final list of prioritized tasks in Table 2.12

Table 2.12: Scoring of tasks

Criteria \Tasks	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Activity frequency	1600	2200	2200	2200	1400	1400	2000	2000	1400	1800	1800
Duration (min)	625	1375	1375	750	875	500	1250	1250	625	1125	1000
Automation rate	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Human Prone Error	2200	2200	2200	1600	1800	2000	2000	2000	1400	1400	1400
Total	6625	7975	7975	6750	6275	6100	7450	7450	5625	6525	6400

Task groups (T1, T2, T3), (T6, T7, T8), and (T9, T10, T11) are all atomic tasks of subprocesses that should be automated wholly and not partly, so average points will be calculated for each subprocess. The sub processes will be referred to as SP1, SP2, and SP3, respectively, according to the order of the tasks. Figure 2.7 shows the final ranking of activities.

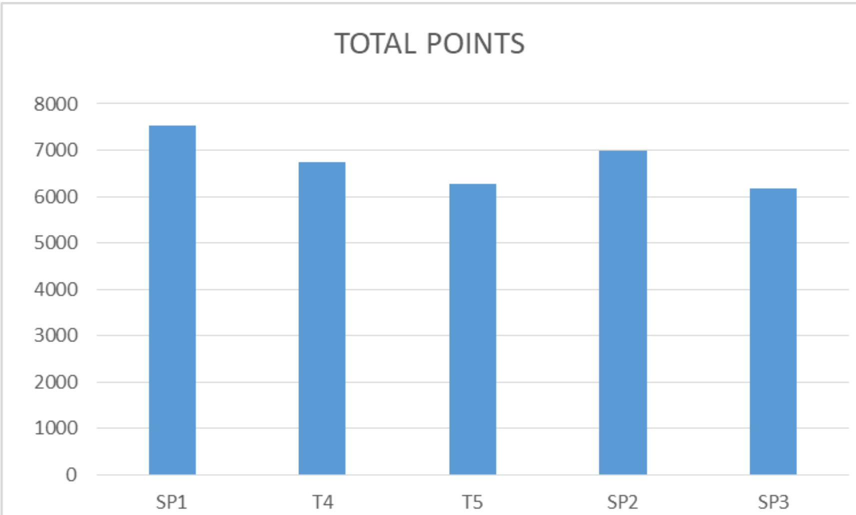

Figure 2.7: Final ranking of activities

As Figure 2.6 shows, SP1 and SP2 hold the topmost priority for automation, followed by T4 and T5, and finally, SP3. This will help us determine which tasks to prioritize for automation in the design and development phase.

2.4 Phase2 : BOT Design and Development

This section transitions from the process analysis and redesign to the technical specifics of RPA bot design and development within GEAT. It focuses on the solution design using UiPath, chosen for its user-friendliness and robust security features. Key activities are mapped out with detailed diagrams showing manual and automated steps. The section also outlines the development process, including the construction of user interaction interfaces and thorough testing protocols to ensure each bot function integrates smoothly and meets the predefined criteria. This ensures that the bots are not only effective but also user-friendly and adaptable to future changes.

2.4.1 Solution Design

UiPath Automation software choice: After the tool comparison in Appendix A, we have deduced that Uipath is the best choice for automation. This is thanks to its ease of use, Flexibility, community and support, compatibility with computer systems, and security (including encryption and algorithms like AES, DES, RC2, Rijndael, and TripleDES). The stakeholders highly appreciate the security aspect.

Before starting the development on Uipath, we have designed the steps of each activity to be automated under activity diagrams , the orange indicates the step is manual, blue means it's automated. As per the order deduced from the previous step, the automation should start with SP1 followed by SP2, however SP2 requires the input of T4 and T5 so the ordering will go as follows : SP1 , T4 , T5 and finally SP2

SP1 : Extract info and fill excel file:

The bot navigates through a predetermined folder for DPL files (supplier files), and for each excel file in this folder; it opens the file.

For each sheet of the current file it gets the Case number, for each line in a specified range it gets the information of each item and stores them along with case number in a Datatable variable to paste them later into the Target all DPL file. The bot only stops when each file in the designated folder is treated. See Figure 2.8 for the correspondent activity diagram. :

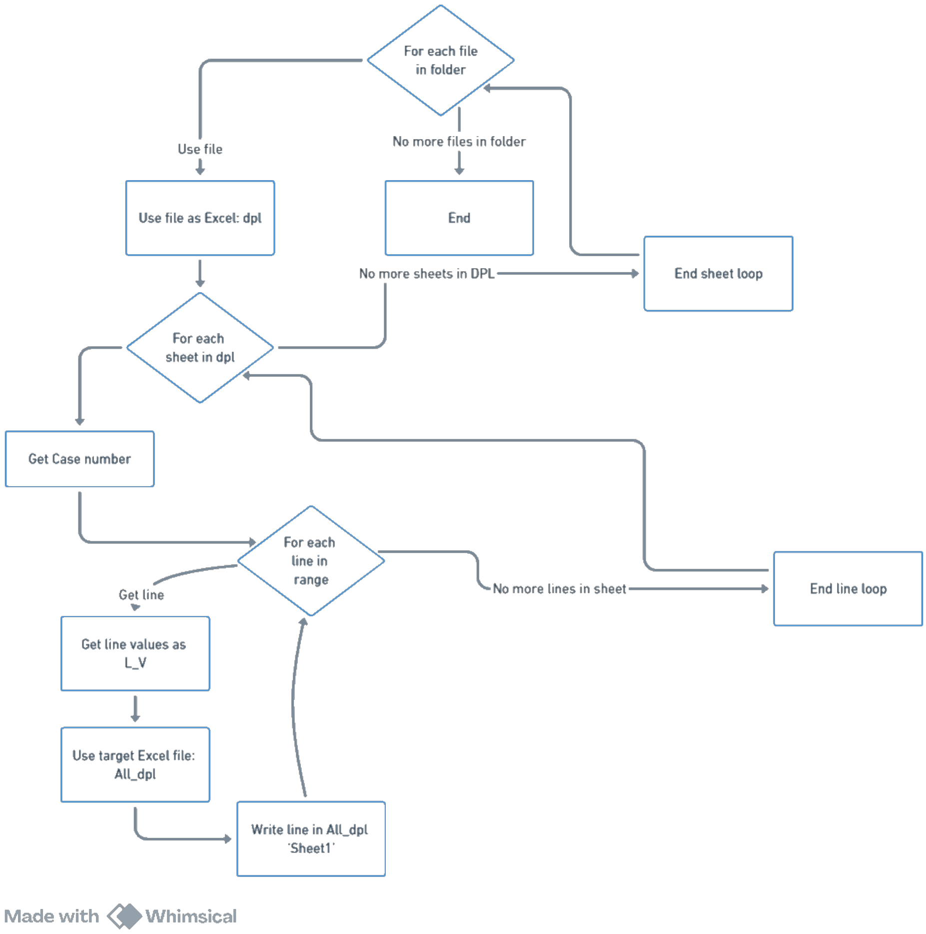

Figure 2.8: Activity Diagram for "Extract info and fill excel file"

T4 : Extract MO code and quantity from MO sheet and paste it to first sheet:

This activity is preceded by extracting MO data from SAP as an excel sheet to be able to continue into this activity. As shown in Figure 2.4.2; the user has to access SAP to get the MO table as an excel sheet and paste it into the All_dpl file, the bot will then find adequate MO quantities and code for each item in the first sheet. See Figure 2.9 for the correspondent activity diagram.

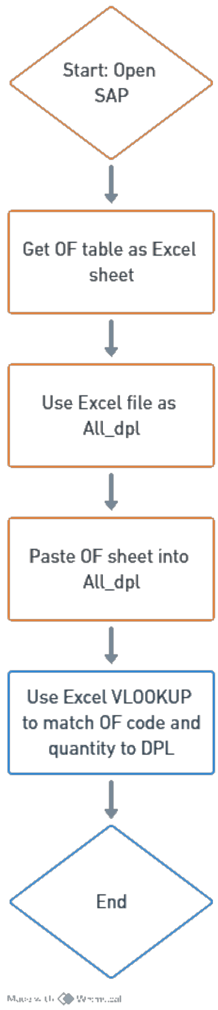

Figure 2.9: Activity Diagram for "Match MO code and quantity to items from dpl"

The manual steps can be later automated if GEAT provides us with access to SAP, else they still will have to be performed manually by users.

T5 : Match DPL to PO and vice versa:

The user needs to extract PO details from SAP into an Excel sheet, then paste this data into the "Détail PO" sheet within the AllDpl document. Afterward, the bot prompts the user to specify the type of input: manual or automatic. For manual input, the user must enter each MLI kit code along with the corresponding PO code. For automatic input, the user fills out a predetermined MLI sheet with the necessary information, and the bot matches them automatically. Subsequently, the bot creates two pivot tables: one comparing PO quantities to DPL quantities, and the other comparing DPL quantities to PO quantities. Once the pivot tables are created, the bot matches the quantities from both tables against each other. See Figure 2.10 for the correspondent activity diagram.

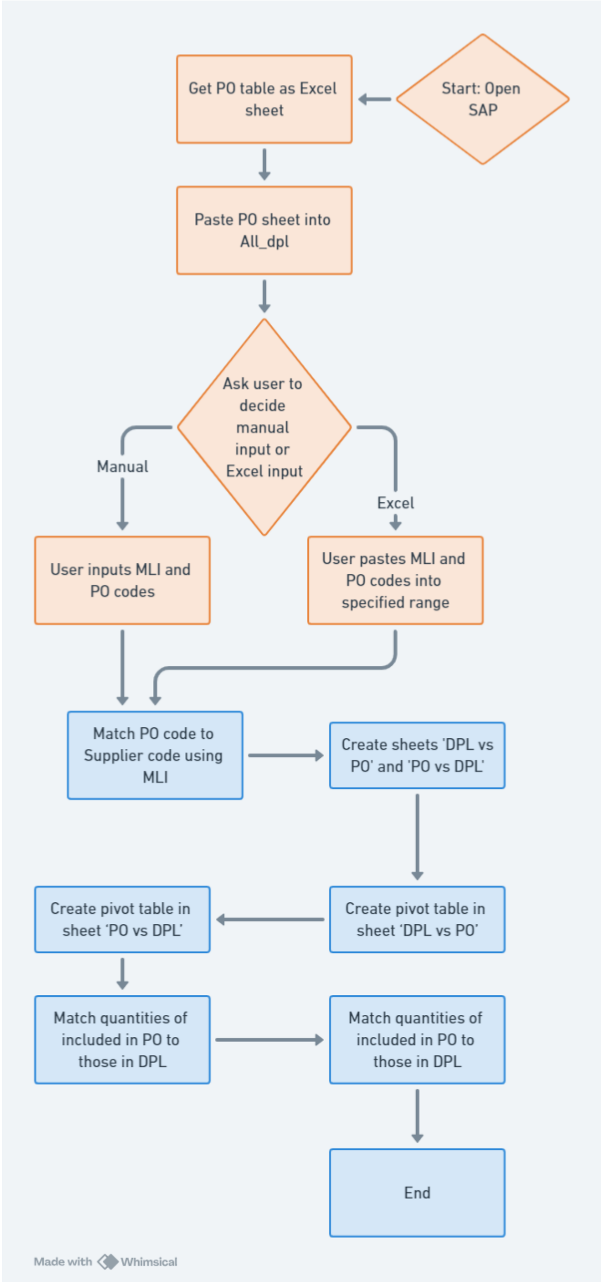

Figure 2.10: Activity Diagram for "Match DPL to PO and vice versa"

SP2 : Create GEAT templates:

In this task, the bot opens the "Sheet1" file within the Alldpl file (created in SP1) and iterates through each line to retrieve the "MO" code. It then checks if the cell is empty. If the cell is not empty, the bot moves to the next line. If the cell is empty, the bot retrieves the value from the Case_number cell and appends it to a list of strings named listofMSD, which will contain a unique set of Case numbers for MSDs. Once the bot completes browsing the lines, it closes the file.

Next, the bot browses DPL files in a predetermined folder. For each file in this folder, it will browse the sheets, retrieve the "case number," and verify if it is in the listofMSD. If it is, the bot will copy the contents of this file and save them under a GEAT template. If it is not, the bot will move on to the next sheet. The bot will terminate the workflow execution once there are no more files to process. Refer to Figure 2.11 for the corresponding activity diagram.

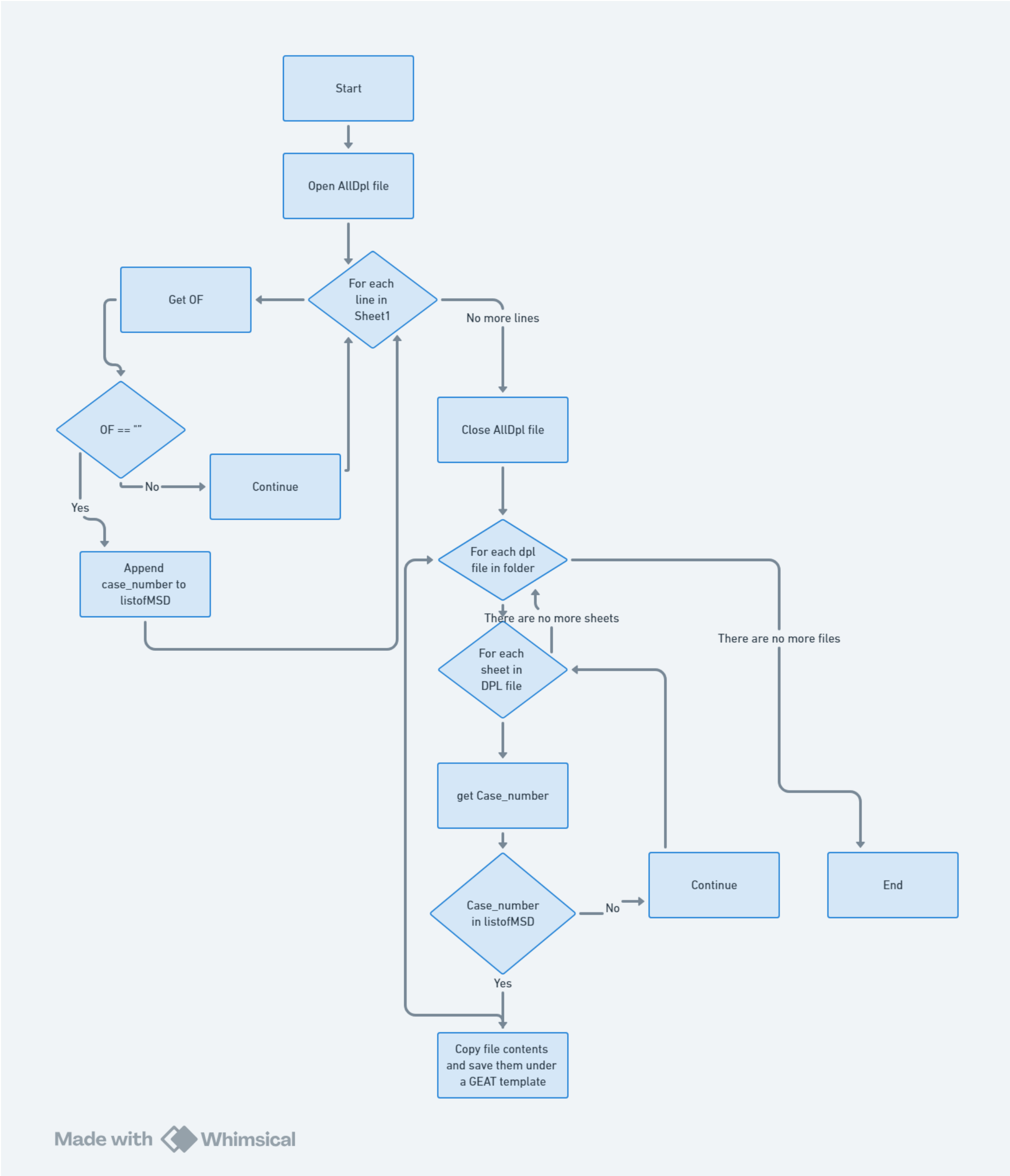

Figure 2.11: Activity Diagram for "Create GEAT templates"

To run and interact with the bot, the users will need a simple interactive interface, the interface should present the user with the choice of which task to run, and then if the user wishes the bot to complete the following tasks or perform only this task. Finally, the bot should remember user choices and start running the workflow based on them, Figure 2.12 depicts the activity diagram for a clearer view.

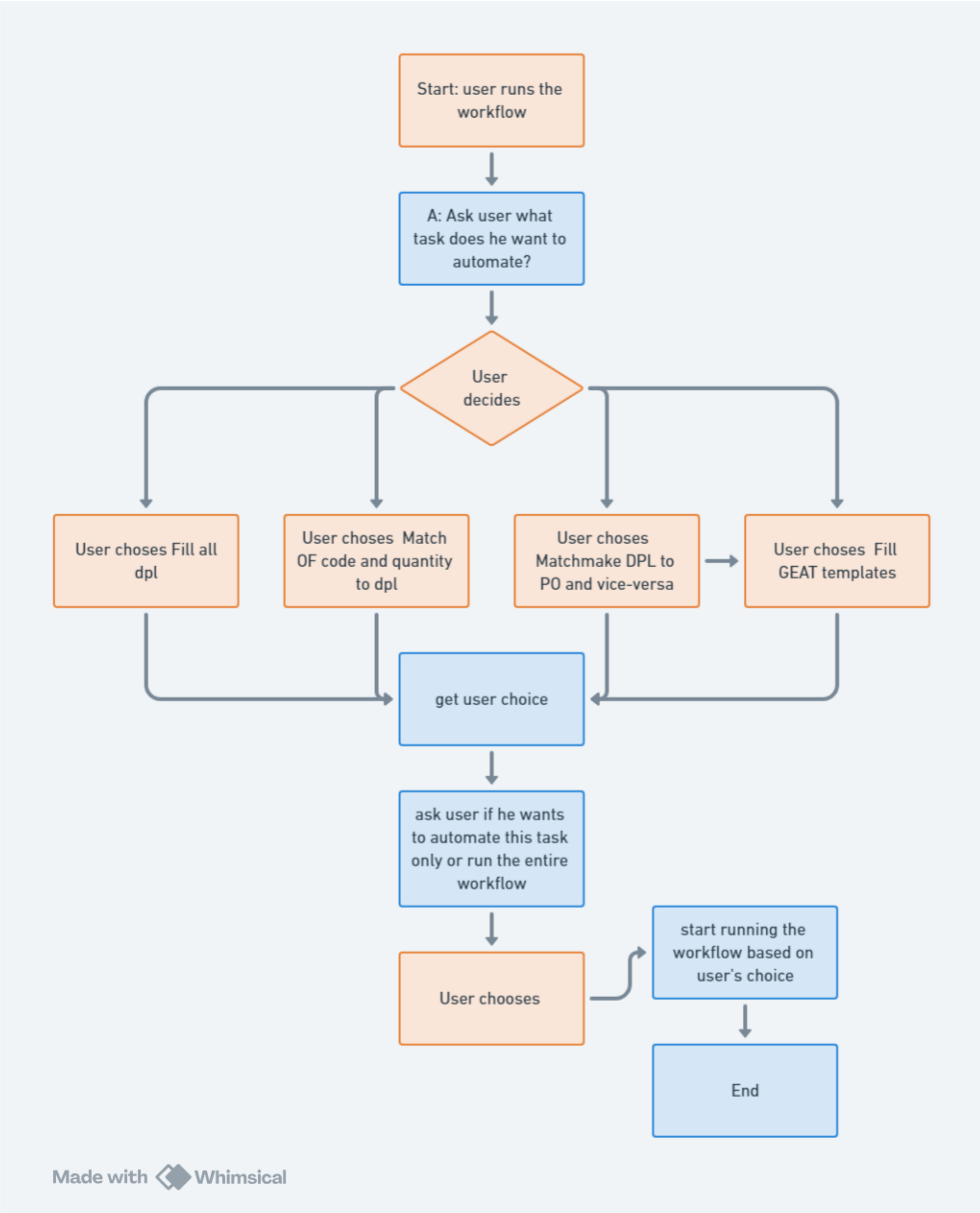

Figure 2.12: Activity Diagram for User-Bot interface

2.4.2 Bot Development and Testing

In this phase, each activity was developed using Uipath depending on the activity diagrams designed for each one. Testing was done during the development of each task by the criteria determined in Technical Testing Plan (see Appendix G) , a table explaining the utilized Uipath activities for each automated task can be found in Appendix F.

