Transforming descriptive BPMN models into executable: AHP-based expert prioritization for workflow automation

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Title	Transforming descriptive BPMN models into executable: AHP-based expert prioritization for workflow automation
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Management Summary

The thesis addresses a critical need for efficiency and automation in business processes at Oxand and the Municipality of Amsterdam. Current business processes, such as the BAP process and the proposal process, rely heavily on manual and semi-automated workflows. This leads to inefficiencies, including delays, a lack of insight and monitoring, resource wastage, and inconsistent performance.

The primary goal of this thesis is to transform business processes modeled at a descriptive BPMN level into fully executable and automated workflows using a BPMS/WfMS. Specifically, the thesis seeks to:

- Optimize and automate workflows for the BAP and proposal processes.
- Enhance workflow automation by integrating a BPMS (using Camunda 7 Run).
- Establish criteria for process transformation and implementation, considering stakeholder priorities through the Analytic Hierarchy Process (AHP) method.

To achieve these objectives, the thesis focuses on transforming BPMN models from descriptive to executable formats. This includes integrating automated workflows, such as automatic user assignment and form-driven processes, to improve efficiency and reduce manual intervention. To create this automated workflow, Camunda 7 Run was chosen for its accessibility, preconfigured setup, and BPMN modeling tools. It provides a practical balance between functionality and ease of use for proof-of-concept implementations. Using the AHP, criteria (efficacy, user-friendliness, conformity, and flexibility) were identified and prioritized to ensure that automation solutions align with stakeholder needs.

By prioritizing efficacy and user-friendliness, as determined by experts using the AHP method, this thesis successfully developed two automated workflows deployed in a BPMS. These workflows enhance efficacy by reducing manual user tasks and introducing automatic workflows. They also improve the user experience through intuitive and maintainable designs. This approach demonstrates how BPMN models can be effectively transformed into executable workflows, providing practical solutions to inefficiencies and inconsistencies in current processes. Moreover, the success of these two processes indicates the potential for similar automation across other workflows within the organization, paving the way for broader business process optimization.

Preface

This thesis marks the completion of my Bachelor's degree at the University of Twente and represents the final milestone of this academic journey. Over the course of my studies, I have grown significantly, both personally and academically.

I would like to start by expressing my gratitude to my university supervisors. My primary supervisor, Mahak Sharma, and my secondary supervisor, Lucas Meertens, have supported me throughout this process. Their feedback, support, and willingness to answer my questions greatly enhanced the quality of my work. I truly appreciate your time and effort, and I am sincerely thankful for your contributions.

Additionally, I would like to thank my company supervisor, Dennis van 't Ende, for his valuable assistance. Despite his busy schedule, he always made time to think along with me. His critical perspective, constructive feedback, and extensive insights significantly elevated the quality of this thesis. I also want to extend my gratitude to Oxand for providing me with an enriching, challenging, and enjoyable work environment where I could gain valuable professional experience.

Finally, I want to thank everyone who has supported me throughout my studies. Whether it was family, friends, lecturers, or fellow students, each of you played a role in helping me reach this point. Your encouragement and collaboration have helped me grow both as an individual and as a professional.

Thank you all.

Milan Mooij
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7PMG	Seven Process Modeling Guidelines
AHP	Analytic Hierarchy Process
BAP	(Dutch) Beheeracceptatieproces / (English) Asset Management/Ownership Acceptance Process
BPM	Business Process Management
BPMN	Business Process Model and Notation
BPMS	Business Process Management System/Suite
CMMI	Capability Maturity Model Integration
CR	Consistency Ratio
EA	Enterprise Architect
ISO	International Standardization for Organization
MDCM	Multi-Criteria Decision-Making
SRQ	Sub-research question
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
VSM	Value Stream Mapping
WfMS	Workflow Management System

1. Introduction

1.1. Company

To effectively analyze and identify the problem, it is crucial to first gain a thorough understanding of the company and the task they have assigned. "Oxand is an international consulting and solutions company that focuses on predictive management and optimizing the performance of real estate and infrastructure in a sustainable way (Oxand, 2024)." The company currently operates in three locations across Europe, including a branch in Utrecht staffed by over 20 consultants, project managers and ICT support personnel. Oxand offers a software tool, Simeo, designed to support asset management decision-making, such as maintenance planning. Alongside this tool, the company provides consultancy and advisory services to its clients.

1.2. Problem

At the moment Oxand has a long-term project with the Municipality of Amsterdam, where they are extensively mapping several business processes down to a descriptive/analytic BPMN (Business Process Model and Notation) level. However, a key challenge lies in understanding the feasibility and methodology of automating workflow management for these processes, which are presently represented at a level between descriptive and analytic BPMN. This is critical to determine, as automation has the potential to improve efficiency, reduce costs, and streamline operations (workflows). The objective is to assess the extent to which these workflows can be automated, whether partially or fully, and to evaluate the effectiveness of such automation. Achieving this requires transforming the BPMN model from its current state into a common executable level, this involves adding the necessary technical details and specifications.

Additionally, Oxand faces challenges within its internal proposal process (a part of the sales process). Unlike the externally focused BPMN project (Municipality of Amsterdam), the proposal phase is less developed and lacks documentation. This process requires definition, starting with an initiation phase and progressing through design and implementation. The lack of documentation makes monitoring and optimizing the sales process difficult. By formalizing and transforming this process into a common executable BPMN model, Oxand aims to achieve greater transparency, control, and insight, ultimately enabling workflow automation. This thesis contributes to that goal by designing and implementing an automated workflow (proof-of-concept), demonstrating its feasibility and providing recommendations for full-scale adoption.

Business Process Management (BPM) is a science that oversees how work and tasks are performed within an organization, it tries to make outcomes consistent and tries to find improvement opportunities (Dumas, *et al.*, 2018). Currently the problem is that both Oxand and the Municipality of Amsterdam experience challenges in the execution, status and performance of their business processes. This makes it difficult to identify bottlenecks and potential areas of improvement. Simulating the BPM, using BPMN, in a Workflow Management System (WfMS) or Business Process Management system (BPMS) has potential to optimize workflows and find inefficiencies. These improvements can eventually reduce human intervention and enhance efficacy.

1.3. Problem Cluster

After initiating the challenges Oxand and the Municipality of Amsterdam face, a problem cluster (Figure 1.1) was created to relate problems that lead to the main challenge: both Oxand and the Municipality of Amsterdam experience challenges in raising awareness for, and in identification of, potential bottlenecks and improvements in their business processes. This means that they currently have no tools or insights to identify improvements, which can potentially reduce cost and execution times. Without this capability, they are unable to improve workflow and overall efficacy. The primary cause is that the current BPMN models are not designed to run directly in a BPMS/WfMS.

Converting these descriptive models to a common executable level is challenging for several reasons. Some tasks involve human decisions, meaning that they are based on human expertise, judgement or knowledge, making them difficult to translate into automated rules. Other tasks may include complex decision points with multiple variables, dependencies, or conditional logic that must be carefully structured. Manual (user) steps, such as document reviews, email approvals, further complicate automation as they often lack standardized input formats or predefined outcomes. Additionally, the models often lack the detail needed to make them executable. To overcome these challenges, a combination of approaches will be used. This includes conducting literature research and consulting experts and users involved in the business processes to prioritize criteria that enhance workflow automation. Other attempts to address this problem may have failed due to the inexperience with automation in a WfMS/BPMS or insufficient collaboration between experts, users, stakeholders and researcher during the creation. Although multiple problems complicate the transformation to common executable level, they can be bypassed by scoping in on a detailed BPM process, using a process that is already detailed and well-designed enough to eventually enable simulation in a BPMS/WfMS.

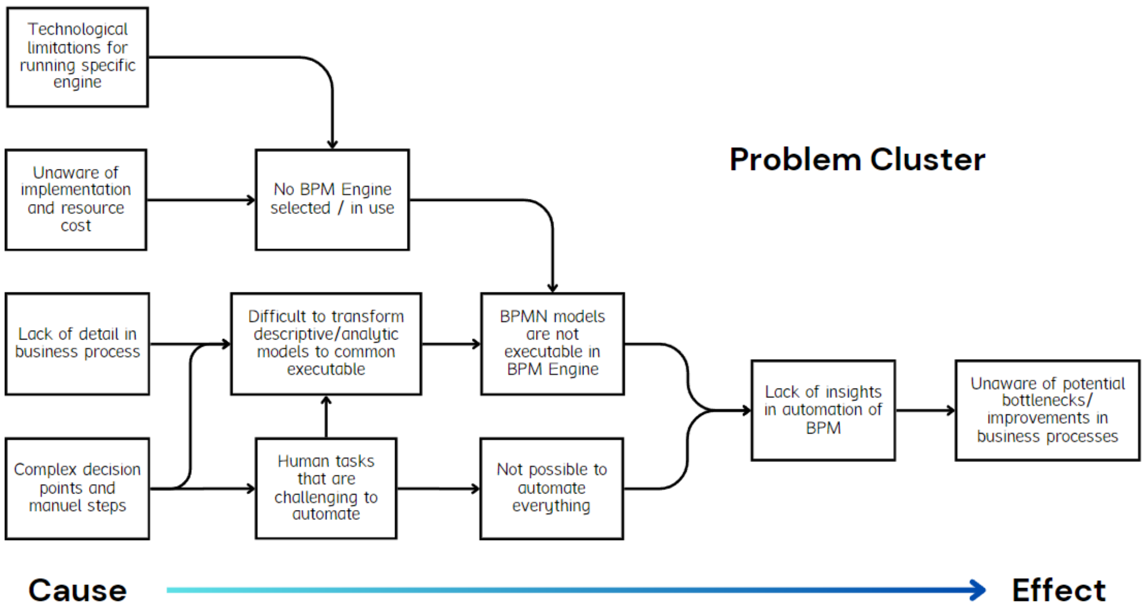


Figure 1.1: Problem Cluster

1.4. Action-problem

Looking at this action problem, there is a gap between the norm and reality. Here the norm is to have BPMN models at a common executable level, allowing for automation, but the reality is that the models are still at a descriptive/analytic level. Both Oxand and the Municipality of Amsterdam (problem owners), face the challenge of transforming there models to an executable level. The key variable to change is to close this gap by increasing the level of detail in the models and thereby making automation possible.

1.5. Problem Approach

After defining the problem, the next step is to outline a problem-solving approach. The problem will be addressed using the Management Problem Solving Method (MPSM, Figure 1.2). The main issue is partially understood: currently, there is no established method to convert descriptive processes into executable ones within the BPMS/WfMS. To tackle this issue, it is essential to identify the root causes and understand them thoroughly. Potential causes may include unclear modeling standards, the complexity of the business processes, or inadequate tools or resources (or not knowing how to use them effectively or which one to use). Once the problems are identified and analyzed, potential solutions can be explored. To guide this effort, the MPSM framework by Heerkens & Van Winden (2017) will be utilized. This methodology consists of seven phases, which are briefly described below:

Figure 1.2: Phases of the management problem solving method (MPSM) (Heerkens & Van Winden, 2017).

1. Problem identification: Understand the problem and figure out what is causing it.
2. Problem approach: Create a clear plan to solve the problem.
3. Problem analysis: Analyze the current business processes (e.g., Oxand's proposal process and the Municipality of Amsterdam's BAP process). Gain insights into how these processes work, including the tools and languages involved.
4. Solution generation: Explore ways to transform descriptive BPMN models into executable ones. Identify important criteria for successful transformation and investigate BPMS/WfMS capable of executing workflows. An expert interview can provide additional insights.
5. Decision making: Apply a Multi-Criteria Decision-Making (MCDM) method, such as Analytic Hierarchy Process (AHP), to evaluate and choose the most important criteria. Test a small portion of a business processes within the selected BPMS/WfMS to assess feasibility and automation potential.
6. Implementation: Implement the selected solution by integrating the chosen BPMS/WfMS and running the processes. Identify and address bottlenecks or issues related to automation, human task management and system integration. Refine the BPMN models as needed.
7. Evaluation: Conclude by evaluating the changes and discussing them with Oxand and the Municipality to make sure the models match the business needs and automation goals. Determine whether the automation has improved the production process and write/provide a brief recommendation/advise.

1.6. Deliverables

- Two business processes designed with BPMN and transformed into (common) executable models to run within a BPMS or WfMS:
    - Oxand Proposal process: A process focused on the proposal part of the sales business process, not only changing to common executable but also mapping out and designing the business process.

    - Municipality of Amsterdam: Asset Management/Ownership Acceptance Process (Dutch ‘Beheeracceptatieproces’, abbreviated in Dutch to ‘BAP’): A smaller portion of the larger BAP process, specifically phases 1 and 2 (application/registration & routing).
- Prioritization Tool: A tool based on the Analytic Hierarchy Process (AHP) to evaluate and prioritize criteria. This enables experts to determine the most effective automation strategies, balancing stakeholder needs and optimizing process automation outcomes.
- Recommendations and Implementation Plan: An implementation plan to recommend and advise for further automation and business process development, including guidance for completing the final two phases of the Management Problem Solving Method (MPSM) and the concluding stages of the BPM lifecycle.

1.7. Scope & Limitations

Workflow automation

This research focuses on exploring the feasibility of running a BPMS/WfMS and assigning tasks to different human actors within the system. It does not include automating tasks like email management, decision support/-making (e.g. with decision model and notation (DMN)), or extensive exception/error handling. The emphasis is on the feasibility of workflow automation rather than full-scale process automation. The rationale behind this scope is that successfully implementing workflow automation provides a reliable foundation for potential future initiatives, such as decision support, robotic process automation (RPA), and advanced automation techniques.

Problem Owners

The problem owners in these business processes are Oxand (Company) and the Municipality of Amsterdam. For the BAP process specifically, it is crucial to understand its position within the Municipality's organizational structure. The BAP process falls under the organization of the Municipality of Amsterdam, within the cluster Ruimte & Economie (Space and Economy cluster), and is managed by the Directie Verkeer en Openbare Ruimte (Directorate of Traffic and Public Space). This directorate was established around 2017 with newly delegated accountabilities (end responsibilities), including asset management and delegated asset ownership. The BAP is a critical and essential tool to support this function, which had previously not been fully addressed within the municipal organization. The department Stedelijk Beheer (Urban Asset Management/Ownership) within the directorate oversees the BAP process as part of its asset management responsibilities. Both Oxand and Stedelijk Beheer are key stakeholders in improving these business processes, but it is important to note that both parties have limited experience with process automation using BPMN.

Automation Level

Understanding the maturity of an organization is essential when assessing its readiness for process transformation and automation. The directorate was only quite recently established, which contributes to its current position estimated by Oxand consultants/experts to be somewhere between Levels 1 and 2 on the Capability Maturity Model Integration (CMMI) scale. At this maturity level, processes are often unpredictable, reactive, and poorly controlled (CMMI Institute, n.d.). While tasks may be completed, they are frequently accompanied by inefficiencies such as delays and budget overruns (CMMI Institute).

This level of automation maturity significantly limits the organization's ability to adopt and effectively implement process transformation, optimization and automation. Similarly, Oxand, although experienced in consultancy, predictive asset management and information system and software development/support/operation, faces challenges in transforming the current descriptive/analytic BPMN models to common executable BPMN models due to limited experience on this particular topic. Given these constraints, the later phases of the Management Problem Solving Method (MPSM, evaluation in Figure 1.2) and the BPM lifecycle (monitoring and controlling in Figure 2.1) are beyond the scope of this research. Instead, the focus will be on developing common executable BPMN models and providing recommendations and an implementation plan for future advancements in process automation.

Processes

The research focuses on two specific processes:

- Oxand Proposal process: A process focused on the proposal part of the sales business process.
- Municipality of Amsterdam: Asset Management/-Ownership Acceptance Process (Dutch 'Beheeracceptatieproces', abbreviated in Dutch to 'BAP'): A smaller portion of the larger BAP process, specifically phases 1 and 2 (application/registration & routing).

Proof of Concept

Due to the current level of automation and the limited timeframe of 10 weeks, this research focuses on developing a proof of concept rather than a full-scale implementation. Process improvement, real-time monitoring, and continuous optimization of workflows are beyond the scope of this research. However, an advisory and implementation plan will be provided, offering recommendations for future implementation and further development in this area.

