

Process Improvement in Serial Number Management of Precision Optical Products using the BPM Lifecycle

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Aos meus pais.

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Abstract

This master's thesis investigates the critical importance of viewing business activities as interconnected processes rather than isolated departmental functions. The primary objective of this project was to improve operational efficiency within all departments concerned with the serial number value chain of a manufacturing company.

To improve the serial number management in precision optical products, the principles of Business Process Management were followed along with a multi-level modeling structure constructed of process diagrams, swimlanes and flowcharts, as tools to better visualize business processes and their activities, finding inefficiencies and problems to be solved.

Leveraging the BPM Lifecycle, the beginning was of process identification, defining the scope of the project, and that the serial number value chain contains three processes: Serial Number Acquisition, Engraving Production, and Integration and Delivery. All components with a serial number that were assembled in Leica Camera Portugal passed through these processes.

The next stage of Process Discovery consisted of visiting all locations and interview all stakeholders that intervened in the serial number value chain to acquire as much evidence and knowledge as possible with the main goal to be to understand how the work is done and with what tasks, and focusing on knowing the objective of those tasks. In this stage, swimlanes and flowcharts were developed as well, feeding the next stage of Process Analysis that problems were identified and analyzed, which in the stage of Process Redesign, proposals for improvement were reached building new models.

The proposals were implemented leading to eight main actions, where a Proof of Concept was successful to build a platform centralizing all information regarding serial number management. Other actions consisted of eliminating previously identified unnecessary activities, while conducting Process Monitoring to achieve clear gains. Additionally, procedures were established to streamline serial number management.

This thesis documents the strategic approaches based on the BPM Lifecycle, employed to discover issues and analyze the overall process providing a roadmap for improvements through redesign, which are in turn implemented and monitored. By demonstrating the benefits of process-oriented thinking, the project offers valuable insights for managers and practitioners aiming to streamline operations and enhance business performance.

Melhoria de Processos na Gestão de Números de Série em Produtos de Precisão Ótica utilizando o BPM Lifecycle

Resumo

Esta dissertação de mestrado investiga a importância crítica de visualizar as atividades empresariais como processos interconectados, em vez de funções departamentais isoladas. O objetivo principal deste projeto foi melhorar a eficiência operacional em todos os departamentos envolvidos na cadeia de valor dos números de série de uma empresa de produção.

Para melhorar a gestão de números de série em produtos óticos de precisão, foram seguidos os princípios de Gestão de Processos de Negócio (BPM), juntamente com uma estrutura multinível de modelos composta por diagramas de processos, *swimlanes* e fluxogramas. Essas ferramentas ajudaram a visualizar melhor os processos de negócios e suas atividades, identificando ineficiências e problemas a serem resolvidos.

Aproveitando o ciclo de vida do BPM, o início foi a identificação de processos, definindo o âmbito do projeto, e constatou-se que a cadeia de valor dos números de série contém três processos: Aquisição de Números de Série, Produção de Gravação e Integração e Entrega. Todos os componentes com um número de série que foram montados na Leica Camera Portugal passaram por esses processos.

A próxima etapa de descoberta do processo consistiu em visitar todos os locais e entrevistar todas as partes interessadas que intervêm na cadeia de valor dos números de série para adquirir o máximo de evidências e conhecimentos possíveis, com o objetivo principal de entender como o trabalho é realizado e com quais tarefas, focando-se em conhecer o objetivo dessas tarefas. Nesta etapa, também foram desenvolvidos *swimlanes* e fluxogramas, alimentando a próxima fase de análise do processo, onde os problemas foram identificados e analisados. Na etapa de desenho do processo, propostas de melhoria foram alcançadas construindo novos modelos.

As propostas foram implementadas levando a oito ações principais, onde um *Proof of Concept* foi bem-sucedido para construir uma plataforma centralizando todas as informações relacionadas à gestão de números de série. Outras ações consistiram em eliminar atividades desnecessárias previamente identificadas, enquanto se conduzia a Monitorização de Processos para alcançar ganhos claros. Além disso, procedimentos foram estabelecidos para agilizar a gestão de números

Esta tese documenta as abordagens estratégicas baseadas no ciclo de vida do BPM, empregadas para descobrir problemas e analisar o processo geral, fornecendo um plano de melhorias por meio de redesenho, que por sua vez são implementadas e monitoradas. Ao demonstrar os benefícios do pensamento orientado a processos, o projeto oferece observações valiosas para gestores e praticantes que visam otimizar operações e melhorar o desempenho empresarial.

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Acronyms and Symbols

APQC – American Productivity & Quality Center

BPM – Business Process Management

BPMN – Business Process Model and Notation

DH – Department Head

ERP – Enterprise Resource Planning

ISO – International Organization for Standardization

LCP – Leica Camera Portugal

LCW – Leica Camera Wetzlar

MRP – Material Requirements Planning

OMG – Object Management Group

PCF – Process Classification Framework

PoC – Proof of Concept

PTL – Product Team Leader

RACI – Responsible, Accountable, Consulted, Informed

SAP – Systems, Applications, and Products in Data Processing

SN – Serial Number

SO-O – Sport Optics Observation

SO-RF – Sport Optics Range Finding

TL – Team Leader

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1. Introduction

This dissertation was conducted in an industrial environment at Leica – Aparelhos Óticos de Precisão, S.A., as part of the Master's in Mechanical Engineering – Production Engineering & Management, of the Faculty of Engineering of the University of Porto.

The project aimed to improve all processes concerning Serial Numbers inside the company.

This introductory chapter begins with the project's framework, outlining the motivation for undertaking the project, followed by a brief presentation of the company, the main goals to accomplish, and the methodology employed. At last, an overview of the dissertation's structure is presented.

1.1. Project Context and Motivation

This dissertation focuses on optimizing serial number management within the organization. It is a critical aspect for operational efficiency and quality assurance. At the same time, there is an objective to standardize or create procedures for all processes involving serial numbers.

In today's business environment, effective serial number management is vital for product traceability, quality control, and regulatory compliance. Accurate tracking of serial numbers supports efficient inventory management, enhances product authenticity, and enables timely identification of discrepancies or defects in the manufacturing process. However, existing processes may face challenges, leading to inefficiencies and potential errors.

By conducting this project, the goal was to address identified inefficiencies and streamline procedures to improve operational performance, reducing costs, and ensure compliance with industry standards and regulations.

The company is certified with ISO 9001 – Quality management systems and this project aligns with ISO 9001 requirements by standardizing and documenting the company's core processes, which is lacking for serial number management.

1.2. The project at Leica - Aparelhos Óticos de Precisão, S.A.

The history of Leica starts in 1849 when Carl Kellner founded a small shop in Wetzlar, Germany, and since then has a rich history rooted in precision engineering and innovation. Company founder Ernst Leitz produced the first 35mm camera, in 1925. Specializing in both photography optics and sport optics, Leica has established itself as a leader in the industry, producing cameras, lenses, binoculars, and other optical equipment renowned for their quality and performance. The name Leica is formed by LEI (Leitz) + CA (camera)

In 1973, Leica Camera AG, expanded its manufacturing facilities to Vila Nova de Famalicão, Portugal, founding the current Leica – Aparelhos Óticos de Precisão, S.A (from now onward called Leica Portugal), that has grown and evolved over the years, becoming a key manufacturing hub for the group. In 2013, the company relocated to new facilities, in Figure 1, in the same city, further enhancing production capacity and capabilities, now incorporating around 800 collaborators.



Figure 1 – Facilities of Leica Camera Portugal in Vila Nova de Famalicão

The company's production process is divided into three main sections. The optical department that crafts precision optical components such as lenses and prisms, the mechanical department that creates high-precision metal parts through machining and surface treatments. And finally, these components are assembled by hand in the assembly department, where optical, mechanical, and electronic elements come together to form the final products.

To support these production sections, Leica incorporates several other essential departments, presented in Figure 2, into its organizational structure, covering various stages of the company's value chain, including research and development, manufacturing, distribution, and customer service. Additionally, Leica maintains stringent quality management practices, holding certifications in ISO 9001 for quality management systems, ISO 14001 for environmental management systems, and ISO 45001 for occupational health and safety management systems.

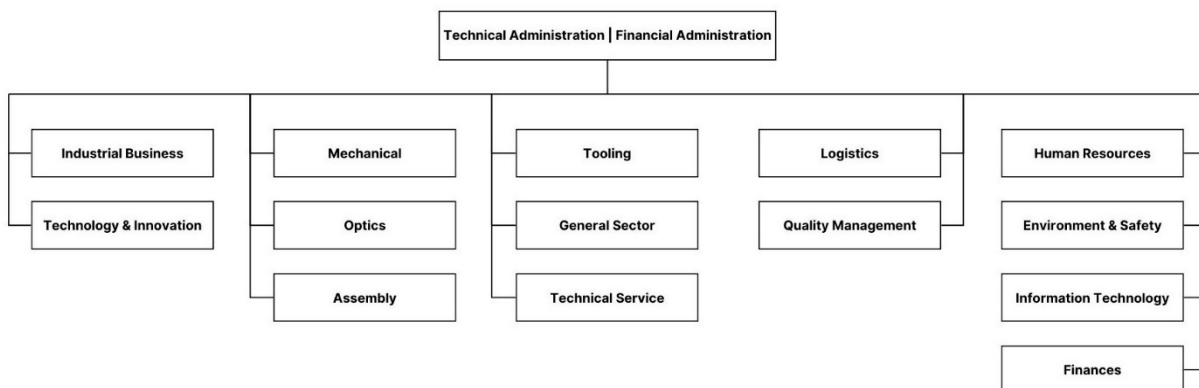


Figure 2 – Organigram of Leica Camera Portugal

Each department is led by a department chief and further divided into teams, each with its own team leader. The project took place within the Strategy team, that is responsible for continuous improvement inside the company, and is embedded in the Quality Management department.

The problem identified within the company pertains to a lack of knowledge, documentation, and standardization in the processes regarding serial numbers. Consequently, this led to operational inefficiencies, and to the problem of serial number duplication, which was previously intercepted inside the company. Addressing this challenge, will streamline operations, enhance accuracy, and mitigate the risks associated with serial number duplication.

1.3. Project objectives

The primary objective of this project is to improve serial number management processes at Leica Portugal, with the overarching goal of enhancing operational efficiency while ensuring customer and industry standards, specifically no duplication of numbers. The following goals are to be achieved by this project:

- **Standardization of Procedures:** Develop standardize procedures ensuring consistency and clarity in operations.
- **Operational Efficiency:** Streamline serial number management processes to minimize errors, reduce costs and time spent performing those tasks.
- **Quality Assurance:** Strengthen quality assurance measures by establishing protocols for verifying serial number accuracy and authenticity throughout the production cycle.
- **Cost Reduction:** Identify opportunities to optimize resource allocation and minimize costs associated with serial number management, ultimately improving the company's finances.
- **Time Optimization:** Minimize the time spent in the processes regarding serial numbers by implementing streamlined processes and efficient workflows.
- **Documentation:** Develop comprehensive documentation on proper serial number management practices, facilitating adherence to standardized procedures and promoting effective workflows.
- **Digitalization:** Implement strategies to provide more readily available information to all stakeholders.

By addressing these objectives, the project seeks to overcome existing challenges in serial number management, ultimately optimizing all processes involved.

1.4. Methodology

This project followed engineering improvements methodologies with emphasis on Business Process Management (BPM) principles. The initial phase involved research of such concepts to create a foundation for process improvement. Subsequently, following an established BPM methodology the current situation for serial number management was evaluated, and improvements were proposed to existing processes to achieve the project objectives. Process modeling was conducted to depict both the current and proposed workflows. Below, in Figure 3, a comprehensive Gantt chart was developed to outline the project timeline and aiding in the planning phase.

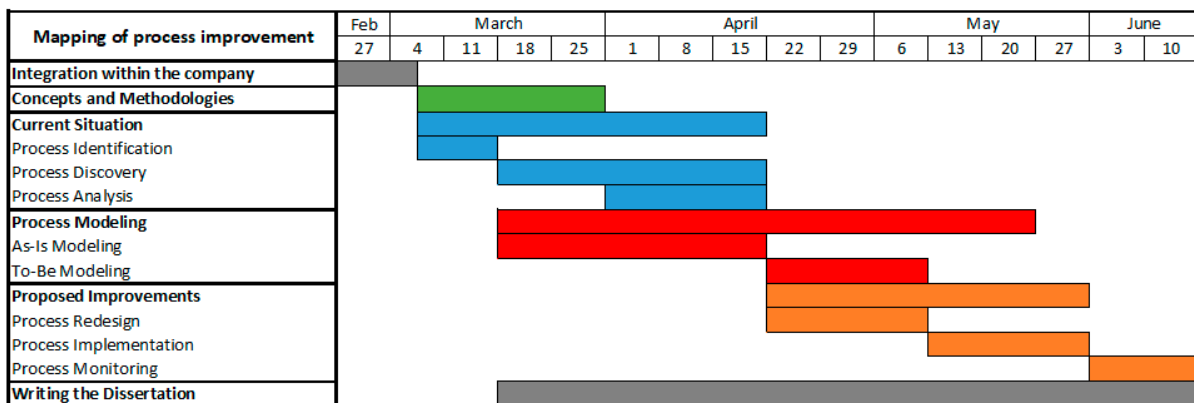


Figure 3 - Gantt chart of the project

Because of the highly functional company with numerous operational components and intricacies, there was an expected need to concurrently execute theoretical research and assess the current situation, by starting process identification and process discovery. This strategic decision was motivated by the constrained availability of stakeholders.

1.5. Structure of the dissertation

The present dissertation is organized in five chapters: 1) Introduction; 2) Literature Review; 3) Current Situation (As-Is); 4) Proposed Improvements (To-Be) 5) Conclusions and prospects for future work.

This first chapter presents the project and the company, while explaining the project motivation, goals, and methods.

The second chapter conveys the literature review with the most important methodologies and tools for the project, while defining key concepts. Highlights the BPM methodology along with the BPM Lifecycle, the BPMN and process modeling techniques and tools whilst illustrating the multi-level modeling.

The third chapter goes through the phases of process identification, process discovery, and process analysis. Through examination and documentation, it unveils the inner workings of the organization operations. The process identification sets the value chain and its boundaries. The discovery phase collects all information necessary to produce the As-Is models for all products. And finally, the process analysis identifies and quantifies the main weaknesses and problems.

The fourth chapter focuses on process improvement by employing the stages of redesigning, implementing, and monitoring. Utilizing the findings of process analysis, it identifies areas for improvement and subsequently redesigns the current state (As-Is model) into an envisioned future state (To-Be model). Follow this the identified changes are methodically implemented into practice, and the ensuing outcomes are monitored and evaluated for effectiveness.

The fifth and closing chapter highlights the main conclusions and suggestions for future work and improvements related to the process scrutinized in this dissertation.

2. Literature Review

In the complex and evolving domain of industrial engineering, the exploration of diverse methodologies and frameworks is pivotal for progress and value addition. An emerging trend involves companies transitioning from traditional departmental structures to process-driven organizations, aiming to improve efficiency and effectiveness of their operation. Companies are increasingly adopting the concept of Business Process Management (BPM) in order to gain competitive advantage and improve their organizational performance (Brajer-Marczak, 2016). By implementing BPM, companies' intent is to optimize their business processes, increase operational efficiency, and effectively respond to changing market conditions.

Through this chapter, the objective is to elucidate the methodology of BPM and its concepts, with emphasis on the BPM lifecycle, while clarifying key concepts that anchor the field such as a hierarchized structure of the process architecture. Modeling will be examined, as a fundamental aspect of BPM, emphasizing its role in process visualization and optimization. The multi-level approach to modelling will guide an in-depth analysis on the structuration of processes. And, Business Process Model and Notation (BPMN) is detailed, offering graphic representation standard for business processes. Lastly, additional tools are included to provide insights into process improvement strategies.

2.1. Business Process Management

Business Process Management assumes a crucial role in improving operational efficiency and effectiveness. It helps organizations streamline their processes, identify bottlenecks, and implement improvements to achieve strategic objectives (Kataev & Bulysheva, 2014). Furthermore, by understanding the interconnectedness of processes, organizations can identify and manage relationships and interdependencies, leading to better overall performance and customer satisfaction (Mustafaev et al., 2020).

The process approach of ISO 9001:2015 defines a process as a set of inter-related or interacting activities that use inputs to deliver an intended result (International Organization for Standardization, 2015). According to Hammer and Champy (2006), in *Reengineering the Corporation: A Manifesto for Business Revolution*, a business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. Also adds that a process main concern are their inputs and outputs, so the means used to achieve results are minor details. For this, the process can be thought of as a box where an input is given, and an output is taken. So, to improve it the focus should be on the end result or value that a process delivers, rather than simply automating or improving individual steps within. This highlights the fundamental elements of a business process, emphasizing the flow of activities aimed at generating value.

In addition, the principles of the methodology according to Hammer (1990) are:

- Organize around outcomes, not tasks;
- Have those who use the output of the process perform the process;
- Subsume information-processing work into the real work that produces the information;
- Treat geographically dispersed resources as though they were centralized;
- Link parallel activities instead of integrating their results;

- Put the decision point where the work is performed and build control into the process;
- Capture information once and at the source.

2.1.1. BPM Lifecycle

The Business Process Management Lifecycle is a structured approach to improving business processes within an organization. The methodology presented is in *Fundamentals of Business Process Management* by Dumas et al. (2018), and it outlines the stages, as depicted in Figure 4, that should be followed for process improvement, and is shown the output of each stage as well.

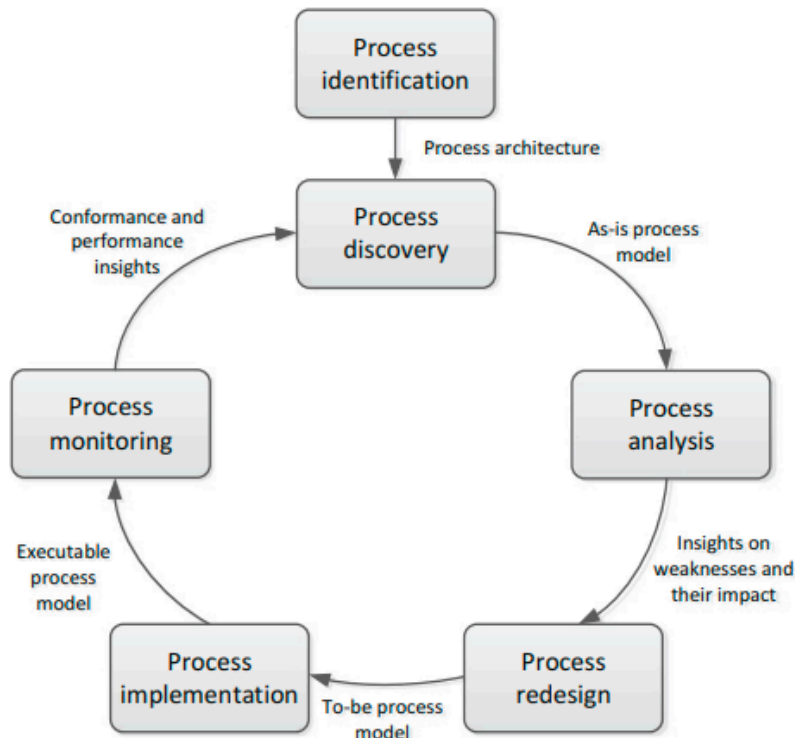


Figure 4 – The BPM Lifecycle
Source: Dumas et al. (2018)

Process Identification

This stage involves clarifying which business processes need improvement. It often starts with identifying operational problems and determining which processes contribute to these issues. The primary goal of process identification is to understand the core activities and workflows that drive organizational operations and deliver value to stakeholders. For this some steps are required: Define the scope and boundaries of the BPM initiative by identifying organizational units, departments, or functional areas involved, and select which individual or groups of business processes are to be examined. Engage with key stakeholders, understanding their perspectives and ensure alignment with organizational objectives by gathering insights into existing processes, pain points, and desired outcomes. For this performance measures should be established. Document the identified processes at a high level, including process boundaries, key activities, and interactions between different process participants. This documentation provides a foundational understanding of the processes and informs subsequent analysis activities. The output of this stage should be a process architecture.

Process Discovery

Is the systematic gathering of information about an existing business process and organizing it into an as-is process model. This involves defining the setting in which discovery of processes

will happen, gathering information, and conducting the modeling of the current situation while assuring the process model quality. Usual challenges involve fragmented process knowledge throughout the organization, domain experts' tendency to focus on case-level descriptions and unfamiliarity with business process modeling languages, requiring process analysts to ask specific questions to extract general process patterns and to translate models into natural language.

The collection of information and the knowledge required to model the process flow and define its rules represents 60% of the time spent on process management projects (Friedrich et al., 2011).

This information can be gathered through different methods such as evidence-based, interviews and workshops. Process Modeling is explained in 2.2.

Process Analysis

In this stage the As-Is process is analyzed to identify inefficiencies, bottlenecks, and areas for improvement. Two types of process analysis can be developed: qualitative such as value-added analysis, waste analysis, root cause analysis; or quantitative like flow analysis using cycle time, queuing theory, and process simulation. The result of this stage should be an organized set of problems, that later can be ranked and prioritized based on their potential impact and estimated effort required to rectify them.

Process Redesign

Also referred to as process improvement since the goal is to optimize performance and align with organizational objectives. For this it identifies areas for improvement within the existing process, analyzing various change options to address the issues previously identified. Ultimately, process redesign and analysis work in tandem, since proposed changes are assessed using process analysis techniques and for areas identified in process analysis, with the most promising transformations being selected and integrated into a revised process. The output of this stage includes a To-Be process model outlining the redesigned process.

Process Implementation

This stage involves implementing the necessary changes applied to the As-Is process by the To-Be process. It entails putting into action the plans and strategies developed during the previous phases, specifically process analysis and redesign. There are two main aspects covered: organizational change management that requires shifts in working practices and automation that requires developed or upgraded IT systems to support the To-Be model.

Process Monitoring

As the name suggests, this stage comprises actions put in place to monitor the new developed process. It collects and analyzes data to assess the performance of the redesigned process and identifies issues prompting corrective action or the commencement of the BPM Lifecycle again, as was shown in Figure 4. This iterative cycle ensures continuous improvement and adaptability to new challenges.

According to Dumas et al. (2018), there are important additional insights to consider:

- **Process Thinking:** Organizations with prior BPM experience may have an inventory of processes and a defined scope, while others may need to identify relevant processes and their interrelations.
- **Performance Measures:** Cost, time, quality, and flexibility, also known as devil's quadrangle, depicted in Figure 5, serve in assessing the current state of processes and as benchmark for evaluating the impact of future improvements.

- **Process Modeling Techniques:** Various tools can be used such as swimlane diagrams, flowcharts, UML Activity Diagrams, and Business Process Model and Notation. It is important to model business processes, as they facilitate understanding and communication among stakeholders.
- **Challenges in Process Redesign:** Process Redesign is a complex task that requires careful consideration of multiple factors. Changes in processes may potentially lead to unforeseen issues and it is important to analyze the impact of proposed changes comprehensively.
- **Organizational Change Management:** Process implementation involves not only technological changes but also organizational change management. It is important to manage stakeholders' understanding and adaptation to new processes through effective communication, training, and transitional arrangements.
- **Continuous Improvement:** The BPM Lifecycle is portrayed as an iterative process, highlighting the importance of continuous improvement. After implementing changes, processes are monitored, and feedback is used to refine and optimize them further, ensuring alignment with organizational objectives and stakeholder needs.

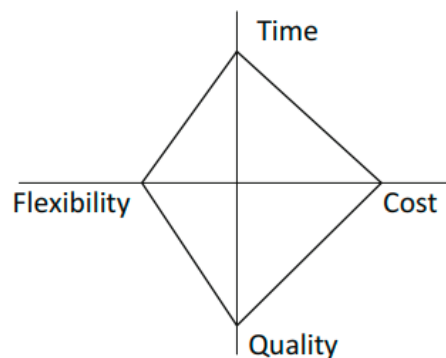


Figure 5 - The Devil's Quadrangle
Source: Dumas et al. (2018)

2.1.2. Process Classification

In this modern business environment, it is hard to get the correct definition of processes without previous planning. According to Sergey Smirnov et al. (2012), processes are complex organizational aspects, inherently distributed with its activities performed by various employees, on different locations, using heterogeneous set of Information Systems (IT) systems. This challenges managers in their efforts to govern or improve processes.

Using the Process Classification Framework® (PCF®), from the American Productivity & Quality Center (APQC), it is possible to define a hierarchized structure representing each level of the process architecture with different levels of detail. This framework also facilitates the identification of possible gaps and overlaps in the structure, contributing for improvement opportunities recognition, efficient management of risk and prioritization and management of daily operated activities (APQC, 2018). In Figure 6 there is a representation of the five levels of the framework, with their definition and practical example.

As previously defined, a process is a set of inter-related or interacting activities that use inputs to deliver an intended result. From this definition it is possible to infer that an activity is in a lower level than the process. And from the framework it is clear that an activity is comprised of several tasks. These tasks are atomic pieces of work, meaning they are not further subdivided into component processes, and that are either carried out in full or not at all (Aalst & Hee, 2022).

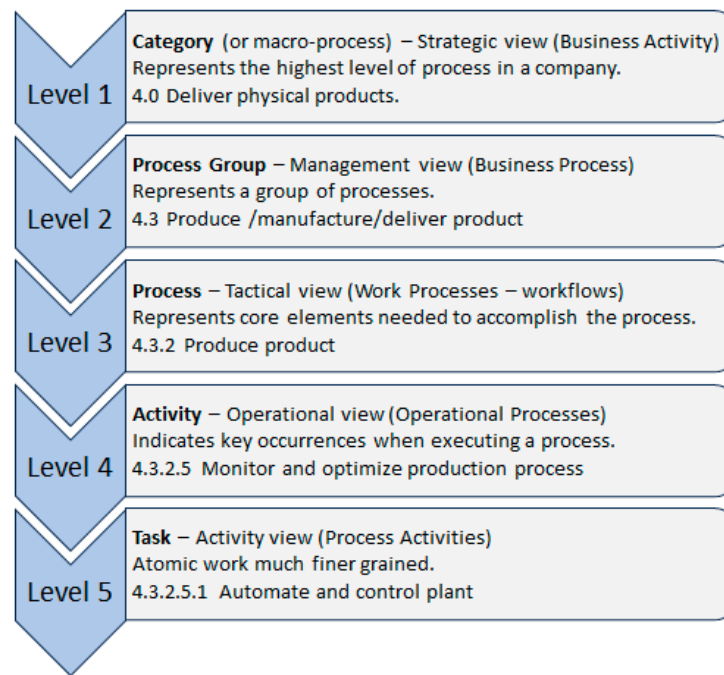


Figure 6 – Process classification framework® levels with definition and example
Source: APQC (2018)

2.2. Business Process Modeling

It is increasingly common to describe organizations as sets of business processes that can be analyzed and improved by methods such as business processes modeling (Melão & Pidd, 2000). It is the approach to graphically display the way organizations conduct their business processes (Indulska et al., 2019). Visual representation serves as a powerful tool for comprehending complex systems and facilitating communication among stakeholders. By translating abstract concepts into tangible diagrams, organizations can streamline decision-making processes, improve collaboration, and align strategic objectives across departments. A process model, representing a true reflection of the business process, is essential to accomplish business process improvement (Damij, 2007).

Business Process Modeling is one of the requirements of the ISO 9000 international standard for quality management and over the years, a lot of research has been done to examine and advance the techniques and tools analysts use to model (Davies et al., 2006).

2.2.1. Responsibility Matrix

Various tools exist to document roles and responsibilities inside an organization, and regardless of the format utilized, the objective is always to ensure that each activity or task has an unambiguous owner and that all team members have a clear understanding of their roles and responsibilities (Project Management Institute, 2013).

A Responsibility Matrix, also called Responsibility Assignment Matrix or RACI Matrix, visually represents the assignment of tasks to individuals or groups, ensuring clarity and avoiding confusion (Jacka & Keller, 2017). Activities are listed on one axis, while the resources (people, teams, or departments) are listed on the other axis, as presented in Figure 7. Each cell of the matrix represents the involvement of the resources in the correspondent activity.

Usually, a convention is used to determine the involvement of the resources, such as the RACI method, a popular variant of the Responsibility Matrix, that specifically defines the level of participation of participation of various roles in completing tasks (Jacka & Keller, 2017).