We will provide the list of activities for each automated task down below as well as the result of the testing done on each task :

SP1:

A main for each file loop was used to browse different Supplier files, for each files we used specific excel activities to browse sheets, lines and acquire necessary data and then paste it to the target file. Figure 2.13 shows the general flowchart of how the bot executes SP1

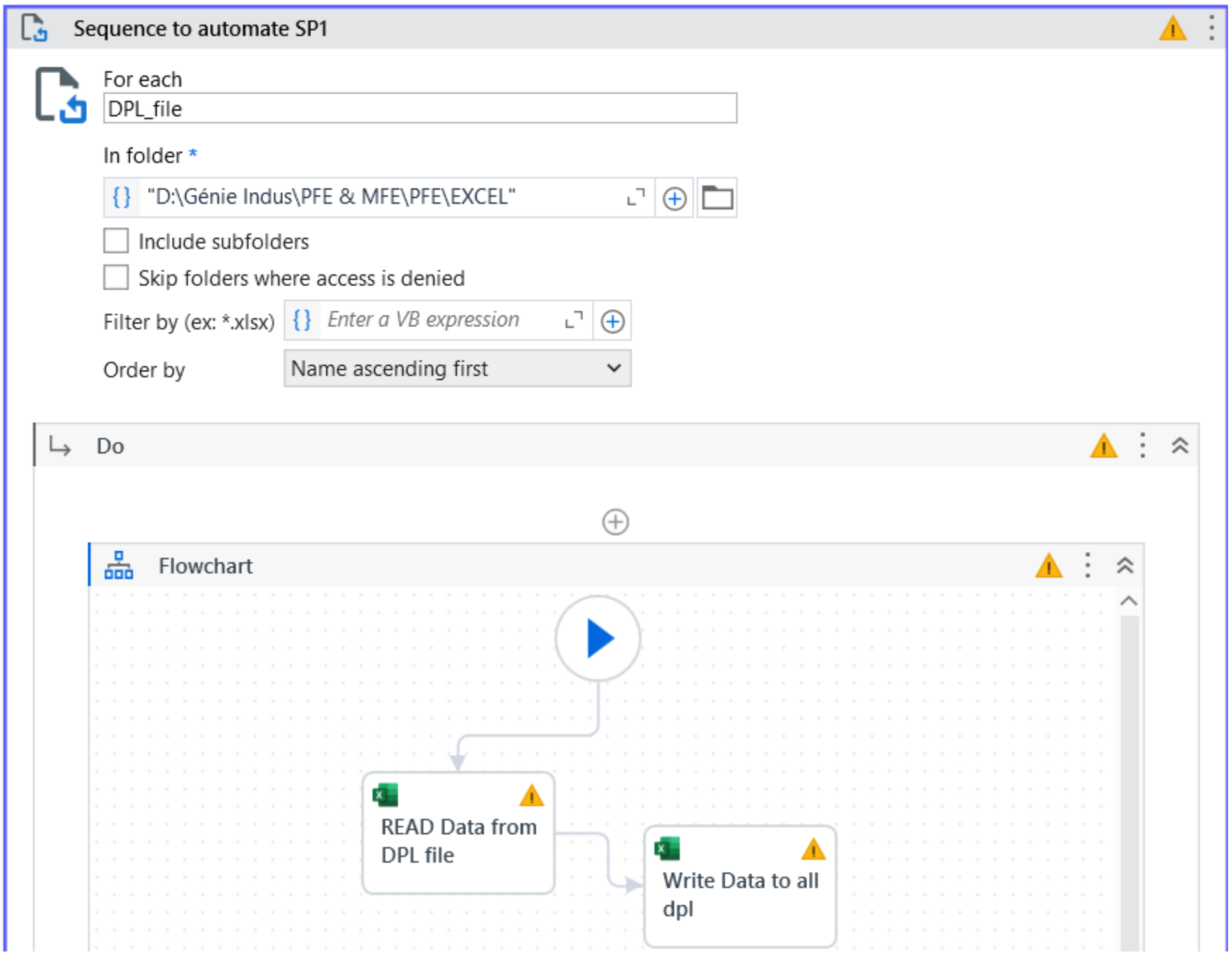

Figure 2.13: The Flowchart of Uipath activities to automate SP1

The excel sequence read data from DPL file copies from each sheet of the DPL file: the case number and the required data and stores them in two variables (see figure 2.14)

The Sequence to write data includes appending the copied range to the target sheet in the target file and fill the case number accordingly (see figure 2.15)

T4 :

For this task, a message would ask the user to input the MO code, two main sequences were programmed. One to fill the MO code and the other to fill the quantity. These sequences include the bot using interacting with UI to write functions to excel directly.Figure 2.16 shows the sequence of activities in Uipath to automate this task.

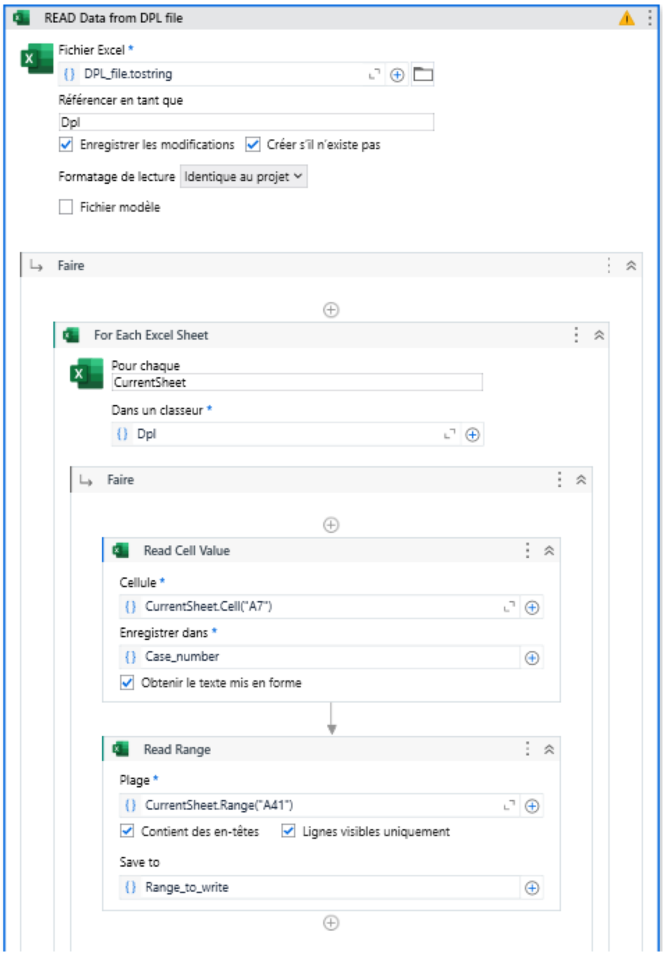

Figure 2.14: Activities included in "READ Data from DPL file"

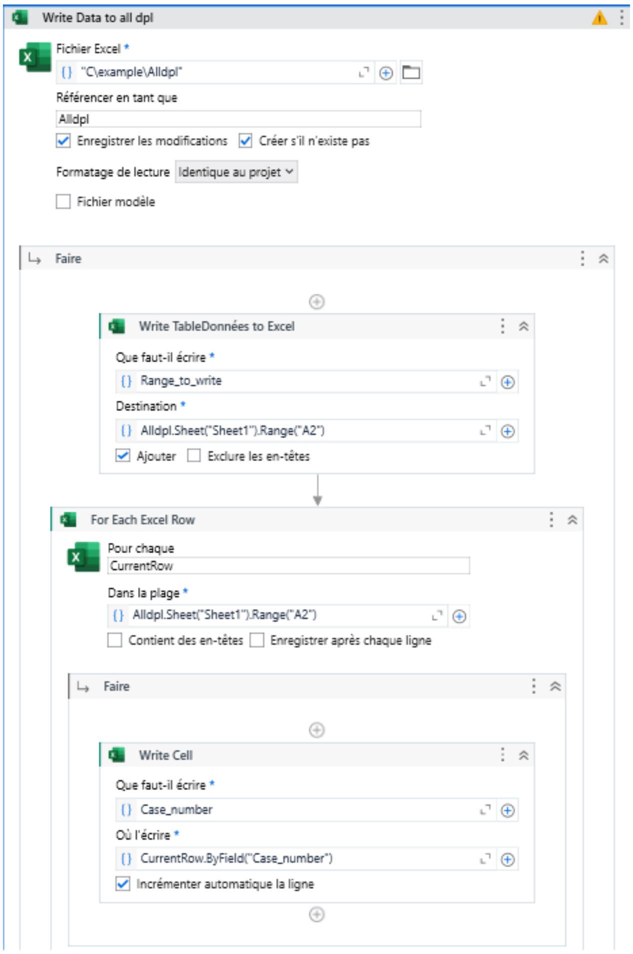

Figure 2.15: Activities included in "Write Data to all dpl"

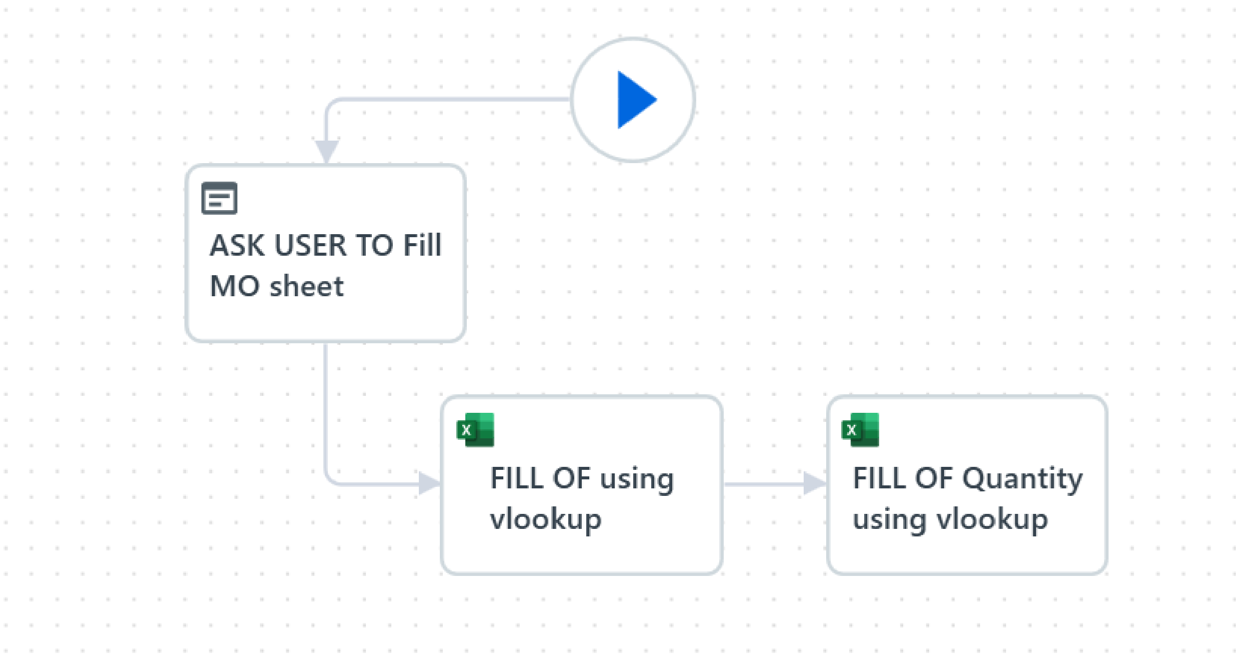

Figure 2.16: Flowchart of Uipath activities to automate T4

T5:

This task involves an initial user choice, so it was imperative to use a flowchart. The first node gets divided depending on what the user chooses. Leading to two sequences, one for excel filling and the other for manual filling. When the list of MLI's is acquired the bot will assign an SAP partnumber to each item. And then, finally creates two pivot tables to compare PO to DPL and vice versa. See figure 2.17

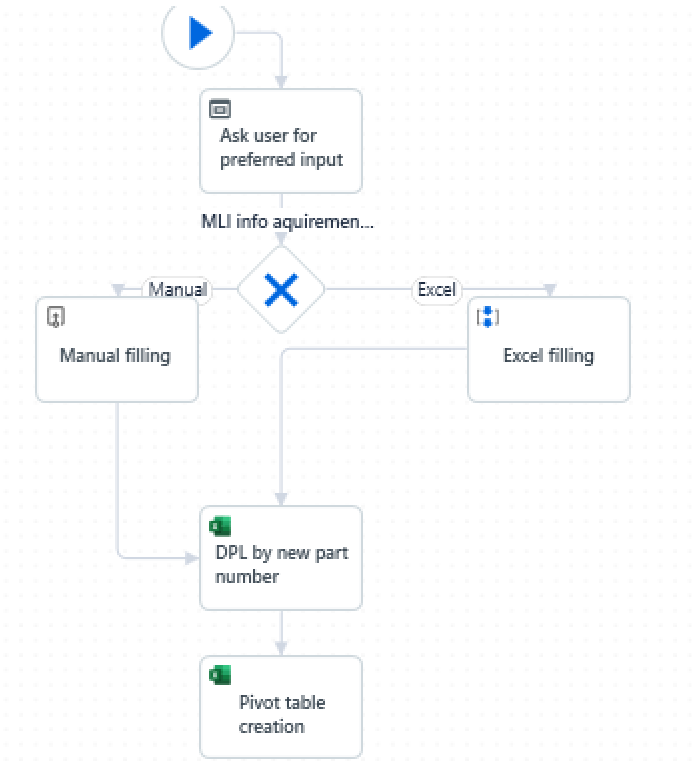

Figure 2.17: The sequence of Uipath activities to automate T4

SP2:

For this activity, the first step is to create a unique list of case_numbers that have no MO code, indicating that they are considered MSDs ready to be shipped to customers. Then, we use a "for each file" loop to browse all supplier DPL files. Within each file, a "for each sheet" loop verifies if the case number in the sheet belongs to the previously created list. If it does, all the contents of this sheet are pasted into a GEAT template. If it does not, the bot continues to the next file. See figure 2.18

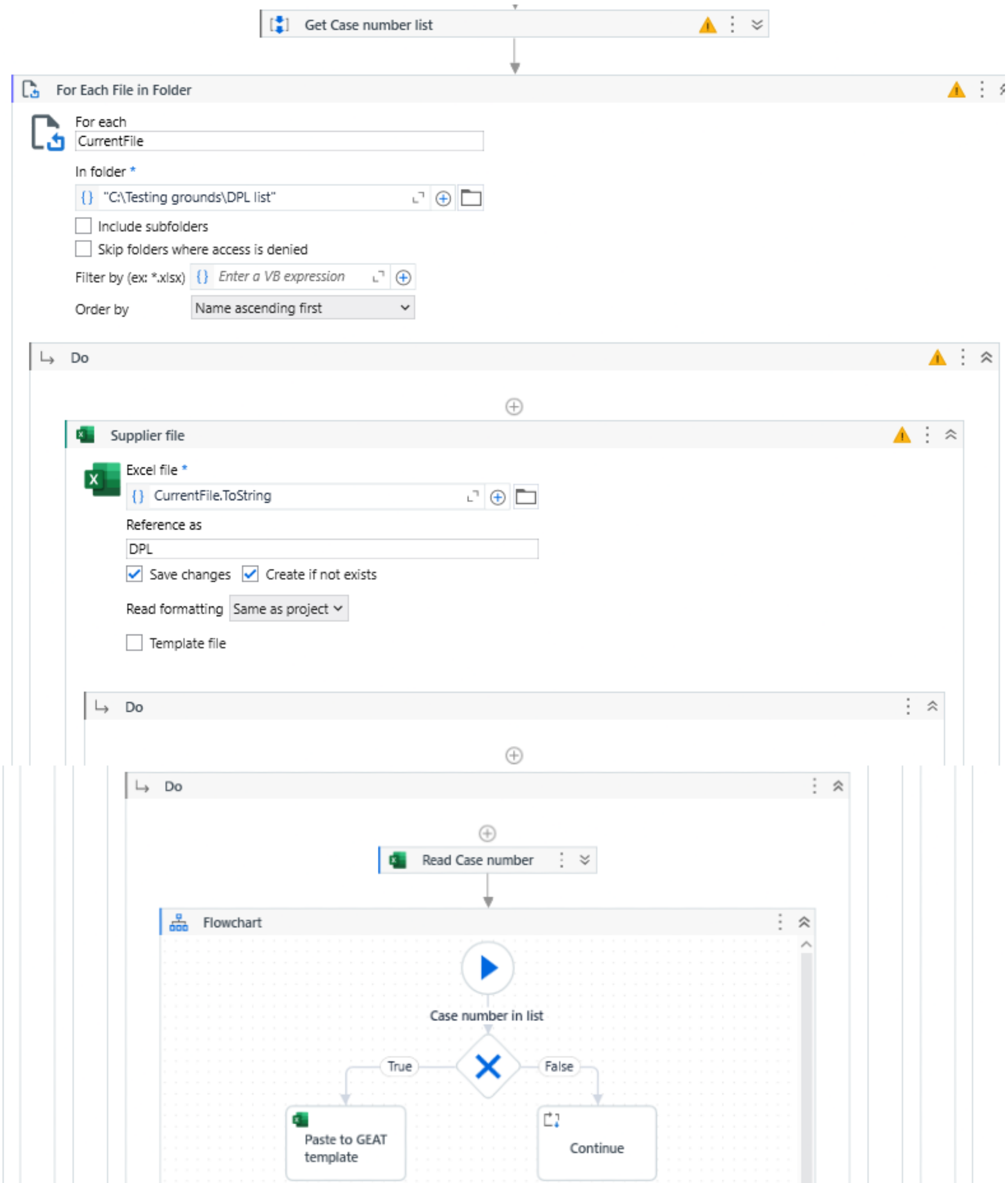

Figure 2.18: Sequence of Uipath activities to automate SP2

Sequence to increase user friendliness of the bot :

We have programmed a simple and effective interaction interface between the user and the bot, where the bot will ask the user for his preferences. As shown in the design phase, the bot will ask the user which task the bot will perform first and then if he wants it to run this task only or all the other tasks in succession. There are already many exception handling sequences in each dependent workflow, however in this section it is more general and will only activate if an exception that is beyond what was programmed in each workflow rises. The flowchart for this execution is shown in figure 2.19