Technical Considerations

In this research open-source tools will be prioritized where possible. For example, the research explores using open-source XML to BPMN tools, with potential opportunities to transform BPMN into XML or adapt the models to different workflow engines.

Researcher's Background

The researcher's expertise is primarily business-oriented, with limited experience in programming and technical implementation. As a result, this research adopts a business-oriented approach rather than a computer science perspective.

1.8. Research Questions

Following an analysis of the core problem and the problem-solving method this thesis seeks to answer the main research question:

- *How can business processes modeled at a descriptive/analytic BPMN level be transformed into an executable format and automated (partially or fully) using a BPMS/WfMS, while considering prioritized criteria?*

To answer this main research question, several sub-research questions (SRQs) are explored. These SRQs align with the phases of the Management Problem Solving Method (MPSM) and are designed to provide the necessary insights and information to address the main question effectively. SRQ 1 analyzes the current business processes to understand their structure and level of detail (aligned with phase 3 of MPSM). It also focuses on the design of the proposal business process for Oxand in BPMN using collaborative sessions (with stakeholders).

1. *What are the current business processes, and how are they structured?*
    1. *How are the processes modeled in BPMN?*
    2. *What does the sales process (proposal phase) look like?*

SRQ 2 focuses on identifying the problem in greater depth (phase 3), but also explores the criteria needed to transform models modeled with BPMN and to create a useful model, to find a possible result (phase 4).

2. *Which criteria influence the transformation and implementation of business processes modeled with Business Process Model & Notation (BPMN) from a descriptive or analytical level to an executable level (to create a model)?*
    1. *How do these criteria apply to various stakeholders and phases in the BPM lifecycle?*

The information gathered in the first two questions will inform decision-making in SRQ3. In this phase experts use AHP to make a decision to answer SRQ3:

3. *Which criteria are most important (according to experts) when transforming and implementing the BAP process modeled in BPMN from a descriptive/analytical level to an executable level?*

SRQ 4 identifies and selects suitable BPMS/WfMS for executing BPMN models (phases 4 and 5 of MPSM), SRQ 5 develops a proof of concept for both models in a BPMS (phase 6) and SRQ 6 develops an implementation plan to continue the research, focusing on future improvements and addressing current limitations (phases 6 and 7 of MPSM).

4. *Which BPMS/WfMS are most effective for running BPMN models?*
5. *How can BPMN process models be transformed from descriptive into executable formats?*
6. *What steps should be included in an implementation plan to further develop and implement BPMN models for automation?*

These sub-research questions collectively address the main research question and contribute to the deliverables. Each SRQ corresponds to specific MPSM phases, guiding the research design and methodology. The answers will provide insights into process transformation, criteria prioritization (using AHP), ultimately leading to proof-of-concept models, and implementation plan and recommendations. A detailed methodology for each SRQ, including data collection and analysis approaches, is provided in chapter 3.

2. Theoretical framework

To establish a solid foundation for this research, it is important to develop a theoretical framework. This framework begins with defining key terms and concepts, after which a review of the BPM lifecycle and relevant literature on the implementation of BPMN models will follow, providing necessary context. Once the theoretical groundwork is in place, the focus shifts to identifying the criteria that influence the transformation and implementation of business processes modeled in BPMN. This includes examining the factors that impact this transformation and how these criteria affect different stakeholders and phases within the BPM lifecycle.

After establishing the theoretical basis, insights will be derived through the Sub-Research Questions, linking the SRQs and their outcomes to address the main research question. The research design chapter will detail the methodologies used to address each SRQ. Combining all the SRQ with the results will contribute to answering the main research question. The theoretical framework supports this process by explaining the key theories, concepts, and variables underpinning the study. Definitions are presented first, followed by a literature review aimed at addressing the identified research questions.

2.1. Definition of key constructs and variables

Business Process Management (BPM) is a science that oversees how work and tasks are performed in an organization, it tries to make outcomes consistent and tries to find improvement opportunities (Dumas, et al., 2018). This is done by managing and improving whole chains, processes and decisions rather than individual activities/tasks (Dumas, et al., 2018). To represent these processes, BPMN is used as the modeling standard, adhering to BPMN 2.0(.2) specifications and verified against ISO 19510 (Object Management Group standards). In BPMN there are three main functions; activities/tasks (rounded rectangles), control nodes/gateways (diamond shapes) and sequence flows (arcs) to determine the order of which the process is executed (Dumas, et al., 2018). These functions are placed in a block representing the specific person or machine that performs these tasks and decisions.

When using BPMN, there are three different levels of conformance sub-classes defined; analytic, descriptive and common executable. A descriptive BPMN model shows the full business process in simple tasks that managers can easily understand, together with the expected outcome of the process (Tay, 2023). An analytic BPMN model shows what is happening for every person or machine itself, it could be a day-to-day guide of the process from the view of the person/machine (Tay, 2023). By changing different factors (yet to be determined) these descriptive and analytic BPMN models can be transformed to common executable, to then be run in a BPMS or WfMS. After creating model using BPMN and converting it to common executable it can be optimized by implementing it in a BPMS or WfMS.

It is first essential to understand how business processes are initiated, designed, and implemented. This is where the Business Process Management (BPM) Lifecycle (Figure 2.1) comes into play. The BPM lifecycle includes the identification, design, implementation, monitoring, control, and improvement of business processes (Dumas et al., 2018). By following these seven phases, a process can progress from its initial identification through to design, implementation, and monitoring. Once the cycle is completed, the process can be refined and optimized through repetition of the cycle.

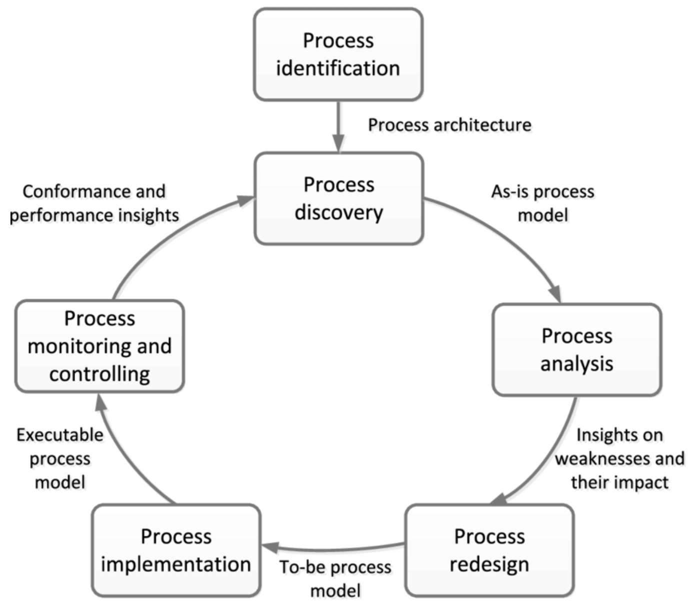


Figure 2.1: The BPM lifecycle (Dumas et al., 2018)

A Workflow Management System (WfMS) is an electronic platform that automates the routing of work tasks between persons or systems within an organization (Sampson, 2003). It automates the business process, when one person finishes a given task, it automatically notifies the next person that they have an outstanding action to complete (Sampson, 2003). A Business Process Management System (BPMS) offers broader functionality compared to a WfMS, supporting all the phases of the BPM lifecycle of business processes based on an explicit process model (Dumas et al., 2018). A WfMS is mostly focused on the modeling and execution of a business process and does not very well support the other phases of the BPM lifecyle (Dumas et al., 2018), meaning that a WfMS is a part of a BPMS. The primary goal of a BPMS is to ensure that work is carried out efficiently by coordinating automated processes so that tasks are performed at the right time by the right resources (Dumas et al., 2018).

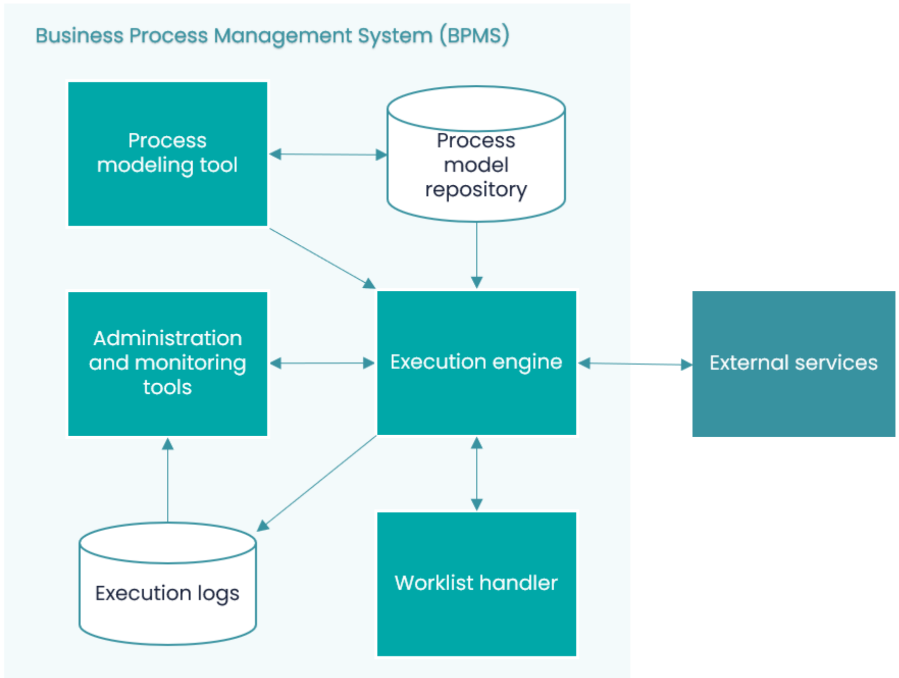


Figure 2.2: The architecture of a BPMS (Dumas et al., 2018)

Before implementing a BPMS, it is essential to understand its architecture and the key components that enable process automation and optimization (see Figure 2.2). At the core of a BPMS is the execution engine, which is responsible for managing and executing business processes. This engine creates executable process instances based on BPMN models, assigns and distributes work to users or automated services, and stores and tracks process data to ensure smooth execution. Additionally, it continuously monitors the progress of ongoing processes and coordinates the allocation of resources, ensuring that tasks move through the workflow. Another crucial component is the process modeling tool, which allows users to create and edit BPMN models. This tool provides the ability to define input and output data for each task, specify user roles and responsibilities and establish business rules and conditions that govern execution. Once a BPMN model is finalized, it is stored in the process model repository, from where it can be deployed to the execution engine for automation.

The worklist handler serves as an interface for users to manage their assigned tasks. It functions like an inbox, where users can view pending tasks, enter required data, and complete activities. Once a task is finished, the execution engine automatically triggers the next step in the workflow, ensuring task progression. A BPMS also includes execution logs and monitoring tools, which track all process activities in real-time. These logs provide valuable insights that can be used to assess process performance. Monitoring tools utilize this data to generate performance dashboards, helping organizations identify inefficiencies and bottlenecks. Additionally, administration tools allow for task reassignment in cases where users are unavailable and manage authentication, user logins, and access permissions to maintain security and operational continuity.

Finally, a BPMS can integrate with external services to enhance its functionality. It can connect to email services for automated notifications, databases for retrieving and storing data, and custom scripts for executing specialized automation tasks. Since a BPMS supports the entire BPM lifecycle, from design and deployment to execution, monitoring, and administration, it provides a comprehensive framework for business process automation and continuous improvement.

2.2. Literature Review

After defining key constructs and variables, the next step is conducting a literature review to identify the criteria that influence the transformation and implementation of business processes modeled in BPMN. This involves exploring the factors that affect this transformation and understanding how these criteria impact different stakeholders and phases within the BPM lifecycle. To establish criteria for the potential automation of processes using BPMN, it is essential to analyze the stakeholders involved (Dumas et al., 2018). Based on consultation with experts in both business processes, the following key stakeholders are identified as playing significant roles in the process:

- Users: The process participants and human actors who perform daily tasks and activities. Users prefer simplicity and usability in the automated processes, avoiding unnecessary complexity or additional workload.
- Managers: The process owners responsible for ensuring the efficient and effective operation of systems. Their focus is on monitoring performance and maintaining smooth workflows.
- Enterprise Architects: They map all processes within the organization, understanding that a specific process, such as the BAP, is part of a broader system. Their goal is to ensure comprehensive and consistent process integration.
- Modeling Experts/System Engineers: These stakeholders handle the design, modeling, implementation, and deployment of BPMN. Their focus is on ensuring the technical (model)integrity and feasibility of the models.

It is crucial to examine if the goals and requirements of the stakeholder are well worked out in the BPMN models (Yahya et al., 2018). This means confirming that the model meets the intended objectives, meaning that each component clearly conveys its purpose (Corradini et al., 2017). Does the model describe the problem as the stakeholders would like it? By considering the BPM lifecycle, stakeholder preferences, ISO standards (ISO 25010 for software quality and ISO 19510 for BPMN), literature research and insights from experts, the following four key criteria (with all four sub-criteria) have been identified as critical for the transformation and automation of business processes: efficacy , user-friendliness, conformity and flexibility.

2.2.1. Efficacy

Efficacy refers to the extent to which a process minimizes resource use, time, and effort while maximizing output. This criterion is particularly significant for process owners, who are responsible for optimizing operations and ensuring that resources are allocated effectively (Dumas et al., 2018). Efficacy emerged as one of the critical focus points during the internal company discussions.

When evaluating efficacy, it is crucial to consider its connection to the purpose of Value Stream Mapping (VSM) and how this purpose informs the creation of BPMN models. While BPMN and VSM each have their limitations and advantages, the key takeaway is to leverage VSM's focus on value optimization when designing BPMN models (Soliman et al., 2022). Value Stream Mapping (VSM) is a technique that divides all processes into two categories: Value-Adding (VA) and Non-Value-Adding (NVA) tasks (Rohac & Januska, 2015). This method visualizes the flow of value throughout a process, aiming to identify and enhance tasks that contribute to the overall purpose of the process while minimizing or eliminating non-value-adding activities (Rohac & Januska, 2015). The goal of VSM is to optimize the value flow, ensuring that each step aligns with the process's purpose and objectives.

Within the BPM lifecycle, VSM supports the process discovery stage, which depends on the process structure. This architecture often includes three main types of business processes; core processes that create value for the organization (e.g., creating goods or services), support processes that enable the execution of core processes (e.g., HR and IT management) and management processes that provide rules and directions for core and support processes (e.g., strategic planning and budgeting) (Dumas et al., 2018; Von Rosing et al., 2014). However, the efficacy of a process is often evaluated during the later stages of the BPM lifecycle, particularly in the monitoring and controlling phases. In the context of BPMN, value-adding and goal oriented activities can be identified and evaluated by considering the following aspects:

- The process must have a clear goal orientation, ensuring that its objective is well-defined and that it creates value for stakeholders, each step aligns with the process's purpose and objectives (Koliadis & Ghose, 2006). Goal-orientation involves meeting the needs, interests, and concerns of all affected parties, both positively and negatively, as effectively as possible.
- Effectiveness refers to the degree to which the process achieves its intended results (Dumas et al.). Effectiveness is defined by ISO 25010 as the accuracy and completeness with which specified goals are achieved. It includes the process's ability to handle exceptions, alternative paths, and error recovery, ensuring consistent achievement of desired outcomes.
- Efficiency involves evaluating the resources required to execute, monitor, manage, and maintain a process. As defined by ISO 25010, it is the relationship between the resources used and the accuracy and completeness of goal achievement. Resource considerations include time, personnel, materials, and integration with existing IT systems.
- Controllability concerns the extent to which a product, system or process can be effectively and efficiently modified and managed by the designated managers (ISO 25010). This

includes ensuring clear ownership and responsibilities at all business levels (task, business process, management system, and enterprise architecture). It also involves the capacity for forecasting resources, adapting to changing circumstances, and planning based on new insights.

By critically evaluating these aspects, business processes can be aligned with efficiency goals, enhancing the overall performance and value of the automated processes.

2.2.2. User-Friendliness

After discussing the main criterion of efficacy and its sub-criteria, which primarily focus on the management side of the business process and stakeholders, it is equally important to address the user side of the business process. This leads to the second key criterion: user-friendliness.