Project Deliverables	Functional Roles				
	Executive Team	Project Champion	Process Owner	Black Belt	Green Belts
Define Phase	I	C	C	A	R
Measure Phase	I	C	C	A	R
Analyze Phase	I	C	C	A	R
Improve Phase	C	A	C	R	R
Control Phase	I	C	A	R	R

Figure 7 – Example of a responsibility matrix

RACI is an acronym for:

R (Responsible) – person tasked with completing the work, and responsible for executing the activity and ensuring it is done correctly.

A (Accountable) – individual with ultimate ownership of the task, approving the work and ensuring it meets the required standards.

C (Consulted) – individuals or groups who provide input and feedback before the task is completed. Typically, either experts or stakeholders.

I (Informed) – need to be informed of the progress and outcomes of the task, not contributing directly but kept in the loop to ensure transparency and communication.

According to (Jacka & Keller, 2017), a Responsibility Matrix helps achieve clear definition and documentation of roles, which is critical to the success of process execution and improvement. This is done by:

- Clarifying roles, by explicitly stating the level of participation of each person for each task, with the RACI method eliminating ambiguity;
- Improving communication, ensuring that the right people are consulted and informed at appropriate stages of the process, minimizing misunderstandings and errors;
- Ensuring accountability, designating the people accountable for each task, with clear ownership, and helping in tracking progress and managing bottlenecks;
- Facilitating collaboration, by defining consultative roles, with necessary expertise being incorporated into the process;
- Optimizing resource allocation, by mapping out all activities and their responsible parties, managers can better allocate resources, avoid overlaps, and identify gaps in responsibilities.

2.2.2. Swimlane Diagram

The primary purpose of swimlanes is to provide a visual representation of the different roles or departments involved in a process, thereby enhancing clarity and understanding. Swimlane diagrams can be categorized into various types based on the criteria used for partitioning lanes. Common types include functional swimlanes, which organize activities according to functional units or departments, organizational swimlanes, which represent activities based on the roles or positions of individuals, and geographical swimlanes, which group activities by geographical locations or regions (Waterhouse, 2021).

Swimlane diagrams can show business processes from end to end and used in the as-is workflow and to design the to-be workflow. Furthermore, they convey the who, what and when of a business process in simple notation requiring little training to understand and high involvement of stakeholders (Sharp & McDermott, 2001). An example of a swimlane diagram is presented in Figure 8.

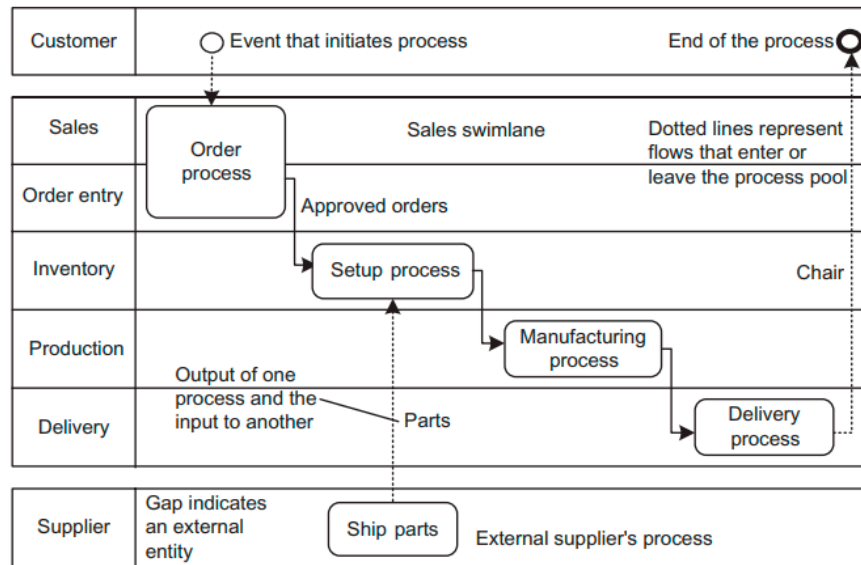


Figure 8 – Example of a sales swimlane
Source: Harmon (2019)

The three main components of these diagrams are:

- Roles
- Activities
- Flows

The swimlane diagram typically consists of horizontal or vertical lanes, each representing a distinct role or participant involved in the process. Roles are the actors who participate in the process and may include departments, teams, individuals, or external stakeholders, depending on the scope of the process being modeled. These actors are represented by departments on the left side of Figure 8.

Activities and tasks are represented within each lane, indicating the specific actions or steps required to complete the process. These activities are arranged sequentially to illustrate the flow of work from one role to another and are shown in Figure 8 in the form of rectangular boxes.

Sequence flow arrows connect the activities, depicting the order in which they are performed and the direction of information or material flow. Feedback loops or decision points also illustrate interactions between roles and facilitate process coordination in defining the path an individual work item will take.

The swimlane diagrams are more efficient in conveying information of a business process to stakeholders than non-swimlane diagrams. Additionally, swimlane diagrams may benefit from including visual clues for external actors, and “handshake” activities such as the “Inventory sends raw materials to Production”, which should be followed by “Production receives raw materials” (Jeyaraj & Sauter, 2014). There are other benefits along with the main challenges of swimlanes in Table 1.

Table 1 – Benefits and challenges of swimlane diagrams

Benefits	Challenges
Improved clarity and understanding	Managing complexity of diagram
Enhanced communication and collaboration	Ensuring scalability as processes evolve
Identification of roles and responsibilities	Maintaining consistency in notation and terminology
Facilitation of process improvement in identifying inefficiencies and bottlenecks	Handling integration with other systems

The best practices for process modeling using swimlane diagrams are:

- Clear and concise layout, with well-defined lanes, activities, and sequence flow arrows;
- Consistent notation and terminology using standardized symbols, colors, and labels;
- Collaboration and validation from stakeholders and subject matter experts;
- Iterative refinement based on feedback received and changes to the process. Continuous review and update is required without over extension;
- Naming convention with verb-noun format without the use of weak verbs like “monitor” or “track” lacking specificity. Instead, it is preferred names like “Take order” identifying the result of the process in “order is taken”.

One challenge in process execution arises during hand-offs between actors, where delays and errors tend to occur, leading to process halts as the next step awaits. Consequently, streamlining these hand-offs becomes a focal point for process re-engineering initiatives aiming to reduce delays and costs. By making the workflow explicit across organizational boundaries, swimlane diagrams serve as the preferred modeling tool for process improvement (Faria, 2021). But in some instances, swimlane diagrams are not the best option such as:

- The majority of activities of the process are executed by the same actor;
- There are many actors that only intervene punctually in the process;
- The flow of the process contains many decision points.

In the aforementioned cases, other Business Process Modeling tools should be applied.

2.2.3. Flowcharts

A flowchart is a formalized graphical representation of a program logic sequence, work or manufacturing process, organization chart, or similar formalized structure (Lakin et al., 1996).

Without constraints of space, flowcharts offer higher flexibility than swimlanes possessing more degrees of freedom, because the graphical elements are similar but with no restriction of lanes representing each actor. Colors can be used to represent each actor (Faria, 2021).

Flowchart modeling offers excellent visibility and understanding for smaller models, but its clarity diminishes as the model increases in size. And, while it provides great flexibility it does not control any gaps which could exist in the process model (Damij, 2007).

This type of modeling is commonly used to show the flow of a process from its start to its end, connecting the main element by lines, leading through a series of steps in the correct sequence order. These main elements are:

- Activities or tasks within a process represented by rectangular boxes denoting a specific action or task that needs to be performed;
- Decision Points are represented by a diamond shaped symbol indicating where a decision must be made based on certain criteria. The process flow must come from only one path but depending on the outcome of the decision, the flow may diverge into different paths;
- Sequence flow represented by lines and arrows connect tasks depicting the sequential order in which they are executed, indicating the direction of the process.

2.2.4. Comparison

In this section it is compared the two techniques to represent Business Process Modeling. Even though flowcharts offer more flexibility and specificity, swimlanes give a broader insight into the participants and activities involved. In Table 2 is presented the main advantages and disadvantages of each model, along with a comparison of purpose, focus, structure, and application.

Table 2 – Comparison between swimlane and flowchart

Aspect	Swimlane	Flowchart
Purpose	Sequence of activities in a process, showing the involvement of different actors.	Flow of tasks, decisions, and information in a process.
Focus	Division of labor and responsibilities among actors or departments.	Sequence of tasks, decisions and data flows highlighting dependencies and interactions.
Structure	Activities depicted within each lane belonging to different actors or departments.	Tasks (rectangles), decisions (diamonds), inputs/outputs (arrows), and connectors (lines).
Application	Process mapping, workflow design, and process improvement initiatives to visualize and optimize processes.	Systems analysis, software development, and BPM to document and analyze workflows and decision points.
Advantages	Easy to understand and assigned responsibilities.	Freedom in disposition of elements and for more complex flows.
Disadvantages	For simpler and linear flows.	Harder to read.

A critical consideration in Business Process Modeling is determining the appropriate level of detail for the model. This involves balancing a high level of detail, capturing intricate nuances but risking over complexity and potentially hinder the model comprehension, with a low-detail model which offers simplicity but may overlook essential elements. The choice between high and low detail is defined by the model's goal. For process improvement, detailed models are required but simpler models are enough to introduce processes to new users (Faria, 2021).

A process model is not as good as the amount of information it includes, but by its clarity and conciseness. Models must align with the audience's needs and objectives. Multi-level models techniques can aid in maintaining clarity while accommodating additional detail.

2.2.5. Multi-level Modeling

It is possible to combine the tools previously presented in Business Process Modeling, leveraging the advantages of each, and diluting their limitations creating a multi-level modeling structure.

According to Dumas et al. (2018), a business process can be defined as a collection of inter-related events, activities, and decision points that involve a number of actors and objects, which collectively lead to an outcome that is of value to at least one customer. This definition references several concepts that will be later presented in more detail.

Also, Michael Porter's *Theory of Competitive Advantage* refers to value what a customer perceives and is willing to pay for (Porter, 1985). Because of this, Harmon (2019) uses value chain as its first level in the multi-level modeling of a business process, representing high-level processes or sets of activities. The value chains selected for analysis are decomposed into major subprocesses, creating a more detailed view of the overall process. These subprocesses may be shown as a value chain as well if they are considered macroprocesses or as swimlanes, representing distinct functional areas or responsibilities. In turn each subprocess can be decomposed into activities and each activity into tasks.

This multi-level structure is represented in Figure 9 with each level offering a progressively detailed view of the business process.

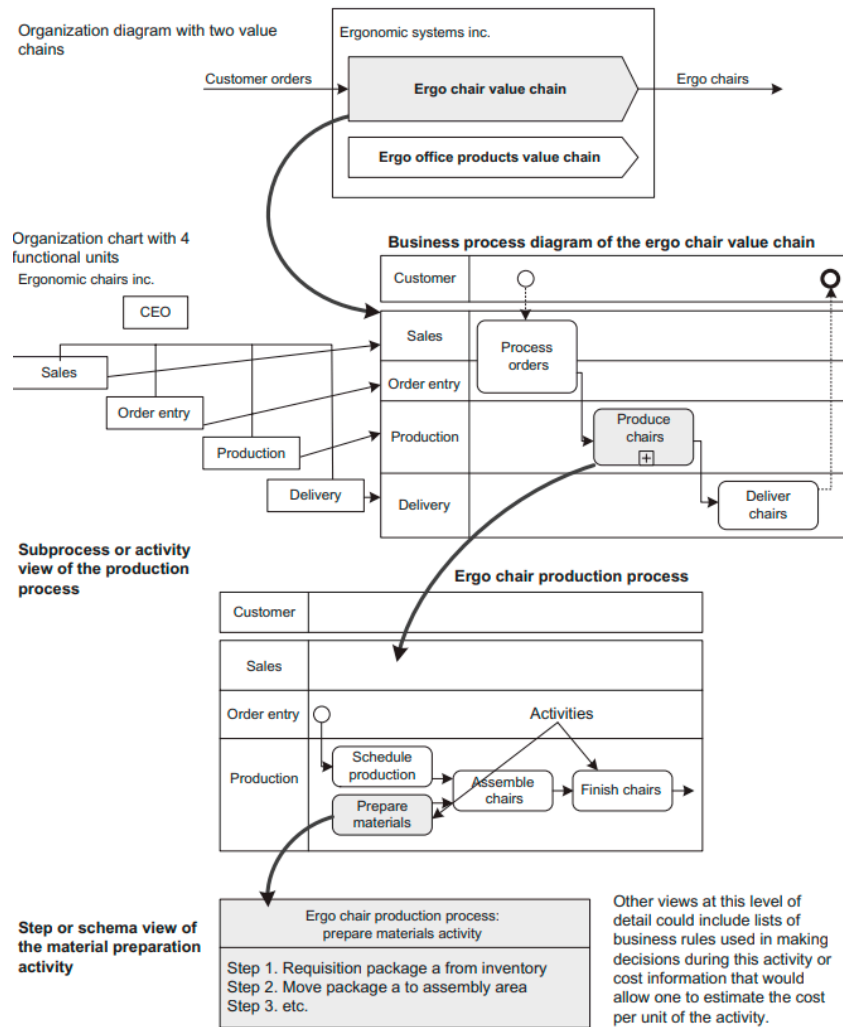


Figure 9 – Multi-level modeling structure
Source: Harmon (2019)

Other multi-level frameworks exist such as the Supply Chain Operations Reference (SCOR) framework of the Supply Chain Council with three levels and the Value Reference Model (VRM) of the Value Chain Group (Harmon, 2019).

2.3. Business Process Model and Notation

The Business Process Model and Notation (BPMN), developed by the Object Management Group (OMG), was created to provide a universal language to business process modeling. The objective was to standardize a notation that bridges the gap between business process design and process implementation, providing a simple means of communication among business analysts, technical developers, and managers (Object Management Group, 2011).

BPMN incorporates best practices from various existing methodologies such as UML Activity Diagram, UML EDOC Business Processes, IDEF, ebXML BPSS, Activity-Decision Flow (ADF) Diagram, RosettaNet, LOVeM, and Event-Process Chains (EPCs).

The primary modeling elements include events, activities, gateways, sequence flows, message flows, and associations which in turn are grouped through swimlanes: pools and lanes.

2.3.1. Elements

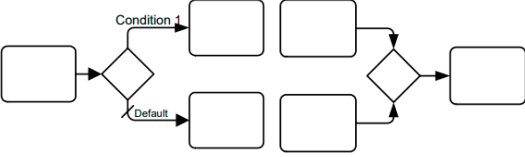
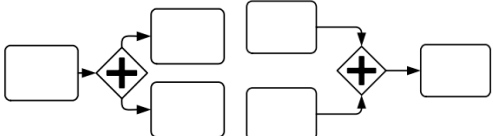
According to Object Management Group (2011) there are five basic categories of elements:

- **Flow Objects:** Main graphical elements including Events, Activities and Gateways;

- **Connecting Objects (Flow):** These elements facilitate the connection between different elements and could be Sequence Flows, Message Flows, Associations and Data Associations;
- **Data:** This category includes Data Objects, Data Inputs, Data Outputs and Data Stores.
- **Swimlanes:** This category involves grouping the primary modeling information using Pools and Lanes;
- **Artifacts:** These elements provide additional information about the process and include Group and Text Annotation.

In Table 3 the most important elements are represented that could be depicted through a business process modeling notation.

Table 3 – BPMN modeling elements

Element	Description	Notation
Event	Happens within a process affecting the flow with a cause (trigger) or impact (result).	 Start  Intermediate  End
Activity	Work performed in a Process. Could be atomic or not, Sub-Process or Task.	
Gateway	Used to control divergence and convergence of flows, determining Parallelism or Decision Points.	 Exclusive  Inclusive  Parallel
Sequence Flow	Used to show the order that Activities will be performed.	
Message Flow	Used to show the flow of Messages between two participants.	
Association	Used to link information and Artifacts.	
Data Object	Provide information of data required or produced by Activities.	
Decision Point Exclusive / Inclusive / Merging	Flow of control can take one or more alternative paths, using gateways. Exclusive – only one path. Inclusive – one or more paths. Merging – combining two or more paths into one (OR-Join).	
Parallelism Split / Join	Dividing one path into two or more (AND-Split) or combining two or more paths into one (AND-Join) using gateways.	
Text Annotation	Mechanism to provide additional text information for the reader.	

2.3.2. Modeling rules

The sequence of processes is depicted by events and activities, which is not linear, so there is a control using splits and mergers represented by gateways. This Flow Objects are connected to one another via Connecting Objects (sequence flows, message flows). This can be observed in Figure 10 but according to Object Management Group (2011) there are additional modeling rules and conventions:

Process Scope

- Identify the who, what, when and why of the process, with the process being the how;
- Determine potential alternative ways to trigger the process using start events and the alternative end states using end events, with flows that end in the same state being merged to the same end event.

Flow Objects

- Activities are executed and formulated actively either automated or manually, whereas events occur and are formulated passively;
- Gateways are used to depict split or merge of flows and do not make decisions, only direct flow. A decision should be determined in an Activity prior to the Gateway. Open and closing gateways should be of the same type to maintain clarity.

Connecting Objects

- Sequence flows indicate the order in which activities are performed and cannot cross sub-process or pool boundaries;
- Message flow show communication between participants of different pools and cannot connect object within the same Pool. This must be modeled across Pool boundaries.

Swimlanes

- Pools: Represent participants that coordinate processes within the pool;
- Lanes: Subdivisions within a pool representing roles, departments, or systems responsible for tasks;
- Each pool should display exactly one complete process, with their span being the entire model width, and height depending on the content inside;
- Lanes should be displayed connected across the entire pool width, and height adjusted to the content.

Diagrams Layout

- Aim is for the diagram to fit in one page;
- Readability should be facilitated by minimizing flow crossing and using consistent layout with horizontal sequence flows and vertical data associations and message flows;
- It should be clear the primary path of the process, avoiding zigzag layouts.

Naming conventions

- Use meaningful keywords relevant to the business;
- Avoid uncommon abbreviations, element types, and articles and pronouns;
- Activities: Name all activities with verb-noun phrases using present-tense active verbs and qualified nouns, ensuring unique names for each activity (e.g., "Approve Request");
- Gateways: Name diverging exclusive gateways with interrogative phrases and do not name converging gateways;

- Events: Name all events using past participles (e.g., “Message Sent”);
- Name pools by the participant’s name not the process name, and lanes by the category name, often representing roles.

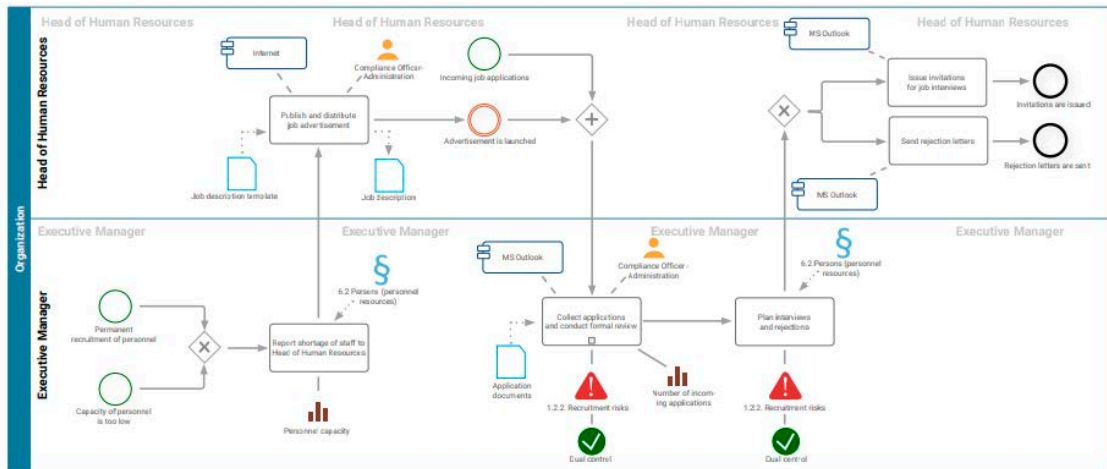


Figure 10 – Example of a process diagram using BPMN

Additionally, hierarchical multi-layered details can be added using extended artifacts such as Roles from an organizational chart, Applications from IT, Norms, Controls, Risks and Performance Indicators.

2.4. Process Implementation Tools

Within the realm of BPM, the pursuit of process improvement is guided by a diverse array of tools, showcasing the flexibility of the methodology, embracing various techniques. Moreover, even these tools exhibit versatility, sometimes serving multiple stages within the BPM Lifecycle.

2.4.1. 5W2H

5W2H is a management and planning methodology with the main objective of developing a clear and efficient action plan. According to (Nagyova et al., 2015) the 5W2H is a method to clarify the problem with the aim of application being to determine the root cause of system failure or occurring problem. Taiichi Ohno, one of the creators of the Toyota Production System, described it as the basis of the Toyota Company’s scientific approach, as an essential item of training in problem solving.

The 5W2H consists of responding to seven specific questions: “What? Why? Where? Who? When? How? How much?”, presented with further explanation in Table 4. The questions never change, applying to all situations, with no limit on the level of detail.

Table 4 – Principles of 5W2H method

	Problem Finding	Action Plan
5W	What is the problem?	What will be done?
	Why is it a problem?	Why will it be done?
	Where is the problem?	Where will it be done?
	Who is impacted?	Who is responsible?
	When did the problem occur?	When will it be done (start and finish)?
2H	How there was a problem?	How will it be done (action steps)?
	How much the problem occurs?	How much will it cost?

The use of this tool can happen in two different stages of problem solving. In finding the problem, investigating in greater detail, and in forming the action plan to solve problems.

2.4.2. Impact-Effort Matrix

The impact-effort matrix is used as an analysis tool allowing an organization to select, prioritize, postpone, and eliminate projects or proposals (Kubiak, 2021). This tool permits each proposal to be assessed against specific criteria with the following rules:

- Proposals appear listed vertically in the first column;
- Select relevant criteria to evaluate the proposals;
- Assign a weight to each criterion, ensuring the total sum is 100%;
- Develop a rating scale to evaluate each proposal against the criteria;
- Rate each proposal;
- Calculate the rank of each proposal using Equation 2.1.

$$Rank_j = \sum_{i=1}^n (Weight_i) (Rating_i) \quad (2.1)$$

The rank scoring is divided into two subtotals, one for total impact, and another for total effort resulting in Figure 11a). The impact is the expected gain to the organization, and the other subtotal is the effort required to execute the proposal. This two-dimensional view proves useful and can be graphed easily such as in Figure 11b), with the projects that require the least amount of effort and yield the greatest impact, that is, provide the most benefit, are the first proposals to be pursued (Kubiak, 2021).

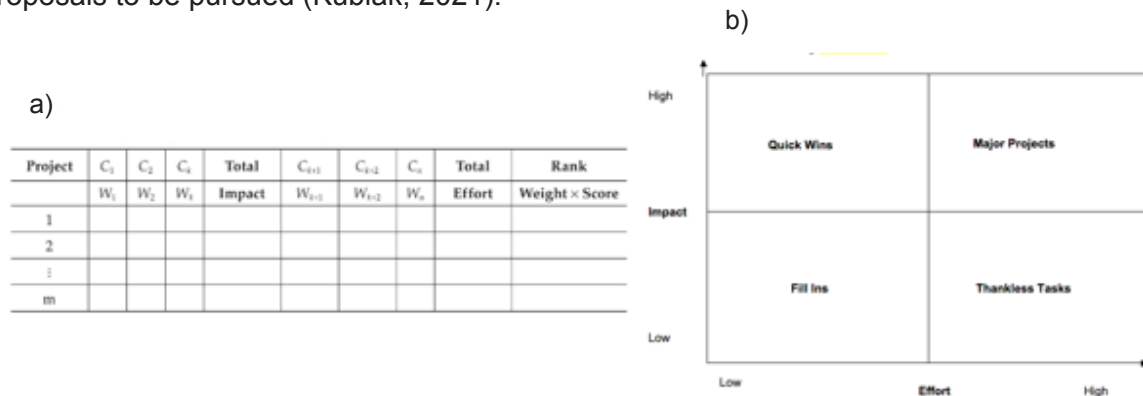


Figure 11 – Impact-Effort a) Ranking, b) Matrix
Source: Kubiak (2021)

Then, it is possible to divide the graphic into four quadrants such as represented in Figure 11b) to better compare all proposals by the dichotomy impact-effort. These four quadrants can be classified as:

- Quick Wins: These are the best proposals, with low effort and high reward, teams should always pursue these solutions first to achieve quick and substantial gain;
- Major Projects: Even though the impact is high, the difficulty is also higher. So, these should be pursued but in a commitment to the long-term goal;
- Fill Ins: Despite the little effort required, these proposals should not be prioritized. Instead, they should be given attention after pursuing better solutions;
- Thankless Tasks: Any project or solution that falls into this category will utilize resources without proportional benefits. These should be avoided if possible or, at the very least, be put at the bottom of the priority list.

Ultimately, the successful use of this tool will allow for better selection and prioritization of proposals.

3. Current Situation (As-Is)

Firstly, utilizing the Business Process Management (BPM) methodology this chapter explores the current state of serial number management at Leica Camera Portugal (LCP), aiming to provide a detailed assessment of existing processes. By documenting these findings, the objectives include gaining a comprehensive understanding of current procedures, identifying areas for improvement, and laying the groundwork for proposed changes. This is done with multi-level modeling and Business Process Model and Notation (BPMN).

This chapter introduces the initial stages of the BPM lifecycle:

- a) **Process Identification**, defining project scope and process architecture.
- b) **Process Discovery**, leading to the creation of the As-Is models.
- c) **Process Analysis**, using the previous discoveries and models to identify inefficiencies and improvement opportunities.

For this, a multi-level model methodology will be developed as is the standard at Leica Camera AG (encompasses Leica Camera Wetzlar and Leica Camera Portugal).

The methodology used is comprised of four levels:

- I. Serial Number value chain;
- II. Serial Number main processes;
- III. Swimlanes of activities;
- IV. Flowchart of an activity.

3.1. Stage 1 - Process Identification

At the beginning of this stage, it was crucial to gather existing documentation and knowledge about the overall process from the Strategy Team, who initiated the project.

The motivation for the project, was to increase digitalization and improve all processes that concern serial numbers in LCP. For this, the starting point was to model the first level, displayed in Figure 12, with the requirements established and understanding the output necessary. This would limit the scope of the project and establish its first boundaries.

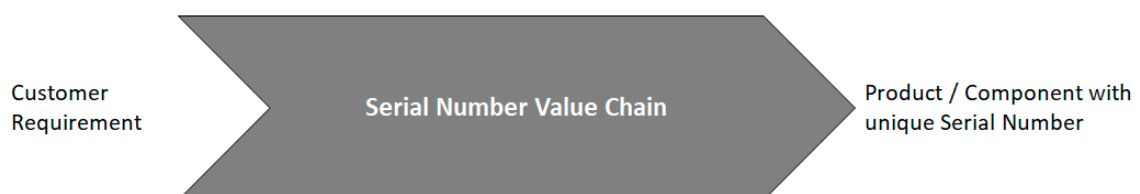


Figure 12 - Serial number value chain

To ensure traceability and meet customer requirements, each Leica product is currently produced with a mandatory serial number consisting of seven digits. It is crucial that every serial number is unique to enable precise tracking of each individual product sold, like the one exemplified in Figure 13.

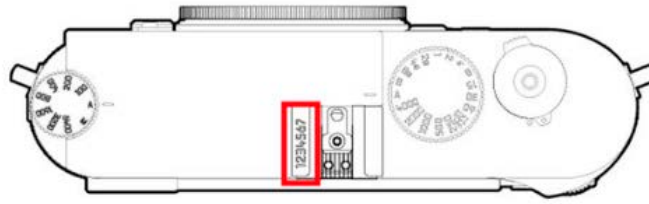


Figure 13 – 7-digit serial number on camera flash support (*hotshoe*) in M system digital cameras

In gaining insight from the Strategy Team, it was possible to understand the stakeholders involved in the project. Specifically, within the context of managing serial numbers, key roles and departments include:

- 1) Serial Number Manager in Leica Camera Wetzlar (LCW), responsible for allocating serial numbers upon request;
- 2) Production does the engraving of serial numbers;
- 3) Assembly, serialized components proceed to the respective assembly lines for the specific product for which they are destined;
- 4) Outbound Warehouse, all products assembled undergo a logistical process, passing through this stage where a final check ensures no duplication of serial numbers before packaging.