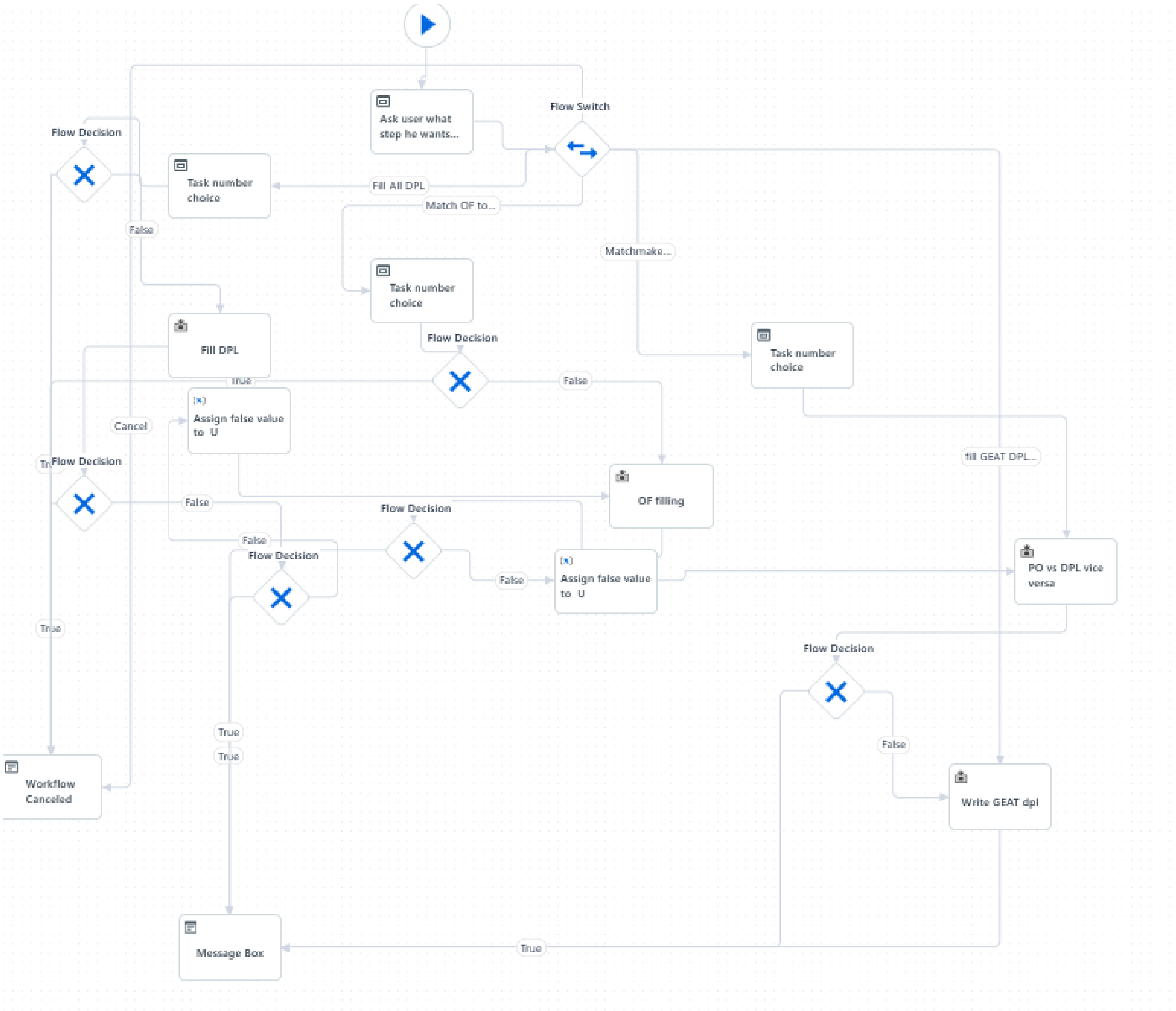

Figure 2.19: A flowchart for how activities are to be run based on the user choice

Running the bot from a user's point of view using UIpath Assistant is expressed in Appendix J.

2.5 Phase3 : User Acceptance Testing and BOT Deployment

To ensure the effective implementation of our automated solution, we coordinated a testing session with the logistics team via email. During this session, we presented the completed solution to the team and conducted comprehensive tests on various automated tasks using different samples. Each sample underwent a series of tasks, allowing us to gather valuable feedback from the users. We meticulously reviewed any errors, bugs, and user-identified mistakes that emerged during the runtime. This collaborative approach enabled us to refine our solution based on real-world testing and user insights.

2.5.1 Solution Testing Plan:

Involvement of End-Users: End-users, Specifically the logistics team who will directly interact with the RPA bot, participate in UAT. They represent the target audience and provide valuable feedback based on their real-world use cases. A well prepared canva presentation was readied to show the users the solution and its apport to their process. As well as to show them how to interact with the bot.

Testing Environment: UAT is conducted in the work environment, specifically in the logistics operation room to simulate real-world scenarios accurately. Work computers should be involved, as well as the direct interaction between users when the actual process is being performed using the bot. All to observe the work handover between the bot and different teammates.

Validation of Requirements: End-users validate whether the RPA bot fulfills the requirements outlined in the initial specifications. They verify that the bot performs the intended tasks accurately and efficiently.

User Feedback: End-users provide feedback on the usability, intuitiveness, and effectiveness of the RPA bot. They may suggest improvements, report any issues or bugs encountered during testing, and offer insights into how the bot can better align with their workflows.

Iterative Testing: UAT may involve multiple iterations as end-users provide feedback and developers make necessary adjustments to the RPA bot. Each iteration aims to address identified issues and enhance the bot's functionality based on user input.

Sign-Off: Once the end-users are satisfied with the RPA bot's performance and functionality, they provide formal approval or sign-off, indicating that the bot is ready for deployment. This sign-off serves as validation that the bot meets the business requirements and user expectations.

Documentation: UAT results, including feedback, issues identified, and resolutions, are documented for future reference. This documentation helps in tracking changes, understanding user preferences, and improving future versions of the RPA bot. The results of the different test can be found in UAT result in Appendix K

2.5.2 Bot Testing and Evaluation:

Due to time constraints, users insisted that we only test the first and the last automated workflows, as the ones in the middle required SAP access in order to be fully automated. We have tested the bot using 3 samples, divided on two different dates. Table 2.13 shows results for running the process for each sample error and proposed remedies can be found in the UAT result in Appendix K.

Table 2.13: Test results for processes SP1 and SP2

Date	Sample	Size by dpl	RUNTIME FOR SP1	RUNTIME FOR SP2	Issues	Comparison with manual	Comments
22/05/2024	GAS TURBINE 8	101	12 minutes	16 minutes	Some sheets were not treated	Errors in manual were reduced	Users Satisfied with the runtime
22/05/2024	GAS TURBINE 3	99	11 minutes	13 minutes	Cells shift, SP2 not aligned with Business needs	Errors in manual were reduced	Cell shift was fixed, Notes were taken to correct the automation
27/05/2024	GAS TURBINE 4	93	8 minutes	1 min 50 seconds	One line shifted and doubled	Runtime drastically improved for SP1 and SP2 according to users	Users Satisfied with fixes in SP2

As shown in table 2.13, runtimes were recorded as well as exceptions and user insight, we have made two testing sessions for 3 different samples. Bugs were fixed as well as the misalignment of the automated execution of SP2 with the actual business needs. The workflow for SP2 was redesigned and development flows were fixed. The redesign of SP2 and the new automated workflow can be found in appendix K.

Execution results for Gas Turbine 4 sample can be found in the Appendix L

2.5.3 Bot Deployment:

After discussing with the IT leader, he installed Uipath in a non utilized desktop that had the requirements to run the BOT. giving the logistics team remote access to this PC. A Process Runbook that includes a setup guide as well as general exceptions and how to deal with them was given to the enterprise. It can be found in Appendix M.

The runbook was given to the team as a support document and training was given to the team during the two testing sessions. The document provided in Appendix M contains contact information and also how to deal with common errors

2.6 Evaluation of The Project:

To depict the difference between the process before and after the optimization and automation project, we modeled both processes using Signavio BPMN. We introduced attributes to the process as a whole and to each activity, based on data gathered during the internship. The three main attributes were the number of resources, the hourly cost, and the cycle time for each activity. It is worth mentioning that the results obtained are approximations, as we could not access the official data from the hosting company.

2.6.1 Simulation of The Process Before Automation:

For the evaluation of the project, a one-case simulation was employed since this process is typically initiated only about eight times annually (figure 2.20), as informed by the head of the logistics department. The simulation revealed that completing the process once incurs a cost of approximately 591.77 euros for the company, considering the waiting time between activities. The cycle time for this process was 668 minutes, with a lead time of 15 days due to significant waiting periods between tasks.

Simulation Parameters: Hourly cost: 3.215 euros/hour, Cycle time: 668 minutes, Lead time: 15 days

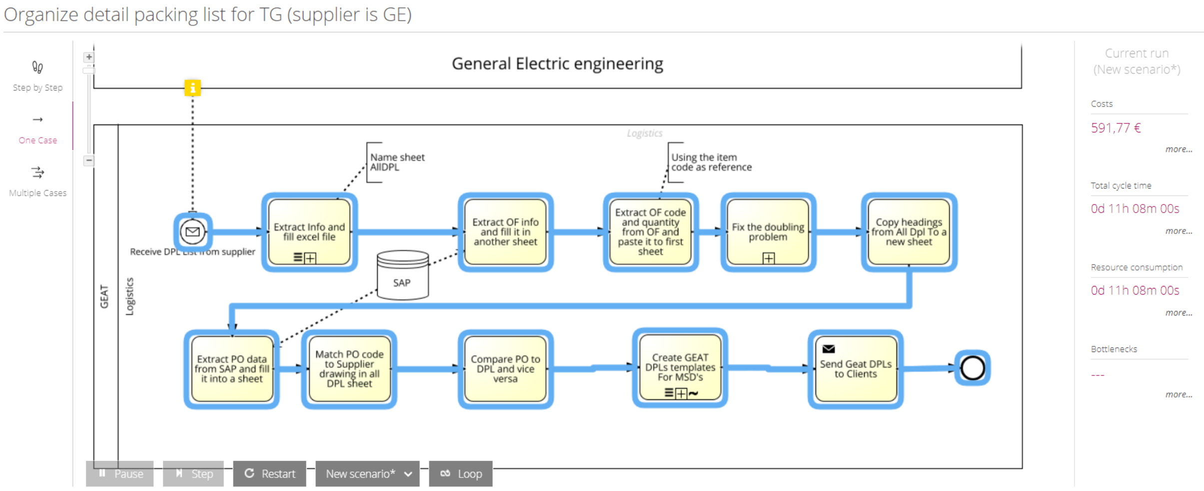

Figure 2.20: One case BPMN Simulation of the DPL process before automation

2.6.2 Simulation of The Process After Automation

Following the waste elimination and the integration of RPA, the execution cost of the process was significantly reduced to 138 euros, accomplished within approximately 133 minutes. The simulation (figure 2.21) demonstrates notable improvements in cost reduction and execution time, highlighting the substantial reduction in waiting time and the minimization of the need for human intervention. The lead time was drastically reduced to 162 minutes, and accuracy improved, eliminating the need for rework.

Simulation Parameters: Hourly cost: 3.215 euros/hour, Cycle time: 133 minutes, Lead time: 162 minutes

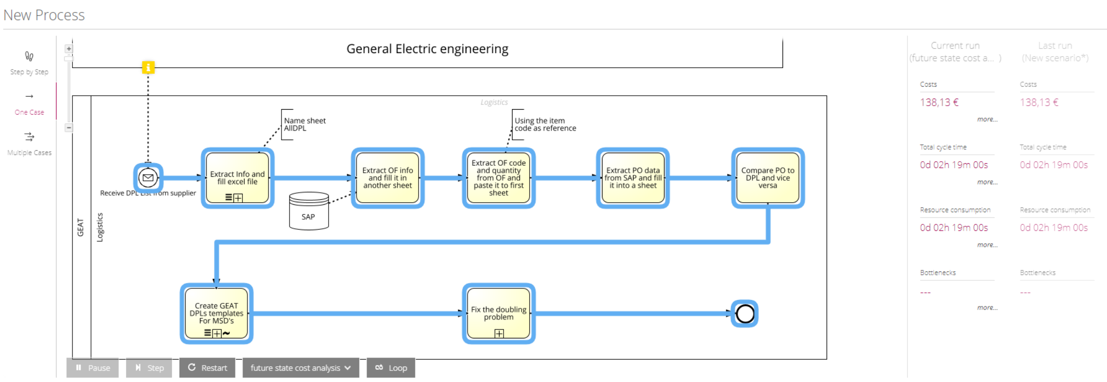

Figure 2.21: One case BPMN Simulation of the DPL process after automation

2.6.3 Comparison

Comparatively, the two scenarios distinctly outline the enhancements in the process post-optimization using lean methods coupled with RPA technology. The execution time saw a reduction of over 80%, paralleled by a similar reduction in costs. Indeed, the actual reduction in execution time might be even more considerable, given that the waiting times between tasks were also eliminated. This simulation, representing a single case, calculates an annual financial benefit of approximately 3,624 euros (calculated as (591.77 - 138) $\times$ 8), attributed solely to this one process.

Additionally, the automation resulted in a significant decrease in human resource requirements; initially, four employees alternated roles to complete the process, whereas post-automation, minimal human involvement is necessary. This not only frees up staff to engage in more value-adding activities but also optimizes overall workforce utilization.

The main performance metrics used to measure the effectiveness of the optimization were cycle time, accuracy, and execution cost. The cycle time was reduced from 11 hours 8 minutes to 2 hours 19 minutes, and accuracy improved to 0 errors, effectively eliminating rework. The execution cost decreased from 591.77 euros to 138 euros, further demonstrating the efficiency gained through the automation process.

The Future state VSM diagram in figure 2.22 depicts better the state of the current state process and adds additional information to help better comprehend the optimization effects.

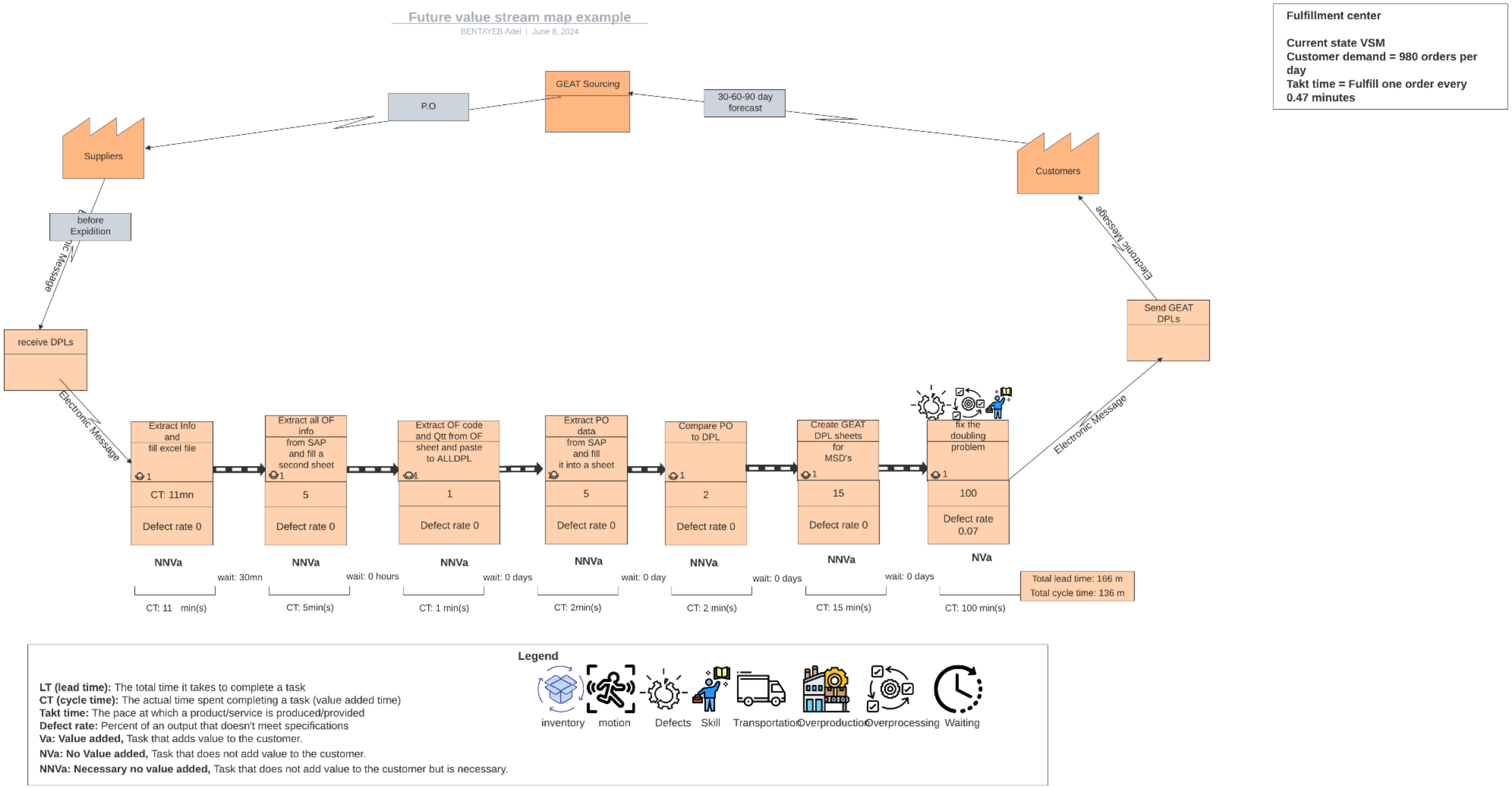

Figure 2.1: Future state VSM of P11

2.6.4 Economic Study

The introduction of the Robotic Process Automation (RPA) bot into our host company's operations has received widespread support following thorough testing and integration with our existing systems. But since we did everything ourselves and used free trial version of the software, our project cost the company virtually nothing, that's why in this section we will outline a comprehensive economic analysis of the costs associated with a project similar to ours, focusing on expert fees (Table 2.14, Table 2.15), licensing (Table 2.16), and the potential financial effects of the integration complexities.

Our project expenses fall into three primary categories:
Lean Expert Fees:

This phase involves a comprehensive examination of the existing processes to identify inefficiencies and areas for improvement. Lean expertise is crucial during this stage to ensure that all forms of waste—such as time delays, redundant steps, and resource mismanagement—are systematically identified and addressed. The moderate complexity of the processes in question requires approximately three weeks of detailed analysis and redesign. Lean experts use various tools and methodologies, such as Value Stream Mapping (VSM), to visualize and understand the flow of materials and information. By mapping out each step, they can pinpoint bottlenecks, unnecessary steps, and other inefficiencies that impede performance. The redesign phase involves reengineering the processes to eliminate these wastes, streamline operations, and enhance overall efficiency. This meticulous approach not only improves process flow but also lays a solid foundation for the subsequent integration of RPA.

Table 2.14: Details the cost breakdown for the Lean Expert Fees.

Detail	**Project structure: project**
Role	Optimizing processes for RPA integration
Hourly/Daily Rates	40000da - 56000da per day
Project Duration	Two to Three weeks (15 working days)
Average Daily Rate	48000 da
Total Duration	10 days
Total Cost	Da 576000
Assumption	One consultant working full-time

RPA Expert Fees:

Despite the widespread claims that anyone can create a bot without coding skills, our internship experience revealed the complexities involved in developing an effective RPA solution. Learning UiPath bot development from scratch took significantly longer than anticipated, underscoring the challenges faced by non-experts. These challenges include understanding the intricacies of process automation, configuring the bot to interact seamlessly with various applications, and ensuring the bot operates reliably under different scenarios. To address these complexities, hiring an RPA expert proved essential. An RPA expert brings specialized knowledge and experience in designing, developing, and deploying bots efficiently. This expert involvement spans approximately three weeks, covering both the development and testing phases. During development, the expert configures the bot to perform specific tasks, ensuring it can handle exceptions and integrate with existing systems. The testing phase involves rigorous validation to ensure the bot functions as intended, identifying and resolving any issues before full deployment. This professional approach not only accelerates the development timeline but also enhances the quality and reliability of the RPA solution.

Table 2.15: Details the cost breakdown for the RPA Expert Fees.