User-friendliness refers to the quality of being accessible (accessibility), easy to use (usability), and facilitating communication (understandability) (Gulshad et al., 2024). This ensures that users can effortlessly engage with tools or systems, thereby enhancing their overall experience and satisfaction (Gulshad et al, 2024). An important aspect of user-friendliness is the user interface design, which plays a critical role in determining how users interact with the system. A well-designed interface reduces perceived complexity, increases trust in the system and facilitates interactivity (Sarkar et al., 2019). While BPMN is not directly an interface, it can be eventually executed in a BPMS for workflows executed by systems that users interact with, making interface considerations indirectly relevant during the modeling phase.

According to Dumas et al. (2018) the quality of a process model depends on three main criteria: semantic, pragmatic, and syntactic quality (Figure 2.3). Among these, pragmatic quality can be linked to user-friendliness (see criterion conformity for other two), as it refers to the usability of a process model, how effectively people can interact with and understand the model (Dumas et al., 2018). Dumas et al. (2018) emphasize that the quality of a business process model can be assessed through certification, which evaluates its usability. In this context usability can be further divided into three key aspects. First, understandability refers to how easily a process model can be read and interpreted by users. Second, maintainability relates to the ability to modify or update the process model and its associated ICT systems as business needs evolve. Finally, the model's real-world representation determines how accurately it reflects the actual business process, enabling users to intuitively grasp the workflow. Ensuring these factors are met is essential for maintaining the overall quality of business process models (Dumas et al., 2018).

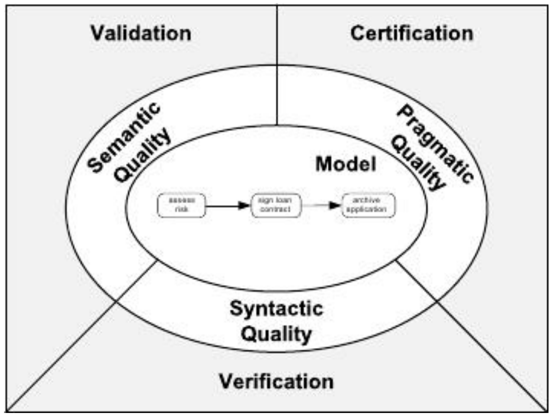


Figure 2.3: Process Model quality aspects and assurance activities (Dumas et al., 2018)

Based on input from experts, literature and the ISO 25010 standard, the following four sub-criteria related to user-friendliness were developed:

- Usability reflects how easily, intuitively, and pleasantly (end) users can interact with the process. An intuitive model minimizes the need for extensive training and ensures that users can efficiently and enjoyably achieve their desired results. As defined in ISO 25010, usability is the degree to which a user is satisfied with the perceived goals achieved, including the outcomes and consequences of using the system.
- Understandability refers to the clarity, unambiguity, and readability with which the process is documented and presented to users. This involves avoiding unnecessary or redundant elements and ensuring readability so that users can understand, use and work with the business processes (Dumas, 2008).
- Accessibility concerns the ease with which users can access and use information and (ICT) systems related to the process, it also concerns the low threshold for obtaining the information needed to work with the process(model) (ISO 25010).
- Maintainability refers to how easily the process model can be adjusted or updated by administrators, as well as how well the (ICT) systems supporting the execution, monitoring, adjustment, and improvement of the business process can be updated (ISO 25010) (e.g., when adding new users) and adapted (e.g., when making changes). The process(model) must be suitable for quickly and efficiently processing changes in the process without significant risks or errors.

By focusing on these four sub-criteria, the criterion user-friendliness tries to create an effective interaction between users and the business process(model).

2.2.3. Conformity

The third main criterion is conformity, which is primarily relevant to modeling experts/system engineers. It focusses mostly on the design phase of the BPM lifecycle. This criterion assesses how well the process(model) adheres to standards, completeness of representation, maintains integrity, and security of the model. When assessing conformity, the two other key aspects of process model quality (Figure 2.3) are particularly important. Syntactic quality refers to whether the model follows the formal rules of the modeling language through verification (Dumas et al., 2018). In the case of BPMN, this means ensuring compliance with BPMN 2.0.2 specifications and verification against ISO 19510 standards set by the Object Management Group. Additionally, adherence to established modeling guidelines, such as the Seven Process Modeling Guidelines (7PMG), helps bridge academic insights with practical applications (Mendling et al., 2009).

On the other hand, semantic quality assesses how accurately the BPMN model represents the real-world business process, this can be done through validation with stakeholders (Dumas et al., 2018). Validation is required to ensure alignment between the model and the actual business operations, which can be facilitated by user-friendly annotations (Born et al., 2007). Besides the fact that the model must show a good real-world business process, it is also important to link the model with other ICT systems and to pay attention to the security of the model. To provide a structured framework, conformity is further broken down into the following four sub-criteria:

- Correctness refers to the extent of which there is adherence to BPMN 2.0 standards (ISO 19510), ensuring the correct use of syntax, symbols, and modeling rules. This ensures technical accuracy and facilitates execution. It also includes implementing requirements and rules in the model properly, reducing the risk of errors (Yahya et al., 2018).
- Completeness assesses whether the process model represents the entire business process comprehensively. This includes validation with stakeholders and documenting all relevant details, such as exceptions and alternative routes (Dumas et al., 2018). Modeling conventions (e.g., like the 7PMG) can help maintain consistency and completeness (Mendling et al., 2009).
- Integrity ensures that all components of the process model align to form a cohesive and logical and integrated whole. The process(model) should be designed in conjunction with the (enterprise) architecture and should work flawlessly with chosen solutions (e.g., other (ICT) systems or components) while following clear (integrated) agreements to prevent confusion and problems (Leopold et al., 2015).
- Security evaluates the model's ability to protect information and data from unauthorized access or manipulation, including access control, ensuring data integrity, and maintaining appropriate levels of authorization for users (ISO 25010). The model must uphold these protections to prevent breaches and ensure reliability.

2.2.4. Flexibility

The final criterion, flexibility, plays a role in the later phases of the BPM lifecycle. It refers to the ability to adapt and modify business processes after implementation. Flexibility is defined as the capacity to respond to changes, such as management adjustments to process structures, or the organization's responsiveness to evolving demands from markets or business partners (Dumas et al., 2018). For example, this may include adding new technologies like AI. This criterion is particularly important for enterprise architects, as they oversee the integration of processes within the broader system. Their focus is not only on consistent integration but also on ensuring reusability and modularity for adaptation across the organization. To comprehensively define flexibility, it can be broken down into four sub-criteria:

- Adaptability refers to how easily processes can be adjusted after deployment, including modifications to accommodate new technologies like artificial intelligence or shifts in market demands. Adaptability is the ability of a system to adjust to evolving environments, whether related to hardware, software, or operational contexts (ISO 25010). Business models should remain relevant and usable even as organizational priorities change (Yahya et al., 2018).
- Scalability refers to the ability of a process to grow and handle increased demand without significant structural changes. Business process scalability is defined as the ability of business processes to manage increasing demands or expand in scope (handle growth in the number of processes), ensuring they remain effective as the organization grows (Yaqin et al., 2017).
- Modularity refers to the extent to which a system is build out of independents modules or sub-processes, so that changes to one modules have minimal impact on the other modules (ISO 25010). This structure allows adjustments to individual components without impacting the entire model (Corradini et al). By breaking down the business models into subprocesses and modules, the model becomes more manageable, reducing the number of errors, increasing the ease of applying changes (Dumas et al, 2018; Yahya et al, 2018 ; Leopold et al., 2015).
- Reusability is the ability of components to be utilized in multiple systems or contexts (ISO 25010), meaning the extent to which components of the process model can be reused in other systems or new models. Reusability is particularly valuable in business process modeling, where parts of one model can often be integrated into other models within the same organization, streamlining development efforts (Dumas et al., 2018).

2.2.5. Summary

The transformation of BPMN models into common executable processes relies on four key criteria, each linked to phases of the BPM lifecycle and stakeholder roles. Efficacy ensures processes minimize resource use while achieving goals effectively, addressing the priorities of managers and process owners during the design and implementation phases. User-friendliness focuses on intuitive, accessible, and maintainable processes, ensuring end-users can interact with systems effortlessly during execution. Conformity emphasizes adherence to BPMN standards, completeness, and integration with broader systems, supporting the work of modeling experts and system engineers during the design and validation stages. Finally, flexibility enables processes to adapt to changing demands through scalability, modularity, and reusability, ensuring sustainability post-implementation. By combining the explanation of key constructs and variables, input from various stakeholders, the role of a BPMS, and the BPM lifecycle, experts can prioritize these criteria to optimize the transformation and automation of business processes.

3. Research Design

In the research design the methods for tackling every SRQ are described and explained. What data gathering method and data analysis are being used? What are the research populations and the limitations of each method? Additionally, the validity and reliability of the methods are being explained.

3.1. Method for every SRQ

The table below outlines each SRQ along with its corresponding phase in the MPSM framework, the data collection methods employed, and the target research population.

Table 3.1: Data gathering method and research population for every SRQ

SQR	Phase MSPM	Data Gathering Method	Research Population
1.	3	Stakeholders Meetings	Stakeholders
2.	3,4	Literature Review & Expert Opinion	Academic Database & BPMN Expert
3.	5	Analytic Hierarchy Process (AHP)	Experts related to the BAP process (Stakeholders)
4.	4, 5	Literature Review & Expert Opinion	Academic Database & BPMN Expert
5.	6	Outcomes of SRQ1-4	-
6.	6,7	Outcome of SRQ 5 & Literature Research	Academic Database

3.2. Data Gathering Methods

For each SRQ specific methods are selected to gather and analyze the necessary data. Each method includes details on the research population, data gathering method, data analysis method and limitations. Both qualitative and quantitative data analysis will be used. The research population consists out of four main sources. Academic databases used for doing literature research, these are e.g. Scopus, arXiv and Google Scholar. Stakeholders who are the individuals and colleagues of the Municipality of Amsterdam and Oxand who assigned the project. Experts that can prioritize the AHP criteria for the BAP process. Last an opinion of an expert that is highly skilled in BMPN models. This expert should have extensive knowledge in BPMN modelling, being able to offer recommendations on model accuracy, feasibility and automation. Someone who has studied BPMN modelling a lot and also transitioned descriptive models to an executable level.

3.2.1. Stakeholders Meetings

Stakeholder meetings, including personal (informal) meetings, consultations and observations play a key role in gathering information about how Oxand and the Municipality of Amsterdam have defined their business processes. These activities are crucial for answering the first SRQ: What are the current business processes, and how are they structured?

For the Municipality of Amsterdam, the processes are already partially detailed. Two sessions are conducted with different participants. A process modeler who explains the technical aspects of how the process is structured in BPMN and a business owner who clarifies the purpose and objectives of the process, providing a contextual understanding. In contrast, mapping out Oxand's proposal process requires more extensive engagement. Five interactive sessions are held with key stakeholders, including the team leader and supervisor. These sessions aim to validate the existing workflow, identify pain points and refine the structure of the process. For the proposal process of Oxand discussions start with an outdated BPMN model and a conceptual plan presented in PowerPoint. Stakeholder feedback is used to create a revised BPMN model that reflects the updated proposal process.

Each week, there is a meeting with colleagues who are currently working with EA and BPM systems. During this meeting findings and questions about these topics are discussed. In addition to the casual conversations/meetings, both companies have separate systems that provide insights in their enterprise architecture and BPM processes. Oxand uses Sparx Systems EA and the Municipality has its own environment. I also have a laptop provided by Oxand that gives access to both environments, what allows me to explore existing data and identify problems and solutions, by trying to understand the already existing business processes.

To analyze the data, it is essential to document the key information during conversation with colleagues and stakeholders. This information should be reviewed by someone else (e.g. colleague or stakeholder) to confirm its accuracy. Using personal observations has some limitations. The data collected is informal, this makes it difficult to validate. Additionally, the method is limited to my own observations. I am the only one documenting and details can be forgotten or documented incorrectly, which reduces both validity and objectivity.

3.2.2. Literature Review

By using a literature review method, SRQ's will be answered through searching, analyzing and evaluating sources to verify their validity. This method combines several sources to come to an answer using the phases described below:

1. Identification of literature that is useful. Using databases (e.g. Scolar, arXiv and Google Scholar) to find articles that are relevant to answer the SRQ. This will be done by using relevant keywords and search terms.

2. Selection and screening of the sources. After scanning the results from the search terms and keywords a short selection of sources is created useful for answering the SRQ.
3. After finding data it can be analyzed through in-depth reading. Writing down/summarizing the most relevant findings of a source.
4. Evaluate and compare the findings of different sources, do they have similarities that answer the SRQ? It is also important to mention the differences and explain if they are useful for the research.
5. Based on the findings, methods will be developed to answer the SRQ. Later on, these methods could be implemented in practice.

There are some limitations when using literature review for this research. Some of the SRQ's require specific tools or extensions, but literature review is limited to text, sometimes it lacks the information on how to create and implement a software system (e.g. BPMS or WfMS). Overall, the validity of literature research is quite good, because it is based on established research that is peer-reviewed.

3.2.3. Expert Opinion (semi structured interview)

The third method for data gathering is expert opinion. The goal is to gain insights from an expert with extensive experience in developing common executable BPMN models that can be implemented in a BPMS or WfMS. This will help answer SRQs related to the implementation and operationalization of business processes. This will involve a semi-structured interview, where questions are prepared. However, this format also allows flexibility to explore and investigate the experts' responses a bit more, giving even more valuable information.

Prior to the interview, consent will be obtained from the expert, and permission will be asked to record the conversation. After the interview, an AI-powered Natural Language Processing (NLP) algorithm will transcribe the audio recording into text, this transcription process supports qualitative research (Cheligeer et al., 2022). The transcription will be carried out using an AI tool (like TurboScribe). After the transcription the researcher will listen and verify the text for accuracy. Once the audio is transcribed, the responses to the questions will be written down, referring to the transcript to ensure accuracy.

A summary of the responses will be created, including question and answers, providing a clear overview of the expert's insights. During the analysis, the focus will be on uncovering deeper meanings and understanding the expert's practical knowledge. Because the interview is partly focused on the practical site, not everything will be recorded. After the recorded part, the expert will give the researcher insights in how the BPMS/WfMS works, more questions about the practical part. The advantage of this method is that the expert has practical knowledge on how these systems work, not only theoretical knowledge, giving useful tips and tricks for building common executable models.

However, this method has some limitations. Analyzing the interview content can be time-consuming, and the expert might not have complete knowledge of every aspect of the models. To validate the expert’s opinions, the insights will be cross-checked against existing theoretical knowledge, as well as information gathered from the literature review. This cross-referencing will strengthen the validity and reliability of the expert's insights, ensuring that the findings align with established theories and practices.

3.2.4. Analytic Hierarchy Process (AHP)

Through literature research criteria have been formulated to answer SRQ 2, the next step is to determine their priority for developing the BAP process into an executable model (SRQ 3). This is achieved by consulting experts who will prioritize the criteria based on their experience, expertise, and knowledge of the BAP process. The group of experts consists of six individuals, including process modelers, enterprise architects, project managers, end-users (or those familiar with the process), and system engineers.

The prioritization of criteria is carried out using a Multi-Criteria Decision-Making (MCDM) method, specifically the Analytic Hierarchy Process (AHP). AHP is a structured MCDM technique that breaks down a complex decision problem into a hierarchical model (Saaty, 2008). The process involves (Al-Rakhami & Almashari, 2019):

1. Defining the goal or objective.
2. Structuring the criteria into a hierarchy of main and sub-criteria.
3. Performing pairwise comparisons to evaluate the relative importance of each criterion.
4. Calculating weights and ensuring consistency through the Eigenvector Method.

The AHP requires a consistency ratio (CR) below 10% to ensure the comparisons are reliable (Saaty, 2012). If the CR exceeds this threshold, experts are asked to revisit and adjust their evaluations to improve consistency. Experts completed the survey by ranking the importance of criteria based on phases 1 and 2 (application/registration and routing) of the BAP process. The focus on these phases ensures that results are directly relevant to the partial automation and implementation of the BAP in a BPMS or WfMS. The AHP method is chosen because of its accuracy and simplicity.