From this process flow, three primary processes emerge:

1. Serial Number Acquisition;
2. Engraving Production;
3. Integration and Delivery.

Understanding the roles and interactions of these stakeholders is crucial for ensuring the smooth flow of operations and the integrity of products.

This holistic view provided the foundation for developing the second model, as observed in Figure 14, incorporating the three processes described earlier. Although initially existing knowledge was leveraged to define these processes, further evidence collection was necessary to confirm the assumptions made.

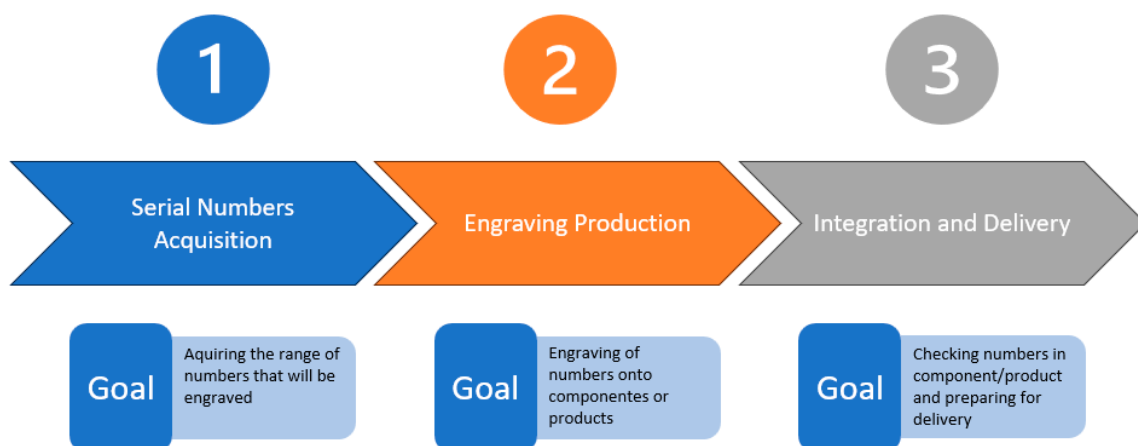


Figure 14 – Serial number business process diagram

In this stage of process identification, the focus lied on defining and delineating the business problem at hand. Processes relevant to the addressed problem were identified and outlined, establishing their boundaries, and understanding their interconnections. This culminated in the creation of a refined process diagram, present in Figure 14, for the Serial Number Value Chain. This architecture serves as a blueprint for selecting the specific processes or sets of processes to manage throughout the subsequent phases of the BPM life cycle.

3.2. Stage 2 - Process Discovery

Building upon the groundwork laid in process identification, the focus shifted to scrutinizing the existing processes within the organization. The primary objective of process discovery, within the BPM lifecycle, is to find inefficiencies, bottlenecks, and improvement opportunities. Mapping and documentation of current processes facilitate decision-making and optimization efforts in subsequent BPM stages.

Now is the time to define all stakeholders involved in the serial number value chain. This was achieved through a series of interviews with all known stakeholders, starting from the outcome of the last process, because all products pass through here before shipping, and work backwards until all triggers are discovered while simultaneously identifying all intermediate inputs and outputs of the processes in Figure 14. These interviews were conducted in the field during a normal day of work making the discovery method applied interview-based but also evidence-based.

3.2.1. Integration and Delivery

The third and final process can be divided into two distinct stages due to the physical necessity for products to transverse separate departments. Starting in the assembly department, where components are assembled into products using their corresponding serial numbers as identifiers. And ending in the logistics department, more specifically the outbound warehouse, where it is made sure that the serial number in each product is unique, and then it is packaged and prepared for delivery.

The term Integration was specifically chosen to distinguish this process from assembly, even though the activities are of assembly the components into its final product and preparing them for delivery.

Outbound Warehouse - Logistics department

The final stage occurs at the outbound warehouse in which all collaborators directly deal with serial numbers, at different *cost centers* (name given for each workstation and not limited by any specific collaborator). All products pass through this site, with or without serial numbers, and can be found in three different forms, representing different stages of their production lifecycle before reaching the finished product state:

- Individual components;
- Final product (for LCP but still undergoing processes in LCW, also called intermediate products);
- Finished products (made in Portugal).

The final product (it will not go under any more changes in LCP) is directly delivered in the first center, not going through any unnecessary transportation or motions, coming from the assembly lines. At this point, the products go through a quality check with the objective of ensuring the uniqueness of each serial number. For this, there is a cabinet full of folders, and each full of adhesive labels (thirteen folders with hundreds of pages and thousands of labels apiece). The folders are divided by family of products and every individual one contains all possible serial numbers for that family. Each label has a unique serial number and a corresponding bar code, and they are printed when a new range of numbers is authorized for engraving by LCW. Most ranges are of two thousand numbers, translating into two thousand labels waiting for their respective product to arrive, and there are labels from the year 2009 and onwards.

This quality check consists of visually corresponding the product serial number to the adhesive label in the folder, and even though these are printed in a serialized manner, the products are not delivered this way, requiring a lot of back and forth between pages of the folder to find the respective labels. These labels are then stuck to the *serial number log sheet*, which accompanies the products and is used to print the labels necessary for packaging, to verify the serial number while packaging, to print the shipping guide and to input the new serial number in *SAP* (enterprise resource planning (ERP) software used at Leica) which is only done after shipping. These activities are represented in Figure 15.

Problems:

- Excessive number of documents are required for verification;
- Certain stored labels are old and very unlikely to be utilized;
- Risk of deterioration of labels over time, leading to missing labels or scanning issues;
- Excessive amount of time in check of serial numbers with folders.

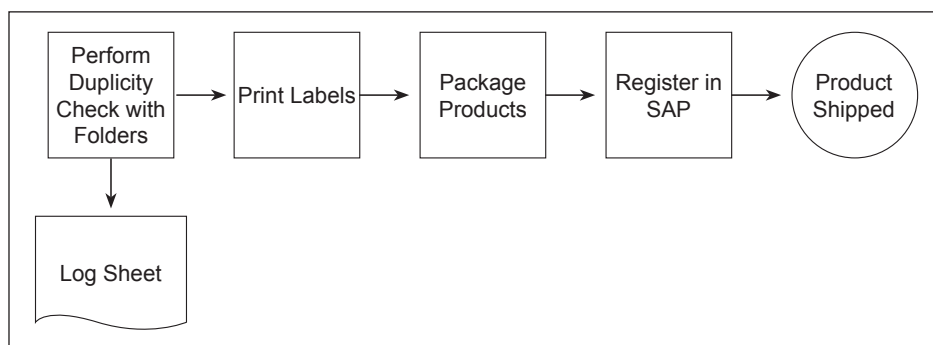


Figure 15 – Integration and Delivery in the Logistics outbound warehouse

In packaging there is a double check, visually corresponding the product serial number to the respective label in the log sheet, serving as an error detection mechanism. However, this check is performed with less diligence, compounded by the limited size of the seven-digit number being inspected, making it challenging to effectively detect any errors from the preceding center, which in turn this same limitation exacerbates the potential of mistakes in the previous check.

At the end of everything, after shipping, using the *log sheet* the products are input in *SAP* by reading each bar code, associating the serial number with their respective product. The shipment is done weekly, every Friday at end of day, but some products are only registered on Monday. This is also the first time the serial numbers are digitized, accessible to all stakeholders, allowing for the registration of any number for any product without detection of errors by *SAP*.

Problems:

- Inaccurate data because of delayed data entry;
- Lack of validation by the system;
- Quality check susceptible to human error.

This part of the final process “Integration and Delivery” is done for all final Leica products of LCP with a serial number, which includes intermediate products and finished products, but not individual components. Finished goods are packed for final customer and sent with serial number labels in the packaging, while intermediate ones are not.

These products can be sent to two locations: to LCW, if they are an intermediate product, or to JAS, the warehouse also in Germany if they are finished packaged products.

There is an exception to all of this: the family of products called Industrial Business, which has the only products in the entire company that will be finished without the Leica logo or brand. This was created recently in an intent to diversify sold goods with already available components. These products are sold to third party companies in a business-to-business transaction and never to individual customers like the rest of the finished products, and because of that, the serial number does not follow any rules of Leica but is instead defined by the third-party company enabling different forms of serial numbers. Another main difference is that products are checked and packaged in the assembly line and are not sent to either JAS or LCW but directly to the corresponding business-client.

The Industrial Business will be dealt individually and not mentioned in some cases.

Assembly lines - Assembly department

Here occurs the first stage of the final process regarding serial numbers where a variety of components are assembled into the final product. This stage falls within the scope of the project as it significantly alters the physical aspect that the serial number identifies, first starting in a small component and ending in a product.

There are seven assembly lines representing seven family of products:

- Sport Optics Range Finding – Binoculars
- Sport Optics Observation – Scopes and Televid
- Sport Optics Observation – Binoculars (Compact and Full Size)
- Camera Digital
- Camera Analog and S
- Industrial Business
- Lenses

Each family has a variety of products and even in each product there can be several models. There was a need to visit every assembly line and interview every product team leader (PTL), and in most cases the process engineer as well. There are only six PTLs because one person encompasses the whole Sport Optics Observation.

At first it was important to find which and how many products fall within the scope of the project, what processes occur regarding serial numbers in each assembly line, and what different variables each possesses such as type of engraving, which component is engraved, where the component is produced, etc.

Types of engraving:

- Laser Engraving (LE) – for non-metallic components;
- Bas-Relief Engraving (BRE) – used in metallic components with the engraving resulting in a small depression of the material as the name suggests;
- Adhesive Label (AL) – for one product (binocular CRF) the serial number, typically engraved, is instead presented on a label, treated as equivalent for project purposes.

Locations of engraving production:

- Mechanical department – possesses laser and bas-relief engravers;
- Assembly department – possesses only laser engraver;
- External supplier.

It was important to note the differences between assembly lines and processes. The main one is that all binoculars and scopes, either for observation or range finding are 100% made in Portugal meaning they are packaged and delivered as finished products, and all cameras

and lenses are made in Germany, their manufacturing is started in Portugal and sent as intermediate product.

In Table 5, it is summarized this information, including the number of models for each product (shown in parentheses).

Table 5 – Product engraving specifications

Product			Production	Type	Component
SO - RF		Geovid PRO (8)	Assembly	LE	Focus Wheel Lid
		Geovid R (4)			
		CRF (2)	External	AL	Body
SO – O	Compact	Monovid (2)	External	LE	Sliding Eyepiece
		Ultravid (8)	Assembly		
		Trinovid (2)			
	Full size	Trinovid HD (4)	Assembly	LE	Focus Wheel Lid
		Noctivid (4)	External	LE	Diopter Scale
		Ultravid HD (8)	Mechanical	BRE	Left Strap Eyelet
	Scopes	Magnus (14)	Assembly	LE	Ocular
		Fortis (14)			
		ER-LRS (3)			
		Amplus (17)			
		PRS (3)			
		Tempus (4)		LE	Body – bottom
	Televid	Televid (8)	Mechanical	LE	Eyepiece Mount
		Okular Vario		BRE	Reference Ring
CAMERA	Digital (6)	M11 (2) - M11P (2) M11 Mono – M11D	External / Mechanical	BRE	Hotshoe
	Analog (5)		Mechanical	BRE	Cap
LENSES	M (5)	2.8/28 – 5.6/28 – 1.2/50 2/50 (2) – 1.4/35 Linz	Mechanical	BRE	Accessory Ring
	SL	35 – 50	Assembly	LE	

For cameras and lenses, specific models are listed, as they are intermediate products and the component with the serial number could be added in LCW therefore falling outside the scope of the project. Currently, this applies to fourteen out of twenty M-Lenses models, as described in Table 5. As for cameras, all models have their *hotshoe* assembled in LCP. The digital cameras section represents the six currently produced models. For analog cameras, the representation includes the five main models, as there are dozens of cameras in total, most of which have been out of production for years.

With the information in the Production column, the source of input for “Integration and Delivery” is already determined.

While acquiring this knowledge, it was crucial to understand the processes involved and the assembly lines workflow. Despite considerable variability in execution, the primary steps adhere to a similar sequence: The components come from production, undergo a pre-assembly (for example, the digital cameras *hotshoe* is added to other components to form the cap), some form of internal traceability is applied (cameras use cards, lenses use a paper called *ID*, binoculars and scopes use labels sometimes placed inside the product), undergo assembly processes until reaching the final product, information is stored in a database and finally, the products are placed in boxes, the count sheet is filled out, and the movement to the warehouse is input in SAP. This is seen more clearly in Figure 16 representative of the digital camera.

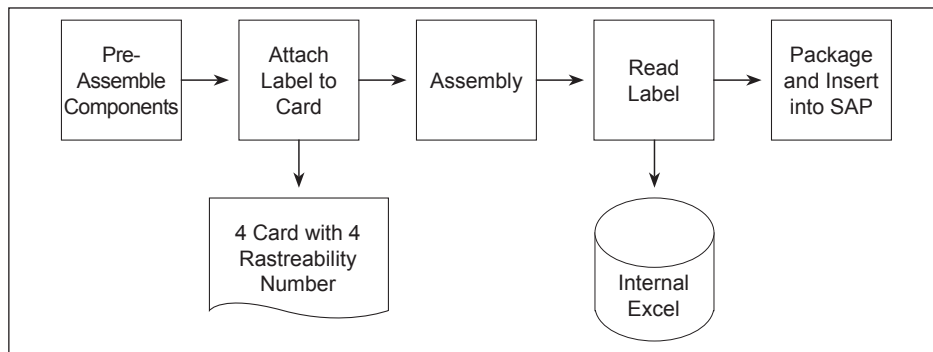


Figure 16 – Integration and Delivery in Assembly for Cameras

The main difference noted is in the lenses assembly line that instead of these five activities, it has seven, because it also confirms the serial numbers with their own folders. The process is then repeated in the outbound warehouse. This will have to be closely looked at in the process analysis stage, and is easily identified comparing Figure 16 and Figure 17.

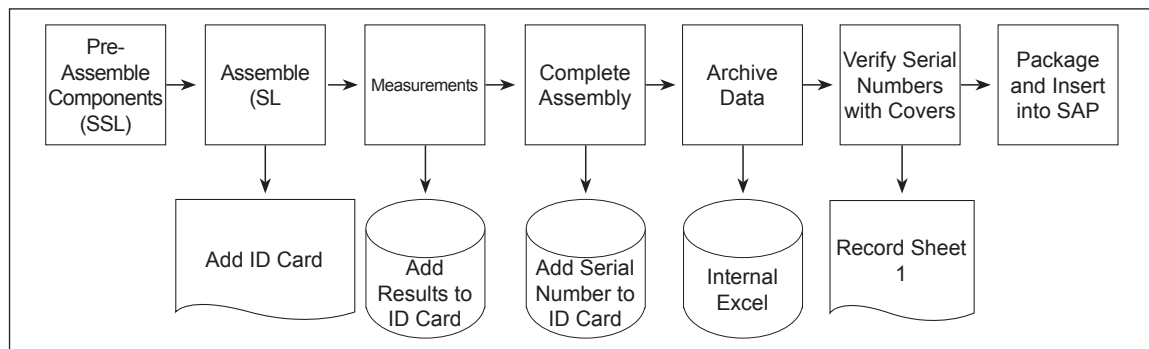


Figure 17 – Integration and Delivery in Assembly for M-Lenses

Problems:

- Repetition of processes;
- Repetition of documents.

Traceability

Serial numbers are used for external traceability, after the product is completely assembled the identifier is the seven-digits. Until then, the serial number only identifies the component in which is engraved. For internal traceability, assembly lines use other numbers and in different fashions:

- Cameras use cards, each card with a label and a data matrix that translates into a reference number stored in an internal database at the end of line. For Digital, the SN is also stored, and there are four cards, one for each of the main components. Analog and S only have one card and do not store the SN;

- Lenses use a four-digit number in ID, and important components are engraved with the week and year of production, adding the SN at end of line to the ID manually;
- Sport optics observation use cards and labels, for scopes and Televid with the serial number added manually to the card at the start of the line, for binoculars only a reference number of the card is used;
- Sport optics range finding use two labels with a data matrix of the serial number, one is placed on a card, the other is placed inside the product.

These cards accompany the product for the whole assembly process, for cameras even going to LCW.

It was decided that the internal traceability falls out of the scope of the project, mainly because it does not use the serial number exclusively and there is no real concern among the assembly lines to ensure the uniqueness of serial numbers per product.

For this reason, the only focus concerning traceability is after the product is finished.

3.2.2. Engraving Production

Within the project, this section serves as a critical juncture where physical alterations are made to components via specialized techniques such as laser engraving, bas-relief engraving, or label application for CRF binoculars. This phase represents the exclusive domain where machinery is deployed for component modification, and is presented in the model of Figure 18, preceding the process of assembly. The resultant output comprises engraved components, laying the foundation for subsequent assembly processes.

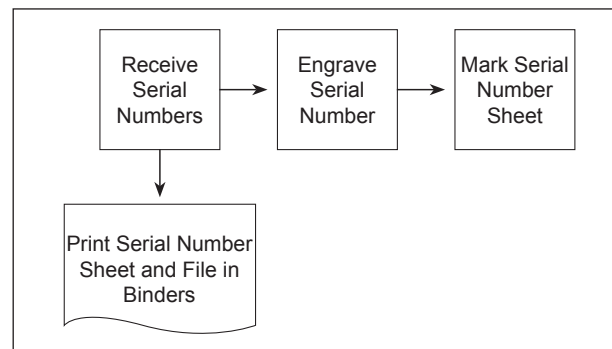


Figure 18 – Engraving Production in Mechanical

Notably, engraving activities are dispersed across three primary locations: assembly, mechanical, and external. In the assembly department, printed sheets containing an extensive array of serial numbers facilitate engraving operations. Each serial number is engraved, with a corresponding barcode label applied next to that number on the sheet. These primarily serve as a reference to track the engraving process and ensure the unique identification of each component. In contrast, the mechanical department employs a similar methodology, substituting the barcode label with an “x” mark denoting the utilization of the respective serial number. However, the operational intricacies surrounding external engraving remain elusive, with our knowledge limited to the involvement of an additional stakeholder – the logistics department’s buyers, who act as intermediaries between LCP and external suppliers.

Problems:

- Lack of standardization in the engraving process.

Now, the remaining aspect in process discovery pertains to the input for engraving production. How production acquires the ranges of serial numbers and the operational procedures governing this acquisition process.

3.2.3. Serial Number Acquisition

This section delves into the acquisition of serial numbers, the procedures in place and differences among departments. Serving as the genesis of the value chain, accurate serial number data is crucial for subsequent operations, and all stakeholders need information about it.

The “serial number acquisition” process can be divided into two stages: first, the request for serial numbers triggered by the needs of production; and second, the transmission of these serial numbers, undertaken by the serial number manager in LCW, which in turn reaches the different interested parties.

Internal Production

In the first stage, when the current serial number range is nearing completion, a request for a new range is initiated. In the mechanical department, the engraver alerts their immediate superior, who then communicates with the department secretary. The secretary, in turn, contacts the serial number manager at LCW, by email. In the assembly department, the engraver directly engages with a specific individual in the quality department. This individual facilitates the request for a new serial number range, as they are perceived to have easier access to the LCW manager. They do so by email as well.

Problems:

- Lack of standardization in the acquisition process;
- Lack of procedures in the acquisition process. More specifically, documentation/information passes through departments unnecessarily;
- The person responsible for soliciting serial numbers is unclear.

The second stage of the process, the transmitting of serial numbers, is started by the serial number manager in LCW, reaching all the interested parties. In the mechanical department, the secretary receives the new range of numbers via email. Subsequently, this information is forwarded to the outbound warehouse to facilitate the printing of new labels. Additionally, the secretary prints new sheets of numbers, which undergo validation by the industrial engineer before being transferred to the engraving station. Meanwhile, in the assembly department, the designated collaborator in the quality department emails the new range to both the outbound warehouse and the engraving station. However, in the warehouse, the process involves not only printing new labels but also generating smaller labels, which are then provided to the engraver. These smaller labels are utilized in the process described in section 3.2.2. Concurrently, the engraver prints the new sheets of numbers to facilitate engraving operations.

External Production

Regarding the engraving process conducted externally, the specific procedures employed remain undisclosed. However, the stages of requesting and transmitting serial numbers persist. This can be done by three separate ways:

- a) External supplier receives the full range of numbers and manages it;
- b) External supplier receives only the numbers corresponding to the quantity of the purchase order;
- c) LCW sends range of numbers directly to the supplier.

This last option is done for the scopes Amplus and PRS and the SL lenses. So, for these products, the “Serial Number Acquisition” is done completely externally to LCP. Option b) is only accomplished for the CRF models. And option a) for the remaining.

Apart from this there are two separate ways, representing two different stakeholders.

One method involves the operational buyer within the logistics department, who can experience both options a) or b) previously mentioned.

For option a) the supplier triggers the process when it reaches the completion of the range of numbers. At this point, the supplier contacts the operational buyer, who, in turn, directly contacts the LCW manager. Once the operational buyer receives the new range, it immediately relays it back to the supplier.

Option b) starts in the operational buyer who upon realizing the need for a serial number for an externally produced component while placing a purchase order with a supplier, directly contacts the LCW manager. Upon receiving the new serial number range, the buyer accompanies it with the new order. As the serial number range typically consists of thousands of numbers and the order quantity is generally only a few hundred components, the operational buyer divides the range into smaller intervals for manageable procurement as needed. Therefore, requests for serial numbers are not made for every purchase order but initiated as needed by the buyer. So, the management of serial numbers is done by the buyer.

Another method of option a), particular for the camera component (referred to as the *hotshoe*), typically produced internally by the mechanical department but is occasionally outsourced, involvement of the logistics collaborator shifts to the strategic buyer for the mechanical department. The strategic buyer dispatches a range of serial numbers to the supplier along with a purchase order, utilizing the entire range received from LCW. Subsequently, the supplier utilizes these numbers as new orders are placed. When nearing depletion of the serial numbers, the supplier notifies the strategic buyer, who then relays the information to the mechanical department, usually to the product engineer initiating the acquiring process within the department. The product engineer further communicates this need to the mechanical secretary. The secretary, in turn, contacts LCW to acquire the new range and sends it to the strategic buyer and the outbound warehouse. In this scenario, the management of serial numbers is done by the supplier.

All this information is discretely categorized by product in Table 6.

Table 6 – Serial number soliciting and management by production department

Production	Solicitor of SN	Process	Products
Assembly	Quality collaborator	Managed by production	Geovid PRO – Geovid R – Ultravid Trinovid – Trinovid HD – Magnus Fortis – Tempus – ER-LRS
Mechanical	Mechanical Secretary	Managed by production	Ultravid HD – Televid Okular Vario – M-lenses Cameras (<i>hotshoe</i> and cap)
External	Logistics Operational Buyer	Managed by production	Monovid – Noctivid
		Managed by buyer	CRF
	Logistics Strategic Buyer Mechanical	Managed by production	<i>Hotshoe</i> for Cameras
	LCW directly		PRS – Amplus – SL-lenses

It is important to note that this process occurs infrequently, typically only a few times a year, due to the extensive range of numbers available, which can last for up to ten years for certain models. For the duration of this project there were only two requests made by the engraver in assembly, one was specifically for the model of the Ultravid binocular, and the last request for that model had been done eight years prior. In the mechanical department there is more repetition but still months or even years apart. This infrequency has led to challenges in the process discovery phase, as sometimes even the involved parties were unsure of the procedures or even if it was within their job description, particularly influenced by changes in personnel since the last acquisition was necessary. Activities of this process are in Figure 19.

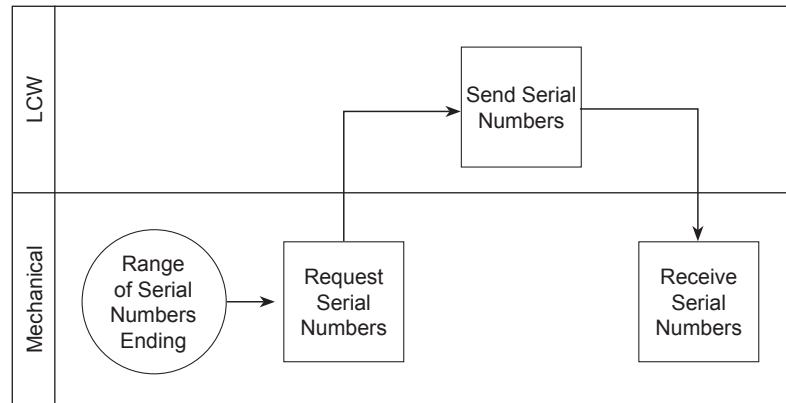


Figure 19 – Serial Number Acquisition in Mechanical

Also, because of the lack of standardized procedures, there was a dependency on the manager in LCW to resolve miscommunications or exchanges of information, this was a problem since it is someone external to the company and added obvious barriers in problem-solving.

Problems:

- Lack of knowledge of the steps necessary to acquire serial numbers;
- Serial number manager is external to the company.

After these discoveries, there was the understanding necessary to define the As-Is model for all different family of products. This is shown in Figure 20. And level III models are available in Annexe A, and level IV models in Annexe C. Some products are combined with others as the process flow and steps taken are the same between them. Other products appear in more than one process flow, as their component can go through different paths, as is the case of the Cameras. Important to note that this Camera component can be produced in the mechanical department or externally, but never in both at the same time. For example, if the *hotshoe* of the Digital Camera M11 Black is being produced in an external supplier, it cannot be produced at the same time internally. But the *hotshoe* for the Digital Camera M11P Black can be produced internally, at that time. And after some time, this can change and the M11 pass to the mechanical department, and even the M11P to the external supplier.

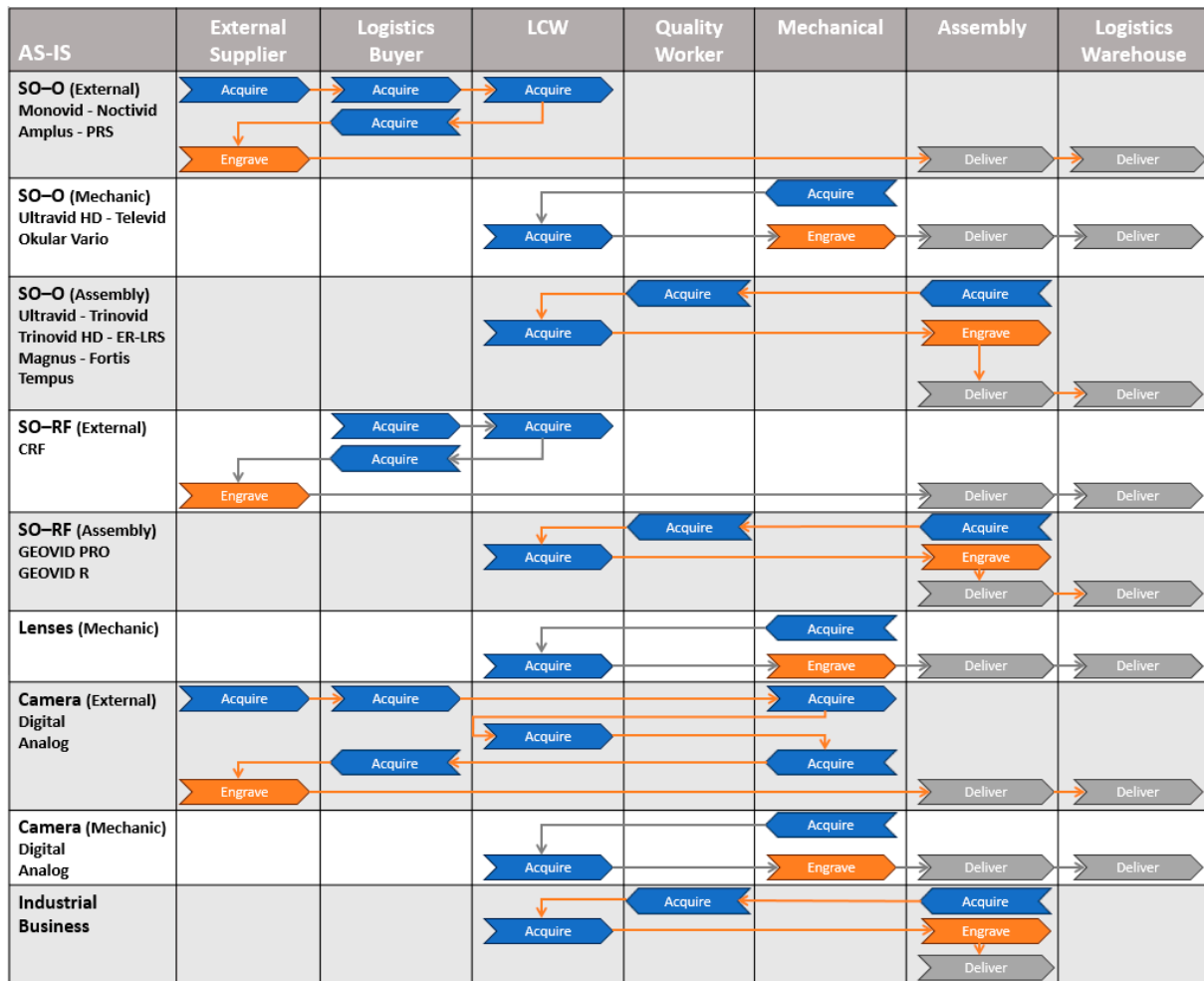


Figura 20 – Serial number process diagram (As-Is) in swimlanes

In conclusion, the process discovery phase has revealed valuable insight into the organization's existing processes, particularly within the Serial Number Value Chain. Through examination, documentation and modeling several challenges have been identified across different departments. Key findings include difficulties in quality checks in the Integration and Delivery process, as well as a lack of standardization and procedures in Serial Number Acquisition and Engraving Production, emphasizing the need for streamlined procedures and improved communication channels. Overall, the process discovery phase provided the As-Is models for all family of products and established the foundation for the current situation, combined with the subsequent analysis will lead to improved performance.