Detail	Project structure: project
Hourly/Daily Rates	Da 5000 - da 7000 per hour; da 30000 - 64000 per day
Project Timeline	Two to Three weeks (10-15 working days)
Average Daily Rate	Da 450000
Total Duration	10 days
Total Cost	Da 450000
Assumption	Covers full lifecycle from concept to deployment

UiPath Licensing Costs:

The commercial version of UiPath offers a range of plans tailored to different automation needs, depending on whether the bot is attended or unattended. Attended bots are designed to work alongside humans, handling repetitive tasks while requiring some level of human intervention. In contrast, unattended bots operate independently, executing tasks without any human involvement, often running 24/7. UiPath's licensing plans include options for using the orchestrator and studio. The orchestrator is a central management platform that allows users to deploy, monitor, and manage RPA bots across the organization. It provides robust capabilities for scheduling, logging, and auditing bot activities, ensuring seamless operation and compliance. The UiPath Studio is a development environment where users can design and build automation workflows using a visual drag-and-drop interface. These licensing options cater to various organizational needs, from small-scale implementations to enterprise-wide automation initiatives. By selecting the appropriate plan, companies can ensure they have the necessary tools and support to maximize the benefits of their RPA investments, balancing cost and functionality to suit their specific requirements.

Table 2.16: UiPath license fees breakdown

Detail	Project structure: project
License Type	Attended bot with orchestration
Number of Bots	One
License Cost Range	Free for individual development 420 USD/month amounting to 5040 USD a year for medium standard automation solutions 18000 USD yearly as an estimation for big and customized automation solutions
Chosen Estimate	5040 $

The data for this economic study were derived from QA sessions with engineers in the hosting company and lean management experts found on LinkedIn (see Appendix B). UiPath licensing fees were obtained from their official website and customer support. By outlining these costs and potential financial benefits, the economic study provides a clear justification for the investment in RPA technology and demonstrates the value it brings to the host company.

The potential financial effects of integrating the RPA bot include significant cost reduction, improved accuracy, and enhanced resource optimization. The implementation leads to a substantial reduction in execution costs and improved process efficiency. While the initial investment in expert fees and licensing is high, it is offset by long-term savings. Increased accuracy eliminates errors and rework, resulting in higher quality outcomes and greater customer satisfaction. Resource optimization frees up human resources to engage in more valuable tasks, enhancing workforce utilization and productivity. utilization and productivity.

2.7 Conclusion

In conclusion, the proposed Robotic Process Automation (RPA) solution for the reception structure of General Electric Algeria Turbines (GEAT) demonstrates the transformative potential of automation in business processes. The project, initiated in alignment with the company's continuous improvement principles, involved a comprehensive analysis and redefinition of processes, followed by the design and development of RPA bots for testing.

The case study, based on real data and precise simulations, illustrates the practical application of theories and tools discussed in previous chapters. It also serves as a valuable reference for evaluating the potential economic impacts and operational improvements that could be brought about by automation interventions.

The tests conducted have shown promising results, with the potential for significant improvements in efficiency, a reduction in cycle time, and enhanced accuracy. The proposed solution also has the potential to decrease human resource requirements, freeing up staff to engage in more value-adding activities and optimizing overall workforce utilization.

The economic study conducted as part of the project outlines the costs associated with a similar project, including expert fees and licensing, and highlights the potential financial benefits of integrating RPA technology.

Overall, the project underscores the potential of RPA to revolutionize business processes, enhancing efficiency, reducing costs, and improving accuracy. The successful implementation of the proposed solution could bring about substantial benefits for GEAT.

General Conclusion

This thesis unifies various aspects of process optimization, process mining, and robotic process automation (RPA) and explores their practical application through a case study. The study aims to amplify business process efficiency and effectiveness by amalgamating these technologies.

The study delves into business process management and optimization, underlining how RPA and process mining can revolutionize operations. These technologies streamline operations and provide insights into process dynamics and inefficiencies, aiding in better decision-making and strategic planning.

In the case study, the practical application of an RPA solution is detailed step-by-step, from selecting and redesigning processes to developing and deploying bots. This real-world example validates the theoretical concepts and illustrates the challenges and adjustments required to achieve optimal results.

The economic analysis demonstrates significant improvements in process efficiency and cost reduction. For instance, the simulation proves that our solution improved process P11 from a cost of 591.77 euros and a lead time of 15 days to 138 euros and 162 minutes, as the process can now be realized in a single session, thus eliminating all waiting times.

Moreover, to address the challenge of inadequate data availability from the company, we employed a dummy dataset and conducted a mock process discovery using process mining.

This approach was crucial to demonstrate the potential effectiveness of process mining in our project. It allowed us to illustrate how this technology could be strategically used to identify and select the most suitable processes for automating their tasks.

The benefits of this project extend beyond immediate operational enhancements. It underscores the strategic advantage of adopting a comprehensive approach to process automation, the proposed framework where continuous improvement and adaptability to new technologies are ingrained in the organizational culture.

Upon conducting this project, we faced several limitations, including the inadequate understanding and mapping of processes, such as with SP2, which resulted from our lack of expertise and GEAT's disorganized database. Another equally important constraint resulted from a restricted time frame and limited access to the ERP system at GEAT. This prevented us from automating the whole process and limited the scope of improvements that could be brought to the bot's performance.

RPA technology is suitable only for simple, rule-based, and repetitive tasks. In the future, RPA can be integrated with AI to enhance its cognitive capabilities, allowing it to take on more complex tasks. Besides, better and more complete frameworks could be put in place to guide RPA projects more thoroughly and to provide more libraries for RPA development to allow it to cope with a broader range of scenarios.

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Appendices:

Appendix A: RPA Tools Description

a. Automation Anywhere (AA) is a software platform that enables businesses to automate their entire business processes using Robotic Process Automation (RPA). Automation Anywhere provides all the features needed for a company in RPA through its Control Room, serving bot development, configuration, and monitoring in one single and central environment. These bots can be used for many tasks, including data entry, validation, and complex calculations, mainly using AI and ML technologies[5]. AA supports three types of bot creation: Task Bots for rule-based tasks, Meta Bots for reusable building blocks, and IQ Bots for processing unstructured data. It also provides three types of recorders to automate functions by replicating user actions. It offers features such as BOT INSIGHTS for data visualization and business insights, BOT FARM for usage-based RPA tool purchases, and BOT STORE for plug-and-play bots.

b. UiPath is one of the top platforms for Robotic Process Automation (RPA), and it offers automation functionality combined with process discovery and analytics. UiPath platform facilitates the software robots (SRs) development, deployment, and management designed to perform automated repetitive and rules-based business tasks. Other vital components are the orchestrator of task management, workflow designers, and analytic tools[21] Components of UiPath are [31]: (1) Core RPA Capabilities: Allows accessible building and deployment. (2) Process Discovery and Analytics Tools: These are business-oriented ideas whereby the impact of the process on automation is provided. (3) Orchestrator: It shall be a central control that manages task assignments and performance appraisal. (4) Workflow Designer allows you to design processes with a drag-and-drop surface (5) Uipath Assistant which is a tool that allows the users to launch and interact with the software bots. These mimic human operations on digital systems and carry out robotic process automation—software Robots (SRs). Advantages of UiPath include improved efficiency, ease of scaling the company, and performance analytics [i]. Disadvantages include the constant updating of the software, its complexity in set-up and management, potential high costs, and dependence on the current IT system. The UiPath software has been actively improved to integrate newer innovations like machine learning and AI as part of its advancing functions.

c. Blue Prism is a robotic automation software used to automate the business processing system through the integration of presentation. This approach, formerly known as "screen scraping," has been remodeled to permit efficient interaction with various applications, simplifying business process automation. It empowers business analysts with the ease of low-technical skills to create and modify automation through direct interaction with application user interfaces. Blue Prism provides functionality that allows the automation of interfaces from contemporary web interfaces to the most mature mainframe applications, including interface automation [15]. Blue Prism mainly includes several components. (1) Visual Business Objects (VBOs) are application interface adapters that graphically create and execute specific tasks, such as logging in or entering data, without using coding through Object Studio. (2) Process Studio is a graphical tool for defining and sequencing the steps in a business process, using VBOs for application interactions. (3) Control Room: This room oversees the execution of Blue Prism processes and handles process control, monitoring, and scheduling. (4) System Manager: Administer users, manage user settings, administer processes, deploy processes, and manage the overall system for successful, efficient, and secure operation. (5) SQL Server Database that stores the details about the processes and VBOs for management and audit purposes. One of the Blue Prism advantages is efficiency: Easily and fast, you can automate business processes easily and quickly through user interfaces without changing the applications. It is cost-effective: It is cheaper than the traditional way of doing things and can be applied in low-value processes. Also, adaptability: Easily variable to changing business changes. It has broad compatibility and can interface virtually any application with a user interface. It ensures robust security, such as safeguarding encrypted credentials and role-based access controls. One of the disadvantages of Blue Prism is performance issues: Complex multi-screen processes and extensive data retrieval can be a struggle. Also, UI Limitation: Only automates tasks that can be managed through the user interface, lacking direct backend access. In addition to some maintenance issues due to updates on the significant changes in application interfaces, Skill Dependency requires a sound fundamental understanding of cutting across the business processes and the Blue Prism tools for effective implementation.

d. TASKT (formerly known as sharpRPA) represents the pioneering instance of a genuinely free, user-friendly, and open-source process automation tool developed within the .NET Framework using C#. TASKT empowers users to create and customize process automation workflows without coding application logic[59]. It offers an extensive suite of task management features, including subtasks, alerts and notifications, task visualization tools, and comprehensive reporting and analytics capabilities. Additionally, its integrations seamlessly connect with other applications, enhancing workflow productivity and efficiency [54]. One of its advantages is that it is free and open-source, making it reachable even for small businesses and individuals. It provides an intuitive interface and accessible commands to automate tasks, making it easy for users to come up to speed quickly. It supports web and desktop applications, thus making it very flexible and allowing for different automation scenarios. One of its disadvantages is that being a smaller project, it may not provide the same level of support or community activity as some of the more extensive commercial RPA tools. It is limited to the Windows environment, implying that this software would be ineffective when implementing across-platform functionality. The smaller project scale can mean less frequency and scope with which updates or new features are made.

e. Robocorp: According to the Robocorp and [48], Robocorp is an RPA open-source tool based on Python that is used for automation across different platforms. This software, purposefully made for non-code and code user interfaces, targets developers and non-developers. That rests on the cloud-native architecture foundation, allowing it to handle data and execute tasks with fortitude, whether on-cloud or on-premise. Its components are the Robocode Lab, An IDE that supports the development of automation scripts, and the Control Room, a central dashboard for deploying, managing, and scaling bots and automation. The Robocorp Cloud offers cloud services for bot execution, making it easier to manage and deploy bots remotely. One of its advantages [50] is the flexibility and Open Source; Robocorp is perfectly poised to give users the ideal flexibility to connect an extensive range of Python libraries and APIs inside their automation workflow, making it functional and flexible. It is cost-effective and supports a consumption-based pricing model since its features are affordable for the user and what is only utilized. It supports Flexibility; the system will expand operations excellently and take in those of small and large businesses; it will do so without the need for colossal infrastructures. It provides community and documentation; the community is robust, and the guides are well-documented. New learners, hence, find the tool accessible for learning and troubleshooting. One of its disadvantages [50] is the complexity of setup; setting up the environment for Robocorp can be time-consuming and challenging for users who need it for quick deployment. Its interface and usability of the tool might not be straightforward for users who do not possess coding skills, therefore increasing the learning curve. Some users added that the tool could use huge memory and space, requiring robust systems specifications for better functionality.

We compared the tools listed below to see the differences between them and the areas where each tool shines (see Table A1)

Table A.1: RPA tools comparison according to some of the criteria mentioned by [31] and [5]

Criteria	**Ui Path**	**Taskt** [59]	[42], [49], [48],	**Automation Anywhere**
Architecture	.Net Framework	.Net Framework	Robot Framework and Jupyter Notebook	Client Server
Availability	Community Edition (Bots cannot be distributed) 60-day free trial (UI Path Pro)	Open Source	Robocop has a consumption-based pricing model with a free trial available. It provides packages for various usage levels, from personal to enterprise, with differing costs based on usage.	One month free trial (Industry edition) community edition (BotCreator rights only)
Usability	Simple	Simple (according to Github)	It is simple (for the paid version) and offers some complexity for the free version.	Complex
Automatable Processes	back/front office	Back/ front office	Back/ front office	back/front office

Criteria	Ui Path	Taskt [59]	Robocorp [49], [48]	Automation Anywhere
Recorders	Innovative, screen, and web (Desktop and web applications)	recorder available	It does not have a recorder.	Primary, web, desktop, image, and Citrix.
Cognitive ability	Medium	Medium	Python allows for integrating advanced machine learning and AI capabilities, making cognitive ability very high.	Medium
Coding	Supports: Drag & Drop and Recording Coding knowledge nonmandatory	Supports: Drag & Drop and Recording Coding knowledge nonmandatory	Non Mandatory for the paid version (it includes drag and drop) The free version requires Python coding knowledge as it supports coding only.	Supports: Drag & Drop and Recording Coding knowledge nonmandatory
Pricing	420 USD/month for small businesses (source) According to customizations for Enterprise approx 18000 USD annually ()	Free (Open Source)	Robocorp offers 1500 free run minutes, with additional minutes billed at a rate depending on the plan and usage (for the paid version). It also includes a free, open-source version.	Cloud Starter pack 750$/month For each additional bot: unattended: 500$(month) attended: 125$ (month) (source)

Criteria	**Ui Path**	**Taskt** [59]	**Robocorp** [49], [48]	**Automation Anywhere**
Reliability and Security	Encryption algorithms like AES, DES, RC2, Rijndael, and TripleDES.	/	AES-256 encryption for data at rest and in transit, compliance with standards like SOC 2 Type II and HIPAA, and features like Control Room Vault for secure credential storage.	Provides a highly encrypted Credential vault to save confidential user information
Certification	Available online	no certification	Available online	Available online

Appendix B: Interviews, Done During Process Collection

Process Questions:

We prepared questions to perform interviews with different stakeholders, the questions and the motivation for each question can be found in Table B1 and Table B2

Table B.1: Core questions

Question	Motivation
What is an example of a process that fits within the description?	This question provokes the interviewee to start talking about a new process.
How does this process start?	To understand the process, it is essential to know if the process is manually started or triggered by another task.
What are the different steps of the process?	This question helps to understand the process thoroughly.
Are these steps always the same?	This question is important because if the steps differ from time to time, the process is not a candidate for automation.
Which applications are involved?	With the answer to this question, consideration can be made as to whether RPA is the correct form of automation.
Which person is executing the process?	To understand the context of the process, it is good to know who is executing it.
How often is this executed?	Only frequent processes are worth automating.
Is there an improvement going on with this process?	If someone within ProRail is already improving the process, then applying RPA is of no use now as it is not known how the future process will look like.
Has this process been improved before?	Based on previous improvements and their results, a better estimation can be made.

Table B2: Closing Questions

Topic	Motivation
Thanking the interviewee	Everyone at GEAT has a very limited time frame, so thanking them for their time is very important.
Ask for other interesting interviewees	After we finish the interview, we ask the interviewee to propose other employees to ask for new processes or for further information on this particular process.

The answers from stakeholders from each department were recorded as shown in Table B3

Table B3: Answers

Question Interviewee	Logistics	Commercial	IT	Quality Control
What is an example of a process that fits within the description?	DPL treatment	Creation of supply request	System Monitoring	Quality documents verification
How does this process start?	At the reception of DPL Excel sheets from General Electric	At the rise of needs from the method office	Everyday, the IT operator logs into the system and checks for anomalies	At each reception, the QC verifies documents
Are the Process steps always the same?	Yes	No	Yes	No, depends on document type
Which applications are involved?	Excel, SAP ERP, Email	SAP ERP, Email	SAP ERP	PDF reader, email, SAP ERP
Which person is executing the process?	Djamal and logistics team	Taha	Amine	Quality controller (Mourad)
How often is this executed?	Around 8 times a year	-	Everyday	At each reception
Is there an improvement going on with this process?	Continuous improvement	-	-	Continuous improvement
Has this process been improved before?	No	Yes, during technological transformation	No	-

Topic	Motivation
What is an example of a process that fits within the description?	Generate financial reports
How does this process start?	At demand
Are the Process steps always the same?	Yes, the data extraction from SAP mechanism is straightforward, then the employee can choose which reports to show
Which applications are involved?	SAP, PowerBI
Which person is executing the process?	Aymen
How often is this executed?	Monthly, quarterly, yearly
Is there an improvement going on with this process?	No
Has this process been improved before?	Yes, the data extraction mechanism has been automated using PowerQuery and

Additionally, we have also asked two experts for Lean and RPA expert fees in an automation o

Table B4: Lean and RPA expert fees

Question\Interviewee	GEAT IT expert	Harrir from Process-up founder
How much would it cost to hire a lean expert to analyze, identify waste and redesign the process in Algeria?	/	The daily fees of a consultant in Algeria vary between 20k and 60k depending on the complexity of the project and his expertise.
How much does it cost to outsource a project such as the implementation of RPA technology to an external subcontractor?	A junior's hourly wage should be around 5000 DA per hour and a senior expert's fees should be between 7000 and 8000 dinars	/

Appendix C: BPMN Process Models for Sourcing and Supply Processes:

Figures C1 and C2 show BPMN models of the whole Sourcing and Supply processes in GEAT (respectively)