However the AHP method has some limitations. One issue is that it relies on expert judgement to decide the importance of criteria, rather than using quantitative data (Munier & Hontoria, 2021). This can make the results less reliable, especially if only a few experts are involved. Increasing the number of experts to six helps reduce this issue, thereby enhancing the reliability of the results. Another limitation is that the method focuses on a limited number of criteria (Munier & Hontoria, 2021). If important factors are left out or given less attention, it could affect the outcome. Despite these challenges, the AHP method is very consistent and systematic. It carefully compares all options using clear, predefined criteria, which makes the process more valid and trustworthy.

3.3. Validity and reliability

For the research is it necessary to ensure a good validity and reliability. Validity refers to how accurate and trustworthy the information is, and whether it truly measures or describes what it claims to (Creswell & Creswell, 2018). Reliability means the accuracy and precision of the measurements methods (Cooper & Schindler, 2014). To ensure consistent results, validity and reliability are crucial. For quantitative and qualitative data, 3 criteria are used to evaluate validity.

This thesis applies three primary criteria to validate quantitative data: internal validity, construct validity, and reliability. Internal validity means how well the conclusion of an experiment shows that the cause truly led to the effect (Cooper & Schindler, 2014). Are the outcomes really the result of the experiment? Are the changes in the dependent variable due to the change of the independent variable and not due to external factors (Creswell & Creswell, 2014). Construct validity is how well an experiment represents the theoretical concepts it aims to figure out (Strauss & Smith, 2009). Does the experiment effectively test or measure the variables it tries to assess? Reliability measures the consistency of the results when the experiments are repeated (Cooper & Schindler, 2014). Are the outcomes and results accurately and precisely when repeated? To increase the validity of quantitative data in this research, variables influencing the outcomes will be carefully controlled, and all key concepts will be clearly defined to align with the theoretical constructs being measured. Data collection methods will be standardized and tests will be repeated multiple times to increase reliability.

For qualitative data, three criteria are applied: credibility, dependability, and confirmability. Credibility refers to how accurate the outcomes of the experiment are (Lincoln & Guba, 1985). Does the data truly shows the respondents' views and their interpretation (Kakar et al., 2023). Dependability is used for measuring the reliability of results over time and under different conditions (Ahmed, 2024). If the data stays the same when repeated under similar conditions, people and settings, then the results are dependable (Kakar et al., 2023). The final criterion is confirmability. Confirmability means how unbiased and fair the results are. It shows that the experiment's results are based on the participants' original answers and are not influenced by any kind of (researcher) bias (Kakar et al., 2023). Increasing confirmability can be done by peer debriefing and member checking, ensuring that the perspective of a participant (e.g. expert) is accurately represented (Ahmed, 2024).

To increase reliability, several measures are implemented. During the creation of the models, continuous validation is carried out by involving multiple stakeholders to review the business processes. For instance, the Oxand proposal process was validated through five consecutive sessions, ensuring consistency and accuracy in the models. Additionally, peer-reviewed articles are exclusively used for criteria and literature research, and findings are cross-verified with multiple sources to improve reliability. During the application of the AHP methodology, a Consistency Ratio of less than 10% is maintained, requiring experts to demonstrate consistency when prioritizing criteria. By involving various experts, including modelers, management, end-users, and enterprise architects, to review the processes and prioritize criteria from different perspectives, the research achieves more reliable outcomes. These criteria collectively ensure the validity and reliability of both quantitative and qualitative data in this research.

4. Context analysis

With the theoretical foundation established and the research design clarified, this chapter focuses on addressing the first three Sub-Research Questions. Section 4.1 delves into the context analysis, exploring how the current business processes are structured and the extent to which they are developed. In Section 4.2, key criteria are identified for transforming business processes into executable workflows. Finally, Section 4.3 applies the AHP method, engaging experts from the BAP process to prioritize the identified criteria based on their expertise and input, laying the groundwork for creating a common executable BPMN model. The results of these analyses form the basis for the application developed in Chapter 5.

4.1. Analyzing current business processes

To analyze the current situation and answer question 1A, it is essential to examine the existing business processes that will be transformed into common executable models using BPMN. Two distinct processes are considered for this research, each at a different stage of development.

SRQ1: What are the current business processes, and how are they structured?

- **1A: How are the processes modeled in BPMN?**
- **1B: What does the proposal process look like?**

4.1.1. Business process 1: Beheeracceptatieproces (BAP)

The first process, the Beheeracceptatieproces (BAP), is part of a larger process framework related to the management of Stedelijk Beheer, within the Traffic and Public Space Directorate of the Municipality of Amsterdam. This process facilitates the integration of external project organizations into the Municipality's systems through the BAP process, which includes the formal acceptance of civil structures into management. Currently, the BAP process have been modeled extensively by enterprise architects and modelers from Oxand (in collaboration with the Municipality), who have been working on various processes for the Municipality. The process consists of seven phases, but this research focuses on the first two (outlined in red, Figure 4.1):

- *Phase 1: Aanmelding* (*Application/registration*) – In this phase, project details are currently submitted using a form connected to a macro. The macro triggers an email that is sent to an individual who manually updates a register and an automated confirmation email is send to the external organization.

- *Phase 2: Routering (Routing)* – This involves assigning the appropriate contact person to a project based on the information provided in the register. This register links the project to a specific contact person.

These phases have been modeled at a descriptive BPMN level, detailing which actors perform specific tasks, as well as the forms, databases, and documents involved. The model spans three hierarchical levels, with the entire process depicted in Figure 4.1, phase 1 (application/registration) detailed in Figure 4.2, and a sub-process within Phase 1 shown in Figure 4.3. The models were created using Sparx Systems Enterprise Architect, a tool supporting BPMN modeling. The main challenge is determining how to transition the descriptive models to executable ones and exploring the workflow automation potential using a WfMS/BPMS.

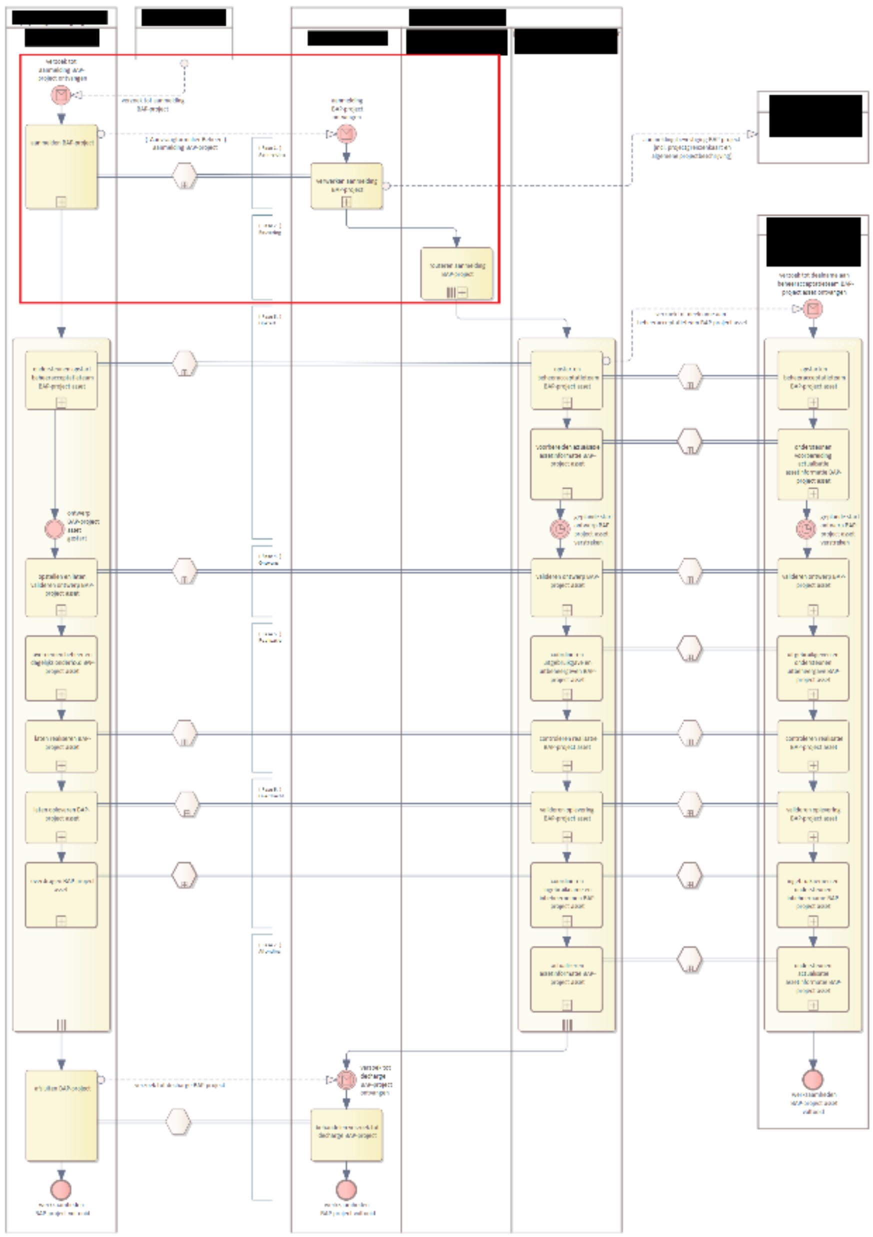


Figure 4.1: Complete BAP descriptive BPMN Model (phase 1&2 outlined in red)

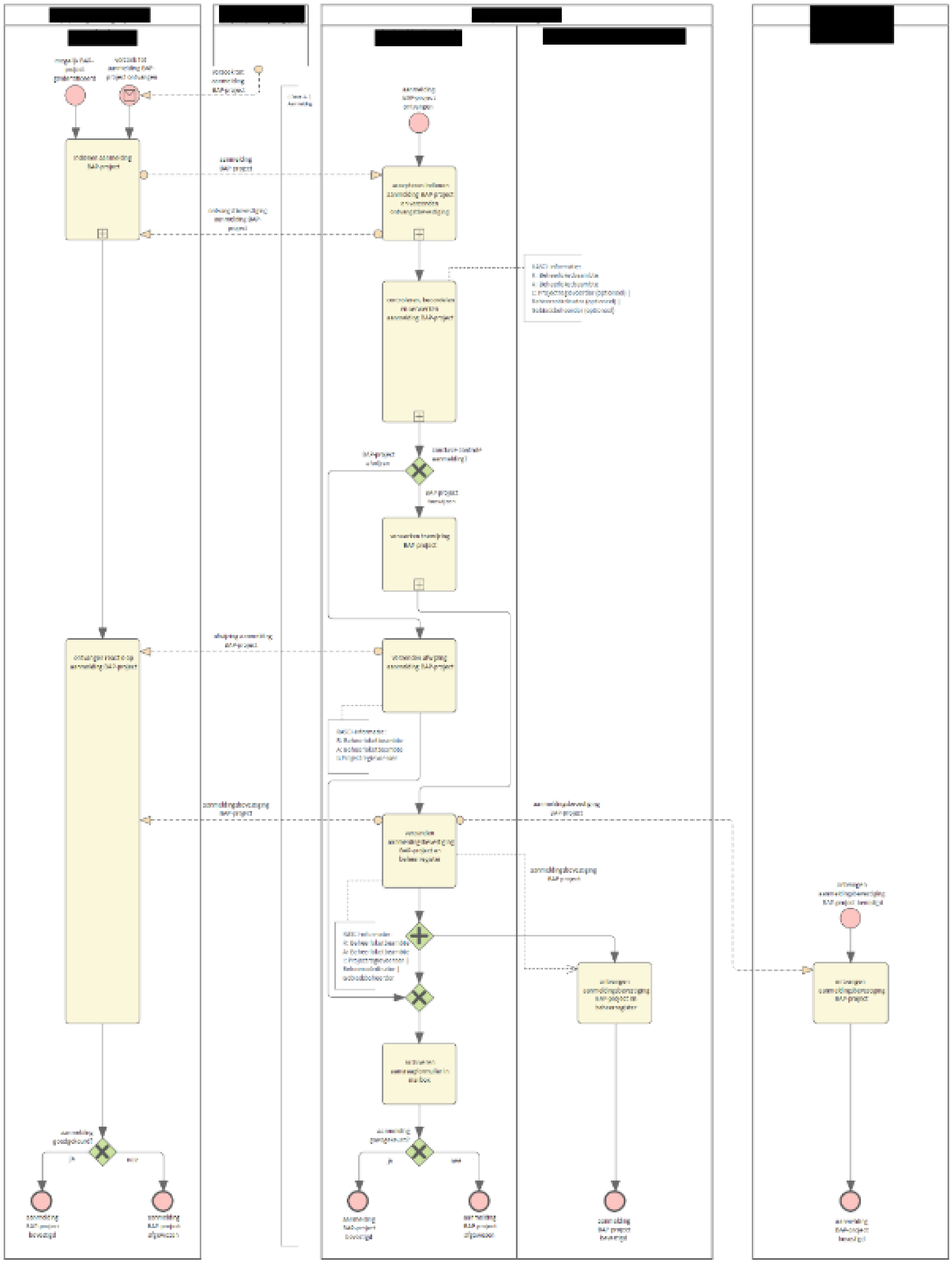


Figure 4.2: Phase 1 BAP descriptive BPMN Model

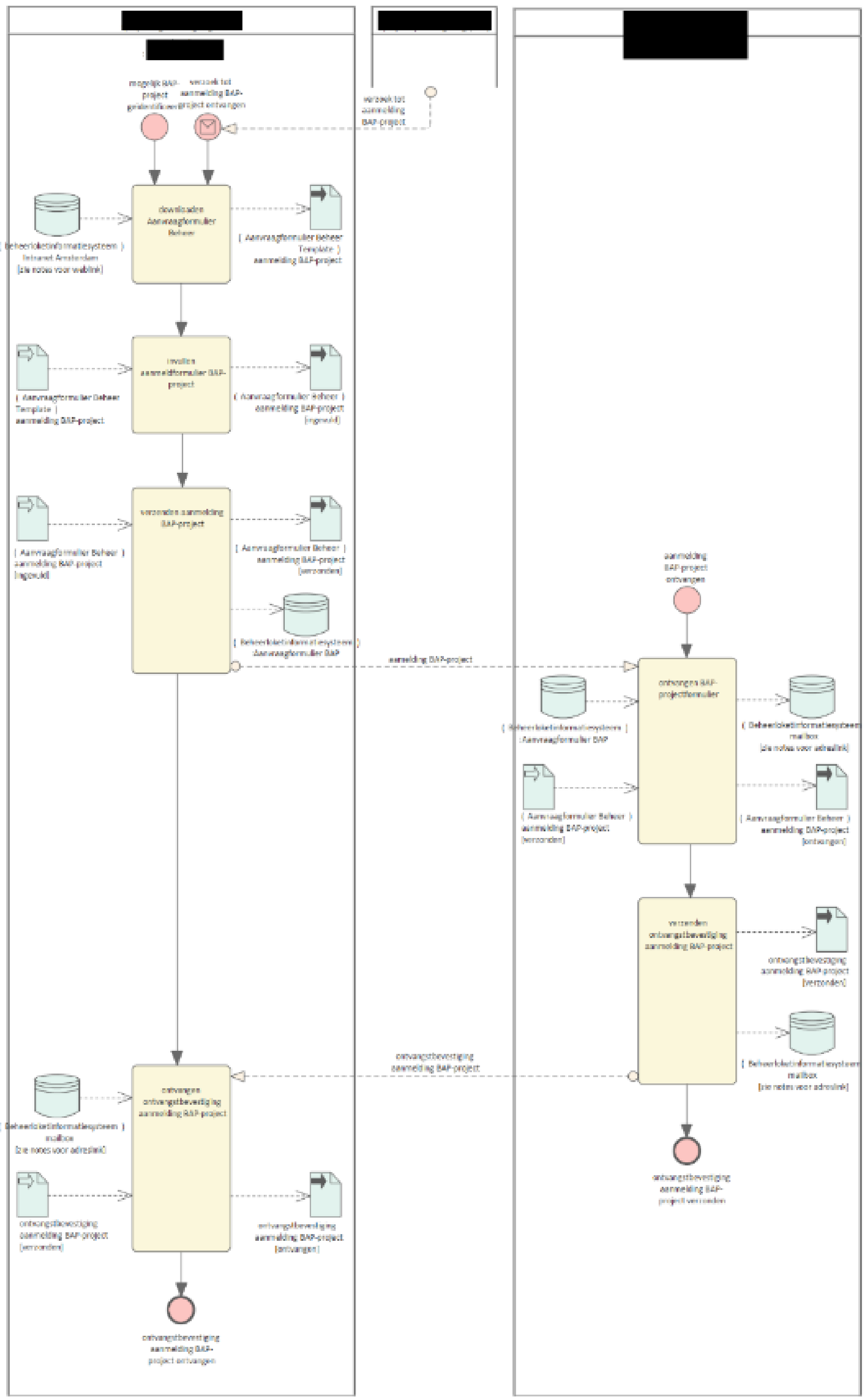


Figure 4.3: Sub-process in phase 1 BAP descriptive BPMN Model

4.1.2. Business process 2: Oxand Proposal Process

The second process is part of Oxand's internal sales process, specifically the proposal phase. Unlike the BAP process, this process is less developed and lacks formal documentation. The focus for this process is to design the BPMN model from scratch and automate it using a BPMS, enabling monitoring and optimization of the proposal process steps.