3.3. Stage 3 - Process Analysis

In this phase, the focus shifts towards a deeper examination of the existing processes, identifying key similarities and differences, and where feasible, quantifying the issues in the current state. The outcome of this stage will be an organized compilation of identified issues, and consequent possible actions for improvement, categorized based on their potential impact and the anticipated effort.

With the current situation already established and modeled we can now use different techniques and tools to improve the existing processes. As previously, the starting point will be the high-level models (I and II), with a broader view of the process, and then going into more detail with the lower-level models (III and IV).

Analyzing Figure 20, it is easy to notice that, apart from Industrial Business, all parties go through the same flow of operations in what process number three is concerned, of Integration and Delivery. Components arrive from production and go through two departments, Assembly, and Logistics. In Industrial Business all the same steps occur in the Assembly line.

Another similarity between all families of products is that there is only one main process of engraving. As explained in 3.2.1, this can happen in three different departments: Mechanical, Assembly and in an External supplier.

From this similarity there is an apparent big difference: products engraved externally go through much more Acquisition processes than products done internally.

3.3.1. Serial Number Acquisition

Internal engraving only requires two occurrences of process one if it is managed by the production in the mechanical department. And there are three occurrences if it is done by the assembly department. The reason for this is visible in the swimlanes, as there is one more department intervening in the form of the quality collaborator. This correlates in added waste especially in unnecessary movement and delay of information, as there must be contact between departments physically apart, and the contact is done in person by the engraver and delivered in person by the quality worker. Additionally, there was even no knowledge by parties involved of whom was responsible to acquire the numbers. This is shown in Annexe A and showcases the problems of lack of procedures in the Acquisition process (**P1.1**).

External engraving requires between three and six process occurrences and there are three different groups being engraved:

- Sport-Optics Range Finding (CRF) with three occurrences;
- Sport-Optics Observation with four occurrences;
- Cameras with six occurrences.

The distinctions between these product families were previously outlined in Section 3.2.3. CRF operates on a purchase order basis, with serial numbers dispatched alongside the order to the supplier. In contrast, binoculars and scopes for observation, and cameras, a request is made by the supplier whenever there is a shortage of numbers (**P1.2**).

The CRF swimlane appears to be the leaner version, with only three occurrences of process one. This family functioned similarly to other externally engraved products but transitioned to a new management approach two years prior to this project. The objective was to assume responsibility for managing serial numbers instead of relying on the supplier. This change ensures that the supplier, upon receiving a range of two thousand numbers, delivers the corresponding two thousand components. This process is monitored by the quality department responsible for supplier quality, which checks the first and last numbers in a batch, as components arrive serialized.

Sport-optics observation presents an additional occurrence, totaling four, as the process is initiated by the supplier rather than the logistics buyer. The process is ongoing, with the supplier requesting more numbers as needed. This can pose challenges, as there is no control over whether the range of numbers sent matches the number of components received (**P1.3**).

For cameras, the process is similar but there are even more occurrences, totaling six, due to extensive back-and-forth interactions. The process flow begins and ends with the supplier, passing through the logistics buyer, LCW manager, and the mechanical department (**P1.4**). Further details were provided in Section 3.2.3. These added steps are unnecessary since the reason given for them is that the mechanical department needs to have this information to be prepared when production comes back internally. But these ranges of numbers are never

shared, and components cannot be engraved externally and internally at the same time. If the component stops being produced in a supplier at that moment, the supplier saves that range for the eventuality of that component comes back in production. And when that component starts to be engraved internally, the mechanical department just asks for a new range of numbers. This is also the case for suppliers that stopped completely the process of engraving serial numbers. The last range is still saved there (**P1.5**).

The processes for sport-optics observation and cameras demonstrate a higher frequency of operational challenges in comparison to CRF. Issues such as inadequate control mechanisms and superfluous intermediary steps increase the risk of losing or not utilizing all numbers efficiently. Conversely, the CRF workflow exhibits a more streamlined and efficient structure. Consequently, transitioning the remaining product lines to adopt a similar operational model to the CRF holds promise for substantial process improvement.

Another problem encountered is that the serial number manager in LCW, being an external entity, struggles to resolve internal miscommunications (**P1.6**). This is particularly problematic when the assembly line requires serial number information, such as for sport-optics range finding. The external manager lacks the ability to identify who is requesting the serial numbers and cannot exercise critical judgment, often providing the information indiscriminately. Additionally, there is a lack of established procedures for requesting serial numbers. The parties involved are unaware of the necessary information and must rely on feedback from one another, specifically from the external manager on what is required to acquire a new range of numbers, particularly model and reference number, leading to delays and further inefficiencies (**P1.7**).

All problems of this process are comprised into Table 7, with the affected parties by departments. In Annexe E there is additional information with consequences of these problems.

Table 7 – Problems in the Serial Number Acquisition

ID	Problem	Parties Involved
1.1	Not clear who contacts LCW in Assembly	Assembly
1.2	External supplier manages their own numbers	Logistics/Supplier
1.3	Lack of control over numbers sent from external supplier	Logistics/Supplier
1.4	Unnecessary steps for subcontracted engraving	Logistics/Mechanical
1.5	Lack of control over numbers sent to subcontracted engraver	Log. /Mec. /Sup.
1.6	Serial number manager is external to LCP	All
1.7	Lack of procedures in requesting serial numbers	All

3.3.2. Engraving Production

Analyzing Figure 20, it is easily understood that for each swimlane, there is only one occurrence of the engraving process. To fully comprehend the intricacies involved, deeper examination is required and specifically analyze level III in the Annexe A.

One of the problems identified is the lack of standardization in the engraving process between departments. For instance, the assembly department places a label with the number next to the engraved number, whereas the mechanical department simply marks it with an 'x'. This

inconsistency leads to confusion and potential errors. Particularly since that during this project an engraving machine broke down, in the assembly department, passing the production to temporarily to the mechanical department, being done by mechanical collaborators but using assembly engraving procedures (**P2.1**).

Furthermore, the mechanical department starts engraving a new batch by leaving the first two numbers blank, which creates gaps in the serial numbering system. This practice complicates the tracking of components but mostly leaves numbers unused and shows lack of procedures since there is no specific reason for this (**P2.2**).

Lastly, there is no procedure for reusing serial numbers when a component is no longer used due to quality issues or other reasons. This lack of standardized approach is troublesome for the internal tracking within production departments. For special series, unused components must be destroyed, and their numbers reused, as the range of numbers is predefined for that series. However, in serial production, the component is merely substituted with a different one, causing the original number to be lost and disrupting the numbering system (**P2.3**).

All problems of this process are comprised into Table 8, with the affected parties by departments. In Annexe E there is additional information with consequences of these problems.

Table 8 – Problems in the engraving production

ID	Problem	Parties Involved
2.1	Lack of standardization in engraving	Assembly/Mechanical
2.2	Lack of procedures in Mechanical	Mechanical
2.3	Lack of procedures for substituting components	Assembly/Mechanical

3.3.3. Integration and Delivery

For this process, level II is also the same for all swimlanes apart from Industrial Business where the whole process is done in the assembly line. For all others, there is an instance in the line and in the logistics warehouse. Analyzing the subsequent levels differences are encountered.

There is a difference in serial number handling. Finished and intermediate products are treated differently in logistics. Finished products (Sport Optics) are sent with serial numbers in the shipping guide while intermediate (Cameras and Lenses) are not, where only the quantity is important to fulfill the purchase order. This does not justify the same activity using the folders and labels being done previously for both finished and intermediate products since for these last ones is not necessary (**P3.1**).

Additionally, while finished products are inserted into SAP on the same day as shipment, cameras and lenses are inserted the following week due to time constraints to do everything on shipment day by the logistics department. This problem is exacerbated if the purchase order of logistics does not match the production planning of assembly leaving a small number of products in inventory in the logistics warehouse. So, the serial numbers inserted in SAP are not the products sent but the quantity sent choosing numbers at random, leaving the rest of the numbers to be inserted later, matching the quantity in inventory (**P3.2**).

Also, this is the first time that any serial number is inserted into a system available to all parties of the company (**P3.3**). And, any number can be manually linked to any model, when there are already predetermined ranges for each model (**P3.4**).

Analyzing the control check in the logistics department it is clear that it relies heavily on physical documentation and manual checks, using large folders of adhesive labels (**P3.5**).

This is time-consuming, with documents deteriorating over time, leading to issues with missing or unreadable labels. Additionally, the quality check involves visual inspection and manual matching, which is prone to human error (**P3.6**).

Now, analyzing the level III swimlanes in Annexe A, there are also differences in each assembly line.

Each assembly line utilizes traceability cards that accompany each product during the assembly process, with for each card being assigned a unique identifier number. However, only for Sport Optics Range Finding the serial number is used as that identifier, and is accompanied by a data matrix of that number. In some products within the Sport Optics Observation line, the serial number is manually inserted into the card during assembly. For all other products, preassigned numbers are used for card identification.

In the digital cameras assembly process, four cards are utilized, and the numbers on each card are stored in a database and matched with the product's serial number at the end of the line. For analog cameras no serial number is matched or stored. As for the lenses, the serial numbers are manually inserted into the card at the end of the line.

It is crucial to note that for cameras and lenses, in case of problems requiring inquiries of the assembly process and traceability is needed, only the card numbers are used, and not the serial number of the product. This introduces complexities in tracking and confirms that the activities performed in logistics for these products are not necessary.

For Lenses specifically, there is a noticeable duplication of activities and documents, which not only wastes time but also fails to ensure additional safety in serial number quality. This redundancy occurs because the lenses assembly line uses its own folders filled with labels and conducts its own control procedures creating a serial number log sheet before sending products to the logistics department for shipping. The following week, the logistics department requests these log sheets and proceeds to create their own log sheets so they can archive one later return the others to the assembly department, that also archives it. With further analysis it was understood that this archive was assumed to be necessary by the parties involved but ultimately not used for anything. For some sets of lenses logistics merely photocopy the assembly log sheet, resulting in unnecessary document duplication (**P3.7**).

All problems of this process are comprised into Table 9, with the affected parties by departments. In Annexe E there is additional information with consequences of these problems.

Table 9 – Problems in the Integration and Delivery

ID	Problem	Parties Involved
3.1	Performing same activities for finished and intermediate products	Logistics
3.2	Delay in inserting products shipped into SAP	Logistics
3.3	Lack of previous integration of serial numbers into system	IT/Logistics
3.4	Any number can be manually linked to any model	IT/Logistics
3.5	Control relies on large physical documents (folders)	Logistics/Assembly
3.6	Control relies on visual inspection and manual matching	Logistics
3.7	Duplication of activities and documents between departments	Logistics/Assembly

4. Proposed Improvements (To-Be)

Transitioning from the analysis of the current state process, this chapter focuses on proposing specific improvements for serial number management at Leica Camera Portugal (LCP). For this, and continuing leaning on the Business Process Management (BPM) methodology, the three subsequent stages of the BPM lifecycle are followed:

- **Process Redesign**, leveraging insights from the As-Is process models to redesign existing processes for better efficiency. The To-Be models are developed to reflect optimized workflows and resource allocation, addressing the identified problems.
- **Process Implementation**, by putting into practice the proposed changes. This involves assessing existing limitations to execute the redesigned process, conducting training sessions for collaborators, engaging stakeholders, and managing change effectively to ensure smooth integration of new workflows.
- **Process Monitoring**, comparing the performance measures utilized to gauge the redesign effectiveness, and the impact of the changes made. And identify areas needing further improvement.

4.1. Stage 4 - Process Redesign

Process redesign is crucial for addressing issues found in the previous stage of Process Analysis. For this it is important to consider the Devil's Quadrangle, which highlights the four key performance dimensions of time, cost, quality and flexibility, when an improvement is proposed. Then translating these solutions to diagrams results in the To-Be models, following the same multi-level modeling of four levels to facilitate the visual comparison of the previous process and the proposed new one.

The principles of BPM facilitated the proposals of improvements present in Table 10, Table 11 and Table 12 for the different processes.

For P1.1, there is a lack of clarity about who requests the serial numbers from LCW, in Assembly. This can be addressed by defining a clear point of contact, but organizing around the outcome necessary which is having the serial numbers for engraving, having the person who uses the output of the process to perform the process, so those who are directly involved manage the process, but building control into the process, reducing workflow complications. These same principals apply for P1.4, where if the person who uses the output of the process performs the person, there is an elimination of steps which do not add value.

For P1.2, P1.3 and P1.5, there is a lack of control over components that are engraved externally. There should be control built into the process which is accomplished by assuming internally the management of the serial numbers, allowing also to capture information once and at the source when the components arrive, and it is possible to confirm the quantity matches the serial numbers sent.

For P1.6, the current process involves an external serial number manager, leading to delays and difficulties in resolving issues when they occur. By bringing this function in-house, LCP can put the decision point where the work is performed and build control into the process, ensuring quicker decision-making and better control, and have those who use the output of the process perform the process.

For P1.7 the lack of procedures creates miscommunications which is exacerbated by P1.6. For this, it is important to implement clear guidelines for the process of serial number acquisition, accomplished by the centralization of real-time information readily available to all stakeholders.

Table 10 – Proposed Improvements for Serial Number Acquisition

Problem	Proposed Improvement
1.1-Not clear who contacts LCW in Assembly 1.4-Unnecessary steps for subcontracted engraving	Define contact with serial number manager
1.2-External supplier manages their own numbers 1.3-Lack of control over numbers sent from external supplier 1.5-Lack of control over numbers sent to subcontracted engraver.	Assume management of SN engraved externally
1.6-Serial number manager is external to LCP	Bring serial number management to LCP
1.7-Lack of procedures in requesting serial numbers	Implement guidelines for requesting serial numbers.

For P2.1, there is a lack of standardization in the engraving process with different steps being followed by different departments. An improvement would be to choose the best practice and standardize but additionally there should be a capture of information at the source and subsume information-processing work into the real work that produces the information. Also, since the physical engraving is performed at this stage this is where the control should be applied and not in later stages.

For P2.2 and P2.3 there is a lack of procedures resulting in numbers not being used. This will be particularly troublesome for the products of Sport Optics Range Finding being the only family of products that uses the product serial number for internal traceability. Initially the engraving process was performed in the Assembly department but because of a malfunction in the engraving machine, it started to be engraved in the Mechanical department using Assembly procedures, thus using all numbers. But the decision taken is to maintain this engraving production in the Mechanical department assuming their own procedures resulting in numbers not being used and complicating the traceability of products in the assembly process, confirmed by the Product Team Leader (PTL).

Table 11 – Proposed Improvements for Engraving Production

Problem	Proposed Improvement
2.1-Lack of standardization in engraving between departments	Standardize process
2.2-Lack of procedures in Mechanical 2.3-Lack of procedures for substituting components	Create procedures to use all numbers

For P3.1 and P3.2, the same activities are performed in Logistics to check serial numbers for both finished and intermediate products. This is inconsistent because for intermediate products the check is not complete since the product goes through additional assembly in LCW and the component or product can return to LCP if there is a problem and pass through the same activity without check, because there is no label in the folder anymore (the number is written in the *log sheet*). Additionally, the products sent are inserted in *SAP* associating the serial numbers which for finished products is done in the day of packaging. But for intermediate ones it is only done the week after shipping, and since the serial numbers are not used for traceability but the numbers in the traceability cards that accompany these products to LCW, this information of serial numbers in *SAP* is not utilized by any stakeholder. An improvement is to start treating

finished and intermediate products differently by organizing around outcomes and not tasks.

For P3.3 and P3.4 there is a lack of control by the ERP system apart from the moment of expedition, and in that instance any number can be associated with any product model. This can be prevented by creating lists of numbers for each model in a previous point of the process, which builds control, and the decision point should be where the work is performed and particularly the information-processing work should be subsumed into the real work that produces this information.

For P3.5, reliance on physical documents for control proves inefficient as it occupies space, creates inventory, and makes the task time-consuming. Also, there are possible errors associated as the labels in the folders are considered as proof that that serial number was never expedited, this creates a duplicity check if the number is passing for the second time and there is no label but because of the physical documents, some labels can start to peel off and fall. The proposed improvement is to use a label placed previously in the process, that accompanies the product through assembly, and it could continue to accompany it into the Logistics department. This focuses on the outcome rather than the task performed and subsumes information-processing work into the real work.

For P3.6, manual vision inspection and matching are time-consuming and prone to human error. Automating the quality control checks of the serial number before expedition would improve accuracy and efficiency, by building control into the process.

For P3.7, duplicating activities, and documents between the departments of Assembly and Logistics for the Lenses with serial numbers creates inefficiencies and increases the risk of errors. By eliminating repeated activities, the organization treats geographically dispersed resources as though they were centralized, improving coordination, and links parallel activities instead of integrating their results, ensuring that the efforts of different departments are synchronized.

Table 12 – Proposed Improvements for Integration and Delivery

Problem	Proposed Improvement
3.1-Performing same activities for finished and intermediate products 3.2-Delay in inserting products expedited into SAP	Treat finished and intermediate products differently
3.3-Lack of previous integration of serial numbers into system 3.4-Any number can be manually linked to any model	Create lists of ranges of numbers for each model
3.5-Control relies on large physical documents (folders)	Label placement previously accompanying the product
3.6-Control relies on visual inspection and manual matching	Automate quality control checks
3.7-Duplication of activities and documents between departments	Eliminate repeated activities

All these proposals considered result in the redesigned process. Because of greater standardization, the level II model, present in Figure 21, and level III models in Annexe B, are now only divided into three groups, which classify where the serial number is engraved onto the product, either externally, in the Mechanical, or Assembly departments. Additionally, key activities are further deepened into level IV models in Annexe D, where process improvement is visually clear.

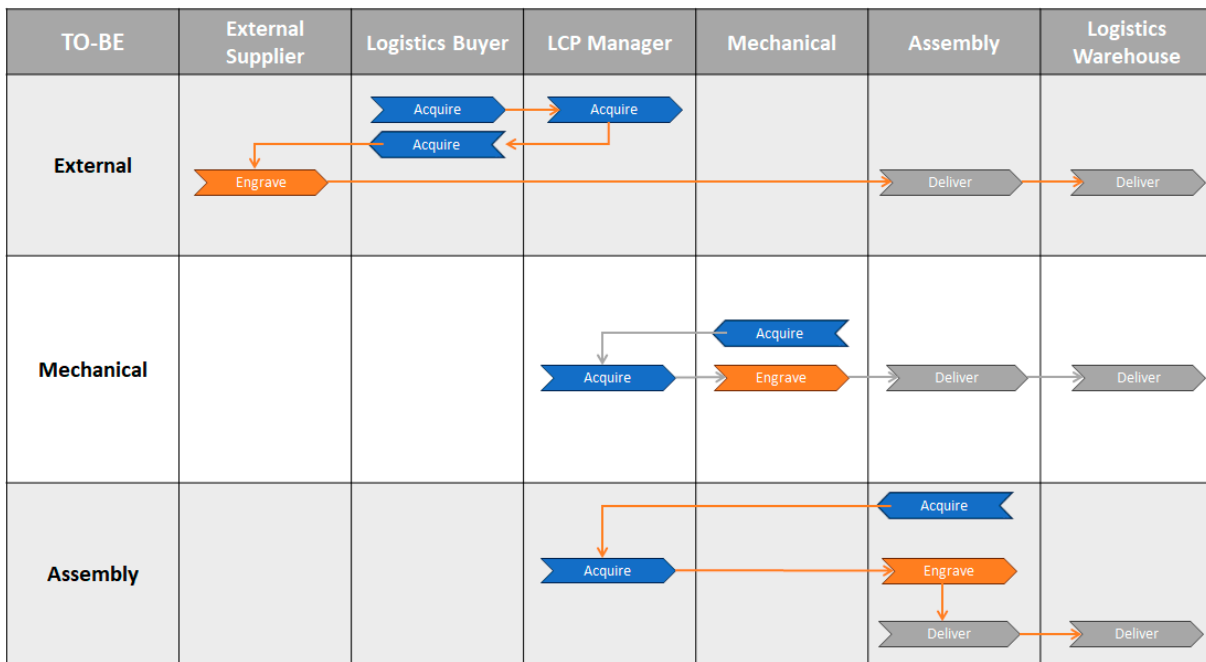


Figure 21 - Serial number process diagram (To-Be) in swimlanes

4.2. Stage 5 - Process Implementation

Process Implementation is a critical phase where theoretical proposals and redesigns of processes are transformed into actionable steps. The primary goal is to translate the To-Be process models into real-world operations. For this, organizational change management plays a pivotal role in the success of this stage. It involves preparing the affected areas for change, managing resistance while fostering a culture of continuous improvement, as the collaborators are the ones doing the actual tasks, and for this have greater knowledge and a big weight in the success of the proposals implemented. So, an effective communication strategy is required to ensure that all stakeholders are informed, capable, and engaged throughout the process.

The implementation phase is not a one-time activity but an iterative process. For this reason, continuous monitoring and feedback mechanisms are established to assess the performance of the new processes, which is aligned with the BPM lifecycle.

4.2.1. Impact-Effort Matrix

To initiate the process implementation a qualitative study was conducted to assess the expected effort and impact of the previous proposals. The setting relied on a workshop among the Strategy team where the proposal was presented and a classification between one and nine was attributed for each proposal of both variables: expected effort to implement, and the possible impact in a positive manner to the organization, using the Devil's Quadrangle as guide.

In Table 13 all proposed improvements are represented with their respective classification for expected effort and impact on the company.

Table 13 - Classifications of effort and impact for each proposed action

Proposed Action	Effort	Impact
Define contact with serial number manager in Assembly	3	2
Direct contact with serial number manager eliminating unnecessary steps	1	3
Assume management of external engraving sending SN with Purchase Order	4	3
Create LCP serial number manager	6	6
Create procedures to use all numbers in Mechanical	2	2
Create lists of ranges of numbers for each model	2	3
Label placement previously accompanying the product	4	6
Automate quality control checks using a virtual vision camera	9	9
Eliminate repeated activities	1	9
Create a platform centralizing and controlling all information of serial numbers	5	7
Platform (Process 1 – Serial Number Acquisition)	3	3
Platform (Process 2 – Engraving Production)	4	7
Platform (Process 3 – Integration and Delivery)	4	7

The results of the workshop were used to categorize the proposed improvements into the four quadrants of the impact-effort matrix: Quick Wins, Big Projects, Fill-Ins, and Thankless Tasks. This classification helps to prioritize the proposed actions based on their feasibility and expected benefits, and can be seen in Figure 22.

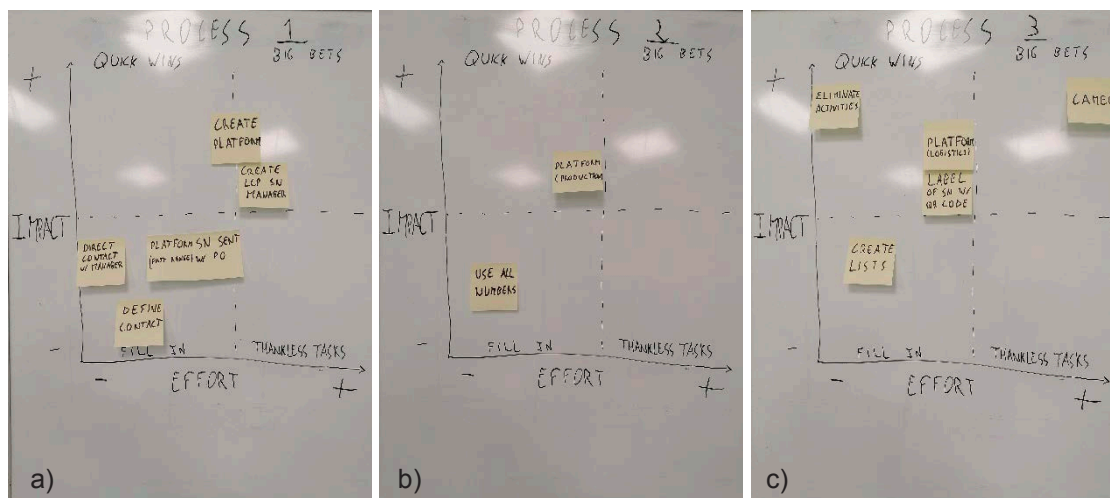


Figure 22 - Impact-Effort Matrix of proposed actions for a) Serial Number Acquisition; b) Engraving Production; c) Integration and Delivery

The first two proposals are about defining the contact for the serial number management, but it was better to separate them since they affect different departments and procedures.

The biggest project is the utilization of a virtual vision camera to perform the quality check regarding serial numbers. This would have great impact as it eliminates the human error fully automating these checks, and with other applications, but it would require a great effort as well in the form of a financial investment of ten thousand euros, according to one vendor.

The proposal to create procedures to use all numbers is solely evaluating the procedure of not using the first two numbers in the engraving process in the Mechanical department. This procedure discovered to have a greater impact than anticipated after the workshop. However, this proposal does not include creating procedures to use all numbers, as some components, due to non-conformities, are eventually not used in any products and are discarded, but the number is not reutilized. The company, at this moment in time, evaluates the effort required not worth the potential impact and particular risk of engraving a different number and the possibility of having two products with the same serial number. For this reason, the proposal to resolve those problems was eliminated at this stage.

Additionally, one major proposal was added to create a platform centralizing and controlling all information of serial numbers affecting all three main processes of the value chain. This is divided into four proposals: the creation of said platform, and the integration of the platform into Processes one, two, and three.

The proposal of process one to implement guidelines to request serial numbers and of process two to standardize the engraving process are included in the proposal regarding the Platform.

4.2.2. Action Plan

Now, an action plan is designed to address the identified problems and subsequent proposals for improvement. Utilizing the 5W2H tool, the plan offers clear guidance on necessary actions. The aim of this pragmatic approach is to translate theoretical analysis and redesign into practical steps, which are implemented, monitored, and follow the continuous improvement cycle continuing to the process discovery phase of the BPM Lifecycle if that is the case.

This resulted in eight main actions, presented in Figure 23, which is repeated in Annexe F for better visualization, following the proposals already identified.