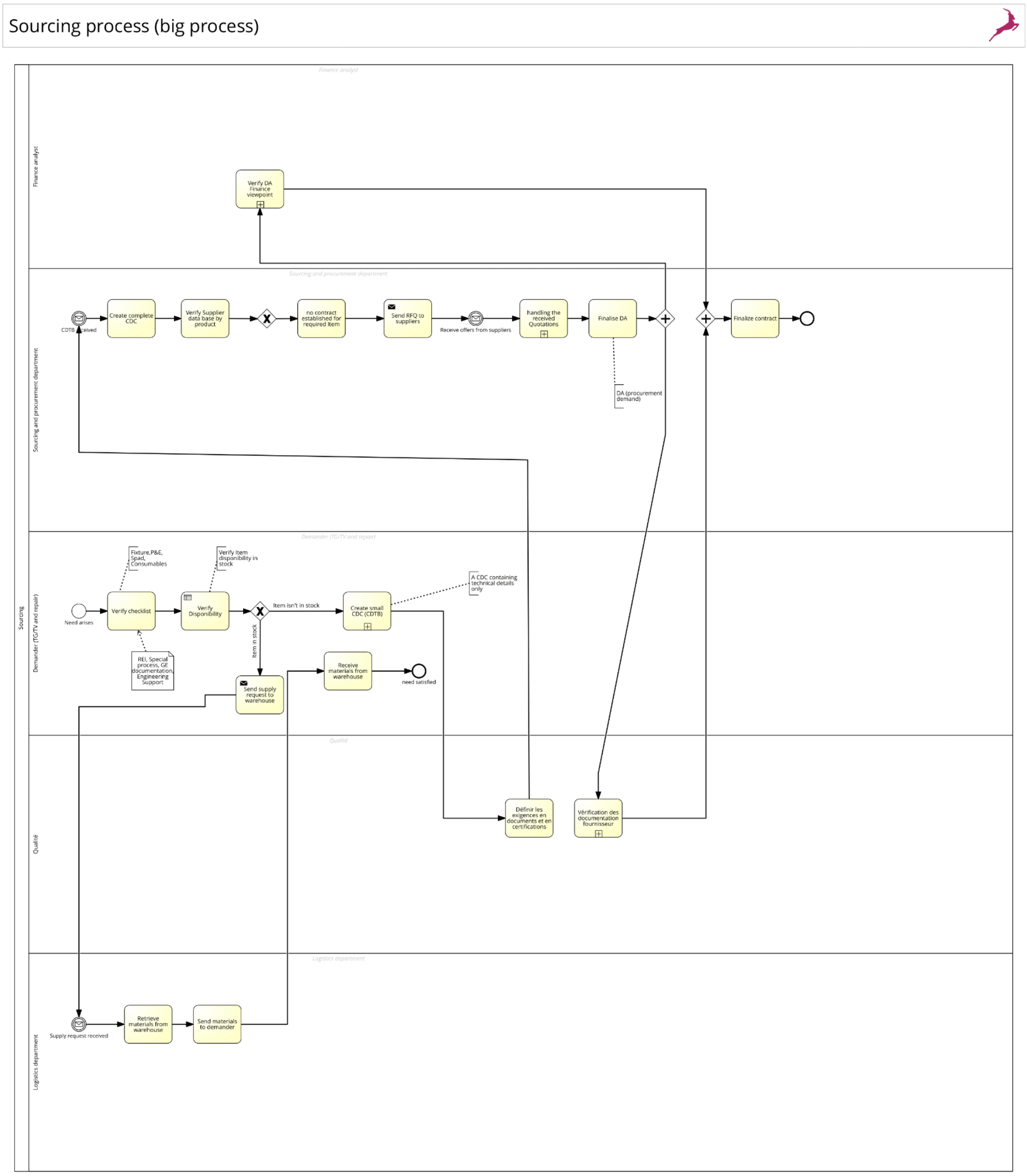


Figure C1: Sourcing Process BPMN model

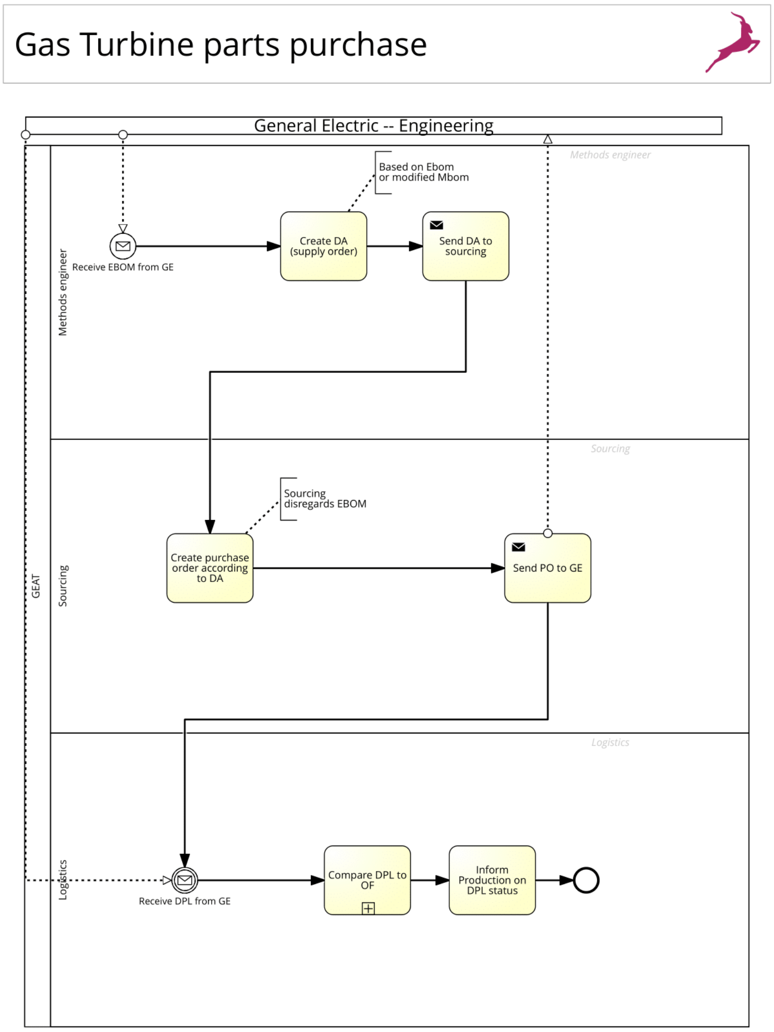


Figure C2: Supply Process BPMN model

Appendix D: RPA Pilot

Using Uipath we have created a pilot that shows stakeholders an example of a task executed by an RPA bot.

The bot starts off by checking unread emails having "P.O" as subject for attachments, then it downloads the attachments, get the text inside the attachment and sends it off to chat GPT (via browser) with a specified prompt so that it will return a well structured data, which is then acquired by the bot and saved in a .txt file. Figure D1 shows the steps.

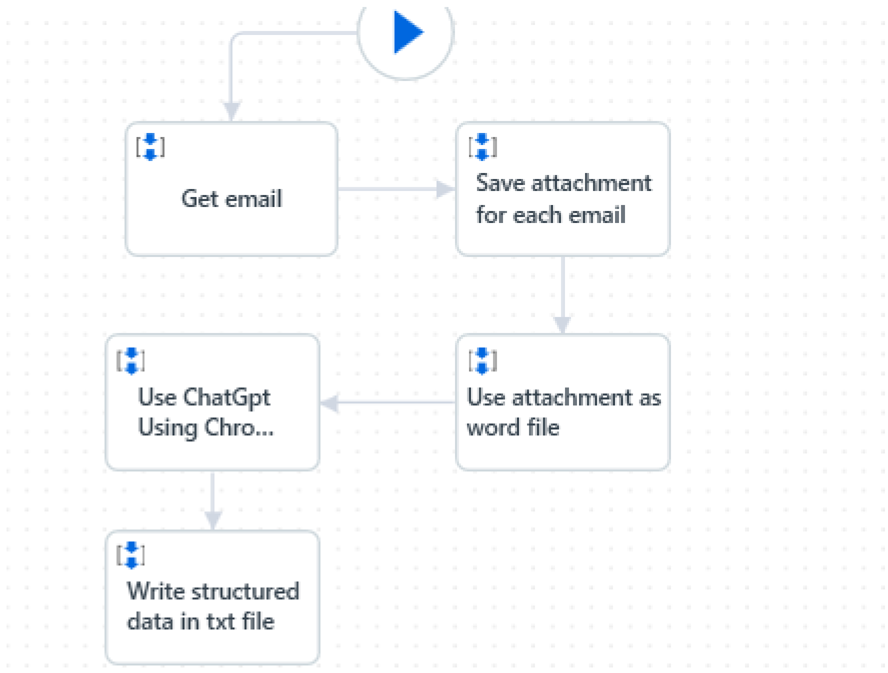


Figure D1: Steps of Pilot execution

And here are details of each step

The bot gets mails having "P.O" for a subject from a designated account and stores them in a variable named M, as it can be seen in figures D2 and D3

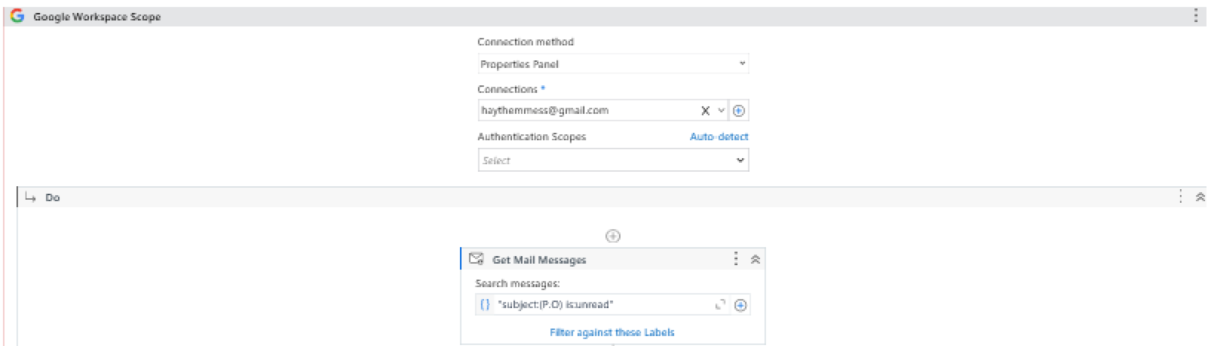


Figure D2: Activities to connect to Gmail account and get messages

Figure D3: Variable that contains emails in a list of emails named "M"

Inside a for each loop, the bot browses through the list of emails “M” and saves attachments of each email in a predefined folder as shown in figure D4:

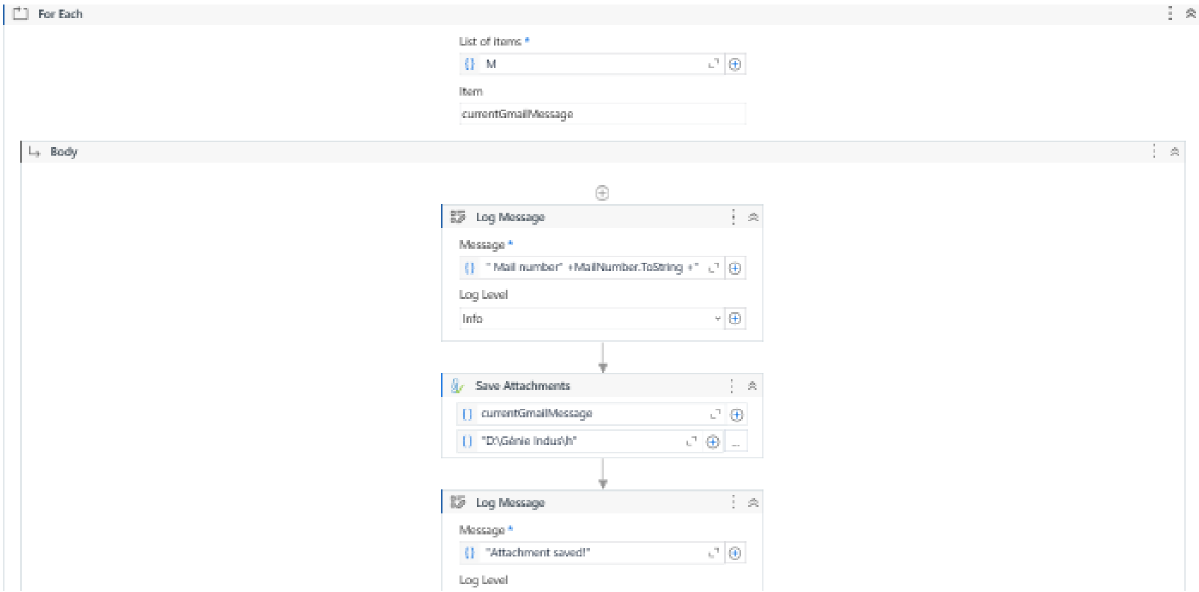


Figure D4: Loop to get attachments

Then, the saved Word file attachments are accessed. To use word activities, a word application scope must be used (see figure D5):

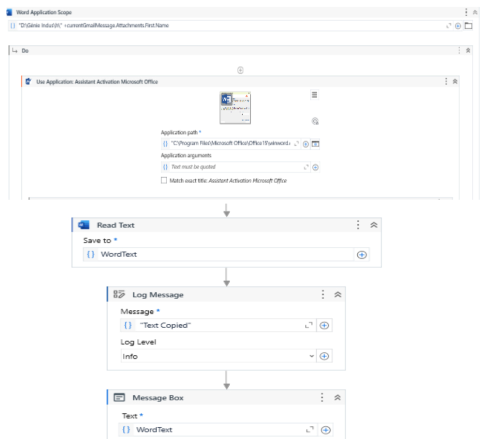


Figure D5: Loop to acquire text from Word files

The acquired text is stored in a string variable named WordText (see figure D6) :

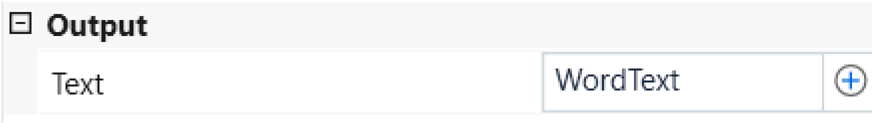


Figure D6: Output of reading the Word document

Next, the pilot bot uses ChatGpt directly and not through APIs mainly because OpenAi API's are no longer free and to give the stakeholder a visual confirmation on how the RPA bot interacts with the UI application, figure D7 shows the sequence of activities to access the browser and communicate with ChatGpt:

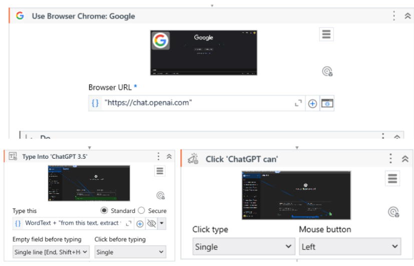


Figure D7: Sequence to access Chat GPT and write prompt

Then after Chat Gpt extracts the data asked of him and writes it under the demanded format, the bot takes that information and stores each aspect of information in a separate variable. (see figure D8)

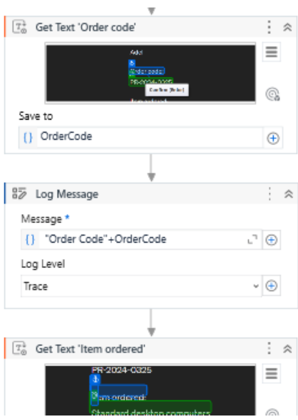


Figure D8: Sequence to get structured information from ChatGpt

After getting all the information required it is then stored into one variable as csv data and written into a .txt file using the application Notepad. The sequence to open notepad, write the text and save the file is expressed in figure D9:

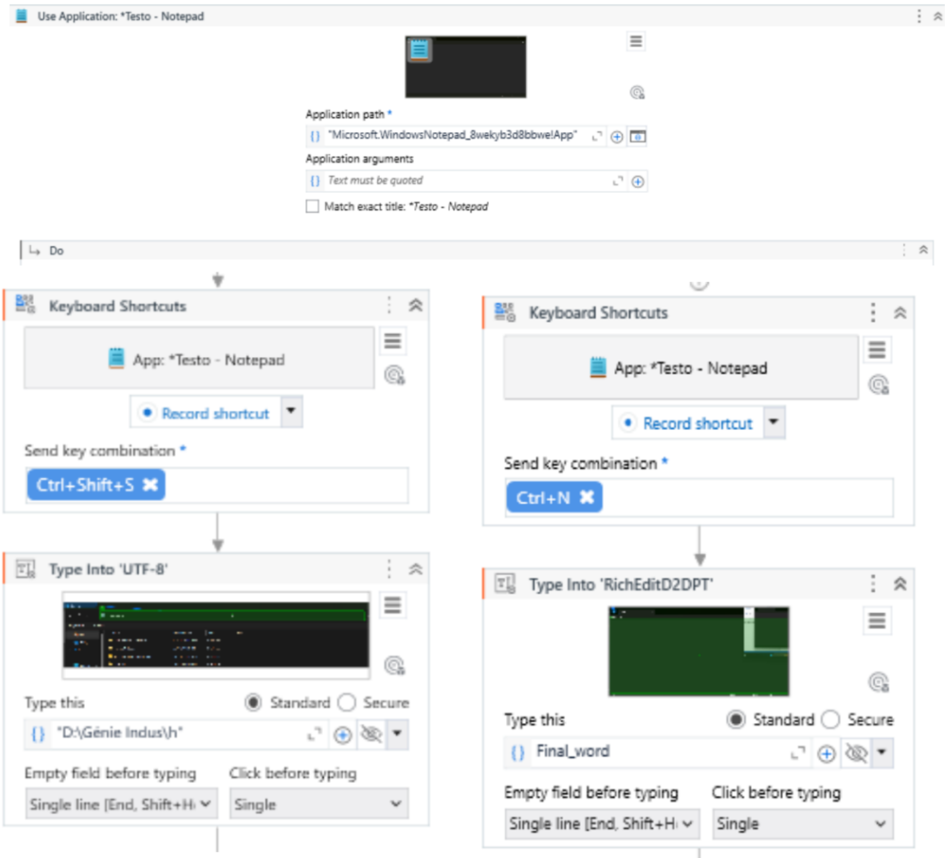


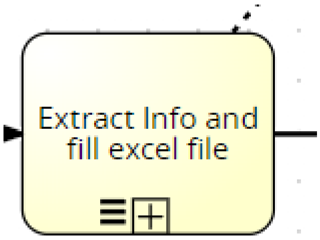
Figure D9: Sequence to write and save the .txt file

Appendix E: SUB PROCESSES

Sub processes for processes before redesign

Sub processes for process P11

Extract info and fill in the Excel file



According to the logistics engineer, this sub-process is the most time-consuming activity. They serially handle multiple files, starting by opening a DPL file and browsing each sheet for the case code. The General Electric DPL template is irregular, so cell alignment must be corrected before the item information can be copied and pasted into the target file. See Figure E1 for reference.

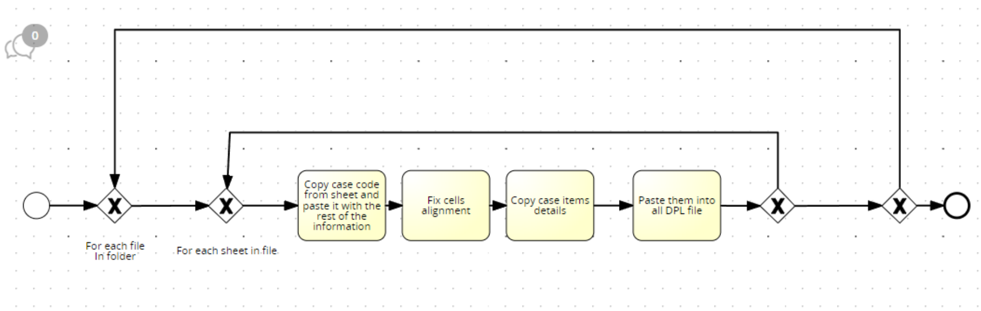
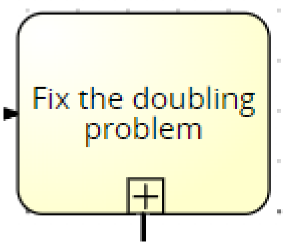


Figure E1: BPMN model for the Expanded subprocess "Extract info and fill excel file"

Fix the doubling problem:



After matching the MO with the DPL, a problem may arise. This issue stems from the fact that even if MO and DPL quantities were planned to be the same, recurring MO quantities may be observed. This occurs because production uses the same item type for more than one MO. The logistics engineer addresses these duplicate occurrences to prevent mistakes in the subsequent analysis. See Figure E2 for reference.