- **1B: What does the proposal process look like?**

The design of the proposal phase for Oxand's sales process was developed through five interactive sessions with key stakeholders, including the team leader and supervisor. These sessions aimed to validate the existing workflow, identify pain points and refine the process structure. The starting point for discussions was an outdated BPMN model and a new conceptual plan presented in PowerPoint. Using feedback from these sessions, a revised BPMN model (Figure 4.6) was created to reflect the updated proposal process. Below is a step-by-step walkthrough to understand the types of tasks involved:

1. Starting Event: The process begins with a start event. Forms are used as input to determine the person responsible for planning and initiating the kick-off meeting.
2. Kick-Off Meeting (Collapsed Subprocess): This subprocess (Figure 4.4) starts with a meeting to define roles within the proposal process. The individual designated as responsible during the starting event ensures these roles are assigned and the task completed. After the meeting, a script task ensures that the roles are properly designated for later use, particularly for the multi-instance tasks in the call activity.

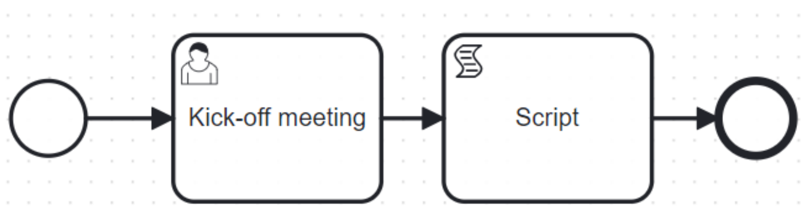


Figure 4.4: Collapsed Sub-Process of Kick-Off Meeting

3. Call Activity (Make Proposal): The process then transitions to a call activity (named "Make Proposal"), which references another BPMN process (Figure 4.5). This subprocess operates as follows:
   - The creator begins by preparing questions and investigating the conditions required for the proposal.
   - Next, a multi-instance task allows 1 to n (currently maximum is eight users because of limited checkboxes) users to provide advice or consultation on the proposal.
   - After all designated participants from the kick-off meeting have provided input, the creator finalizes the proposal, completing this subprocess.

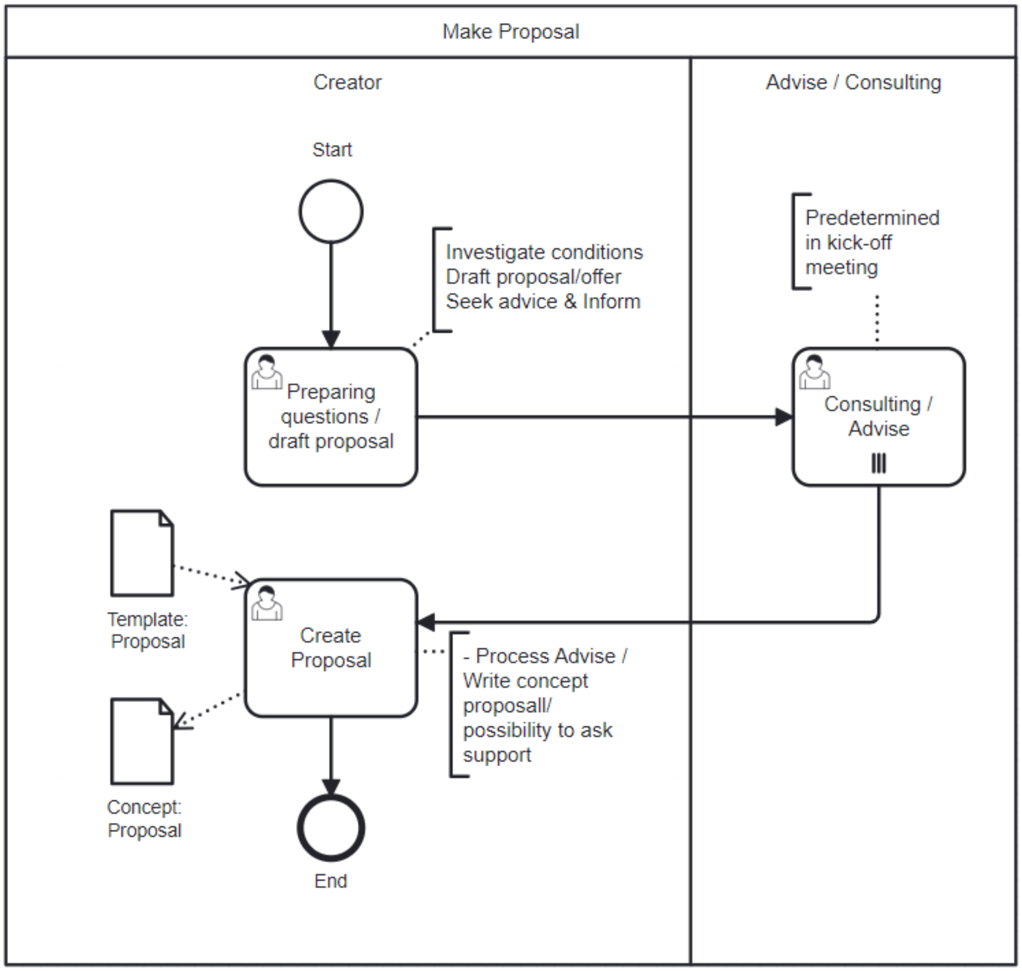


Figure 4.5: Make Proposal (call-activity)

4. Proposal Review: Once the proposal is created, it undergoes reviews by three designated persons. Each can approve or reject the proposal, potentially sending it back to the "Make Proposal" process for revisions. The decision is managed via an exclusive gateway.
    - First Control: Typically performed by the service lead.
    - Second Control: Usually conducted by Finance & Control.
    - Third Control: Performed by the consulting director.
5. Signing the Proposal: After all three persons approve the proposal, it proceeds to the signing stage, which is typically handled by the consulting director.
6. Sending the Proposal: Finally, the proposal is sent to the customer, completing the proposal process.

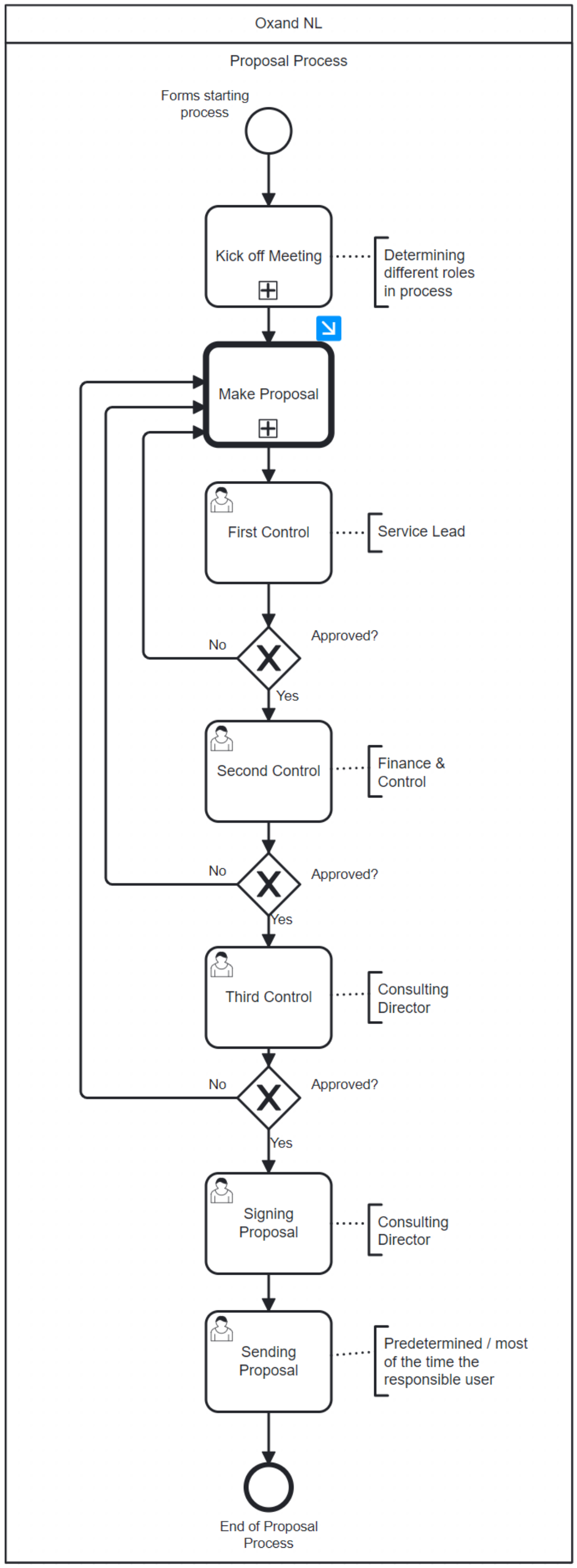


Figure 4.6: Proposal Process of Oxand NL (BPMN)

4.1.3. Summary

The BAP is modeled at a descriptive BPMN level, detailing key actors, tasks, and interactions. This includes the first two phases, which involve manual and semi-automated steps like form submissions and person assignments. These models, created in Sparx Enterprise Architect, require enhancement to transition from descriptive to common executable BPMN level, with a focus on automation and integration via a BPMS. To achieve this, it is essential to establish clear criteria and involve experts in the BAP process to prioritize these criteria, ensuring the creation of an optimal workflow automation.

The Proposal process first lacked formal documentation and was developed from scratch through five interactive sessions with stakeholders. These sessions addressed existing inefficiencies and refined the process structure. Using outdated models and a new conceptual plan, a BPMN model was designed to map out the proposal business process (Figure 4.6), this process is now ready to be transferred into executable format.

4.2. Defining transformation criteria

To create a transformation of business processes into automated workflows using executable BPMN models, it is critical to establish and prioritize relevant criteria. This leads to the second sub-research question:

> **SRQ 2: Which criteria influence the transformation and implementation of business processes modeled with Business Process Model & Notation (BPMN) from a descriptive/analytical level to an executable level (to create a model)?**
>
> - **How do these criteria apply to various stakeholders and phases in the BPM lifecycle?**

The transformation of descriptive BPMN models into common executable requires identifying the components that contribute to their success. These components were established through a combination of literature research, insights from the BPM lifecycle, stakeholder analysis and an expert interview. His insights emphasized the dynamic nature of criteria and their dependence on specific goals and stakeholder perspectives.

The transformation process aligns closely with the BPM lifecycle, which consists of seven phases: identification, design, implementation, monitoring, control, and improvement of business processes (Dumas et al., 2018). These phases guide the evolution of a process from its initial conception to design, implementation, and refinement. To ensure a comprehensive transformation, the criteria must address all stages of the BPM lifecycle.

Effective automation requires integrating the perspectives of various stakeholders, as they directly interact with and depend on the workflows. Users, as the participants performing daily tasks, prioritize simplicity, usability, and avoiding unnecessary complexity or additional workload.

Managers, who oversee process efficiency and effectiveness, focus on maintaining smooth workflows and monitoring performance. Enterprise architects, responsible for mapping organizational processes, aim for comprehensive integration of specific workflows, such as the BAP, within broader systems. Meanwhile, modeling experts and system engineers, who design, model, and implement BPMN processes, emphasize technical feasibility, adherence to standards, and model integrity. Together, these diverse perspectives shape the criteria for successful automation.

Four main criteria, each with four sub-criteria, were identified based on literature, the BPM lifecycle and stakeholder considerations. These formed the basis for a survey (see appendix for Dutch and English versions). The criteria are:

1. Efficacy: Ensures processes achieve goals effectively while minimizing resource use. This criterion aligns with the priorities of managers and process owners during the design and implementation phases.
2. User-Friendliness: Focuses on creating intuitive, accessible, and maintainable processes, enabling end-users to interact effortlessly with systems during execution.
3. Conformity: Emphasizes adherence to BPMN standards, completeness, and seamless integration with broader systems. This is critical for modeling experts and system engineers during design and validation stages.
4. Flexibility: Ensures adaptability to changing demands through scalability, modularity, and reusability, supporting long-term sustainability post-implementation.

These criteria, combined with the Analytic Hierarchy Process (AHP) method, enable experts to prioritize aspects critical to creating automated workflows, including executable WfMS/BPMS models. By addressing the diverse needs of stakeholders and aligning with the BPM lifecycle, the criteria provide a structured approach to process transformation.

A limitation of this approach is that the "best" model depends entirely on its intended purpose. A good model is one that successfully fulfills its intended purpose. The specific requirements for such a model are entirely dictated by that purpose. IT professionals seek detailed and comprehensive information, whereas managers value simplicity and an easily understandable overview. This variability means that AHP outcomes may differ depending on individual priorities and perspectives. For details on the survey results, the AHP method and related conclusions, see section 4.3.

4.3. Decision Making using the AHP Method

After establishing the criteria to develop the BAP process into an executable model, the next step is to determine their priority. This is achieved by consulting experts who will prioritize the criteria based on their experience, expertise, and knowledge of the BAP process. The group of experts consists of six individuals, including process modelers, enterprise architects, project managers, end-users (or those familiar with the process), and system engineers. The prioritization of criteria is carried out using a Multi-Criteria Decision-Making (MCDM) method, specifically the Analytic Hierarchy Process (AHP, 3.2.4). This prioritization addresses the following sub-research question:

> **SRQ 3: Which criteria are most important (according to experts) when transforming and implementing the BAP process modeled in BPMN from a descriptive/analytical level to an executable level?**

The survey (appendix A & B) is developed based on the criteria identified in SRQ2 (efficacy, user-friendliness, conformity and flexibility). It includes an explanation of the survey's purpose and the context of the BAP process. This is followed by detailed descriptions of each main and sub-criterion, along with examples to improve understandability. Experts completed the survey by ranking the importance of criteria based on phases 1 and 2 (registration and routing) of the BAP process. The focus on these phases ensures that results are directly relevant to the partial automation and implementation of the BAP in a BPMS or WfMS.

Survey results, including individual expert rankings (E1–E6, detailed appendix D) were aggregated by calculating the geometric mean. These results were then ranked to produce the final prioritization, as shown in Table 4.1 and Table 4.2. Consistency in responses was validated by ensuring a consistency ratio (CR) below 10%, thereby confirming the reliability of the rankings.