Action Plan									
 Objective: Monitor the actions for improvement regarding serial numbers Coordinator: Miguel Ribeiro Date of Emission: 22/05/2024 Team: Strategy Version n.º: 5 Distribution: Date of Version: 14/06/2024									
5W					2H				
N.º	What? (Action)	Why? (Problem)	Where? (Location)	When? (Initial Date / Finish Date)	Who?	How? (Action plan)	How much effect?	Status	
1	Change SN management of internal production.	1.1-Not clear who contact LGW in Assembly.	Logistics	17/05/2024 / 25/05/2024	Logistics D. H.	Logistics MRP Planner responsible to assign range of numbers to production. Point of contact is Product Team Leader.	PTL is the new point of contact	Closed	
2	Change SN management of external production.	1.2-External supplier manages their own numbers. 1.3/1.5-Lack of control over numbers engraved externally. 1.4-Unnecessary steps for subcontracted engraving.	Logistics	22/05/2024	Logistics D. H.	Only Logistics Purchaser manages Serial Numbers, which are sent with the Purchase Order to the External Supplier.	Presented and accepted	Open	
3	Create LCP Serial Number Manager.	1.6-Serial Number Manager is external to LCP.	Logistics	22/05/2024	Logistics D. H.	Assign the responsibility to one Logistics MRP Planner of managing Serial Numbers.	Presented and accepted	Open	
4	Create a platform centralizing and controlling all information of serial numbers.	1.7/2.1/2.2-Lack of procedures/standardization. 3.5-Control relies on large physical documents (folders).	Logistics Outbound Warehouse	20/05/2024 / 24/05/2024	Material Flow T.L.	Create Excel for activities required in process 3 (Proof of Concept).	Functional Excel	Closed	
5	Create lists in SAP.	3.3-Lack of integration of serial numbers into the company's system. 3.4-Any number can be manually linked to any model.	Logistics	15/05/2024	Material Flow T.L. I.T. D. H.	Insert lists into SAP and compel the system to check if the numbers expedited belong to those lists.	Presented and accepted	Open	
6	Use label in traceability card for SO-RF products for duplicity check.	3.5-Control relies on large physical documents (folders).	Assembly / Logistics	03/06/2024 / 14/06/2024	SportOptics RangeFinding P. T. L. Material Flow T. L.	Test run using the traceability cards and Excel as substitution of the platform (Proof of Concept).	Proof of Concept successful	Closed	
7	Eliminate duplicity check for Cameras.	3.1-Performing same activities for finished and intermediate products. 3.2-Delay in inserting products expedited into SAP.	Assembly / Logistics	06/06/2024 / 02/06/2024	Logistics D. H.	Confirm with all stakeholders the impact of elimination of Serial Number Log Sheets and expedition dates in SAP for cameras.	All stakeholders confirmed not using information	Ongoing	
8	Eliminate duplicity check in Logistics for Lenses and register in SAP in real time.	3.2-Delay in inserting products expedited into SAP. 3.7-Duplication of activities and documents between departments.	Assembly / Logistics	06/06/2024 / 14/06/2024	Lenses Process Engineer Material Flow T. L.	Insert labels into given pack in Assembly. Eliminate duplicity check in Logistics Outbound Warehouse. Insert serial numbers into SAP at the day of packaging.	Duplication eliminated successfully	Closed	

D. H. - Department Head, T. L. - Team Leader, P. T. L. - Product Team Leader

Figure 23 - Action Plan using 5W2H

Management of Internal Production

This action concerns the change of serial number management regarding internal production. After meetings with key stakeholders, particularly within the Assembly and Logistics departments, it was decided to change the management of serial numbers inside the company when components are to be engraved. This change affects particularly Process 1 of Serial Number Acquisition and Process 2 of Engraving Production.

Before, the production areas requested more serial numbers whenever they were reaching the end of the previous range of numbers for that model. This led to inefficiencies in workflow and even time wasted in resolving miscommunication issues.

Now, the numbers will be inserted into the platform (that encompasses all information regarding serial numbers) by the MRP Planner from the Logistics department. This passes the management of serial numbers to the department that already manages the production in the form of production orders, ultimately linking both activities: serial numbers accompanying the production order.

This change is not yet fully implemented as it requires further development of the platform. However, regarding this project, the action was closed once the achievable change was implemented by clearly defining the point of contact in the Assembly department. The Product Team Leader (PTL) has been designated as the new point of contact. This decision was made because the PTL is the primary user of the output from the engraving process and manages the engraving production, providing direct control over the process. This concerns the products engraved in Assembly which belong to the Sport Optics family (Cameras and Lenses are engraved in the Mechanical department), affecting two PTL which were present in the decision-making of this change. The process pertaining the internal production in the Mechanical department will remain the same until the platform is implemented.

Management of External Production

This action addresses the change in serial number management for external production. Following best practices that were identified for the CRF product, this change aims to extend those practices to all products engraved externally. This change impacts the process by which the serial numbers are assigned and managed, specifically focusing on improving control and efficiency.

The serial number management for externally engraved components was less efficient. For the particular case of the *hotshoe*, component with the serial number for the Cameras, the serial number acquisition had a multi-step process, creating inefficiencies.

Now, the management of serial numbers can be centralized under the Logistics Purchaser, generating and managing the serial numbers, sending the appropriate range of numbers along with the Purchase Order to the supplier. This range matches the number of components to be engraved, ensuring tighter control and traceability.

The Logistics Purchaser is now the only bridge between the serial numbers and the external supplier, streamlining the process and eliminating unnecessary steps.

This action remains open as it was presented and accepted by the Logistics department but had not been fully implemented by the end of this project.

Internal Serial Number Manager

This action focuses on changing the role of the serial number manager from an external position to an internal one within the company. Currently, the serial number manager is an Industrializer at LCW, responsible for assigning the new ranges of numbers whenever asked

to. This external management has led to inefficiencies and communication difficulties that could be mitigated if the role were internal.

In response to feedback from key stakeholders, and particularly, knowledge-based opinions about the inner workings of the company, the decision was made to assign the role of serial number manager to the MRP Planner.

Previously, all ranges of serial numbers were requested from and assigned by LCW. The proposed change is to transition the role to the MRP Planner within the company. This transition is to happen gradually to ensure a smooth changeover.

The change would be implemented gradually, with the MRP Planner still contacting the Manager in LCW for a new range of numbers at first, but ultimately assuming the sole role and all documentation necessary.

The way this manager would expedite the serial numbers would be through the platform as well, by inserting new ranges whenever necessary and ultimately managing them in a way where no communication was needed to ask him for new ranges, as he assures that the numbers are available whenever needed.

By internalizing the role of the serial number manager, the company can streamline processes and reduce the delays caused by external management. The internal management facilitates quicker resolution of any issues or miscommunications that arise, and the MRP Planner can ensure better control over the assignment and tracking of serial numbers, contributing to more efficient production processes.

This action remains open as the transition is ongoing. The new process was presented and accepted by the relevant departments, and particularly by the Logistics department, but had not been implemented by the end of this project.

All of the previous changes regarding Serial Number Acquisition resulting in the model present in Figure 24, that encompasses all products. This was done using the BIC Cloud from the GBTEC Group, which is the software used at Leica for BPM. Additional information and the Responsibility Matrix can be found in Annexe G.

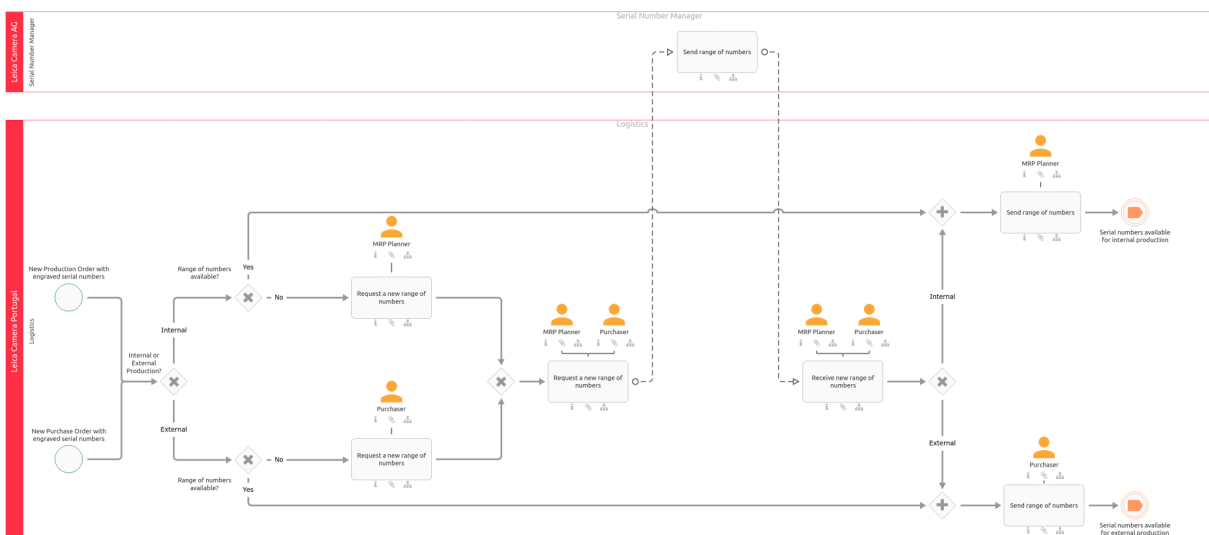


Figure 24 - Serial Number Acquisition (To-Be) in BPMN

Centralization of Serial Number Management

The current processes for managing serial numbers at LCP involve multiple manual steps across different stages. The proposed centralized platform will automate the control checks and streamline these processes, reducing errors and improving efficiency.

The plan is to create a platform centralizing and controlling information for all three main processes:

1. At first the serial numbers were inserted into the platform by the MRP Planner which would feed the engraving process;
2. The engraver receives the numbers available for engraving in the platform and inserts the numbers engraved;
3. The duplicity check is performed, and the numbers expedited are inserted onto the platform.

Before there was a lack of real-time visibility and control over the assigned serial number which the platform will correct ensuring that they are accurately tracked from the outset.

Also, the verification of serial numbers in the engraving process is done using physical labels, and no immediate feedback mechanism for errors such as duplication exist. This can be improved with the engravers accessing the serial numbers via the centralized platform, using tablets or existing devices at the engraving sites (use to calculate the overall equipment efficiency and worker's productivity). Then, after engraving one number, instead marking the sheet with an 'x' or sticking a label next to the serial number, which are the current procedures in the engraving process, the number is inserting onto the platform. This would permit real-time validation ensuring that only valid numbers are recorded, with immediate alerts for any discrepancies (duplication, numbers from different models). And additionally cross-validation with the initial ranges also producing a warning sign if the number is invalid. This engraving process would result in Figure 25 representing the To-Be model for engraving production of serial numbers for components of all products.

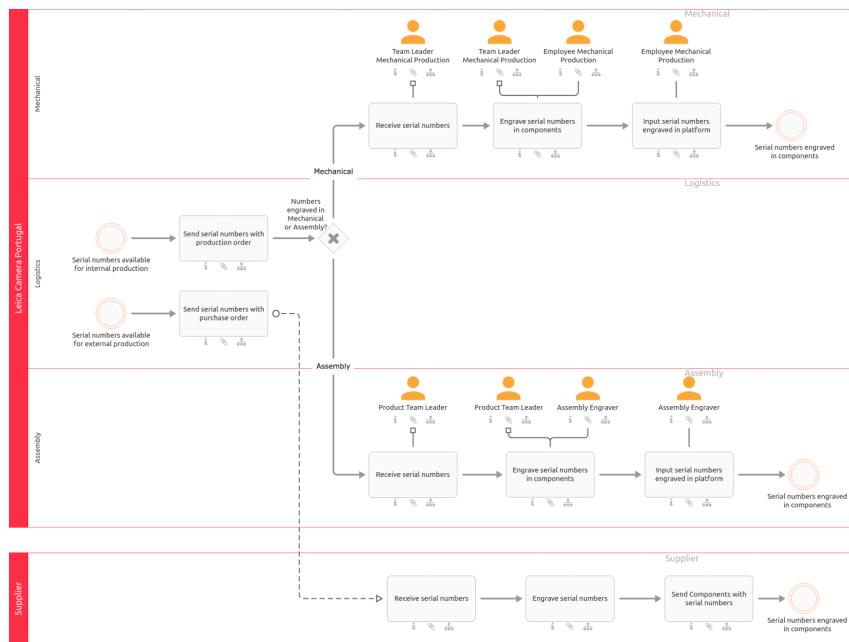


Figure 25 - Engraving Production (To-Be) in BPMN

In the third stage, numbers would also be inserted onto the platform and the same warning signs would appear if the number was not in the initial list, if it was not engraved, if it was from a different model, or if it was duplicated. This would ensure control just before packaging and after all the assembly processes.

Ultimately the IT department should be involved in the creation of this platform and the best-case scenario would be to implement all this using SAP, the ERP system used by Leica. As of now, the action plan culminated in a Proof of Concept (PoC) test run only for activities required in Process 1 and Process 3 to ensure compatibility between process and that the actual changes improve the current process.

Proof of Concept

Using Microsoft Excel, a proof of concept for the proposed centralized serial number management platform was developed. It contains three key sheets, each corresponding to different activities within the serial number management process.

1. Initial Serial Numbers
2. Product's Expedition
3. Insert in SAP

Sheet 1: Initial Serial Numbers

This is part of the process 1 of Serial Number Acquisition and it contains four columns:

- Date: The date when the serial number is added.
- Responsible: The person responsible for inserting the serial number.
- Serial Number.
- Status: The current status of the serial number (available or used).

This would function as a database and can be used to cross-validate serial numbers during the final stage of Process 3 in Integration and Delivery, which the next two sheets belong to.

Sheet 2: Product's Expedition

- Date: Automatically appears with the current date when a serial number is entered.
- Responsible: The person responsible for expediting the product, selected from pre-defined list of three collaborators that currently perform this activity.
- Serial Number.
- Status: Automatically determined and displayed using formula 4.1.

There three possible statuses:

1. Sent: The serial number is valid and appears in green.
2. Duplicated: The serial number is repeated within this sheet and appears in red.
3. Error: The serial number does not match any initial number and appears in red.

This visual management was achieved through conditional formatting functionalities of MS Excel and highlights the status to alert collaborators to any issues.

Sheet 3: Insert in SAP

With the purpose to streamline the insertion of serial numbers into the SAP system and automatic data transfer occurs with the correct serial numbers, along their respective dates, are automatically transported to this sheet. Instead of an individual entry as is done currently, the collaborator can select all valid numbers and insert them in the systems efficiently altogether. The automatic data transportation is facilitated through macros which are explicit in Annexe H.

The proof-of-concept (PoC) offers several key benefits. Improved accuracy is achieved through the automation of status checks and visual alerts, significantly reducing the risk of errors in serial number management. Efficiency is enhanced by streamlining workflows with automated data entry, status checks, and SAP insertion, saving both time and effort. The system ensures traceability by centralizing data entry and validation, providing a clear audit trail and maintaining accountability throughout the process. Additionally, real-time validation and visual alerts help identify and correct issues immediately, preventing them from escalating further.

This action was closed as a functional test platform was achieved but ultimately with the involvement of the IT department, which was not possible for this project, a more robust platform can be built with the integration of all three stages.

SAP-Integrated Lists

In the discovery phase of the project a possibility was brought up of the creation of lists integrated into SAP containing range of serial numbers available for each model of all products. As of now the SAP already performs a duplicity check when each number is inserted, with a warning appearing if the same number is inserted twice. But for cameras and lenses this is not robust enough as this insertion into the system is only done the week after expedition. Another problem is that any serial number can be associated to any product if it is being inserted for the first time. To improve the control in this process lists of serial numbers per model can be created and inserted into SAP. This could be integrated into the platform and when the serial number manager would insert the serial numbers available for engraving, concurrently these lists would be created. But as of now, the information can already be integrated into SAP by the Material Flow Team Leader with the assist of the IT department which did not occur during the project and for that reason the action remains open.

Duplicity Check Automation for Finished Products

To address the issue of duplicity checks for finished products, the project implemented a solution to use labels on traceability cards for Sport Optics Range Finding (SO-RF) products. This approach aimed to automate and digitize the duplicity check process, which previously relied on large physical documents (folders) for control.

A proof of concept (PoC) test run was conducted from June 3 to June 14, 2024. This involved using the Microsoft Excel file developed in Action number 4. The goal was to test the system on one model of SO-RF products for a week. The modification required traceability cards to follow the products to the Logistics department after assembly, instead of stopping at the end of the assembly and being stored until scanned and destroyed later. This scanning process happens in an antechamber between the Assembly and Logistics departments, where products already pass through for packaging.

The first test of the PoC revealed several issues. The labels on the traceability cards were difficult to read, and in some cases, completely unreadable. This issue was traced back to the SO-RF assembly line, where quality checks are performed and matched with the product's serial number. It was discovered that when printing a series of labels for a particular model in large batches, the data matrix code on the labels deviated incrementally, making them harder to read. These labels, which contain a data matrix code of the serial number, are read using a reader. The easier-to-read labels took an average of three seconds per label to scan, while the harder ones took an average of ten seconds because these last ones are not read but inserted manually, since some are impossible to read with a trial being performed on four labels and stopped after thirty seconds for each of no number appearing on the screen. To address these issues, better labels were printed and affixed to the cards in the assembly line, which are both presented in Figure 26.



Figure 26 - Traceability cards of SO-RF using previous and new label

Despite everything, the first test was useful as it provided valuable operational insights and process improvements. Feedback from the collaborator performing the test highlighted the need for traceability cards to accompany the products more effectively. In the initial test, the cards were sent in a bunch inside the product boxes, which made it difficult to match the cards with the correct products during packaging. Labels for packaging are printed in a specific order that corresponds to the order followed by the packaging collaborator. Each box of binoculars has space for six products. A new procedure was reached by attaching the cards to the product using a rubber band after the product is involved in plastic at the end of assembly, since this is the procedure followed during assembly. This can be seen in Figure 27, with the collaborator reading the traceability cards for the Excel perform the necessary check.

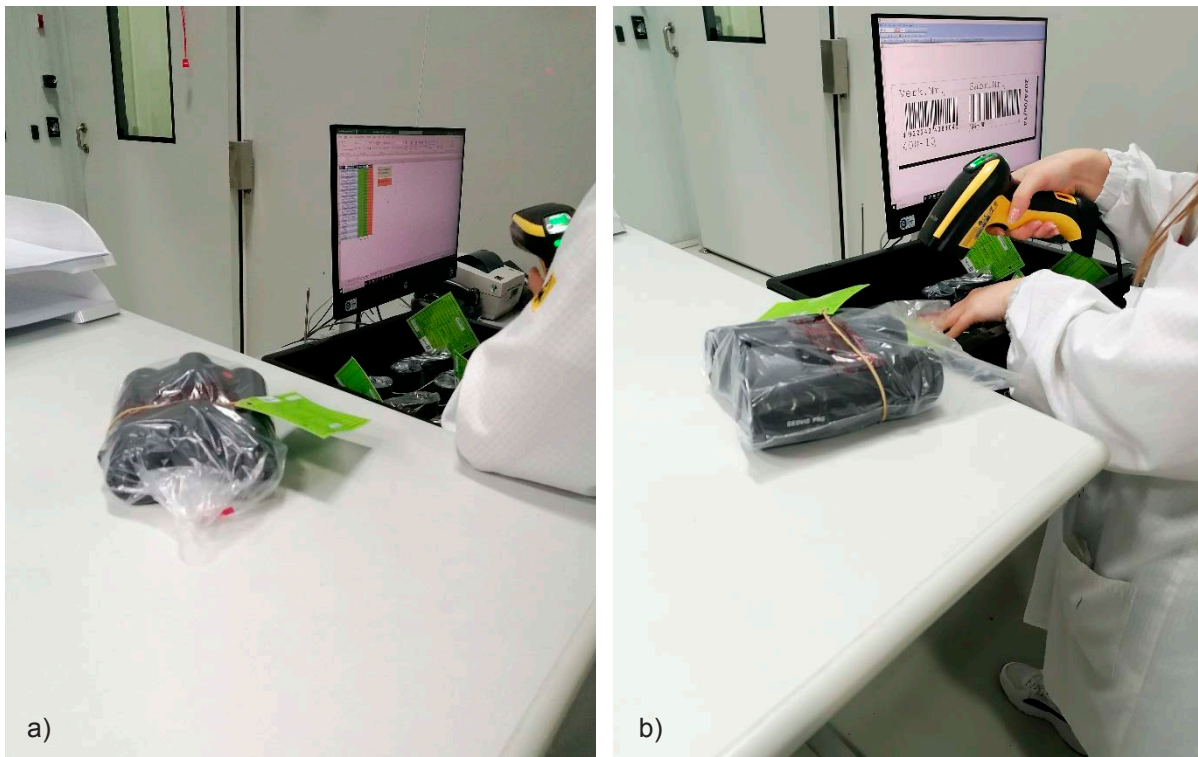


Figure 27 - Reading of cards for a) Duplicity check using the Excel b) Print of labels for packaging

A subsequent test run was performed using the Excel file for duplicity checks and to verify the validity of the serial numbers and for inserting them into SAP, by reading the traceability cards. This test also involved reading the cards for the Zebra Designer software to print the packaging labels. Ideally, these two activities should be integrated to require only one read of the card. The PoC was successful, with the time taken for the duplicity check and data entry being three minutes for sixteen products in one instance. This was a significant improvement compared to the As-Is process, which took 5'28", 5'17", and 5'15" for the same sixteen products in three different trials. These time measures are further explained in Annexe I.

All SO-RF products are equipped for this time gain using these new procedures, with the upgrade of the readable labels which will improve for two locations: Assembly and Logistics. This should be standardized to SO-O as well, by using serial number labels in the traceability card which will result in a similar gain.

Elimination of Duplicity Check for Cameras

The action to eliminate duplicity checks for cameras originated from the broader proposal of treating finished and intermediate products differently. This approach aims to optimize processes by recognizing that finished products, such as Sport Optics items, require serial numbers for traceability, especially when sold and leaving the company. In contrast, intermediate products

do not use serial numbers for traceability either internally or externally, making the activities of storing serial number information redundant and unnecessary. This proposal led to two specific actions: the elimination of activities for Cameras and for Lenses, with the latter discussed in the next subchapter.

All stakeholders confirmed that the serial numbers for cameras are not utilized in their operations. The Analog Assembly line does not record or perform any activities regarding serial numbers apart from assembling the component with it. The Digital Camera line also assembles the component and additionally registers the number in their database matching it with the four main components of the camera that have traceability cards with their own numbers. However, this process lacks robustness, particularly from the perspective of LCP and the camera as a complete product. Issues in LCW often lead to the dismantling of cameras, causing a loss of traceability and mismatches in component sets. This can be confirmed in Figure 28 with a serial number log sheet full of numbers instead of labels as it is supposed to be.

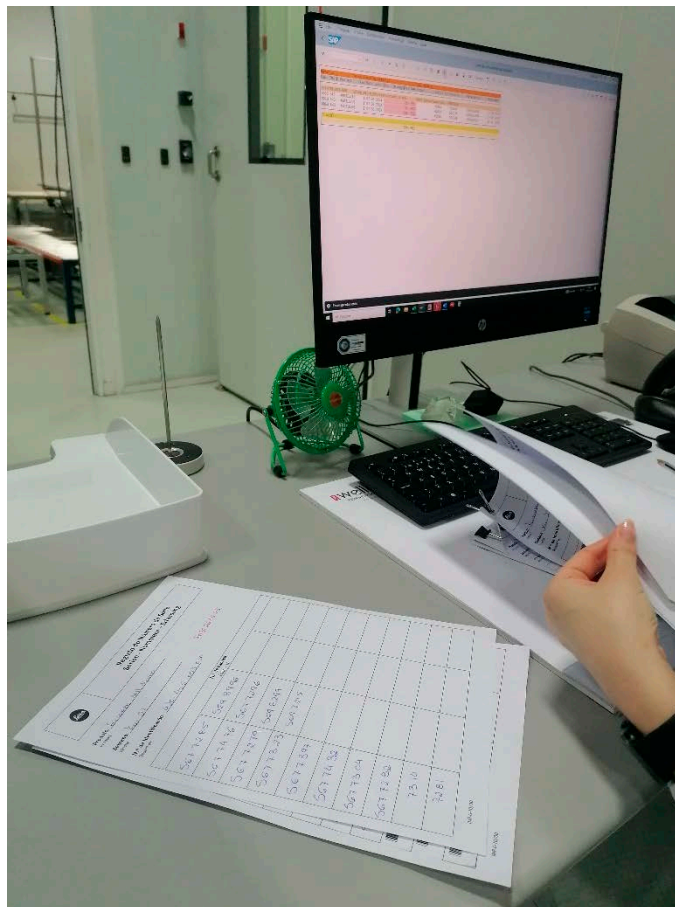


Figure 28 - Duplicity check for Cameras

Although the action of stopping the duplicity check was not fully implemented by the end of this project, all stakeholders confirmed the lack of need for it. The Quality department also confirmed that they never used these serial numbers since any issues are resolved using the numbers on the traceability cards. The elimination of the duplicity check by the Logistics department would result in significant time savings. Specifically, it would save almost three hours per week. This time gain is particularly valuable in the bottleneck occurring on the last day of the week, which is the day of shipping, when the majority of products finish assembly, and are packaged for delivery. For cameras, more than 50% of the weekly production is completed on Friday, making this time-saving measure critical for improving efficiency and reducing delays, which normally results in overtime hours for this functional area of the Outbound Warehouse. These time measures are further explained in Annexe I.

Elimination of Duplicated Activities for Lenses

Continuing from the previous subchapter on Cameras, the action to eliminate duplicity checks in Logistics for Lenses and register them in SAP in real-time originated from the same proposal: treating finished and intermediate products differently to eliminate unnecessary activities. For Lenses, particularly the six sets of M-Lenses that leave LCP with the serial number component already assembled, this proposal was intended to optimize processes.

Unlike Cameras, the proposal to treat Lenses differently than finished products was not accepted by the Assembly department. They argued that ensuring the validity of the serial numbers in their components and performing the duplicity check was essential. This requirement stems from the more robust process in place for Lenses compared to Cameras, where the component with the serial number is rarely replaced and is mostly assembled in LCW, with the sets with serial numbers assembled in LCP representing 25% of Lenses products.

Given this context, the focus shifted to enhancing the robustness of the existing process and aligning it with the finished product process, particularly in Process 3 – Integration and Delivery. The duplicity check, which for Sport Optics occurs in the Outbound Warehouse, is performed in the Assembly department. Here, the process involves continuing using folders to perform the check and placing the labels into the given packs that transport the assembled lenses for packaging, instead of in the log sheet.

The SAP profile for this Lenses was activated. So, in Logistics, labels are read as done for finished products. Additional labels for packaging, now including the serial numbers, are printed and registered in SAP on the same day of packaging.

This action was successfully implemented, resulting in the elimination of repeated activities, particularly the duplicity check that was previously performed in two locations. It also eliminated the duplication of documents. The process improvement included a gain of two minutes per batch of Lenses by sticking the labels into the given pack instead of the log sheet, which translates to twenty minutes per week. Moreover, the major gain was the elimination of duplicated activities, saving forty minutes per week. These time measures are further explained in Annexe I.

All these changes resulted in Figure 29 that resents the new process of Integration and Delivery, with better visualization and additional information in Annexe E.

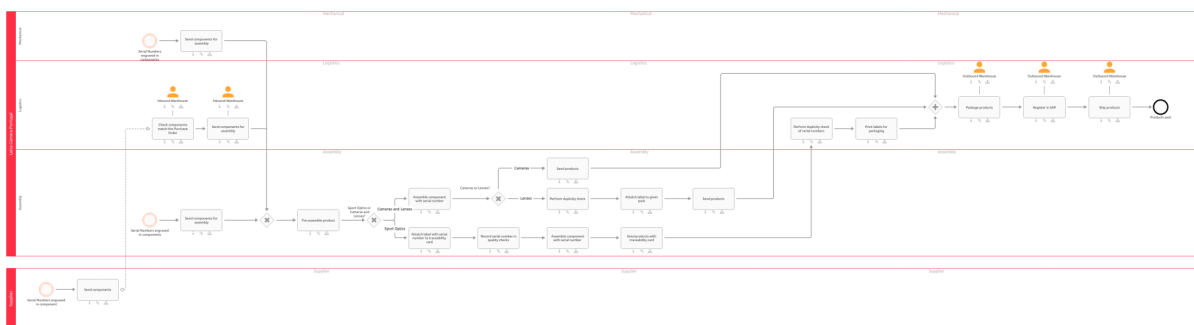


Figure 29 - Integration and Delivery (To-Be) in BPMN

5. Conclusions and Future Work

This Master's Dissertation underscores the critical importance of efficient serial number management within the operations of a manufacturing company. The primary focus was on serial number management improving operational efficiency.

The project highlighted the critical importance of process thinking in identifying and rectifying problems and inefficiencies within serial number management. By adopting a systematic approach grounded in Business Process Management (BPM) principles, stakeholders meticulously analyzed existing processes, pinpointing areas of improvement and devising effective solutions. Utilizing the BPM Lifecycle provided a structured framework for guiding activities from initial process identification to implementation and beyond, ensuring a comprehensive and methodical approach at every stage.