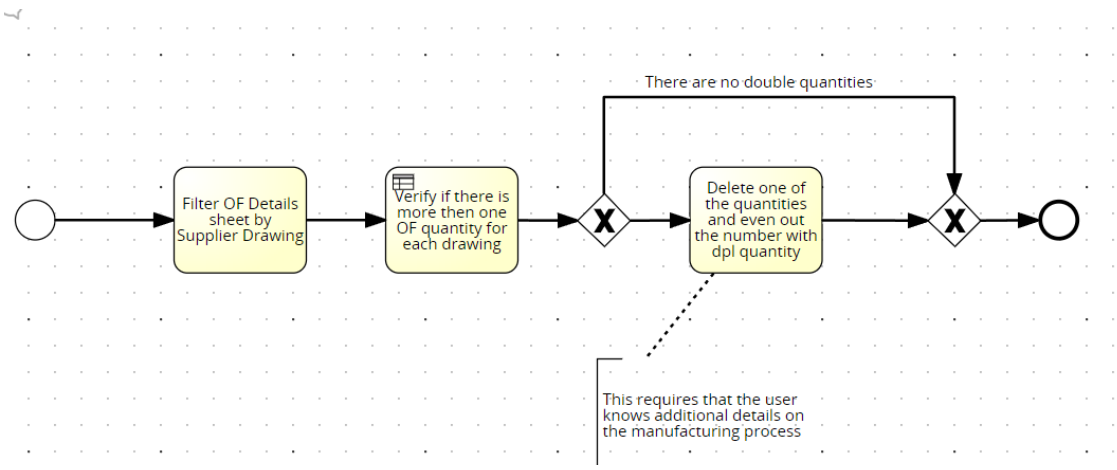
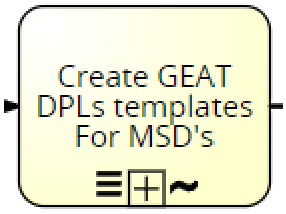


Figure E2: BPMN model for the Expanded subprocess “Fix the doubling problem”

Create GEAT DPLs templates for MSDs:



The logistics team finally created new GEAT templates for items considered MSDs (items with no MO code) to send DPLs under GEAT templates to their clients. This sub-process works ad hoc; refer to Fig E3

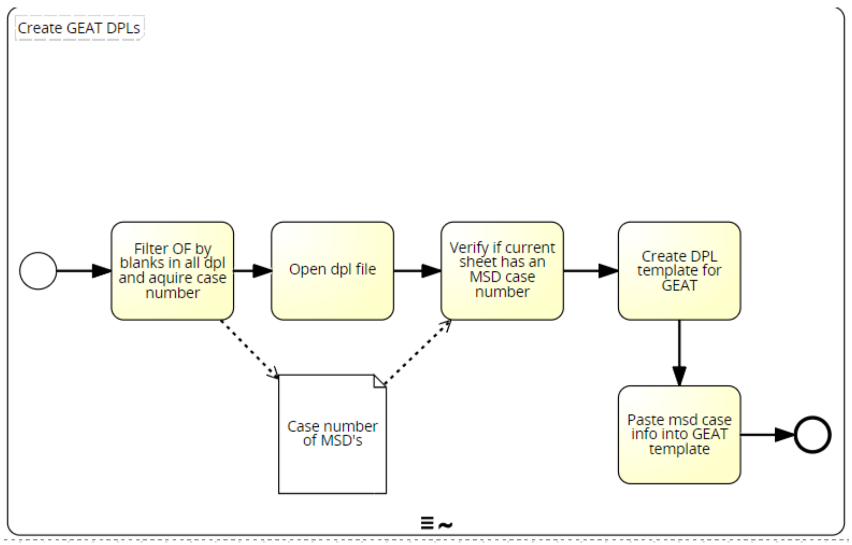


Figure E3: BPMN model for the Expanded subprocess “Create GEAT templates”

Sub processes for process P5

“Verify Hardware components” was also modelized; see Fig E4

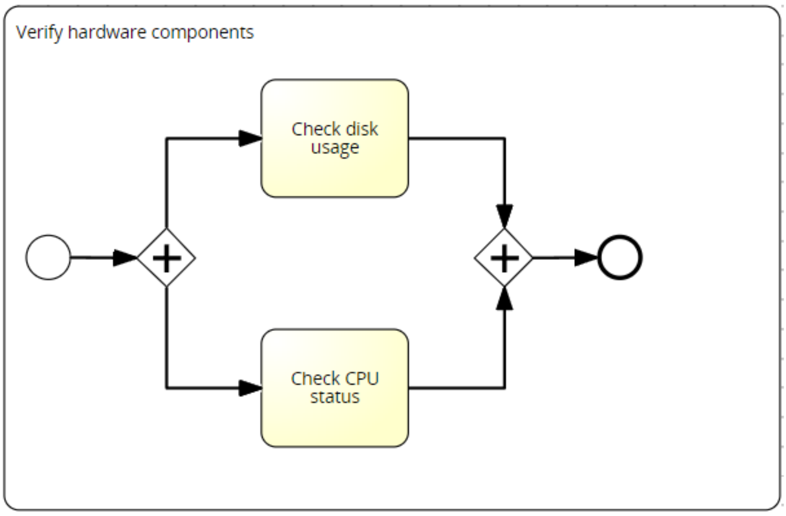


Figure E4: BPMN model for the Expanded sub-process "Verify Hardware components"

Sub processes for process P12

Create Excel file:

QC creates an Excel file, preparing columns and filling them with article code, description, quantity, and file path. He also fills the requirements column based on how they were specified in the CDC (short for Cahier de Charge, which means specification sheet). See fig E5

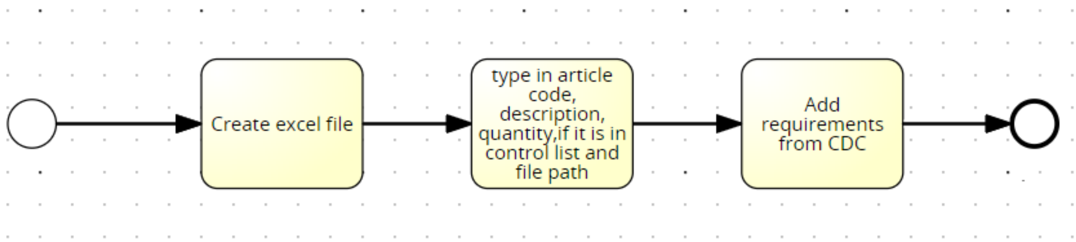


Figure E5: BPMN model for the Expanded sub-process "Create Excel File"

Match Requirements:

A QC team member opens the supplier document and starts by verifying whether the specification requires a part number and description verification.
If yes, the part number and description should be verified, and other specifications (as per CDC) should be verified.

Otherwise, only other specifications (as per CDC) are verified. See fig E6

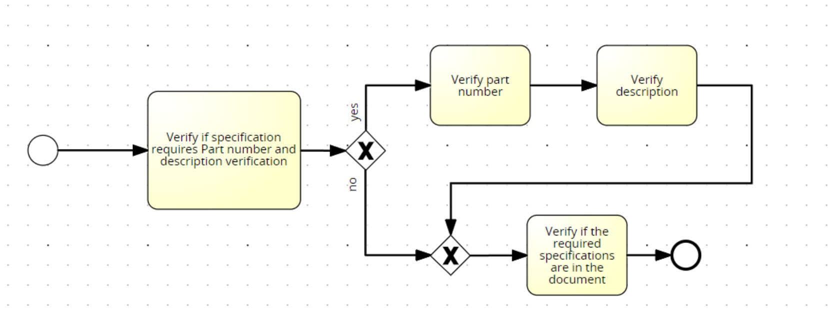
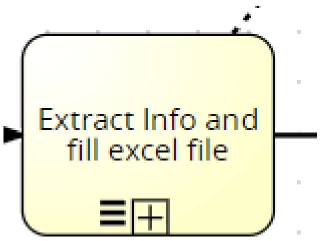


Figure E6: BPMN model for the Expanded sub-process "Create Excel File"

Subprocesses of redesigned process P11

Extract the info and fill it out in the Excel file.



The tasks in this process were lowered to 3 functions, which are fully automated, see Fig E7

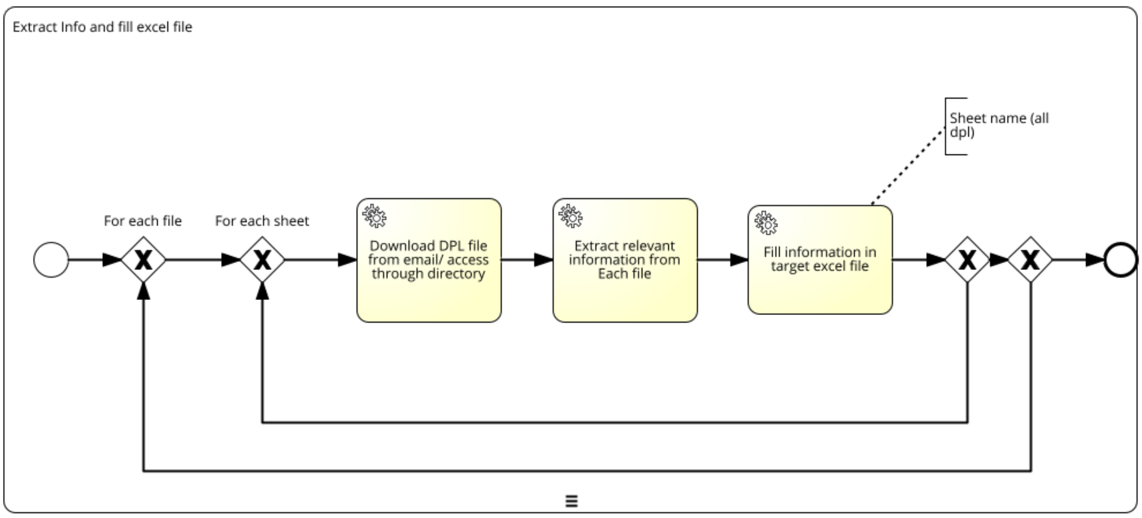
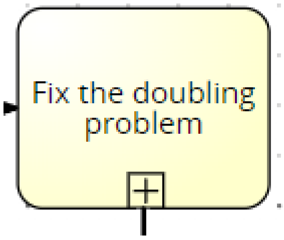


Figure E7: Subprocess "Extract Info and fill Excel file" after the redesign

Fix the doubling problem:



The tasks of this process were kept as they were but are also considered candidates for automation. see fig E8

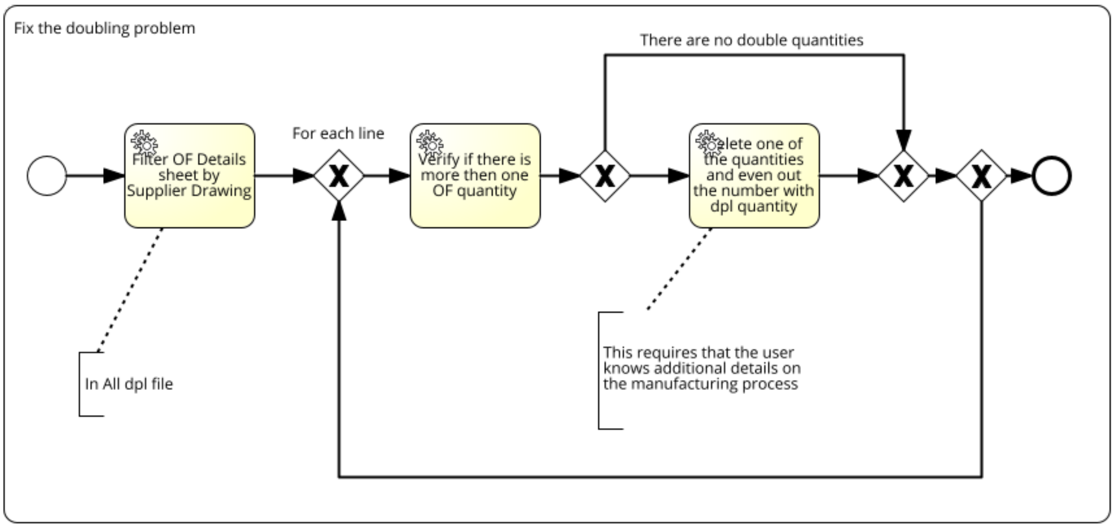
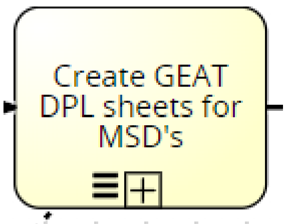


Figure E8: Subprocess “Fix the doubling problem” after the redesign

Create GEAT DPL sheets for MSD’s



As described in Table 2.7, this subprocess was organized into a series of well-organized tasks to be fully automated. See fig E9

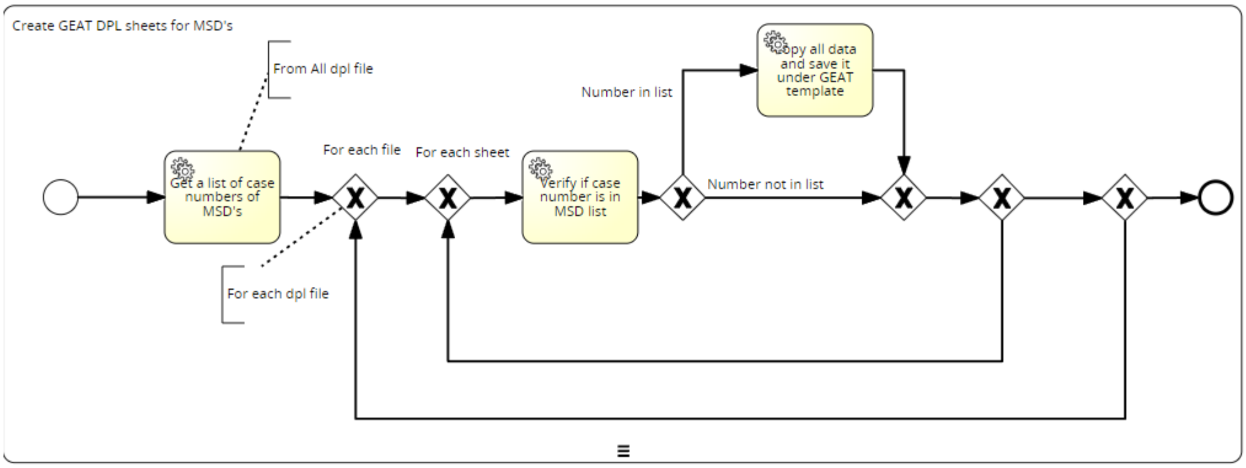


Figure E9: Subprocess “Create GEAT DPL” after the redesign

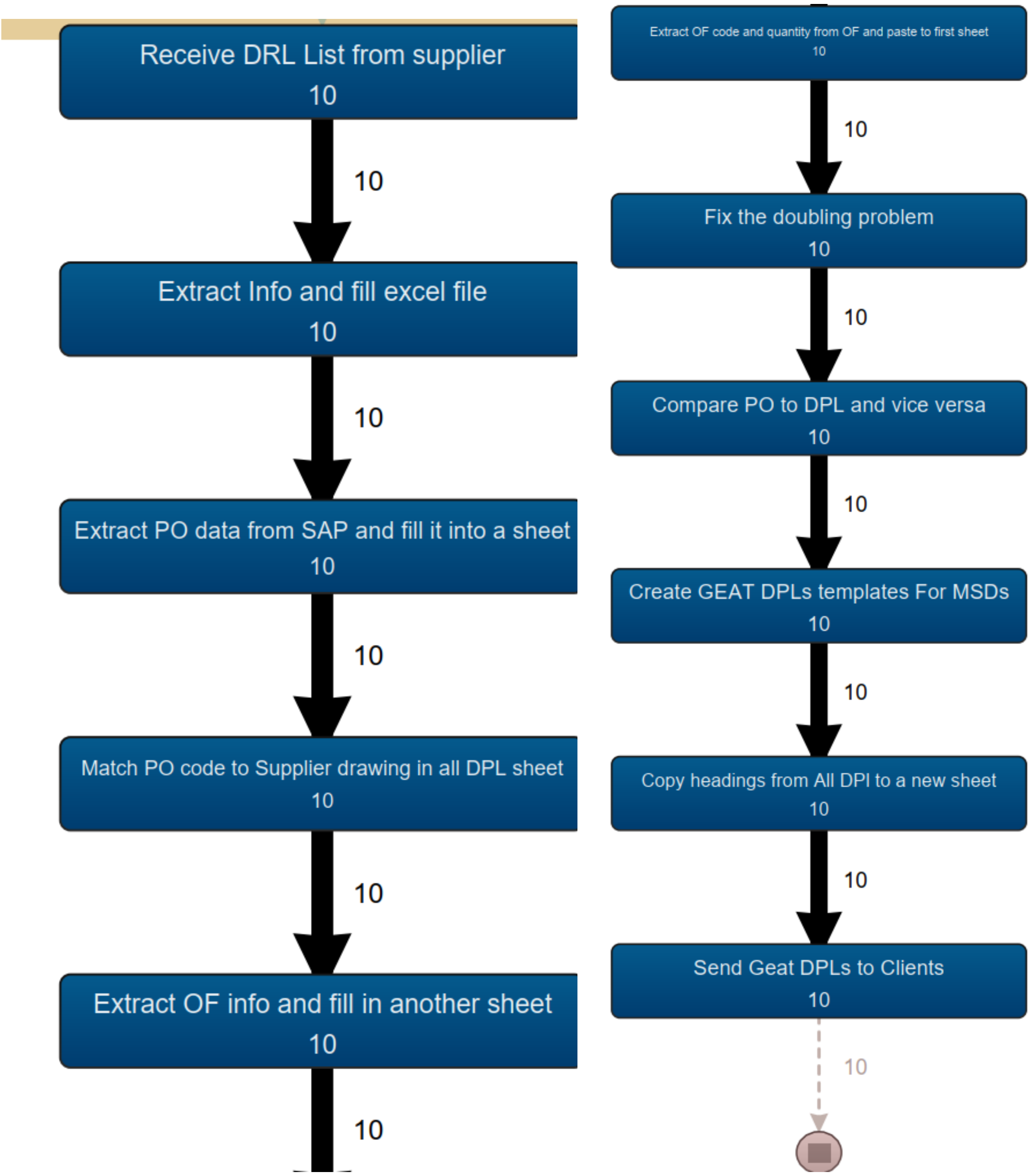


Figure E10: the discovered process using process mining

Appendix F: Criteria

These criteria were mostly taken from the PLOST framework with some alterations to make them suitable for our case study. Process mining could not be performed due to the lack of traceability in the partner organization's database.

Criteria for Process Analysis (Final Process Selection)

1. Lead time : The average time (including waiting times) that the process takes from start to finish
2. Cycle Time: The cycle time of the process is the average handling time that is needed to go from the process start to the process end.
3. Case Frequency: The frequency is the total amount of occurrences in a specific time.
4. . Length: The length of the process is the average amount of tasks/events/activitiesthat occur per process/case. The longer a process is, the more different tasks have to be automated to automate the complete process.
5. . Automation rate: With the percentage of events performed by the system the automation rate is determined. A high automation rate means a high percentage of events performed by the system. A condition for this metric is that the performer is known.
6. . Human Error Prone: The rework rate of the process tells how prone the process is for human employees to make mistakes. The rework rate is the number of activities that are executed more than once during the execution of a process.

Criteria For Task Analysis (Final Task Selection)

1) Activity Frequency: The average number of iterations in a task during one process instance.
2) Duration: The average duration of the total number of executions of the task.
3) Automation Rate: The percentage of occurrences performed by the system.
4) Human Error Prone: The rework rate of the task, which is the amount of activities

executed more than once during the execution of a process.

5) Domain knowledge : True or false, if the task requires expertise it takes the true value, else the false value

Appendix G: Task Selection Process

As per the PLOST framework :

- Points will be attributed to each criterion for each task where : the criterion with the highest value will take N points (N equals the number of tasks), the next best value will take N-1 points. Criteria with the same value are attributed an equal amount of points.
- The desired outcomes values determined by the stakeholders will be then multiplied by the points attributed to criteria. Each criterion matches with at least one of the desired outcomes. Table G1 shows which desired outcomes match each criterion:

Table G1: Outcomes that match each criterion

Criteria	**Time saving**	**Accuracy**	**Flexibility**
Activity frequency	yes	yes	yes
Duration	yes	no	no
Automation rate	yes	yes	yes
Human error prone	no	yes	no

- When many desired outcomes match with one criterion, the highest value of the desired outcomes will be multiplied by the points of the criterion.
- Finally, the task with the highest points will be the post prioritized task for automation.

Appendix H: Testing Plan

The testing plan was followed as per the Technical Testing Plan document, which was used from the Uipath repository. Figures H1,H2 and H3 are screenshots of some of the contents of the document enacted before the start of the development and testing phase of the bot:

Technical Testing Plan

1 Introduction

1.1 Purpose of Document

This document is intended to outline testing as a criteria for completing Development & Testing a
This document will clearly identify what the test deliverables will be and the timelines for these.

1.2 Test Execution Team

The names must be included in the table below.

Role	*Responsibilties*	*Name*
Executor	Build the test cases in code. Work with the Approver to ensure the bot is works as designed	*Haythem*
Approver	Review Test Results and provide approval. Sign-off on Completion	*Adel*

Figure H1: Introduction of the Technical Testing Plan

2. Testing Types

2.1 Intro

This section is intended to outline many possible testing areas that a solution might need to encounter. This is dependent on requirements, so not all testing types need to be covered.