Table 4.1: Final Ranking of main-criteria

Criteria	E1	E2	E3	E4	E5	E6	Geometric Mean	Ranking:
1: Efficacy	0,632	0,495	0,263	0,28	0,39	0,508	0,407280918	1
2: User-Friendliness	0,251	0,31	0,511	0,481	0,168	0,151	0,280316032	2
3: Conformity	0,06	0,061	0,066	0,09	0,053	0,265	0,082060006	4
4: Flexibility	0,057	0,134	0,16	0,149	0,39	0,075	0,132150445	3

Table 4.2: Final ranking of sub-criteria

Subcriteria:	E1	E2	E3	E4	E5	E6	Geometric Mean	Ranking:
1a: Goal-Orientation	0,227856	0,202455	0,065487	0,07784	0,0351	0,120904	0,099965263	3
1b: Effectiveness	0,200586	0,143055	0,14991	0,112	0,24102	0,306324	0,18134868	1
1c: Efficiency	0,061812	0,04752	0,032612	0,04032	0,01794	0,059436	0,040036232	9
1d: Controllability	0,115746	0,101475	0,015254	0,04984	0,09594	0,021844	0,051526003	4
2a: Usability	0,095004	0,11594	0,23506	0,12025	0,043512	0,08003	0,101356159	2
2b: Understandability	0,027573	0,10726	0,034237	0,12025	0,099792	0,008758	0,046899392	6
2c: Accessibility	0,122577	0,06138	0,076139	0,12025	0,007896	0,017818	0,046174164	8
2d: Maintainability	0,027573	0,02542	0,166075	0,12025	0,016968	0,044243	0,04680088	7
3a: Accuracy	0,023746	0,020618	0,017688	0,05517	0,002438	0,01378	0,01588243	14
3b: Completeness	0,023746	0,025193	0,034914	0,01872	0,011077	0,15582	0,029616713	10
3c: Integrity	0,01085	0,008906	0,008844	0,00801	0,02968	0,067575	0,015474167	15
3d: Security	0,00372	0,006344	0,004488	0,00801	0,009858	0,02756	0,007830267	16
4a: Adaptability	0,0413	0,063784	0,07344	0,06258	0,03237	0,034725	0,048861766	5

4b: Scalability	0,0059	0,028274	0,01168	0,057812	0,16263	0,02565	0,027882477	11
4c: Modularity	0,0059	0,012998	0,04784	0,00894	0,16263	0,008175	0,01876107	12
4d: Reusability	0,0059	0,028944	0,0272	0,019668	0,03237	0,00645	0,016345831	13

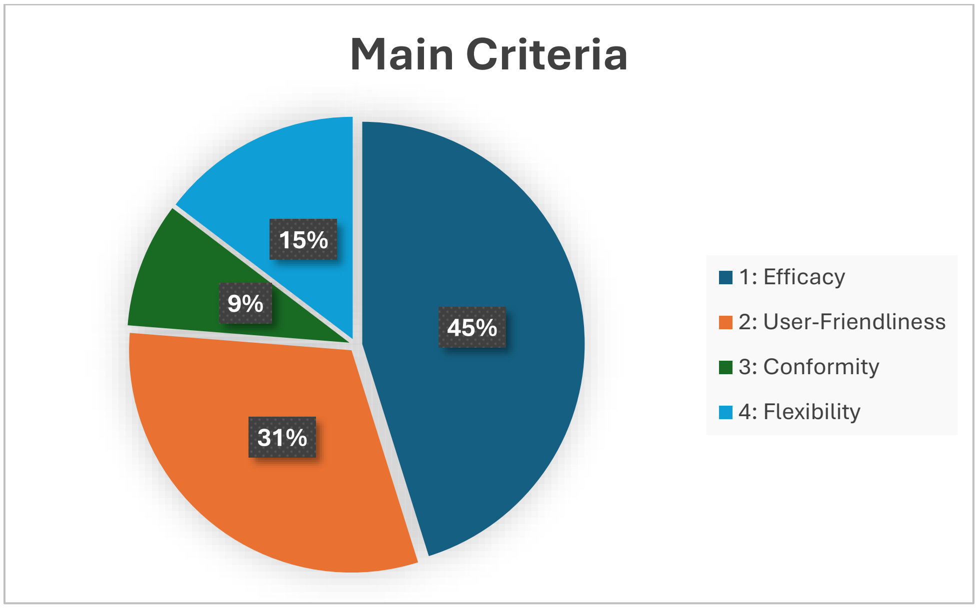


Figure 4.7: Results AHP of main-criteria

The AHP results reveal that two main criteria were most prioritized (see Figure 4.7): efficacy (45%) and user-friendliness (31%). These results align with the motivation for automating the BAP process, namely to reduce the significant time and resources required for its current execution. Efficacy is crucial to ensuring that automation optimizes resource usage while achieving its intended goals. User-friendliness is the second most prioritized criterion, reflecting the importance of making the transformation accessible and intuitive for users. Without user adoption and satisfaction, the automated workflow risks being underutilized, which would counteract its purpose. Conformity (9%) and flexibility (15%) were ranked lower in importance. This outcome reflects the experts' current focus on addressing the immediate challenges of the BAP process rather than ensuring flexibility for future adjustments or strict adherence to BPMN modeling standards. As long as the process achieves its immediate objectives, certain syntactic and modeling conventions can be applied more loosely to prioritize functionality over compliance.

The sub-criteria rankings (see Figure 4.8) further elaborate on the experts' priorities. Goal orientation (13%) and effectiveness (23%) were the top-ranked sub-criteria, emphasizing the importance of ensuring the process achieves its intended purpose effective for each instance. Goal orientation ensures clarity regarding whom the process serves and what results it must deliver, while effectiveness assesses whether the intended outcomes are realized. Usability (13%) ranked third, underscoring the need for processes that users can interact with easily, intuitively, and pleasantly, requiring minimal training and ensuring an enjoyable experience. Controllability (6%) and adaptability (6%) followed, highlighting the importance of monitoring and adjusting processes where necessary and allowing for changes after implementation. The remaining sub-criteria of user-friendliness; understandability, accessibility, and maintainability, ranked 6% each, emphasizing the need for clear, unambiguous, and easily manageable workflows. These aspects ensure users can quickly access the information they need and maintain the process with minimal effort.

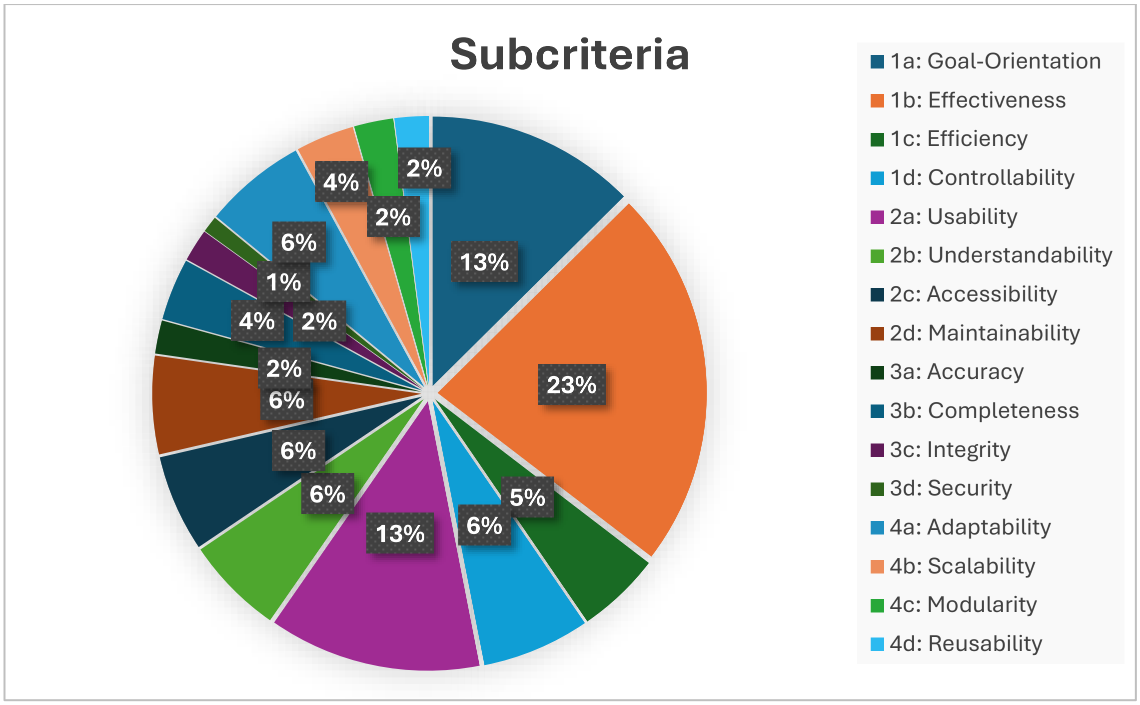


Figure 4.8: Results AHP of sub-criteria

The AHP results indicate a clear focus on immediate functionality and user satisfaction in transforming the BAP process into an executable model. Efficacy and user-friendliness emerged as the most critical criteria, aligning with the project's goals of optimizing resource usage and ensuring user adoption. While conformity and flexibility were deprioritized, their significance may increase once the process stabilizes and broader organizational needs come into play.

For the BAP process, a crucial aspect of developing the application is designing the interface and functionality with end-users in mind to ensure ease of adoption and satisfaction, emphasizing user-friendliness. It also means that the application must focus on solving the current inefficiencies (e.g., time consumption, resource wastage) while ensuring usability. To achieve efficacy, the application should focus on minimizing steps and optimizing resource usage, include dashboards and reporting features for managers to monitor performance and make adjustments. By aligning the application with these takeaways, the BAP process can be transformed into an automated workflow that meets the organization's immediate needs.

5. Application: Creating a BPMS

This chapter outlines the process of selecting the most suitable BPMS/WfMS to run BPMN models within the project's research limitations and business-oriented scope (SRQ4). It then addresses SRQ5: How can the BPMN models be transformed from descriptive into common executable formats? This involves first examining engine configuration and then outlining the steps required to convert descriptive models into executable workflows. Subsequently, the BAP process and proposal process are explained and created as automated workflows, guided by the expert prioritizations established in Chapter 4. Finally, an implementation plan is proposed to facilitate future research and development while aligning with the final phases of the BPM lifecycle and MPSM (SRQ6).

5.1. Selecting BPMS/WfMS

This research focuses on selecting a BPMS/WfMS that aligns with the thesis's limitations and business-oriented scope. The primary considerations include ease of use, limited programming or technical implementation experience, and alignment with open standards. Open-source solutions are particularly critical, as Oxand positions itself as a company that leverages open standards. Additionally, the selected system should offer resources for learning and troubleshooting, such as forums, tutorials, and videos, to support understanding and implementation. That is why the following SRQ is asked:

SRQ 4: Which BPMS/WfMS is most effective for running the BPMN models?

A BPMS is favored over a WfMS for its advanced automation, monitoring, and continuous improvement capabilities (see chapter 2.1). While Power Automate (Microsoft) is currently being used for the new workflow automation of the BAP process, it was ruled out because it is not open source and does not support BPMN models. After evaluating alternatives such as Activiti, Bonita, Monday, Flowable, and Camunda, Camunda emerged as the most suitable option. Camunda's comprehensive functionality aligns with the project scope, offering open-standard compliance, local engine deployment for proof-of-concept development, and an extensive community network for support. Camunda's modeler simplifies BPMN model creation and exportation, while the Camunda 7 Run distribution provides preconfigured tools, eliminating the need for significant technical Java expertise.

5.1.1. Camunda 7 Run

Camunda 7 Run (Figure 5.2) is a lightweight, prepackaged distribution of Camunda 7 (Figure 5.1), that does not require advanced Java programming skills. It includes tools such as the Cockpit for monitoring processes, the Tasklist for managing tasks across users, and Admin for overseeing roles and permissions. Its REST API and engine are preconfigured, enabling the automatic execution of resources like .bpmn and .form files (in the resources map). The YAML files, such as default.yml and production.yml, provide a flexible means of customizing the Camunda 7 Run environment. These files allow users to adjust predefined REST API functions and modify key system settings to suit project-specific requirements. This capability ensures that even preconfigured tools can be tailored to support unique organizational needs. This simplicity and flexibility make Camunda 7 Run a powerful option for managing BPMN models in this project.

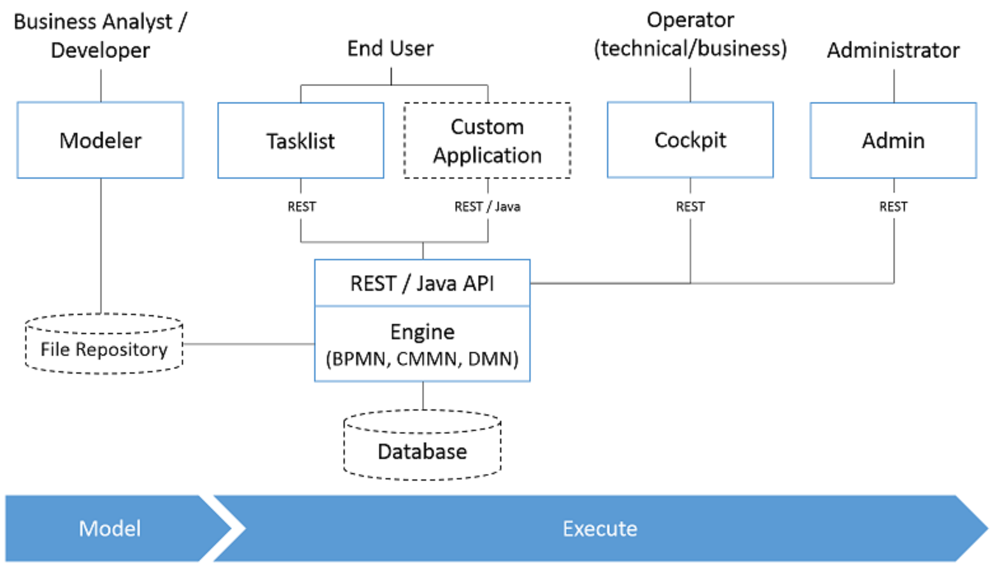


Figure 5.1: Camunda 7 overview of most important components along with some typical user roles (https://docs.camunda.org/manual/7.22/introduction/)

```
camunda-bpm-run
├── configuration/
|   ├── keystore/
|   |   └── put your SSL key store here if you want to use HTTPS
|   ├── resources/
|   |   └── put your BPMN files, forms and scripts here
|   ├── sql/
|   |   └── necessary SQL scripts to prepare your database system
|   ├── userlib/
|   |   └── put your database driver and other required JARs here
|   ├── default.yml
|   └── production.yml
├── internal/
├── start.bat
└── start.sh
└── shutdown.sh
└── shutdown.bat
```

Figure 5.2: Structure of Camunda 7 Run

5.1.2. Camunda Modeler

The Camunda Modeler is a desktop application designed for creating, editing, and managing BPMN and DMN models, as well as user forms. Key functionalities include:

- BPMN File Creation: Enables the visual design of business process models, automatically generating XML representations in the background.
- Form Creation: Supports the development of .form files, which can be filled out by users or external actors. These forms generate keys (outputs) that can serve as inputs for decision gateways or user assignments.
- Integration of Models and Forms: Both .bpmn and .form files are linked within the Modeler, simplifying the creation of workflows where forms and processes interact.

5.2. BPMS Configuration

This section focuses on configuring the BPMS to transform BPMN models from descriptive to common executable formats, answering:

> **SRQ 5: How can BPMN process models be transformed from descriptive into common executable formats?**

5.2.1. Engine & Database Configuration

Creating common executable BPMN models involves adding detail to descriptive models. While conceptually straightforward, this process often requires addressing technical and operational complexities. The transformation begins with understanding and configuring the default.yml file (Figure 5.3), which establishes the Camunda 7 Run environment. This YAML configuration sets up the environment and includes important details related to administration, deployment, security, and database connections.

```yaml
camunda.bpm:
  admin-user:
    id: demo
    password: demo
  filter:
    create:
      name: All tasks
  authorization:
    enabled: true


  run:
    port: 8080
    cors:
      enabled: true
      allowed-origins: "*"
    rest:
      disable-wadl: false
    deployment:
      deploy-changed-only: false
      resource-pattern: classpath*:**/*.bpmn, classpath*:**/*.form
    example:
      enabled: false

# Datasource configuration for H2
spring.datasource:
  url: jdbc:h2:./camunda-h2-default/process-engine;TRACE_LEVEL_FILE=0;DB_CLOSE_ON_EXIT=FALSE
  driver-class-name: org.h2.Driver
  username: sa
  password: sa

  database:
    schema-update: true
  history-level: full

# Enable the H2 console
spring:
  h2:
    console:
      enabled: true

spring.web.resources:
  static-locations: NULL
```

Figure 5.3: Contents of default.yml file

Table 5.1: Camunda 7 Run Configuration settup (default.yml)

Camunda 7 Run Configuration (default.yml)	
Webapps configuration	
admin-user	id: demo: Sets the default administrator's username to demo. password: demo: Sets the default administrator's password to demo
filter.create	All tasks: Creates a default filter named "All tasks" in the Tasklist, displaying all tasks assigned to the user.
authorization	enabled: true: Activates authentication for the web applications and REST API. Users must log in to access resources.
run.port	8080: Specifies that the Camunda BPM engine will run on port 8080, accessible via http://localhost:8080.
cors	enabled: true: Enables Cross-Origin Resource Sharing (CORS), allowing external applications to interact with the Camunda REST API. allowed-origins: "*": Permits access from all origins. In production, this should be restricted to specific domains for security.