Moreover, the multi-level modeling structure, along with tools such as swimlanes and flowcharts, proved invaluable in visualizing complex business processes and activities. These tools provided a clear and concise representation of process flows, enabling stakeholders to better understand the intricacies of serial number management and identify potential bottlenecks or inefficiencies. By leveraging these modeling techniques, stakeholders fostered collaboration, facilitated communication, and drove consensus, ultimately leading to more informed decision-making and effective problem-solving.

In essence, the success of the initiative underscores the transformative power of process thinking, the BPM Lifecycle, and multi-level modeling techniques in driving organizational improvement. Embracing these methodologies and tools enables organizations to gain deeper insights into their operations, streamline processes, enhance efficiency, and ultimately achieve strategic objectives with clarity and precision.

Quality assurance measures were strengthened through the establishment of robust protocols for verifying serial number accuracy and authenticity at various stages of the production cycle, while also augmenting digitalization. Comprehensive documentation of best practices ensured adherence to standardized procedures, promoting consistency across operations and streamlining training efforts.

Significant strides were made in time optimization, resulting in tangible cost reductions for Leica Camera Portugal. Through the implementation of streamlined workflows and efficiency-enhancing measures, the project yielded annual savings of €3967, calculated based on the tariff structure of the company. This reduction in costs underscores the effectiveness of the time optimization efforts, highlighting their direct impact on the company's financial bottom line.

The utilization of the impact-effort matrix enabled the prioritization of actions based on their potential impact and the effort required for implementation. This strategic approach ensured that interventions were focused on areas where they could yield maximum benefits with manageable resource allocation. Concurrently, the 5W2H framework provided a structured methodology for defining action plans, ensuring thorough consideration of all implementation aspects.

By automating control checks and streamlining processes across all three main processes, namely Serial Number Acquisition, Engraving Production, and Integration and Delivery, errors

were reduced, and real-time visibility was enhanced. This centralized approach ensured that serial numbers were accurately tracked from inception to delivery, minimizing discrepancies and delays.

The automation of duplicity checks for finished products, particularly for Sport Optics Range Finding (SO-RF) products, brought about substantial improvements in efficiency and accuracy. By replacing manual checks with automated label scanning processes, errors were minimized, and processing times were significantly reduced. This not only streamlined workflows but also contributed to enhanced traceability and accountability throughout the production cycle.

Recognizing the unnecessary redundancy in duplicity checks for M-Lenses products, this action led to notable time savings and process optimizations. By eliminating duplicity checks, particularly in the Logistics department, significant efficiency gains were realized. This streamlined approach allowed for smoother workflows, reduced delays, and improved productivity, particularly during peak production periods.

Similarly, for Cameras products activities were identified to be wasteful, particularly understanding the difference to Leica Camera Portugal between intermediate products that undergo further assembly in Leica Camera Wetzlar, and finished products in which the customer is the consumer.

Overall, these actions collectively contributed to significant improvements in serial number management within precision optical products at Leica Camera Portugal. By leveraging automation, centralization, and process optimization, operational efficiency was enhanced

Moving forward, several key actions remain unfinished, necessitating further work to fully realize the benefits of the project. Firstly, the development of the centralized platform for serial number management, automating control checks and streamlining processes, thereby reducing errors and improving efficiency. Additionally, implementing procedures to send serial numbers corresponding to components in the Purchase Order is crucial for enhancing control in the process. By aligning serial numbers with specific components, the company can ensure tighter control and traceability throughout the production cycle.

Furthermore, there is a pressing need to eliminate unnecessary activities that persist within the current processes. For instance, the redundant duplicity check for cameras, which occurs at the end of the value chain, remains in place despite its reliance on a less robust process. Integrating the platform into the engraving process will embed control directly into the workflow, minimizing the need for manual checks and reducing the risk of errors. By addressing these outstanding actions, the company can further optimize its serial number management processes, enhancing efficiency, accuracy, and overall operational performance.

The transition of the serial number manager role from external to internal within the company is a vital step in enhancing process efficiency. This ongoing transition necessitates continued efforts to ensure smooth integration of the new role into existing processes. By internalizing serial number management and assigning it to the MRP Planner, the company can streamline processes, reduce delays, and enhance control over serial number assignment and tracking.

Additionally, the Responsibility Matrix, used in conjunction with BPMN diagrams, has helped delineate roles and responsibilities within each process, ensuring that all stakeholders are aware of their duties and contributions.

In conclusion, this dissertation highlights the substantial benefits of process-oriented thinking over departmental silos. By demonstrating the impact of efficient serial number management and the elimination of redundant activities, the project provides a strategic roadmap for similar improvements in other areas. The success in improving operational efficiency through better serial number management offers valuable insights for managers and practitioners aiming to optimize business performance, maintaining a competitive advantage in the marketplace.

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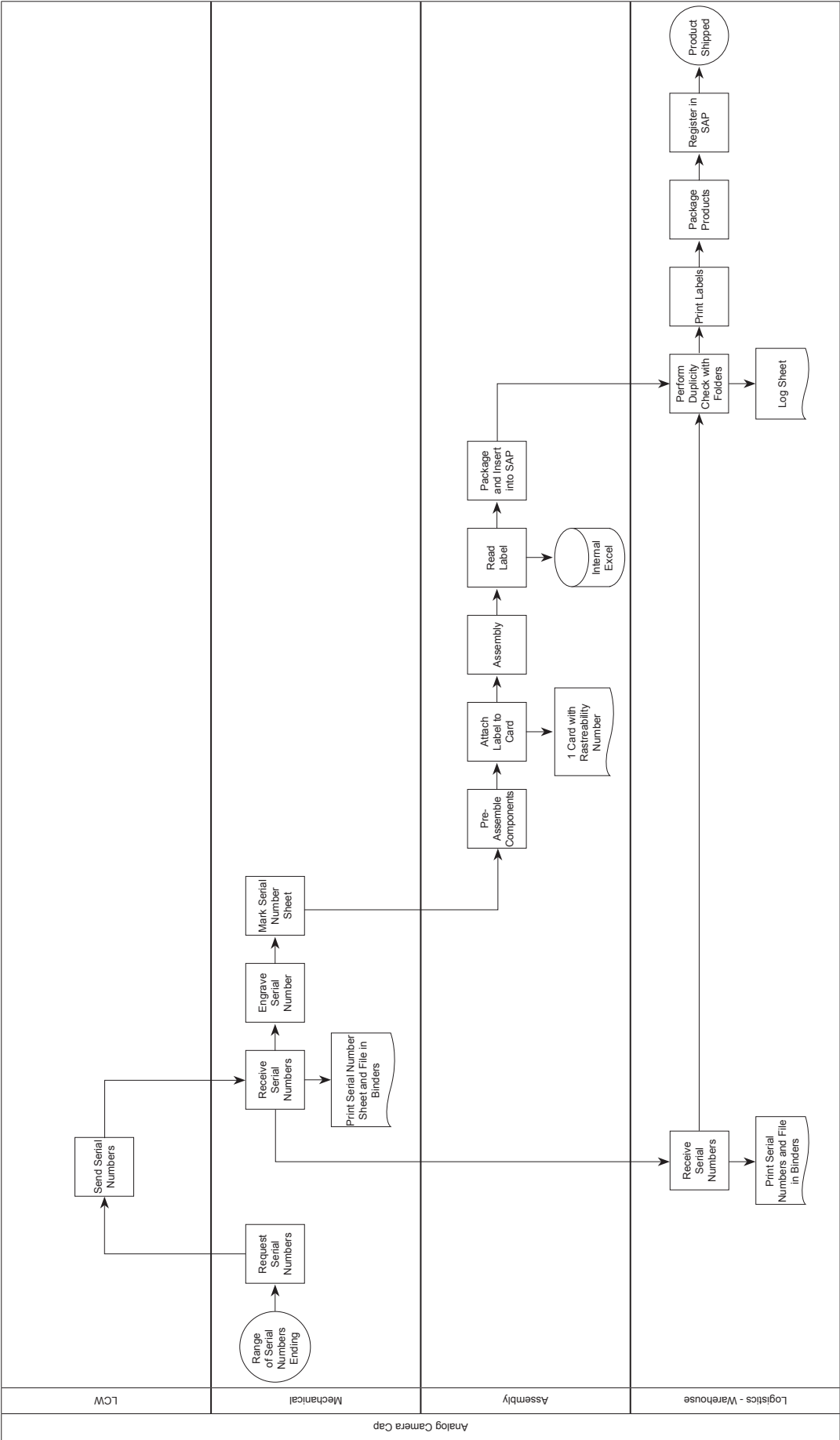
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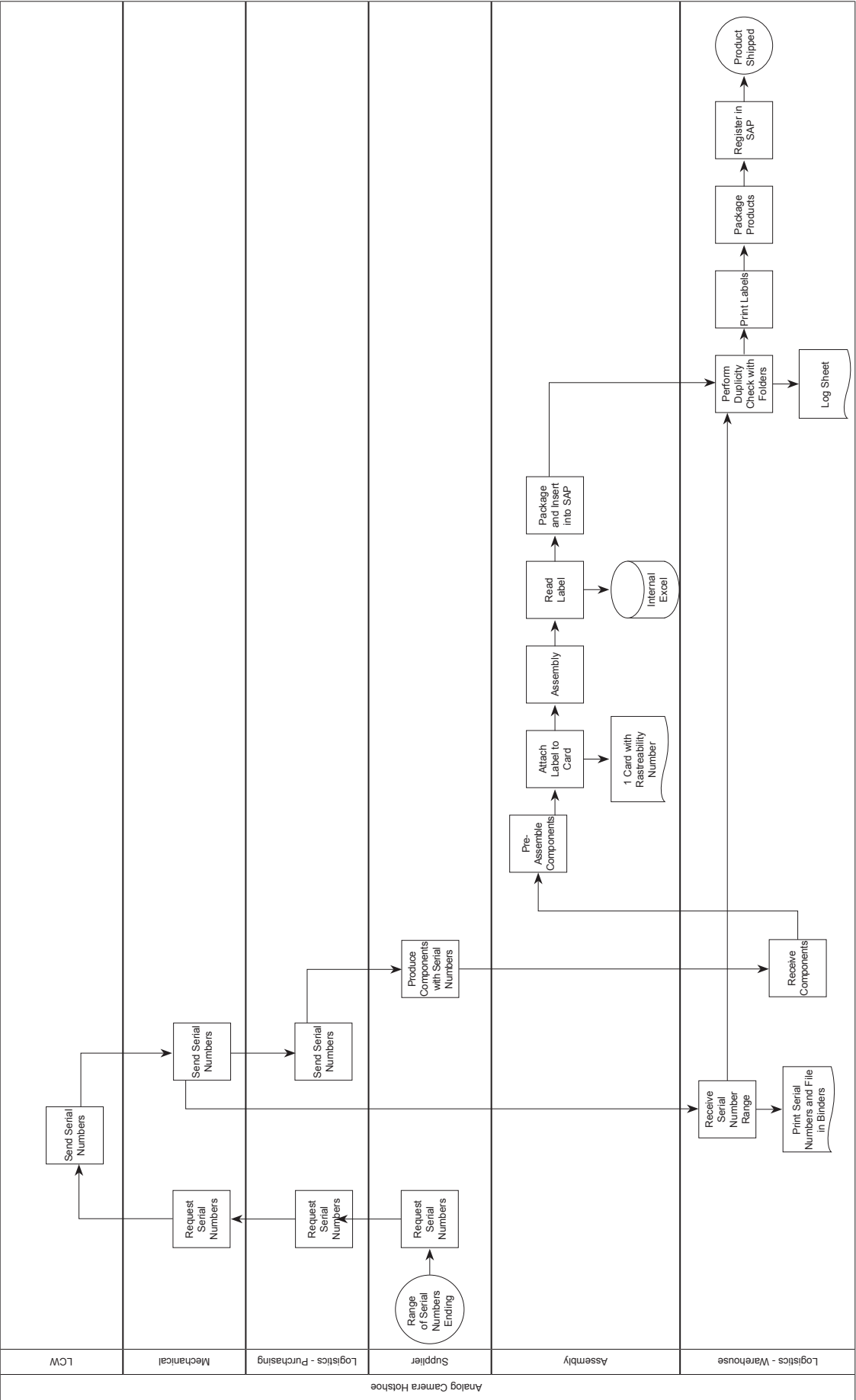
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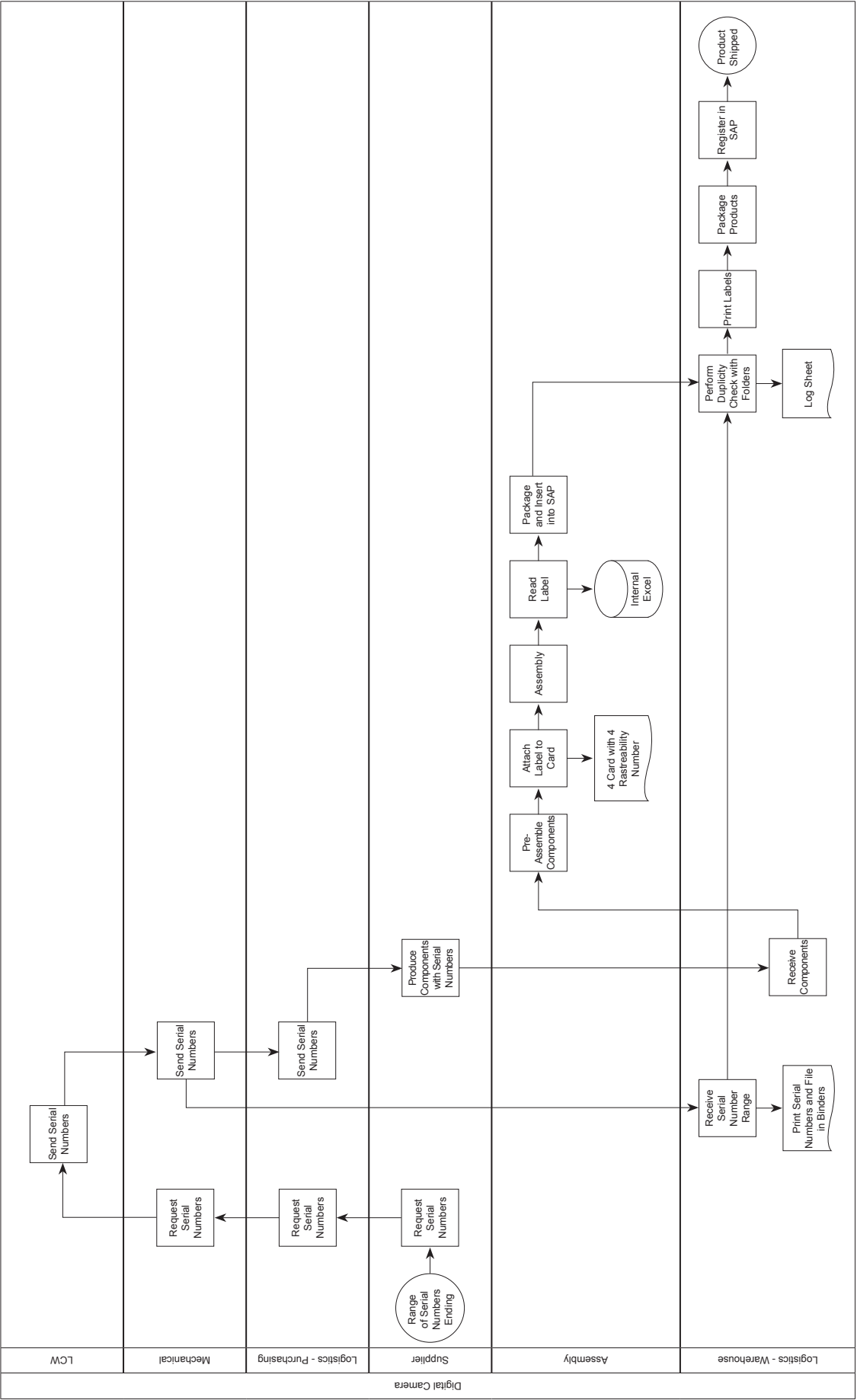
Contribution to Sustainable Development Goals

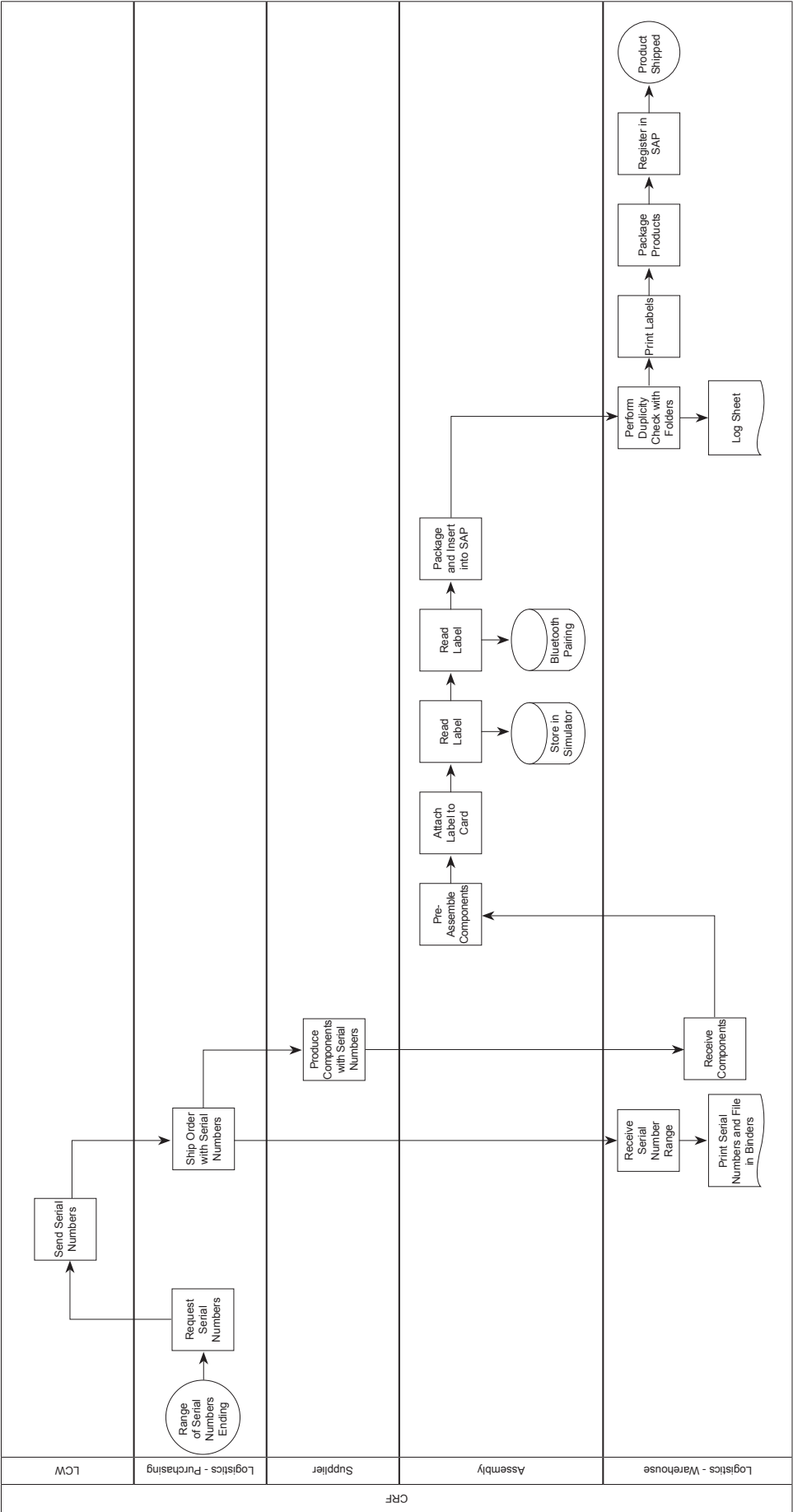
SDG	Goal	Contribution	Performance indicators and metrics
SDG 8: Decent Work and Economic Growth	Target 8.2: Achieve higher levels of economic productivity through diversification, technological upgrading, and innovation	The dissertation focuses on improving operational efficiency within the serial number value chain in a manufacturing company. By implementing Business Process Management (BPM) principles, the project aims to enhance productivity and streamline processes, contributing to economic growth and the creation of decent work environments.	– Increase in operational efficiency measured by reduction in process cycle times. – Number of unnecessary activities eliminated. – Improvement in overall process performance and productivity metrics.
SDG 9: Industry, Innovation, and Infrastructure	Target 9.1: Develop quality, reliable, sustainable, and resilient infrastructure	The project leverages process diagrams, swimlanes, and flowcharts to visualize and improve business processes, fostering innovation in the management of serial numbers for precision optical products. The implementation of a centralized platform for serial number management exemplifies the application of innovative solutions to industrial challenges.	– Successful implementation of the centralized serial number management platform (Proof of Concept). – Quantitative improvements in process tracking and management. – Enhanced integration and delivery processes as indicated by stakeholder feedback.
SDG 12: Responsible Consumption and Production	Target 12.5: Substantially reduce waste generation through prevention, reduction, recycling, and reuse	By identifying inefficiencies and proposing improvements, the dissertation promotes responsible production practices. Streamlining serial number management processes reduces waste and enhances resource efficiency, aligning with sustainable production goals.	– Reduction in waste generated during the serial number management process. – Efficiency gains in resource utilization. – Metrics showing improved alignment with sustainable production standards.

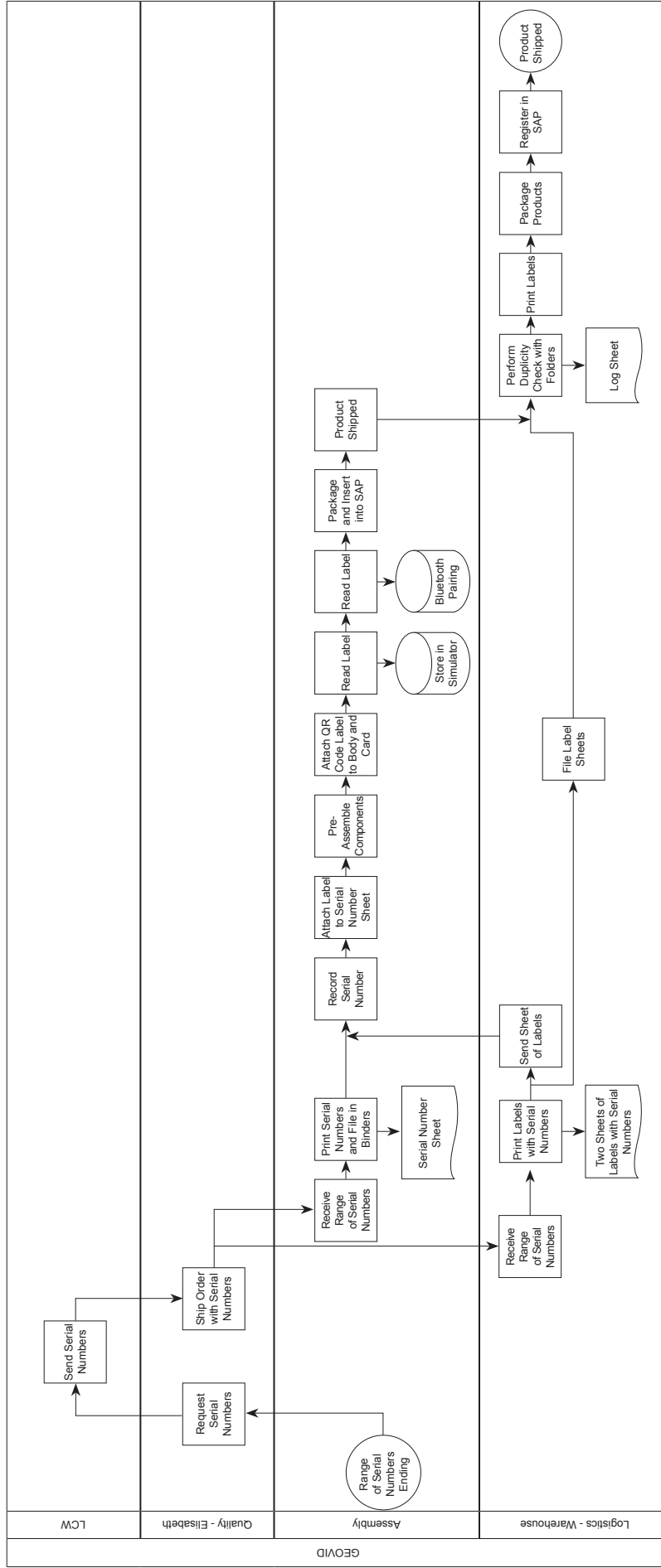
ANNEX A: Level III Swimlanes (As-Is Models)