2.2 Functional Testing

Type	Description
Unit	*Unit testing evaluates individual workflows separately to ensure they function correctly and to identify defects early in development.*
Integration	*Verifies interactions and communication between components, identifying issues in integrated workflows to ensure overall solution performance.*
System	*Ensures the automation system functions fully and performs as expected, accessing all applications in its intended environment.*

3.2 Non-Functional Testing

Parameter	Description
Performance	*Evaluates automation's performance and responsiveness under load conditions to ensure it handles workload and identifies bottlenecks.*
Usability	*Evaluates automation's ease of use and user experience to ensure it is user-friendly and identifies usability issues.*
Compatibility	*Ensures seamless operation across platforms; critical for attended automations with large user bases, less so for unattended automations.*

Figure H2: Definition of testing types

3 Test Environment

Details for hour testing will occur during the development phase

System/Application	Version
OS	Windows 11 (64) and Windows 10 (64)
Excel	Excel 2013 and Excel 2016
Machine(s)	i5 12500H 24 gb ram 3200 mhz
	i7 1265 U 32gb ram 4800 mhz

Figure H3: Definition of testing environment

Appendix I: Description of The Utilized Uipath Activities

Figure 55: Table I1: explanation for each activity that was used in botdevelopment.

Icon	Description	Input variable	Output Variable	Package
Sequence	Executes a set of child activities according to a	/	/	System.Activities.Statements
Flowchart	Models workflow using the flowchart diagram	/	/	System.Activities.Statements
For Each File in Folder	Repeats the contained activities for each file in a predefined folder	/	/	Uipath.Core.Activities
For Each	Repeats the contained activities for each file in an	List (Of type)	Item of the list	Uipath.Core.Activities
Assign	Sets workflow variable values	Any type	Any type	Uipath.Core.Activities
Log Message	diagnostic message at the specified level. These messages are	String	Text message in Orchestrator	Uipath.Core.Activities
Excel Process Scope	Opens or resuses an excel process, to be used with "Use excel file"	/	/	Uipath.Excel.Activities.Business
Use Excel File	excel file to use in automation, It ustilizes a file path to	String (File path)	/	Uipath.Excel.Activities.Business
For Each Excel Sheet	contained activities for each sheet in workbook	String (File path)	/	Uipath.Excel.Activities.Business
For Each Excel Row	Repeats the contained activities for each line in Range	String (Range)	/	Uipath.Excel.Activities.Business
Read Cell Value	Reads a value from a spreadsheet cell	IreadWriteRange	String (cell value)	Uipath.Excel.Activities.Business
Read Range	Reads the value of an excel range as a datatable	IreadWriteRange	DataTable	Uipath.Excel.Activities.Business
Write Cell	Enters a text or a formula in a cell	IreadWriteRange,String	/	Uipath.Excel.Activities.Business
Write DataTable to Excel	Writes data from a datatable to a workbook	DataTable	/	Uipath.Excel.Activities.Business
Save Excel File As	Saves excel file to Path	String(File name)	String (Path)	Uipath.Excel.Activities.Business
Create Pivot Table	Create a pivot table in a specified range	IreadWriteRange, String	/	Uipath.Excel.Activities.Business
Filter	Creates a filter in table, range or sheet	String	/	Uipath.Excel.Activities.Business
Copy/Paste Range	Copies a range from a workbook and pastes it into another range	IreadWriteRange	IreadWriteRange	Uipath.Excel.Activities.Business
Keyboard Shortcuts	Sends one or more keyboard shortcuts to UI	Keys (keyboard keys)	UI Interaction	Uipath.AutomationNext.Activities
Type Into	Enters text in a specific UI element, for example a text box	String , UI element	/	Uipath.AutomationNext.Activities

Appendix J: Running The Bot From The User's Point Of View:.

Users don't need to use the workflow designer, instead they can use the Uipath assistant, which is described in Appendix A.

The assistant is very easy to use, as it can be seen in figure J1 , the published automations appear in the "Home" section. Users only have to press "Run" to launch the attended automation.

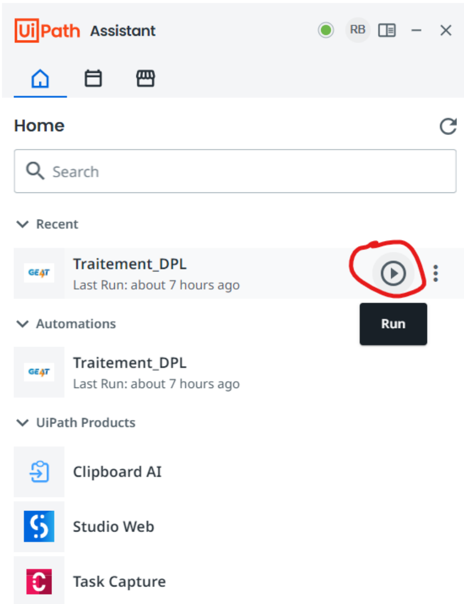


Figure J1: First step to launch the automation

After the automation is launched a menu will appear giving users the option to choose which Activity to launch,names of the activities in the assistant according to the codes attributed in Table 2.9 are shown in table J1 . figure J2 shows how menu appears to users:

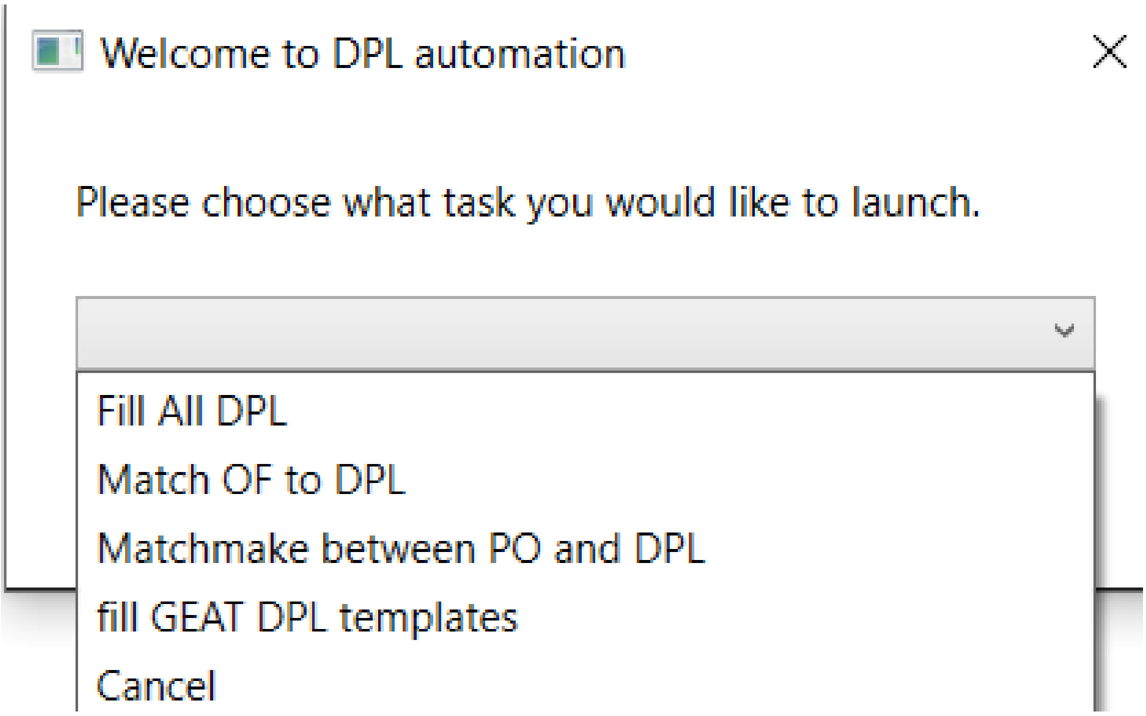


Figure J2: Menu to choose what task to launch

Table J1: Activity codes

Task name in assistant	Code
Fill All DPL	SP1
Match OF to DPL	T4
Matchmake between PO and DPL	T5
Fill GEAT DPL templates	SP2

After the user chooses one of the three first activities, another menu (see figure J3) will appear to ask him if he wants to launch this task to run alone, or for the succession of the other tasks to continue.

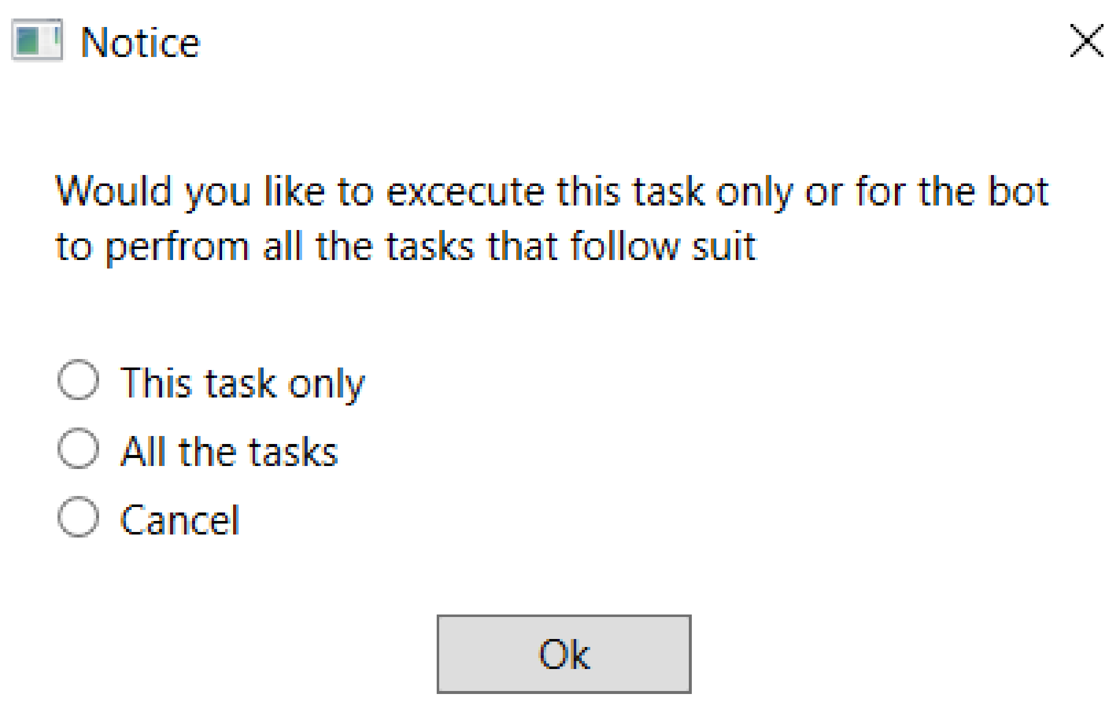


Figure J3: Menu to choose what task to launch

Activities SP1 and SP2 are fully automated, so the user is free to handle other tasks while the bot performs them. However, the activities T4 and T5 require users to input some data in order to function.

So if the user chooses to launch T4 the bot will ask him to fill a designated sheet in Alldpl file named “Détails OF”, the message that appears is shown in figure J4 :

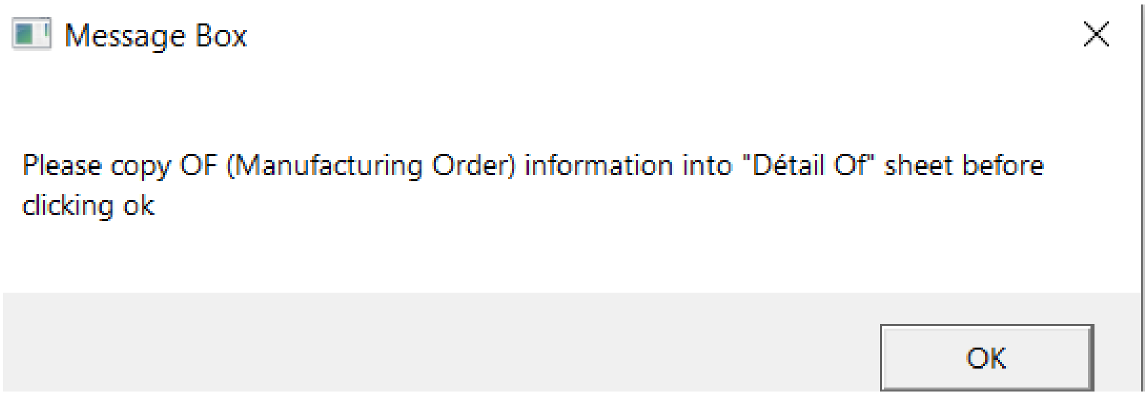


Figure J4: Message to ask user to fill designated sheet

If the user chooses to launch T5, the bot will ask the user to copy PO details into a designated sheet in AllDpl named “Détails PO” the message is shown in figure J5

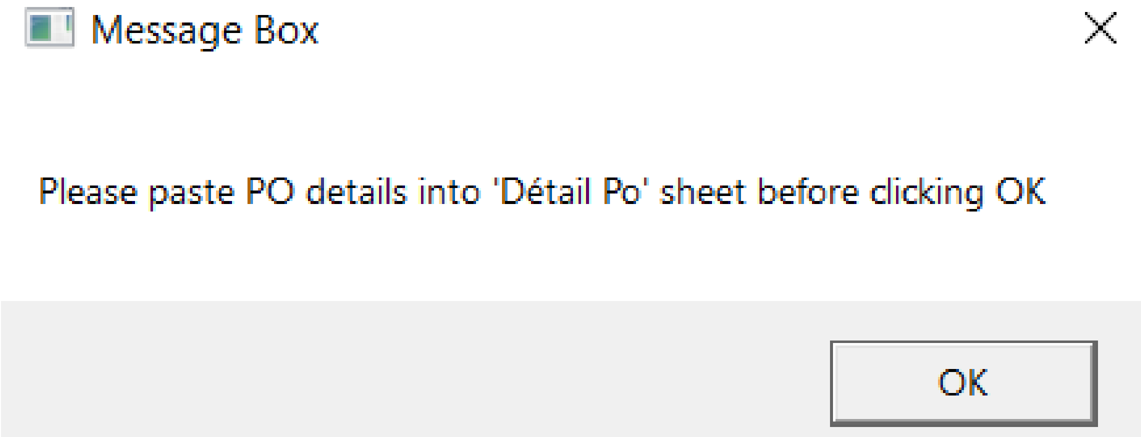


Figure J5: Message to ask user to fill designated sheet

After the user fills the sheet and clicks OK the bot will ask the user to input MLI kit codes, there are two modes for this input manual and excel. A menu would appear to ask him what kind of input does he wish to choose (see figure J6)

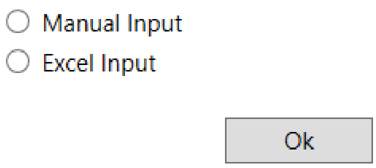


Figure J6: Input Kind

If the user chooses Manual Input : he two text input boxes would appear, one for the kit code and the other for corresponding PO code (see figure J7):

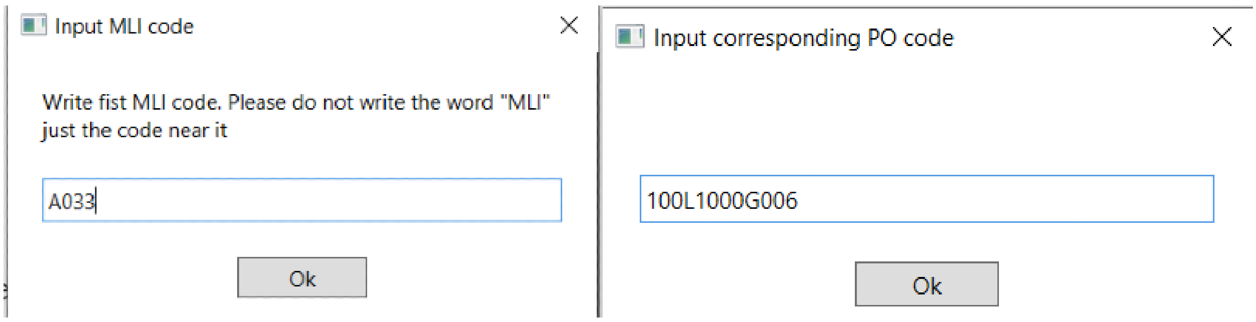


Figure J7: Text input boxes

If the user chooses Excel Input, he has to paste a data table of MLI codes with corresponding Po codes in a designated sheet in the AllDpl file named "MLI".

After the user finishes providing the data, the bot will continue to perform the rest of the tasks in the activity (T4 or T5).

Finally, when the bot finishes running, a text box will appear showing if the workflow finished successfully or with exceptions. (See figure J8)

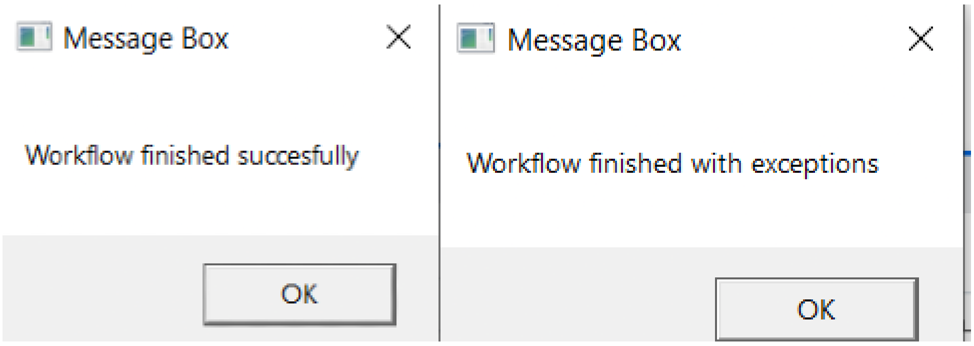


Figure J8: Text boxes after the bot finishes running

Exceptions and error messages can be found in the orchestrator to be later fixed by the developer.

Appendix K: UAT Testing Results

Notes on issues, analysis and remedies were all taken into account in the UAT issues document, resumed in table K1.

Table K1: Details on issues found during UAT

S.No	Issue/Change	Issue Raised On	Analysis	Issue Type	Action Owner	Status	ETA	Remedies
1	Some sheets in the Supplier DPL list were not treated by the bot	22/05/2024	The data was not copied from some sheets in the supplier files,	Error	Client	Closed	25/05/2024	BOT was redesigned to adapt to some uncommon changes in the supplier files
2	Some cells shift in All dpl Sheet1	22/05/2024	In some rows, all the cells that are on the right on the Unit Of Measure were shifted by one case to the right	Error	Client	Closed	25/05/2024	The column separator in the script was changed
3	Fill GEAT templates does not conform to business needs	22/05/2024	The Process model for "Fill GEAT templates" was not modeled correctly thus leading to inconsistencies in the whereabouts of the execution and thus wrong results	Process Definition	Client	Closed	25/05/2024	Process was remodeled to be aligned with business needs and the script was fixed
4	Item quantities were copied and pasted under date format	27/05/2024	In some rows, the quantities were pasted as dates for example 30,5 as 30/05/1999 and could not be fixed by changing format	Error	Client	Closed	27/05/2024	Variable type was changed in the bot from String to Double
5	One line shifted and doubled	27/05/2024	One line in the AllDPL result Sheet1 doubled and all its values shifted to the right	Error	Client	Pending	Pending	This error had to do with the users altering the supplier dpl file, so it could be evaded for now by not altering the file before the execution

As it can be seen in the table K1, The first , second and fourth issues were script related and were fixed accordingly.

The third issue was modeling related, an error in business analysis. SP2 was later redesigned and its automation workflow fixed accordingly. Figure K1 shows the fixed design of SP2 in an activity diagram.