Deployment	deploy-changed-only: false: When set to false, all resources in the specified patterns are redeployed, even if unchanged. Set to true in production to avoid unnecessary redeployment. resource-pattern: classpath*:**/*.bpmn, classpath*:**/*.form: Specifies patterns for files to be deployed automatically. This includes: - .bpmn: BPMN process models. - .form: Form files for user tasks.
example	enabled: false: Disables the default example processes provided by Camunda to keep the environment clean.
Datasource Configuration	
spring.datasource	url: jdbc:h2:./camunda-h2-default/process-engine: Configures the H2 database connection URL. The database is stored in a local file (./camunda-h2-default/process-engine), ensuring persistence across restarts. TRACE_LEVEL_FILE=0: Minimizes logging for the H2 database to reduce file size. DB_CLOSE_ON_EXIT=FALSE: Prevents the database from closing when the application stops, ensuring the data remains accessible. driver-class-name: org.h2.Driver: Specifies the H2 database driver. username: sa: Sets the database username to sa (default for H2). password: sa: Sets the database password to sa.
database.schema-update	true: Automatically updates the database schema when Camunda starts. This is convenient for development but may not be suitable for production.
history-level	full: Enables full history tracking, recording all process-related data (e.g., process instances, tasks, and variables). This is useful for auditing and analysis.
spring.h2.console	enabled: true: Activates the H2 console (database), accessible via http://localhost:8080/h2-console
Static Resources configuration	
spring.web.resources.static-locations	NULL: Disables serving static files (e.g., HTML, CSS, JS) from default locations. This ensures that the application is not serving unintended files.

The configuration of the environment, as explained in Table 5.1, includes settings for the web applications, engine, and database. These configurations establish the foundational setup required to run Camunda 7 Run. With the environment configured, the next step is to transform descriptive BPMN models into executable formats, enabling the creation of automated workflows within the BPMS using Camunda 7 Run.

5.2.2. Transforming descriptive BPMN files from descriptive to common executable level

With the Camunda 7 Run environment configured, the next step involves transforming descriptive BPMN models into common executable formats (Table 5.2). This transformation ensures that the models can be implemented in the workflow engine to create automated workflows. Beyond creating the files, this process requires adding detailed information and linking tasks to specific users or roles.

Table 5.2: Steps for transforming descriptive BPMN files to executable for automated workflows in Camunda 7 Run

Steps:	**Explanation:**
Step 1: Model Creation	Begin by ensuring that all BPMN models accurately represent the current processes, including all relevant tasks, gateways, and flows. Incorporate essential details such as task descriptions, priorities, and expected durations. Only automate processes or tasks that can feasibly be automated (manual tasks or tasks performed by external entities should be excluded), as they cannot be managed within your workflow.
Step 2: Create .form Files	Develop .form files for tasks that require user input. These forms are used during process execution to collect necessary data. Additionally, the output from these forms (e.g., user assignments) can be used to drive further workflow automation.
Step 3: Link forms to user tasks	Attach the created .form files to specific user tasks within the BPMN models. Assign forms to input fields where users or external systems will provide data during execution.
Step 4: Utilize Form Outputs for Decisions and Assignments	Use the outputs of the forms (e.g., key-value pairs) to drive decision-making within the process. Use gateways to configure decision gateways to route process flows based on form outputs. Use user assignment to leverage form outputs to dynamically assign tasks to specific users or roles (e.g., using multi-instance tasks or script activities). Write additional scripts where necessary to handle advanced logic.
Step 5: Optimize Engine and Database Configuration & Organize Files	Update the default.yml file to include necessary configurations (e.g., Camunda 7 Run Configuration settup (default.yml)Table 5.1), such as enabling automatic deployment of .bpmn and .form files. Ensure that all created .bpmn and .form files are placed in the resources folder of the Camunda 7 Run environment for smooth integration.
Step 6: Create Users and Configure Step Authentication in Camunda Webapps	As an administrator, define users, groups, roles, and authentication settings within the Camunda platform. This step ensures that users are properly assigned tasks and have appropriate access to processes. For example, administrators can manage user groups and determine visibility for tasks, ensuring data security and compliance.
Step 7: Execute the Process	Start the Camunda 7 Run engine. Once running, the workflow is operational: - Users can interact with their assigned tasks and provide inputs. - Managers can monitor and manage the processes using dashboards and reporting tools.

	- Administrators can update user roles, permissions, and system configurations as needed.

5.3. Creation of automated workflow models (‘Proof of Concepts’)

This section focuses on automating two processes within the Camunda 7 Run environment, incorporating insights from AHP and stakeholder sessions.

5.3.1. Model 1: Proposal Process

The automation of the Proposal Process begins with the creation of BPMN files, which serve as the foundation for the workflow automation (see steps in Table 5.2). The BPMN files were created and validated through five dedicated sessions with stakeholders, ensuring that the process meets all requirements. The validated BPMN files provide a descriptive overview of the Proposal Process within the Oxand NL Sales Process, as referenced in Figure 4.6.

Following the creation of the BPMN files, forms were developed to facilitate data collection and help process execution. The starting event of the process is linked to a Starting Form (Figure 5.4), which serves as the initial input point for the workflow. One critical form, the Kick-Off Meeting Form, captures essential details such as roles and responsibilities in the Proposal Process (Figure 5.5). Each text field in the form generates an output variable, identified by a unique key, as shown in Figure 5.6. These keys play a vital role in assigning tasks and enabling decision-making within the workflow. To enhance usability, features such as required fields, validation rules, and pre-filled default values were added to the forms. Default values, for instance, assign tasks to users typically responsible for specific actions, while retaining the flexibility to update them during form submission.

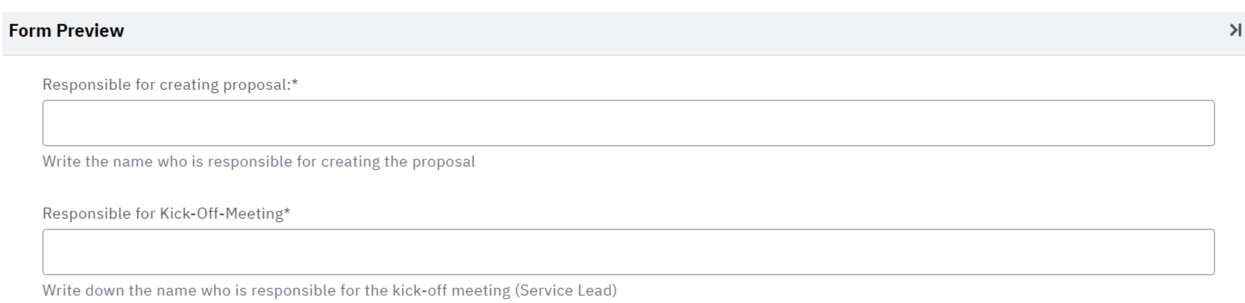
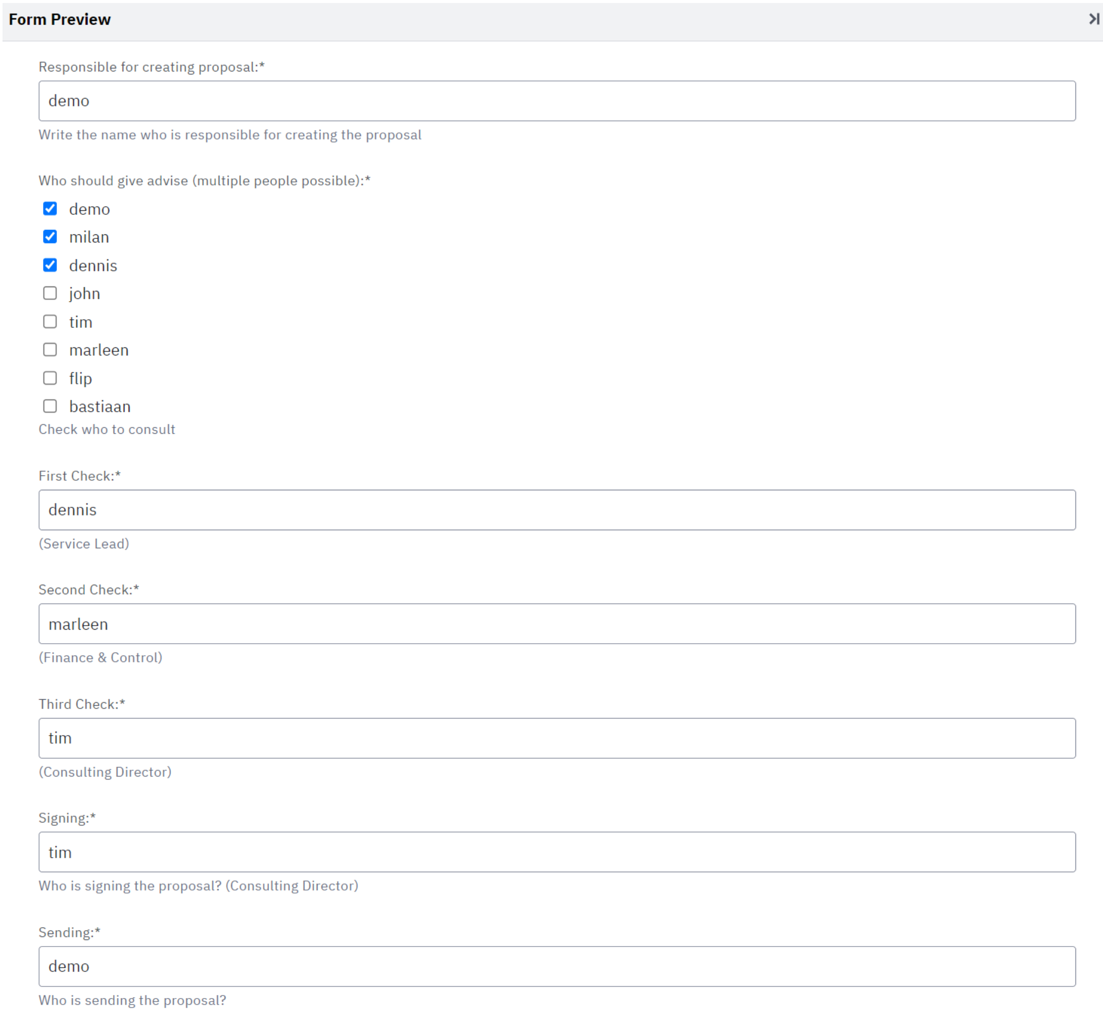


Figure 5.4: Starting Form



Form Preview

Responsible for creating proposal:*

demo

Write the name who is responsible for creating the proposal

Who should give advise (multiple people possible):*

- [x] demo
- [x] milan
- [x] dennis
- [ ] john
- [ ] tim
- [ ] marleen
- [ ] flip
- [ ] bastiaan

Check who to consult

First Check:*

dennis

(Service Lead)

Second Check:*

marleen

(Finance & Control)

Third Check:*

tim

(Consulting Director)

Signing:*

tim

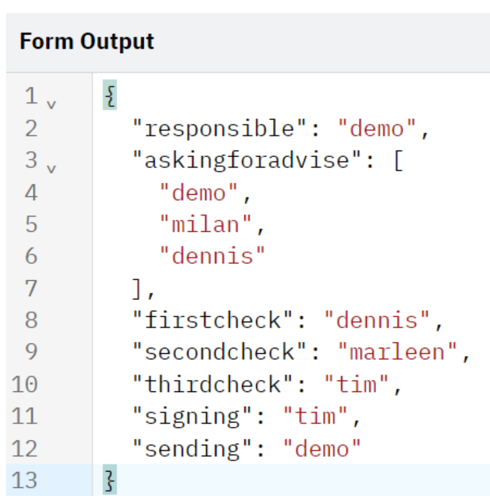
Who is signing the proposal? (Consulting Director)

Sending:*

demo

Who is sending the proposal?

Figure 5.5: Form Kick-off Meeting (filled in)



Form Output


```json
{
  "responsible": "demo",
  "askingforadvise": [
    "demo",
    "milan",
    "dennis"
  ],
  "firstcheck": "dennis",
  "secondcheck": "marleen",
  "thirdcheck": "tim",
  "signing": "tim",
  "sending": "demo"
}
```


Figure 5.6: Form Output Kick-off Meeting (filled in)

In addition to user input forms, an approval form (Figure 5.7) was created to support decision-making at exclusive gateways in the BPMN model. The approval form generates a Boolean output, as illustrated in Figure 5.8, which determines whether the process will proceed along the "Yes" or "No" path of the exclusive gateway (Figure 5.11). The binding of forms to BPMN tasks is a crucial step, as shown in Figure 5.9. Outputs from the forms become variables that inform subsequent tasks and decisions, ensuring that every user task is executed based on input from the forms (Figure 5.10). The integration of approval logic at gateways ensures the process flow aligns with business rules and approvals.

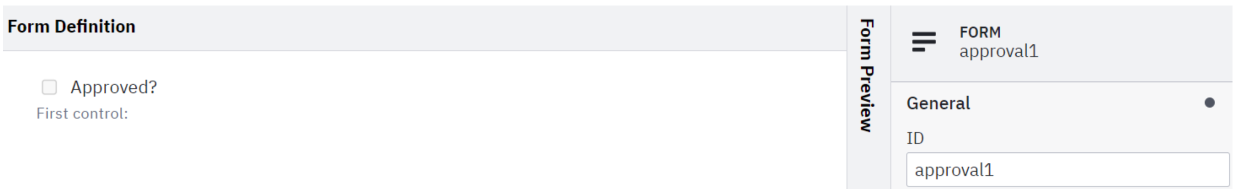


Figure 5.7: Approval Form (with form ID)

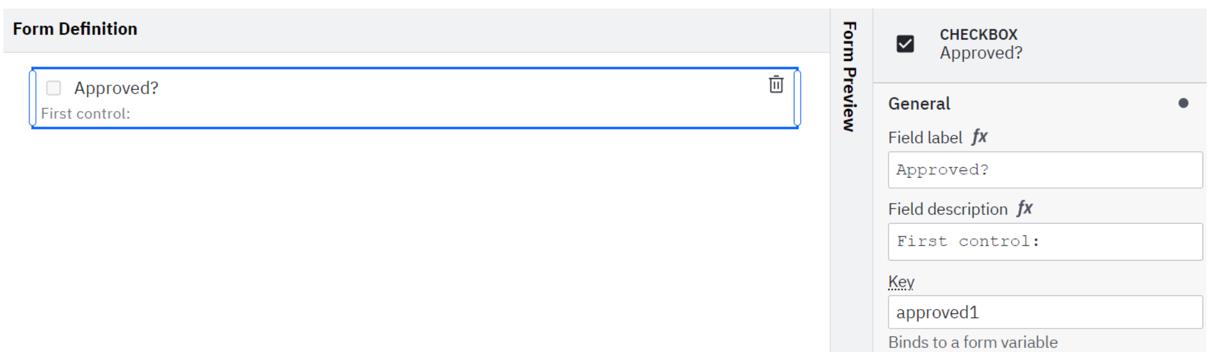


Figure 5.8: Approval Form (with checkbox selected)

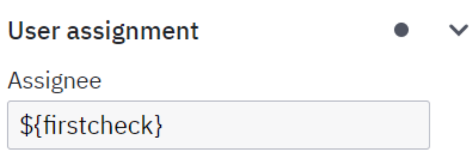


Figure 5.9: User assignment of First Control (User Task in Proposal Process)

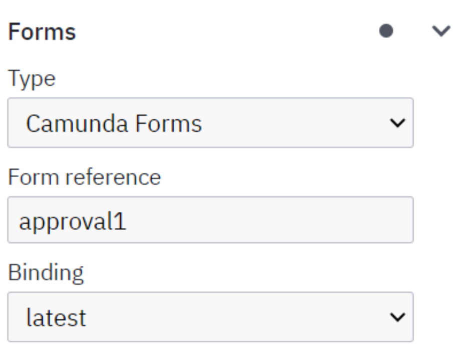


Figure 5.10: Forms binding of First Control (User Task in Proposal Process)

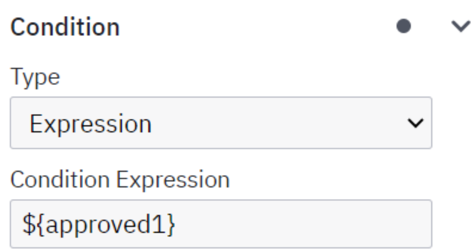


Figure 5.11: Option "Yes" after first exclusive gateway

The automation of the Proposal Process is further enhanced by handling tasks involving multiple users. For instance, in the multi-instance user task, the output from a checkbox in the Kick-Off Meeting Form is processed through a script task. This script converts the form data into variables that dynamically assign tasks to multiple users, as can be seen in Figure 5.12 and Figure 5.13. This functionality allows the workflow to adapt to varying requirements and ensures that all relevant users are included in task execution.