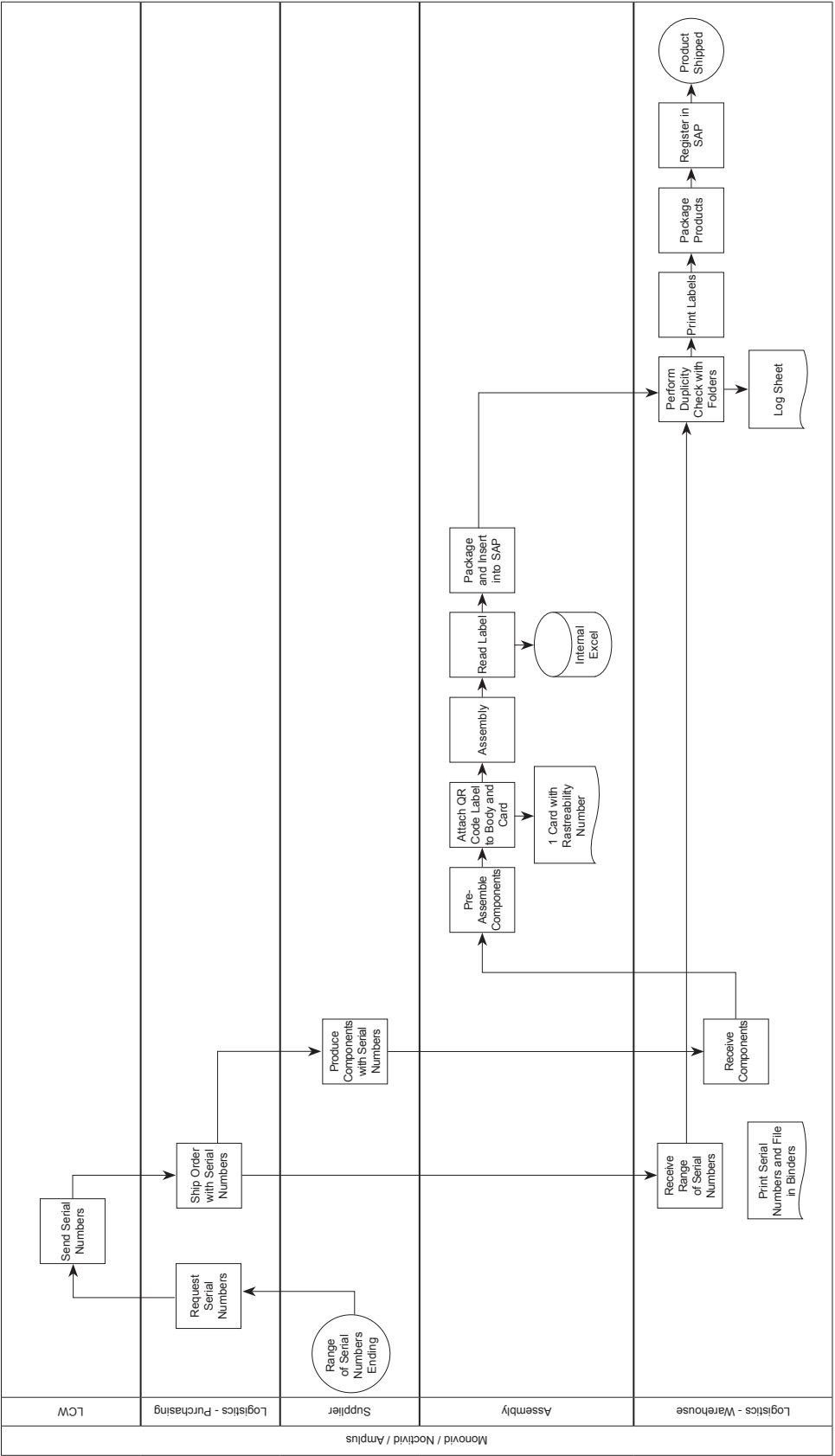


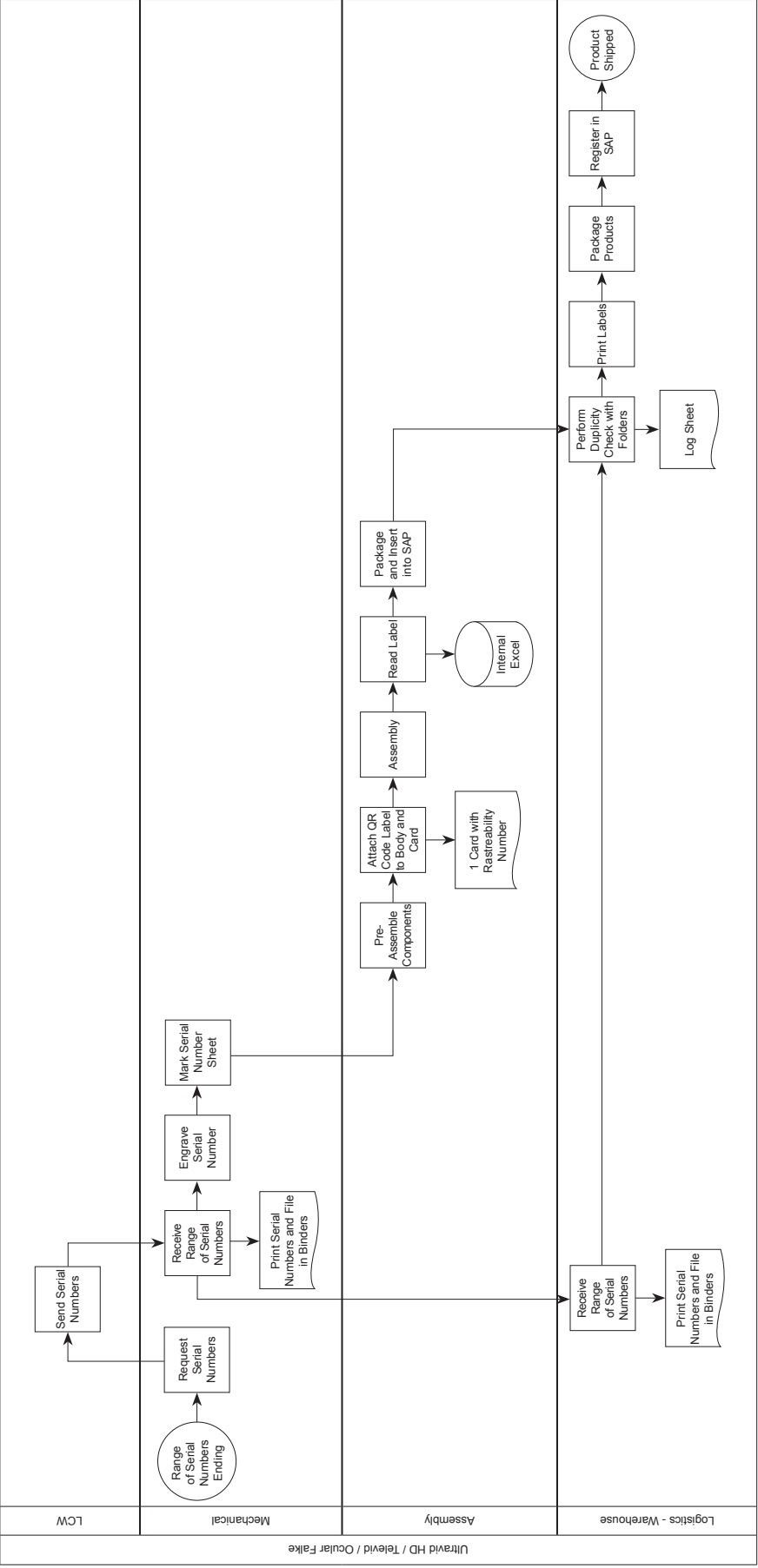


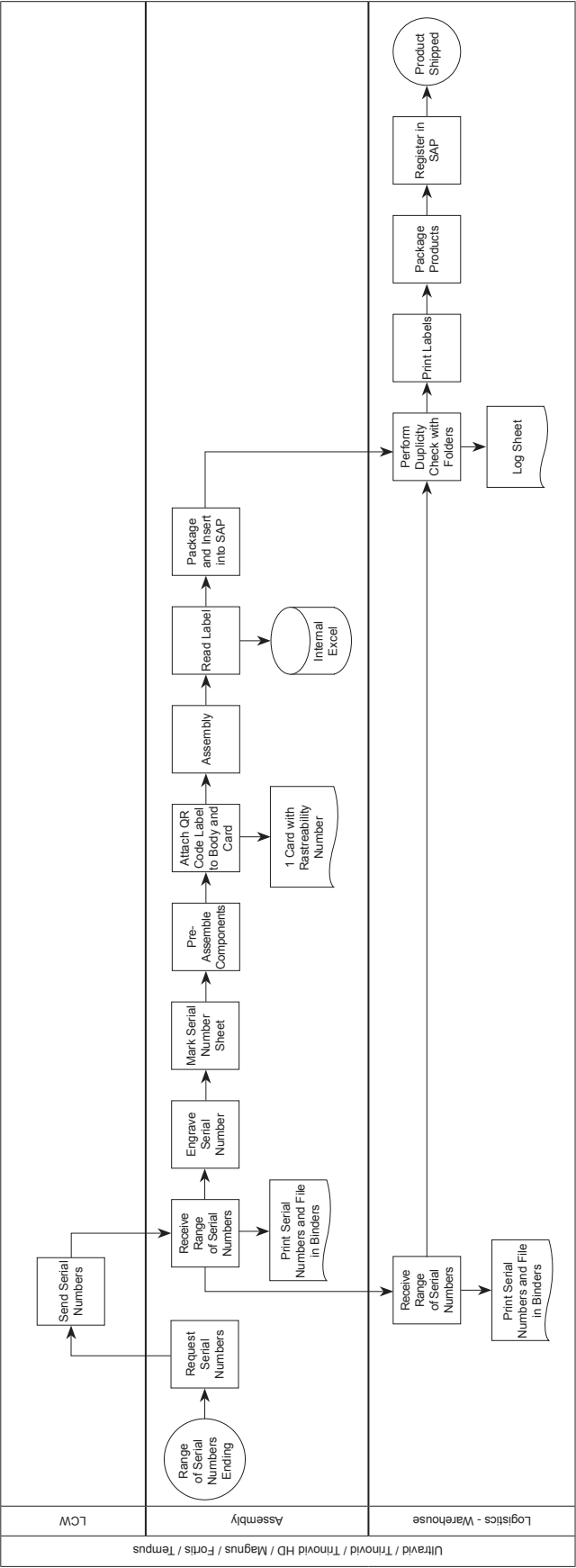


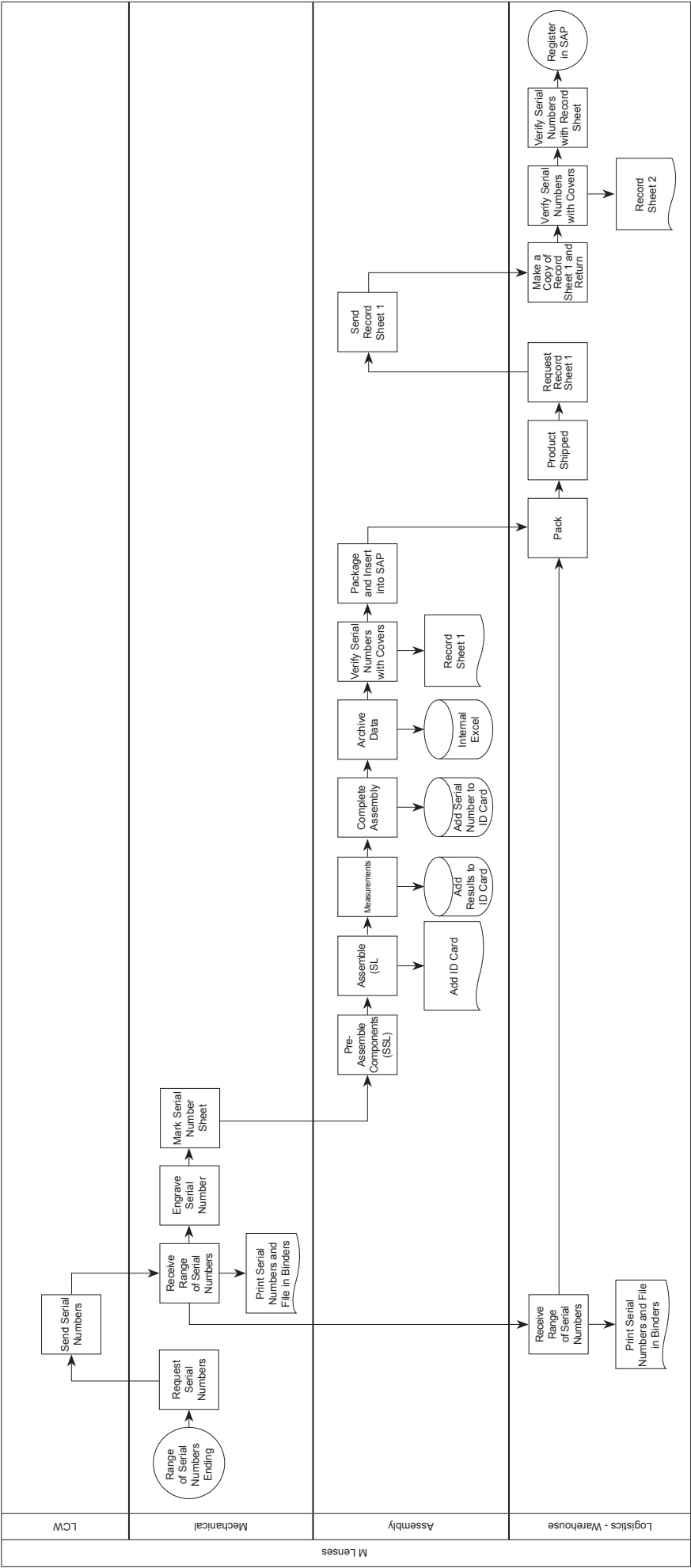




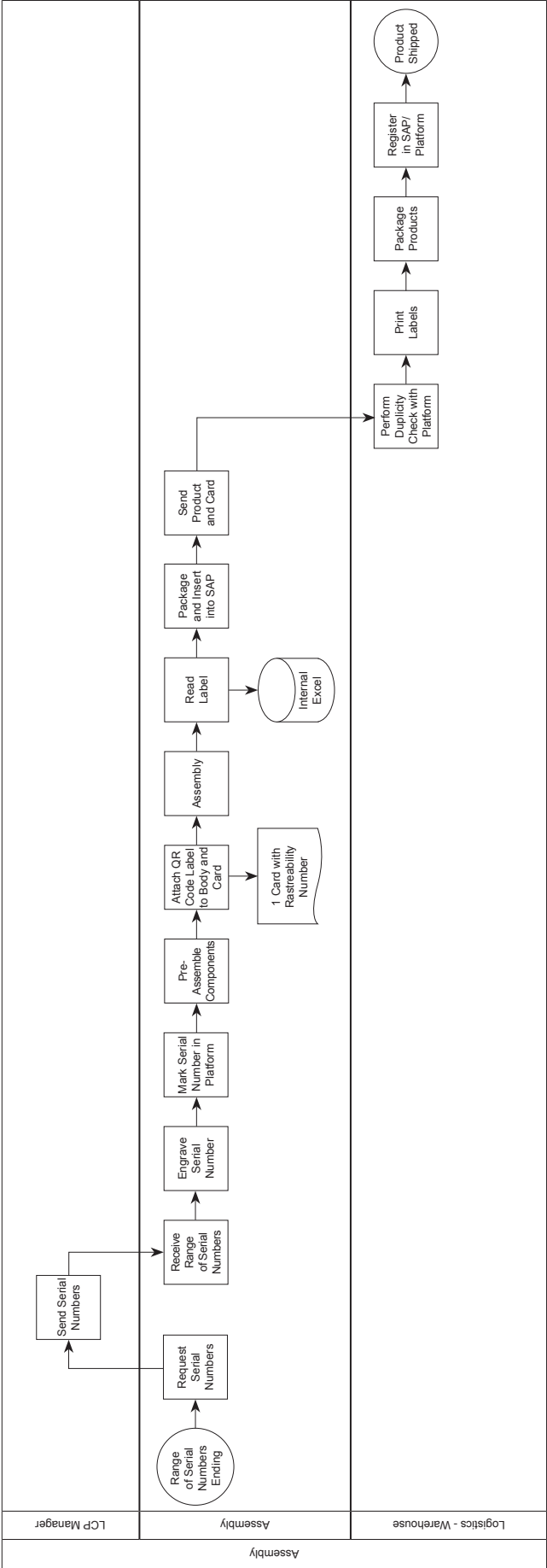


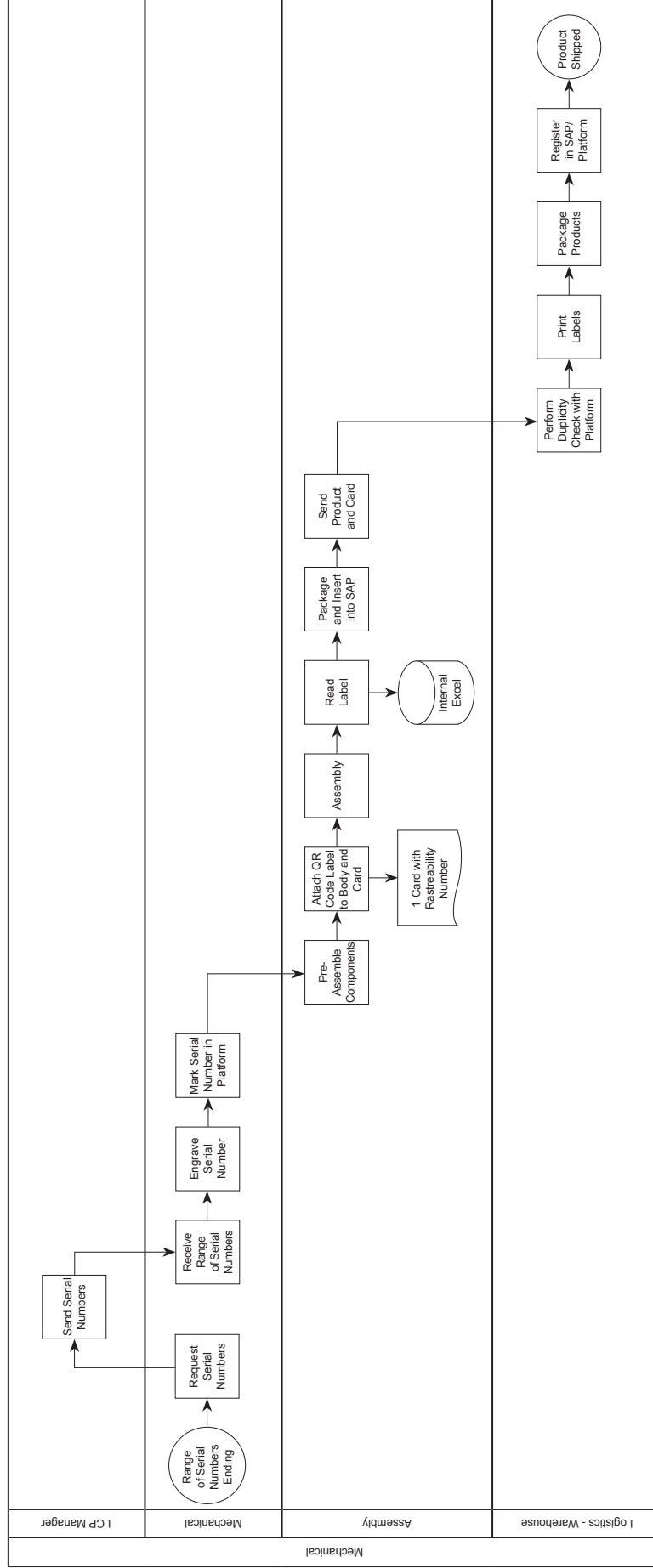


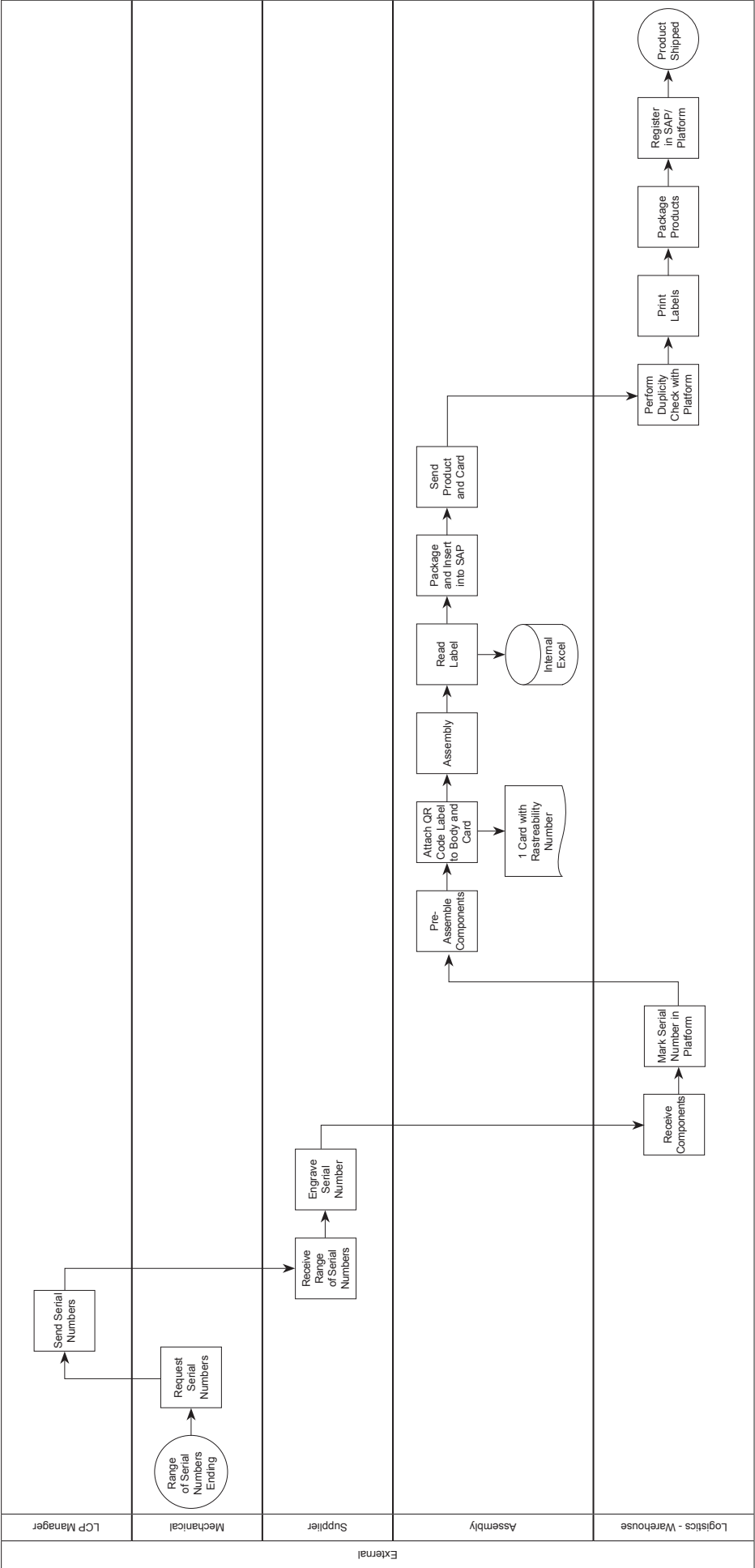




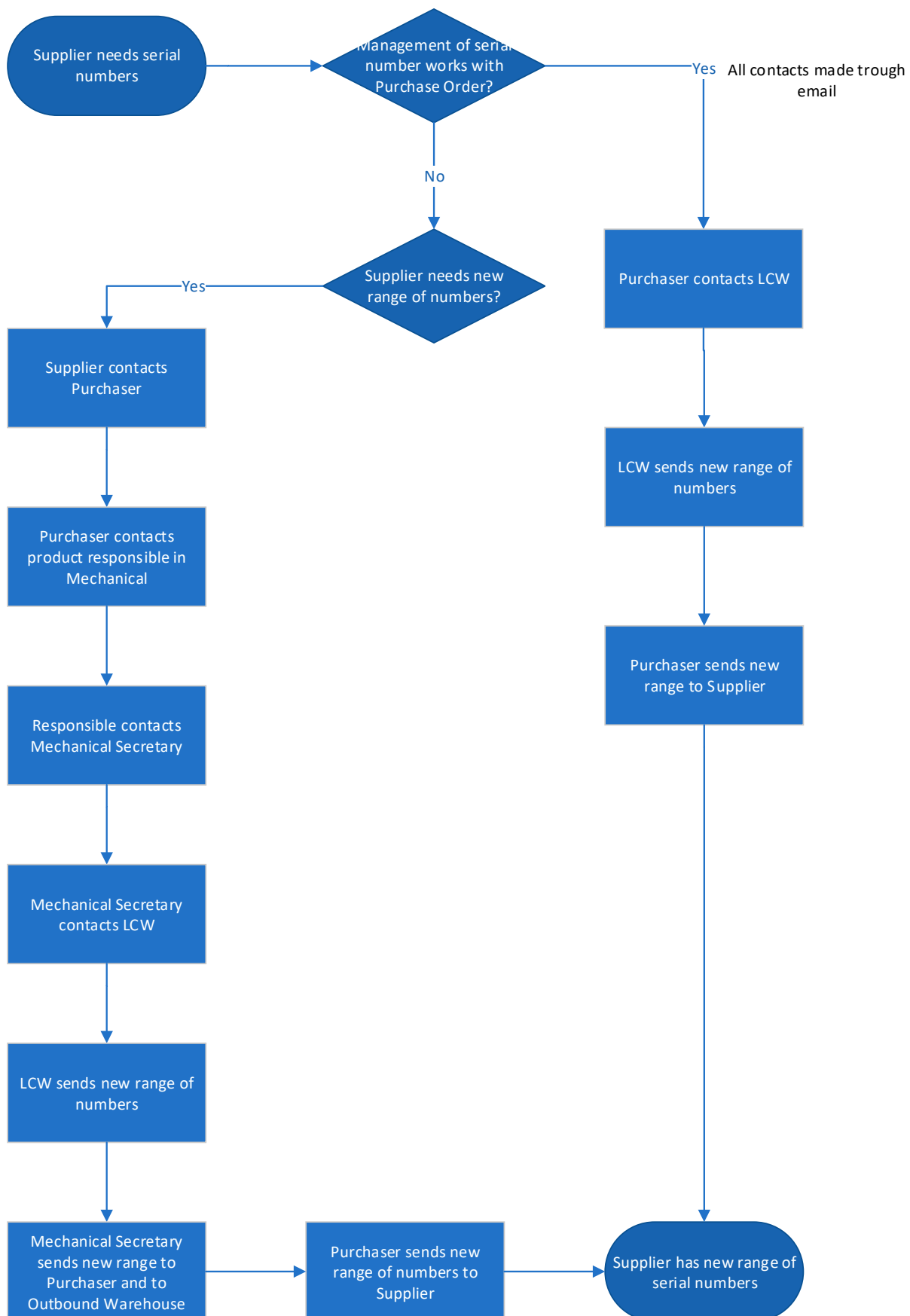
ANNEX B: Level III Swimlanes (To-Be Models)

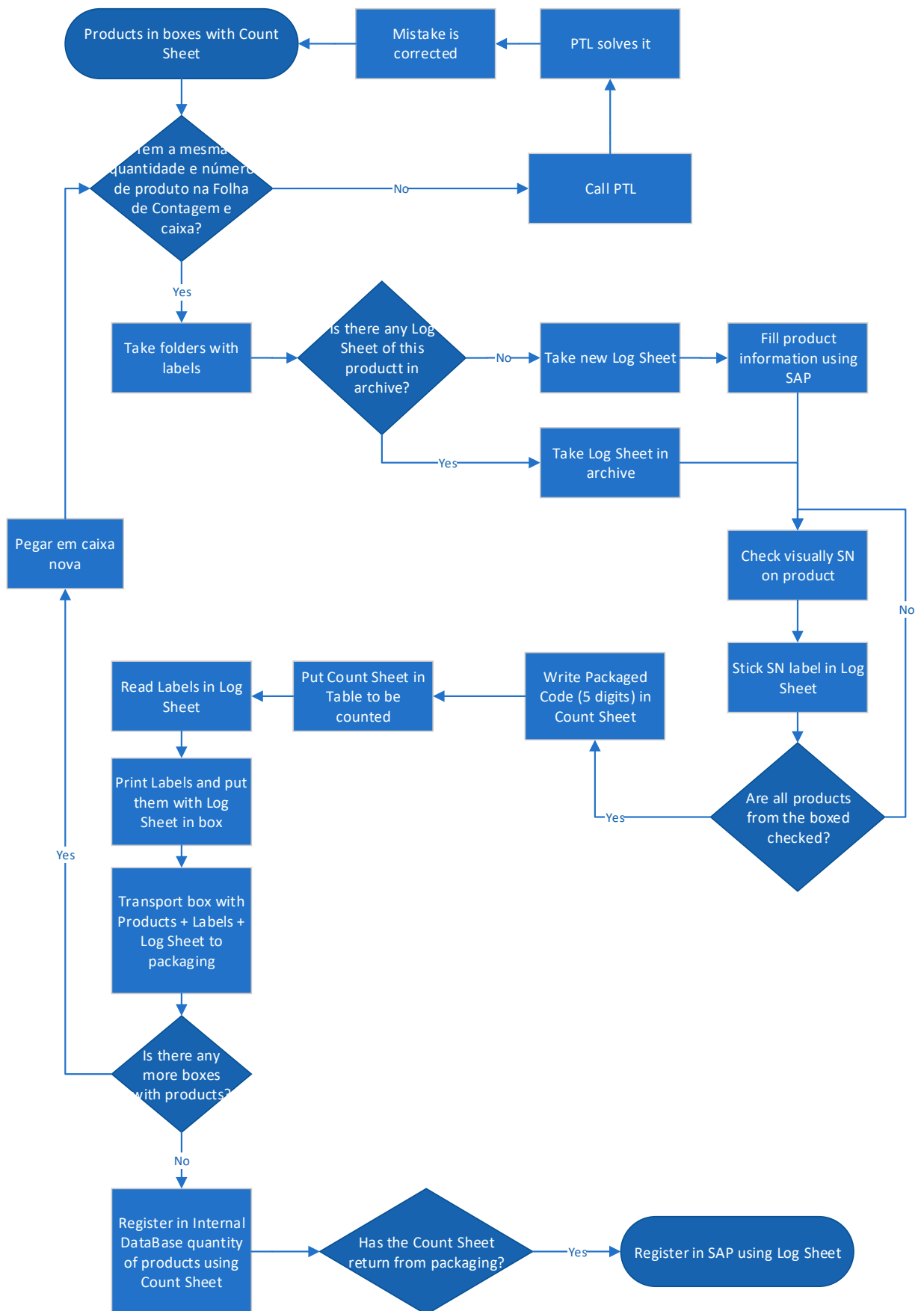




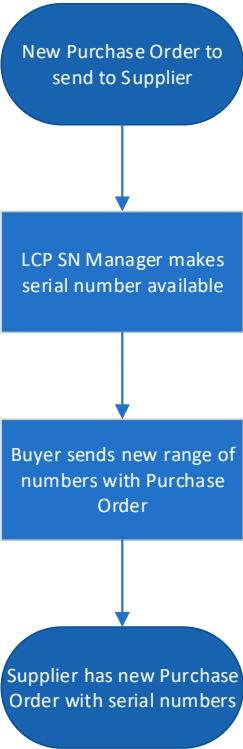


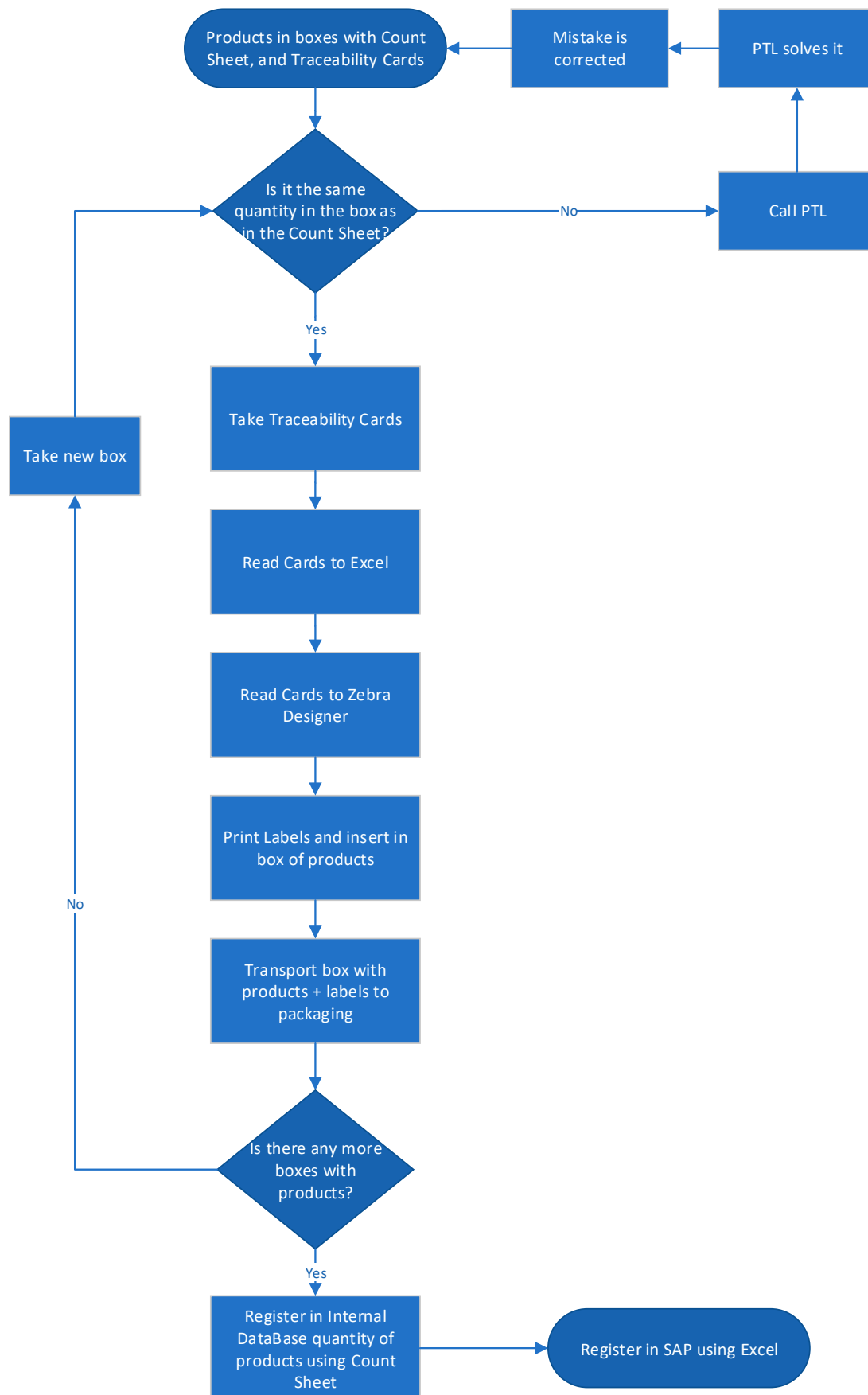
ANNEX C: Level IV Flowcharts (As-Is Models)