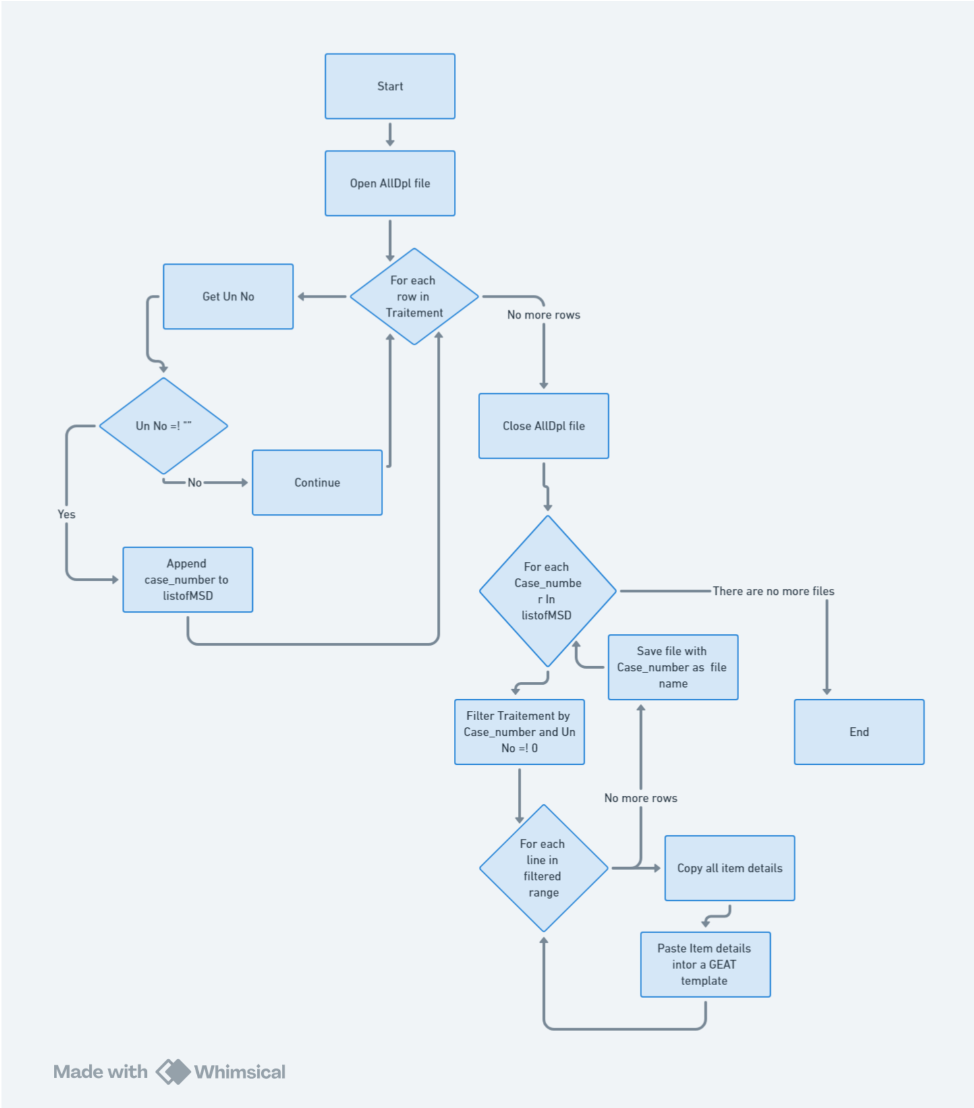


Figure K1: Activity diagram for the fixed activity

As the workflow for the bot was redesigned, the automated workflow was also modified, there are are still the two same sequences as before (figure 2.15) however the activities of each sequence were modified to conform with the new design as it can be seen figure K2:

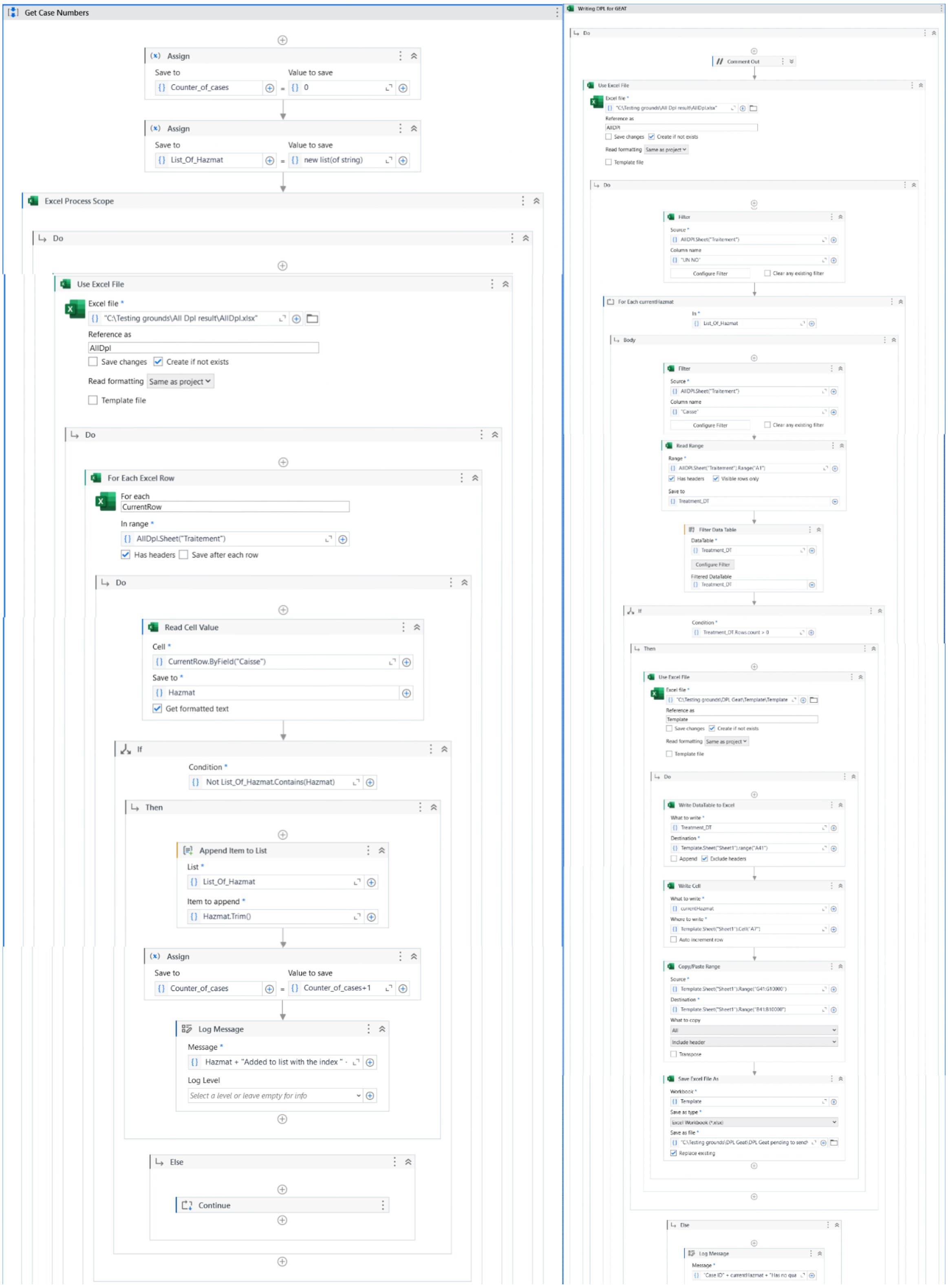


Figure K2: Sequences after fixing the inconsistencies

Appendix L : Execution Results For a Single Sample

The figures below show execution results for the Gas turbine 4 sample, after running the automated SP1 and SP2

SP1:

Runtime : 8 minutes
The resulting excel file contained all the items from the 93 cases, figure L1 shows a screenshot of the resulting file:

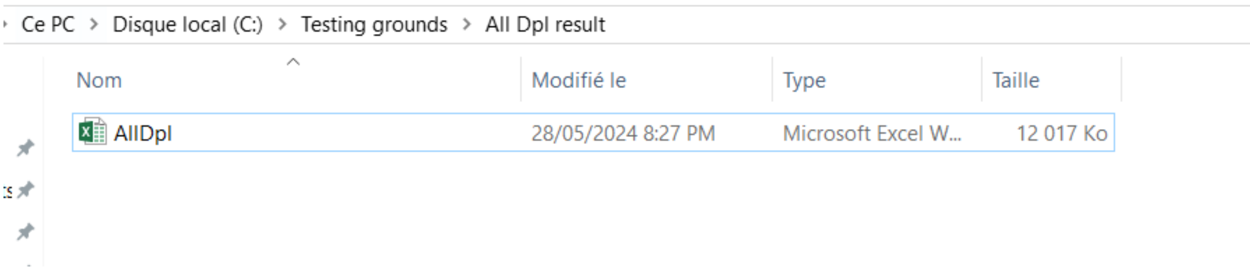


Figure L1: The file in the directory

Figure L2 shows a part of the resulting file from executing the automated SP1, details could not be shown for security reasons.

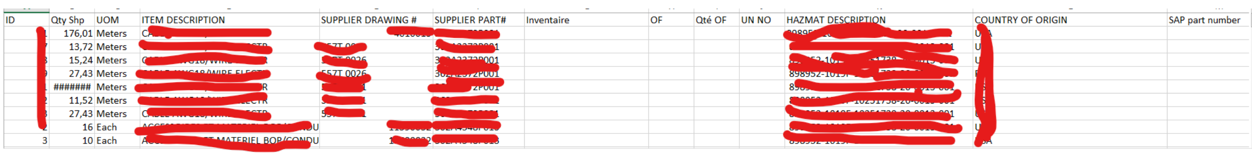
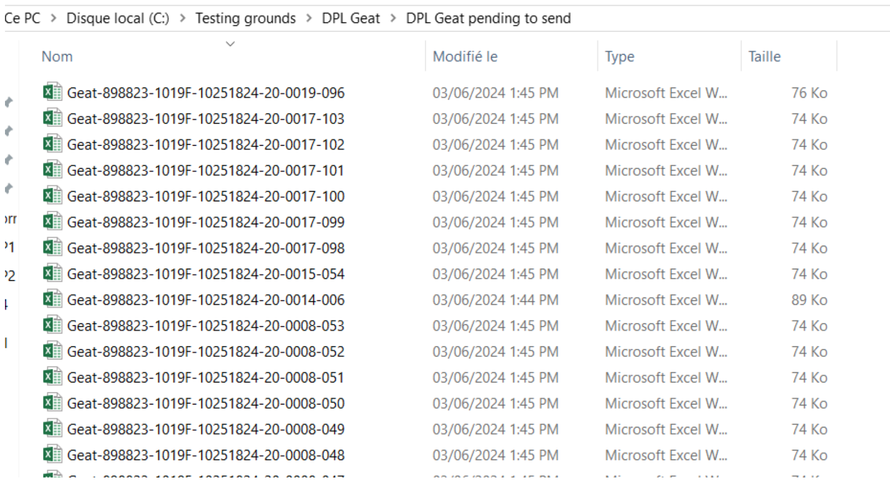


Figure L2: Contents of “Sheet1” in AllDpl file

SP2:

Runtime : 1 min 50 seconds

The resulting files showed all the cases that had MSD items (amounting to 43), the results were confirmed to be correct by users in the UAT, figure L3 shows the resulting files waiting to be sent:

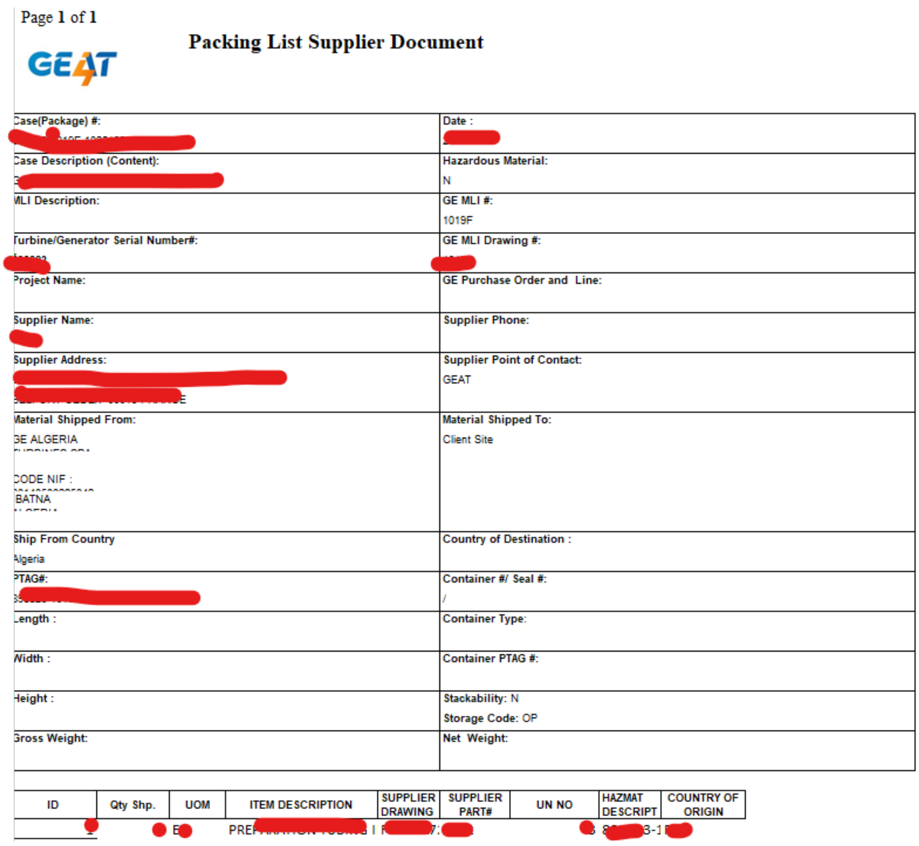


Ce PC > Disque local (C:) > Testing grounds > DPL Geat > DPL Geat pending to send

Nom	Modifié le	Type	Taille
Geat-898823-1019F-10251824-20-0019-096	03/06/2024 1:45 PM	Microsoft Excel W...	76 Ko
Geat-898823-1019F-10251824-20-0017-103	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0017-102	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0017-101	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0017-100	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0017-099	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0017-098	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0015-054	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0014-006	03/06/2024 1:44 PM	Microsoft Excel W...	89 Ko
Geat-898823-1019F-10251824-20-0008-053	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0008-052	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0008-051	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0008-050	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0008-049	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko
Geat-898823-1019F-10251824-20-0008-048	03/06/2024 1:45 PM	Microsoft Excel W...	74 Ko

Figure L3: The files in the directory

These files had the same contents as the Supplier MSD files, however they come under a GEAT template so that they can send them to their client. Figure L4 shows what a GEAT DPL file looks like :



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Packing List Supplier Document

Case(Package) #: [redacted]	Date : [redacted]
Case Description (Content): [redacted]	Hazardous Material: N
MLI Description:	GE MLI #: 1019F
Turbine/Generator Serial Number#: [redacted]	GE MLI Drawing #: [redacted]
Project Name:	GE Purchase Order and Line:
Supplier Name: [redacted]	Supplier Phone:
Supplier Address: [redacted]	Supplier Point of Contact: GEAT
Material Shipped From: GE ALGERIA CODE NIF : BATNA	Material Shipped To: Client Site
Ship From Country Algeria	Country of Destination :
PTAG#: [redacted]	Container #/ Seal #: /
Length :	Container Type:
Width :	Container PTAG #:
Height :	Stackability: N Storage Code: OP
Gross Weight:	Net Weight:

ID	Qty Shp.	UOM	ITEM DESCRIPTION	SUPPLIER DRAWING	SUPPLIER PART#	UN NO	HAZMAT DESCRIPT	COUNTRY OF ORIGIN
[redacted]	[redacted]	[redacted]	PRE[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Figure L4: Detailed Packing list under GEAT format

Appendix M: Process Runbook

The enterprise was provided with a process runbook. Some contents of the process runbook can be found down below:

About this document

The run book is created as UAT ends. This document will be passed on to the support team and any future developers as the primary resource on how the automation runs and how to debug any potential issues.

How to use this document

This document is a resource to the support team. It can be used for setting up machines to run the automation, but also as a starting point for debugging any issues with the automation. Any time there are common issues that the support team manages, they should add them to this run book. Table M1 shows details on this version of the document.

Table M1: Revision history

Doc Version	Date Revised	Author	Change Summary
1.0	27/05/2024	MESSAI Haythem	First version, setup guide and execution guide were written

Process description

Please refer to Solution Definition Document, it contains the description of how the bot should run and the work handover between the bot and the human employees. Table M2 shows details on the published automation.

Table M2: Automation details

Process Name	DPL files treatment
Package Name and Version	Traitement DPL 1.0.12
Robot Type (Unattended/Attended)	Attended
Number of robots running	1
Orchestrator Used? Yes/No	No
Support Team Email	A_bentayeb@ensta.edu.dz
Developer Team Email	H_messai@ensta.edu.dz
Business Team Email	Geat_Rpa_bot@outlook.fr
Average Handling Time per Automation Run	30 minutes
Code Repository	/

Dependencies of the automation and must be available for the automation to run are shown in Table M3.

Table M3: Dependencies

Package Name	Version
Uipath Studio	22.0 or above
Uipath Assistant	22.0 or above
Microsoft Office	Activated Office 13 or above

Setup guide:

Uipath setup files are provided In the given zip file. Follow instructions in ReadMe.txt. After installing Uipath Studio launch assistant and put the credentials found in ReadMe.txt

Automation inputs and Outputs

Each automation step includes Inputs and outputs. Tables M4, M5, M6, M7, M8, M9, M10, and M11 show inputs and outputs for each automated activity.

Fill all DPL file (SP1):

Table M4: Input for SP1

Input	Description
DPL files	Put supplier DPL files in the directory C:\Testing grounds\DPL list

Table M5: Output for SP1

Output	Description
AllDpl	A file containing a grouping of all the items included in supplier DPL files. It can be found in the directory C:\Testing grounds\All Dpl result

Fill MO code and quantity (T4):

Table M6: Input for T4

Input	Description
Manufacturing Order (MO) details	Get MO details from SAP and write them in AllDpl file sheet “Détail OF”

Compare PO to DPL and vice versa (T5):

Table M7: Output for T4

Output	**Description**
MO codes and quantities	MO codes and quantities will be automatically matched to DPL items.

Table M8: Input for T5

Input	**Description**
PO details	Get MO details from SAP and write them in AllDpl file sheet "Détail OF"
MLI kit codes	Get kit codes from production and fill it in the sheet "MLI" or input manually as described in the presentation sent previously in email

Table M9: Output for T5

Output	**Description**
Pivot tables	Two pivot tables "PO_Vs_Dpl" and "DPL_VS_PO" containing a comparison between their quantities with the unit of measure

Table M10: Input for SP2

Input	**Description**
Traitement	Fix the double quantities and assign to each item the exact quantity needed for MO as well as the remaining quantity for each item
GEAT template	GEAT template can be modified. It can be found in the directory C:\Testing grounds\DPL Geat\Template

Table M11: Output for SP2

Output	**Description**
GEAT DPL files	After the workflow ends the GEAT DPL files can be found in the directory C:\Testing grounds\DPL Geat\DPL Geat pending to send

Table M12: Known exceptions that come up when running the automation

Exception Type	**Details**	**Responsible Team**	**Action to Take**
Cell shift	Altering the supplier DPL files may cause shifting in cells in AllDpl file	Logistics team	Verify if the source documents were altered in any way and rerun the process
Orchestrator not connected	Sometimes the assistant won't run saying that the orchestrator is not connected	IT team	This problem occurs when there are network problems, sort network problems and try reopening the Assistant
Inconsistent Data types	Rarely, data types can be altered for example from integer to date, resulting in wrong output	Logistics Team	Skim through the treatment results. This problem can be noticed easily, as cells with wrong data types will have #### written.