ANNEX D: Level IV Flowcharts (To-Be Models)





ANNEXE E: Problems, Consequences, Proposals and Actions

Serial Numbers Acquisition

Problems	Consequences
1.1 - Not clear who contacts LCW in Assembly. 1.4 - Unnecessary steps for subcontracted engraving.	➤ Complicated workflow
1.2 - External supplier manages their own numbers. 1.3 - Lack of control over numbers sent from external supplier. 1.5 - Lack of control over numbers sent to subcontracted engraver.	➤ Numbers not used
1.6 - Serial number manager is external to LCP. 1.7 - Lack of procedures.	➤ Difficulty in resolving internal issues

Engraving Production

Problems	Consequences
2.1 - Lack of standardization.	➤ Different ways of recording by department.
2.2 - Lack of procedures. 2.3 - Lack of procedures.	➤ Numbers not used

Integration and Delivery

Problems	Consequences
3.1 - Performing same activities for finished and intermediate products. 3.5 - Control relies on large physical documents (folders). 3.7 - Duplication of activities and documents between departments.	➤ Wasted time
3.2 - Delay in inserting products shipped into SAP. 3.4 - Any number can be manually linked to any model	➤ Misidentification of products
3.3 - Lack of previous integration of serial numbers into system.	➤ Difficulty in tracking numbers
3.6 - Control relies on visual inspection and manual matching.	➤ Human error

Serial Numbers Acquisition

Problems	Proposal
1.1 - Not clear who contacts LCW in Assembly. 1.4 - Unnecessary steps for subcontracted engraving.	➤ Define contact with serial number manager
1.2 - External supplier manages their own numbers. 1.3 - Lack of control over numbers sent from external supplier. 1.5 - Lack of control over numbers sent to subcontracted engraver.	➤ Assume management of SN engraved externally
1.6 - Serial number manager is external to LCP.	➤ Bring serial number management to LCP
1.7 - Lack of procedures.	➤ Implement guidelines for requesting serial numbers

Engraving Production

Problems	Proposal
2.1 - Lack of standardization.	➤ Standardize process
2.2 - Lack of procedures. 2.3 - Lack of procedures.	➤ Create procedures to use all numbers

Integration and Delivery

Problems	Proposal
3.1 - Performing same activities for finished and intermediate products. 3.2 - Delay in inserting products shipped into SAP.	➤ Treat finished and intermediate products differently
3.3 - Lack of previous integration of serial numbers into system. 3.4 - Any number can be manually linked to any model	➤ Create lists of ranges of numbers for each model
3.5 - Control relies on large physical documents (folders)	➤ Label accompanying the product
3.6 - Control relies on visual inspection and manual matching.	➤ Automate quality control checks
3.7 - Duplication of activities and documents between departments.	➤ Eliminate repeated activities

Serial Numbers Acquisition

Problems	Action
1.1 - Not clear who contacts LCW in Assembly.	➤ Assign one coordinator per product
1.2 - External supplier manages their own numbers. 1.3 - Lack of control over numbers sent from external supplier. 1.5 - Lack of control over numbers sent to subcontracted engraver.	➤ Logistics sends range of numbers with PO
1.4 - Unnecessary steps for subcontracted engraving	➤ Logistics contacts directly SN manager
1.6 - Serial number manager is external to LCP.	➤ Create LCP serial number manager
1.7 - Lack of procedures.	➤ Create a platform centralizing all information of SN

Engraving Production

Problems	Action
2.1 - Lack of standardization.	➤ Insert number into platform
2.2 - Lack of procedures.	➤ Use all numbers while engraving

Integration and Delivery

Problems	Action
3.1 - Performing same activities for finished and intermediate products. 3.2 - Delay in inserting products shipped into SAP. 3.7 - Duplication of activities and documents between departments.	➤ Stop performing control check for intermediate products
3.3 - Lack of previous integration of serial numbers into system. 3.4 - Any number can be manually linked to any model	➤ Create lists of ranges per model in SAP
3.5 - Control relies on large physical documents (folders)	➤ For Sport Optics: standardize label with QR code of serial number in traceability card
3.6 - Control relies on visual inspection and manual matching.	➤ Insert number into platform

ANNEXE F : Action Plan



Action Plan

1

Objective : Monitor the actions for improvement regarding serial numbers

Coordinator: Miguel Ribeiro

Team: Strategy

Distribution: _____

Date of Emission: 22/05/2024

Version n.°: 5

Date of Version: 14/08/2024

5W				2H					
N.°	What? (Action)	Why? (Problem)	Where? (Location)	When? Initial Date	When? Finish Date	Who?	How? (Action plan)	How much effect?	Status
1	Change SN management of internal production.	1.1-Not clear who contact LCW in Assembly.	Logistics	17/05/2024	28/05/2024	Logistics D. H.	Logistics MRP Planner responsible to assign range of numbers to production. Point of contact is Product Team Leader.	PTL is the new point of contact	Closed
2	Change SN management of external production.	1.2-External supplier manages their own numbers. 1.3/1.5-Lack of control over numbers engraved externally. 1.4-Unnecessary steps for subcontracted engraving.	Logistics	22/05/2024		Logistics D. H.	Only Logistics Purchaser manages Serial Numbers, which are sent with the Purchase Order to the External Supplier.	Presented and accepted	Open
3	Create LCP Serial Number Manager.	1.6-Serial Number Manager is external to LCP.	Logistics	22/05/2024		Logistics D. H.	Assign the responsibility to one Logistics MRP Planner of managing Serial Numbers.	Presented and accepted	Open
4	Create a platform centralizing and controlling all information of serial numbers.	1.7/2.1/2.2-Lack of procedures/standardization. 3.6-Control relies on large physical documents (folders).	Logistics Outbound Warehouse	20/05/2024	24/05/2024	Material Flow T.L.	Create Excel for activities required in process 3 (Proof of Concept).	Functional Excel	Closed
5	Create lists in SAP.	3.3-Lack of integration of serial numbers into the company's system. 3.4-Any number can be manually linked to any model.	Logistics	15/05/2024		Material Flow T. L. I. T. D. H.	Insert lists into SAP and compel the system to check if the numbers expedited belong to those lists.	Presented and accepted	Open
6	Use label in traceability card for SO-RF products for duplicity check.	3.5-Control relies on large physical documents (folders).	Assembly / Logistics	03/06/2024	14/06/2024	SportOptics RangeFinding P. T. L. Material Flow T. L.	Test run using the traceability cards and Excel as substitution of the platform (Proof of Concept).	Proof of Concept successful	Closed
7	Eliminate duplicity check for Cameras.	3.1-Performing same activities for finished and intermediate products. 3.2-Delay in inserting products expedited into SAP.	Assembly / Logistics	06/06/2024	02/08/2024	Logistics D. H.	Confirm with all stakeholders the impact of elimination of Serial Number Log Sheets and expedition dates in SAP for cameras.	All stakeholders confirmed not using information	Ongoing
8	Eliminate duplicity check in Logistics for Lenses and register in SAP in real time.	3.2-Delay in inserting products expedited into SAP. 3.7-Duplication of activities and documents between departments.	Assembly / Logistics	06/06/2024	14/06/2024	Lenses Process Engineer Material Flow T. L.	Insert labels into given pack in Assembly. Eliminate duplicity check in Logistics Outbound Warehouse. Insert serial numbers into SAP at the day of packaging.	Duplication eliminated successfully	Closed

D. H. - Department Head, T. L. - Team Leader, P. T. L. - Product Team Leader

ANNEXE G: Process Diagrams in BPMN of BIC Cloud



SN Acquisition To-Be

SN Acquisition To-Be



Leica Camera AG
Leica Camera Portugal
Logistics
MRP Planner
Purchaser
Serial Number Manager











Responsible	Gomes, Rui
Examiner	01_BIC Kernteam (Editoren)
Author	Araújo, Elisabeth, Ribeiro, Miguel, Silva, José
Last modified	June 14, 2024, 3:49:57 PM

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Responsibilities in the process

R=Responsible, A=Accountable, C=Consulted, I=Information; Interfaces to other processes are in bold font.

Process step		
1. Receive new range of numbers	R - Logistics R - MRP Planner R - Purchaser	
2. Send range of numbers	R - Logistics R - MRP Planner	
3. Request a new range of numbers	R - Logistics R - MRP Planner	
4. Send range of numbers	R - Logistics R - Purchaser	
5. Request a new range of numbers	R - Logistics R - Purchaser	
6. Request a new range of numbers	R - Logistics R - MRP Planner R - Purchaser	
7. Send range of numbers	R - Serial Number Manager	



Matrix

Aktivitäten / Akteure	Logistics	MRP Planner	Purchaser	Serial Number Manager	Input	Output	Applikation	Risiko
Receive new range of numbers	R	R	R					
Send range of numbers	R	R						
Request a new range of numbers	R	R						
Send range of numbers	R		R					
Request a new range of numbers	R		R					
Request a new range of numbers	R	R	R					
Send range of numbers				R				



SN Engraving To-Be

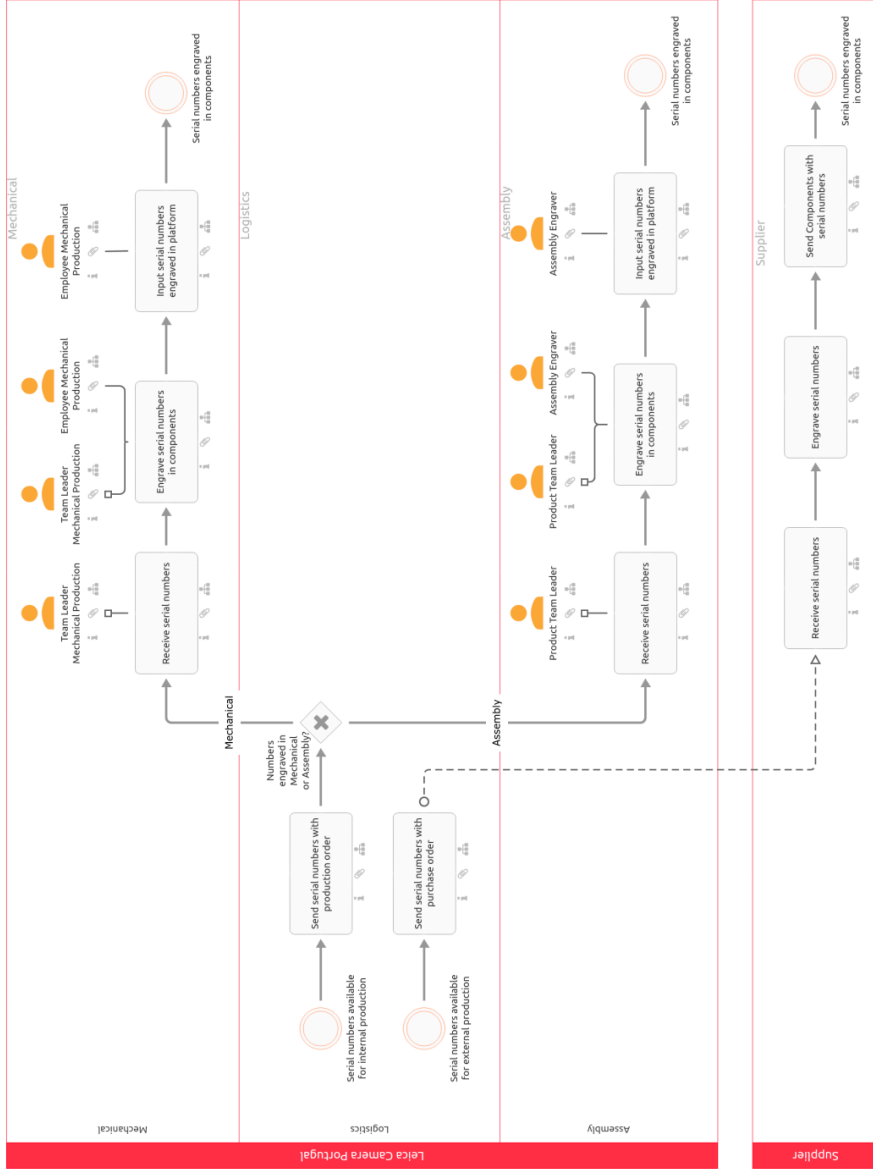
Process overview



Responsible	
Examiner	Araújo, Elisabeth, Ribeiro, Miguel, Silva, José
Author	
Last modified	June 15, 2024, 4:35:26 PM



Process graphic

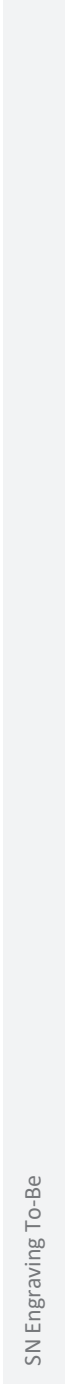




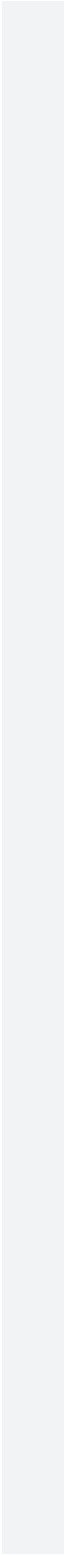
Responsibilities in the process

R=Responsible, A=Accountable, C=Consulted, I=Information; Interfaces to other processes are in bold font.

Process step		
1. Send serial numbers with production order	R - Logistics	
2. Receive serial numbers	R - Mechanical A - Team Leader Mechanical Production	
3. Engrave serial numbers in components	R - Employee Mechanical Production R - Mechanical A - Team Leader Mechanical Production	
4. Input serial numbers engraved in platform	R - Employee Mechanical Production R - Mechanical	
5. Receive serial numbers	R - Assembly A - Product Team Leader	
6. Engrave serial numbers in components	R - Assembly R - Assembly Engraver A - Product Team Leader	
7. Input serial numbers engraved in platform	R - Assembly	



Process step	
	R - Assembly Engraver
8. Receive serial numbers	R - Supplier
9. Engrave serial numbers	R - Supplier
10. Send Components with serial numbers	R - Supplier
11. Send serial numbers with purchase order	R - Logistics





SN Engraving To-Be

Matrix

Aktivitäten / Akteure	Assembly	Assembly Engineer	Assembly Engineer	Employee Mechanical Production	Logistica	Mechanical	Product Team Leader	Product Team Leader	Supplier	Team Leader Mechanical Production	Input	Output	Appliation	Risiko
Send serial numbers with production order					R									
Receive serial numbers						R				A				
Engrave serial numbers in components				R		R				A				
Input serial numbers engraved in platform				R		R								
Receive serial numbers	R						A							
Engrave serial numbers in components	R		R					A						
Input serial numbers engraved in platform	R	R												
Receive serial numbers									R					
Engrave serial numbers									R					
Send Components with serial numbers									R					
Send serial numbers with purchase order					R									

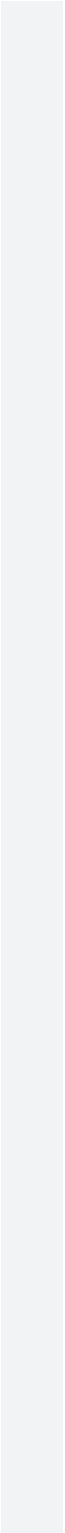


SN Delivery To-Be

Process overview

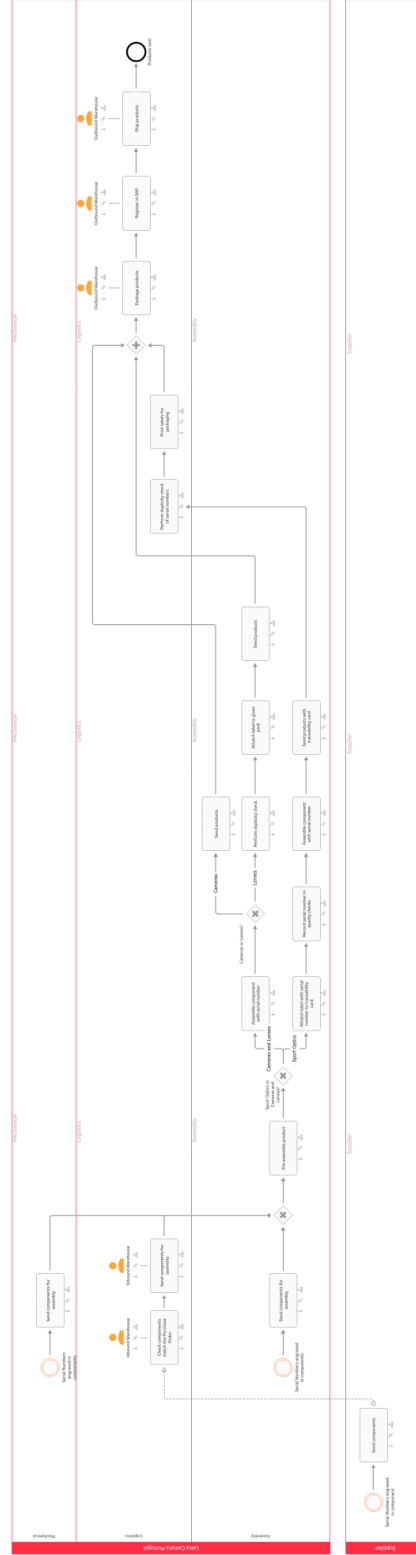


Responsible	Gomes, Rui
Examiner	01_BIC Kernteam (Editoren)
Author	Araújo, Elisabeth, Ribeiro, Miguel, Silva, José
Last modified	June 14, 2024, 4:42:29 PM





Process graphic





Responsibilities in the process

R=Responsible, A=Accountable, C=Consulted, I=Information; Interfaces to other processes are in bold font.

Process step	
1. Send components	R - Supplier
2. Send components for assembly	R - Mechanical
3. Check components match the Purchase Order	R - Inbound Warehouse R - Logistics
4. Send components for assembly	R - Inbound Warehouse R - Logistics
5. Send components for assembly	R - Assembly
6. Pre-assembly product	R - Assembly
7. Assemble component with serial number	R - Assembly
8. Perform duplicity check	R - Assembly



Process step		
9. Attatch label to given pack	R - Assembly	
10. Send products	R - Assembly	
11. Send products	R - Assembly	
12. Attatch label with serial number to traceability card	R - Assembly	
13. Record serial number in quality checks	R - Assembly	
14. Assemble component with serial number	R - Assembly	
15. Send products with traceability card	R - Assembly	
16. Perform duplicity check of serial numbers	R - Logistics	
17. Print labels for packaging	R - Logistics	
18. Package products	R - Logistics R - Outbound Warehouse	
19. Register in SAP	R - Logistics R - Outbound Warehouse	
20. Ship products	R - Logistics R - Outbound Warehouse	

[illegible]

Aktivitäten / Aktiere	Assembly	Inbound Warehouse	Logistics	Mechanical	Outbound Warehouse	Outbound Warehouse	Supplier	Risk
Send components							R	
Send components for assembly				R				
Check components match the Purchase Order		R	R					
Send components for assembly		R	R					
Send components for assembly	R							
Pre-assemble product	R							
Attach label with serial number to traceability card	R							
Record serial number in quality checks	R							
Assemble component with serial number	R							



Matrix

Aktivitäten / Akteure	Assembly	Inbound Warehouse	Logistics	Mechanical	Outbound Warehouse	Outbound Warehouse	Outbound Warehouse	Supplier	Input	Output	Application	Risiko
Send products with traceability card	R											
Perform duplicity check of serial numbers			R									
Print labels for packaging			R									
Assemble component with serial number	R											
Perform duplicity check	R											
Attach label to given pack	R											
Send products	R											
Send products	R											
Package products			R				R					



Matrix

Aktivitäten / Akteure	Assembly	Inbound Warehouse	Logistics	Mechanical	Outbound Warehouse	Outbound Warehouse	Outbound Warehouse	Supplier	Input	Output	Application	Risiko
Print labels for packaging			R									
Assemble component with serial number	R											
Perform duplicity check	R											
Attach label to given pack	R											
Send products	R											
Send products	R											
Package products			R			R						
Register in SAP			R				R					
Ship products			R		R							

ANNEXE H: Macros for test run using MS Excel

```
Private Sub Worksheet_Change(ByVal Target As Range)
```

```
    Dim cell As Range
```

```
    Dim ws As Worksheet
```

```
    Set ws = ThisWorkbook.Sheets("Envio do Produto")
```

```
    If Not Intersect(Target, ws.Columns("C")) Is Nothing Then
```

```
        Application.EnableEvents = False
```

```
        For Each cell In Target
```

```
            If cell.Value <> "" And ws.Cells(cell.Row, "A").Value = "" Then
```

```
                ws.Cells(cell.Row, "A").Value = Date
```

```
            End If
```

```
        Next cell
```

```
        Application.EnableEvents = True
```

```
    End If
```

```
    Call AtualizarInserirSAP
```

```
End Sub
```

```
Sub AtualizarInserirSAP()
```

```
    Dim wsEnvio As Worksheet
```

```
    Dim wsInserir As Worksheet
```

```
    Dim lastRowEnvio As Long
```

```
    Dim lastRowInserir As Long
```

```
    Dim i As Long
```

```
    Dim dict As Object
```

```
    Set dict = CreateObject("Scripting.Dictionary")
```

```
    Set wsEnvio = ThisWorkbook.Sheets("Envio do Produto")
```

```
    Set wsInserir = ThisWorkbook.Sheets("Inserir em SAP")
```

```
    ' Limpa a aba Inserir em SAP antes de atualizar
```

```
    wsInserir.Range("A2:B" & wsInserir.Cells(wsInserir.Rows.Count, "A").End(xlUp).Row).
```

```
ClearContents
```

```
    lastRowEnvio = wsEnvio.Cells(wsEnvio.Rows.Count, "A").End(xlUp).Row
```

```
    For i = 2 To lastRowEnvio
```

```
        If wsEnvio.Cells(i, "D").Value <> "Erro" Then
```

```
    If Not dict.Exists(wsEnvio.Cells(i, "C").Value) Then
        dict.Add wsEnvio.Cells(i, "C").Value, wsEnvio.Cells(i, "A").Value
    End If
End If
Next i
```

‘ Copia os dados únicos para a aba Inserir em SAP

```
lastRowInserir = 2
```

```
For Each Key In dict.keys
```

```
    wsInserir.Cells(lastRowInserir, 1).Value = dict(Key)
```

```
    wsInserir.Cells(lastRowInserir, 2).Value = Key
```

```
    lastRowInserir = lastRowInserir + 1
```

```
Next Key
```

```
End Sub
```

ANNEXE I: Time Measures

Activity	Product	Location	Unit of Time
Read Labels	SO-RF	Assembly	Seconds

Batch Size (Products)	Read Labels	
	As-Is	To-Be
1	10:08	03:57
1	09:05	03:52
1	07:32	03:16
1	07:42	02:54
1	11:57	01:48
1	08:43	02:20
1	08:29	02:58
1	10:54	03:44
1	-	02:32
Time/Product	09:18	03:02

Activity	Product	Location	Unit of Time
Duplicity Check	SO-RF	Logistics	Minutes

Batch Size (Products)	Duplicity Check + Print Labels	
	As-Is	To-Be
16	05:28	-
17	05:17	-
16	05:15	02:59
7	02:55	01:50
Time/Product	00:20	00:13

Activity	Product	Location	Unit of Time
Duplicity Check	M-Lenses	Assembly	Minutes

Batch Size (Products)	Duplicity Check	
	As-Is	To-Be
14	-	03:40
10	05:02	-
11	-	02:34
8	04:24	-
9	04:32	-
5	-	00:56
Time/Product	00:31	00:13

Activity	Product	Location	Unit of Time
Read Labels	Cameras	Logistics	Minutes

Batch Size (Products)	Read Labels	
	As-Is	To-Be
8	02:45	-
16	05:35	-
9	03:41	-
8	03:23	-
8	03:11	-
8	03:13	-
6	03:30	-
Time/Product	00:24	00:00

Activity	Product	Location	Unit of Time
Read Labels	Cameras	Logistics	Minutes

Batch Size (Products)	Insert in SAP	
	As-Is	To-Be
331	21:33	-
Time/Product	00:08	00:00

Daily Takt	Gain/Product	Total Gain	
160	06:16 s	19:46 s	
Days /year	Gain/year	Tarif/min	Gain/year
253	184 min	0,42 €	77,52 €

4.2.2.6 - Improved Labels in Traceability Cards

Daily Takt	Gain/Product	Total Gain	
80	00:07 min	10:00 min	
Days /year	Gain/year	Tarif/min	Gain/year
253	2530 min	0,3 €	759 €

4.2.2.6 - Check Automation for Finished Products

Daily Takt	Gain/Product	Total Gain	
15	00:17 min	04:22 min	
Days /year	Gain/year	Tarif/min	Gain/year
253	1108 min	0,42 €	465 €

4.2.2.8 - Elimination of Duplicated Activities for Lenses

Daily Takt	Gain/Product	Gain/day	
65	00:32 min	35:09 min	
Days /year	Gain/year	Tarif/min	Gain/year
253	8885 min	0,3 €	2666 €

4.2.2.7 - Elimination of Check for Cameras