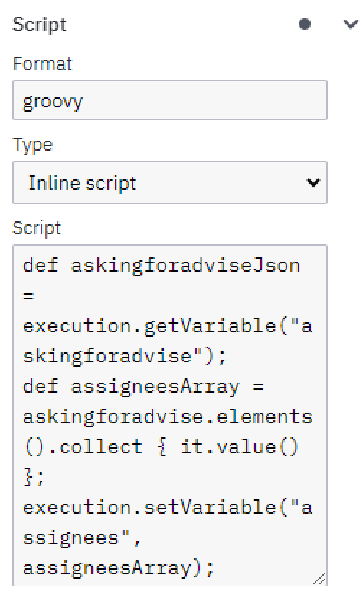


Figure 5.12: Script Task to convert checkbox data for Multi-Instance User Task

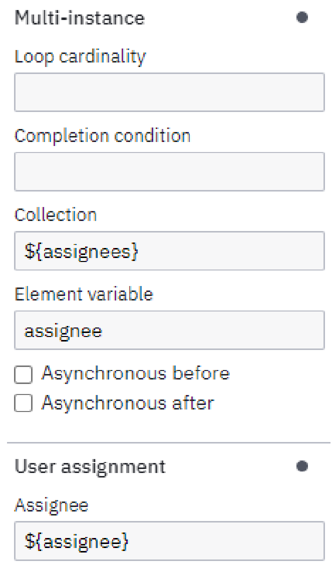


Figure 5.13: Multi-instance User Task (input)

With steps 1-4 of the transformation process complete, including the creation and linking of BPMN files and forms, the next steps involve optimizing the Camunda engine and database configuration. These settings are critical for enabling automatic deployment of the process files. The .bpmn and .form files are placed in the resources folder of the Camunda environment to ensure seamless deployment.

The final steps involve creating users and configuring authentication in the Camunda platform. As an administrator, users, roles, and permissions are defined within the Camunda Admin Dashboard (Figure 5.14). Once these configurations are complete, the process can be executed and the workflow becomes operational. Managers can monitor and manage processes via the Camunda Cockpit (Figure 5.15 and Figure 5.16), while users access tasks assigned to them through the Camunda Tasklist (Figure 5.17). This comprehensive approach ensures an efficient, automated workflow that transitions from descriptive BPMN models to a fully executable process.

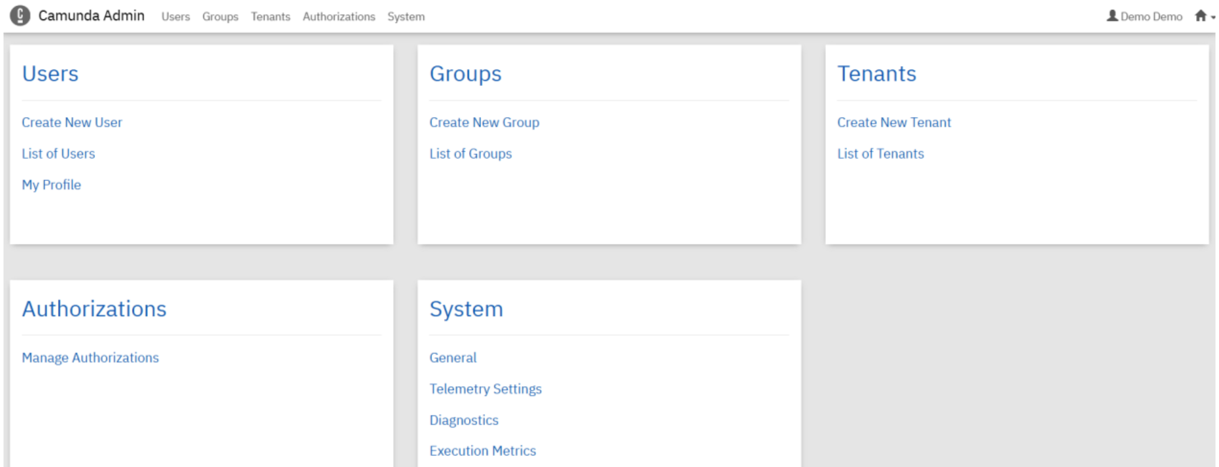


Figure 5.14: Dashboard Camunda Admin

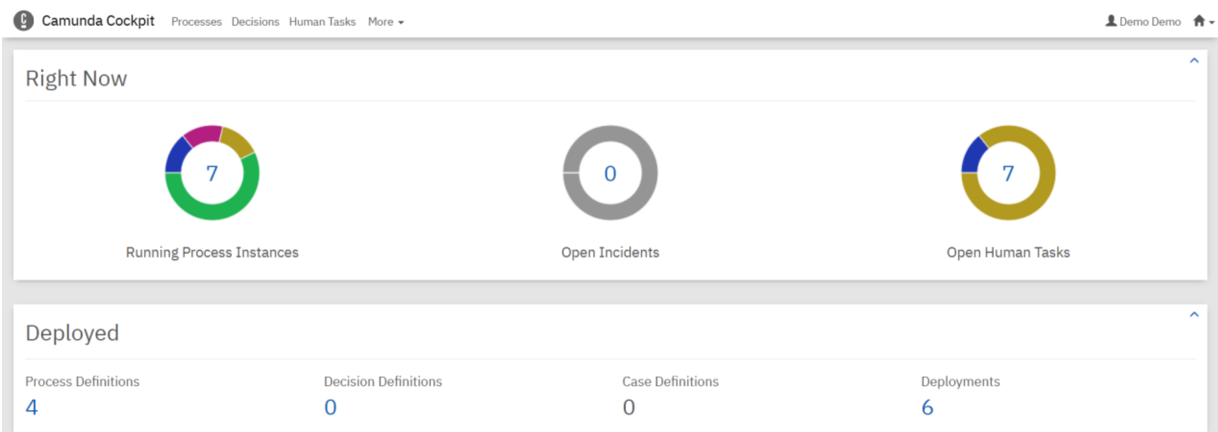


Figure 5.15: Camunda Cockpit

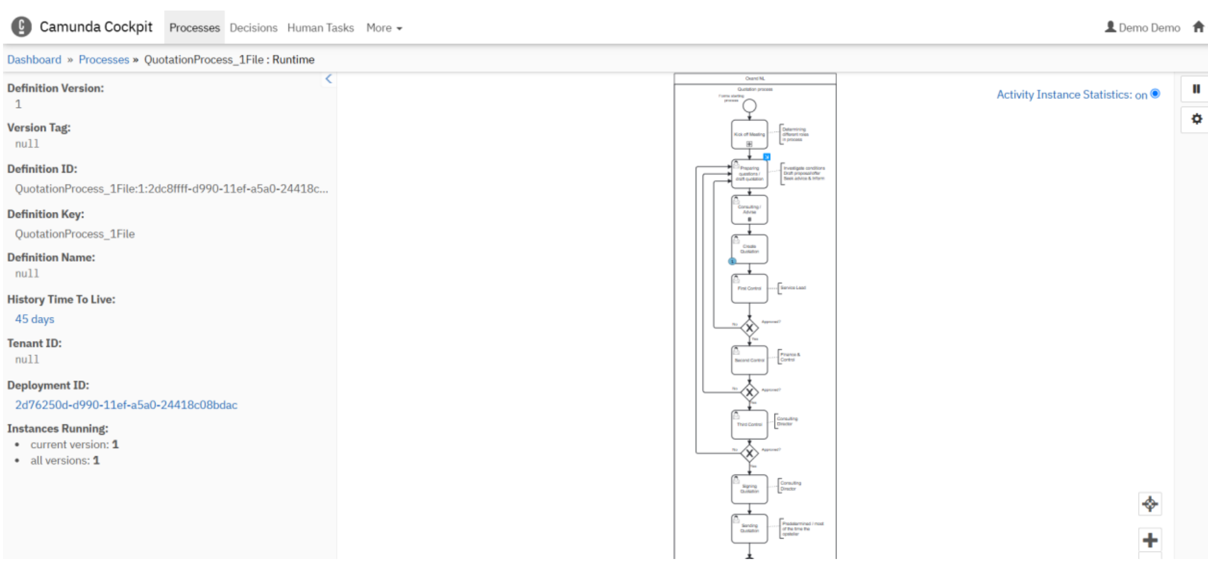


Figure 5.16: Camunda Cockpit zooming in on the deployed proposal process

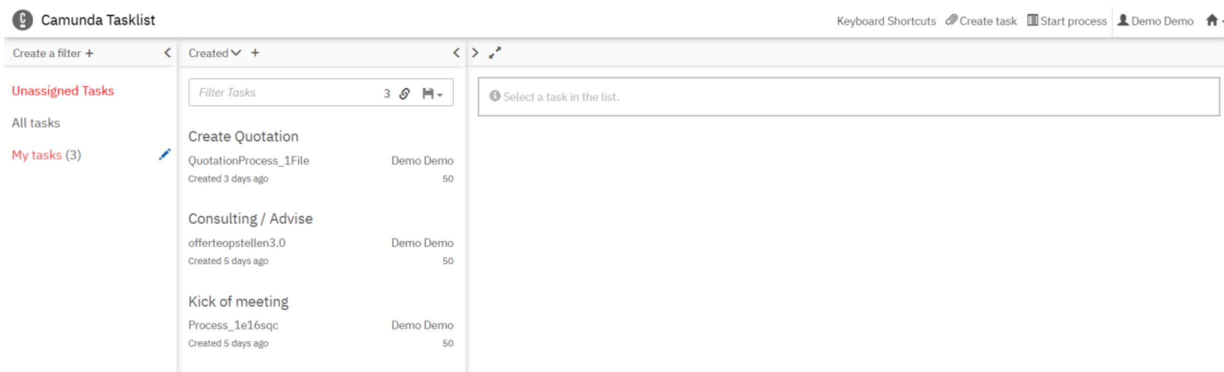


Figure 5.17: Camunda Tasklist (User)

In conclusion, while the steps below automate a handful of critical processes within the Proposal Process, it is essential to recognize that this represents only a portion of the entire workflow. To fully realize the potential of automation, the same methodology has been applied to the remaining tasks. By following the approach, the proposal process has been implemented within a BPMS.

5.3.2. Model 2: BAP (Phase 1&2)

For the BAP process, the BPMN files were already created at the descriptive BPMN level, but certain modifications were required to optimize the workflow. These adjustments aim to align the process with expert recommendations, which emphasize the importance of efficacy and user-friendliness in the new executable workflow implemented in a BPMS. The existing descriptive BPMN model is comprehensive, but some tasks could be revised or automated to improve efficiency. Furthermore, it is vital that the processes remain easy to understand and useful for users. To address these considerations, a new model was developed using the Camunda Modeler, as shown in Figure 5.18.

This model outlines the first two phases of the BAP process, with notable differences compared to the previously Proposal Process. The tasks of the BAP workflow are described in detail below:

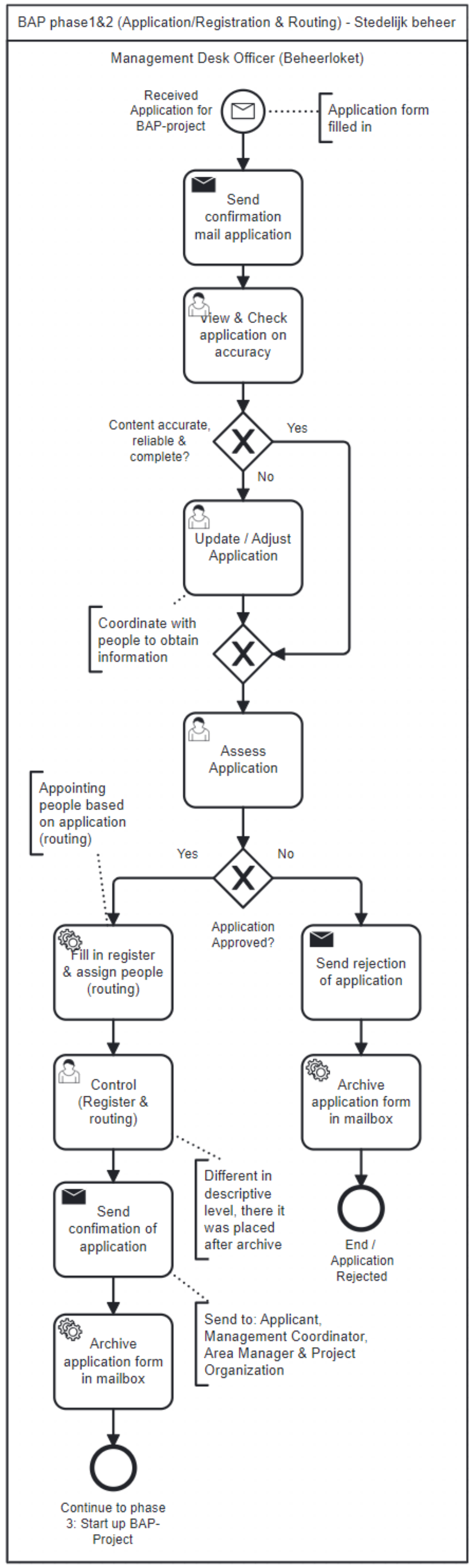


Figure 5.18: BAP Process

BAP Process phase 1 & 2:

1. Application Submission (start event): The process begins with the submission of an application form for a BAP project. Applicants complete and submit the form, which triggers an email notification to the Management Desk Officer (Beheerloket).
2. Confirmation Email (send task): A confirmation email is sent to the applicant, acknowledging their application submission.
3. Application view and check (user Task): The Management Desk Officer views and checks the application to ensure it is accurate, reliable, and complete.
4. Content Verification (exclusive gateway): based on the output of the prior user task, this decision point assesses whether the application content meets the required standards.
    a. If Yes: Proceed to assess the application.
    b. If No: The application is updated or adjusted as necessary.
        i. The officer coordinates with other individuals to gather the required information and ensure completeness before reassessment.
5. Application Assessment (user task): The officer assesses the application to determine its approval status.
6. Approval decision: (exclusive gateway)is the application approved (based on output of user task)?
    a. If yes:
        i. Register the application and assign people to handle specific tasks or responsibilities (routing)(service task).
        ii. Perform a control check, ensuring the registration and routing are correct (user task).
        iii. Send a confirmation email to the applicant and users involved in the routing (send task).
        iv. Archive the application form in the mailbox (service task).
        v. Proceed to Phase 3 (Start Up BAP Project)(end event).
    b. If no:
        i. Send a rejection email to the applicant (send task).
        ii. Archive the application form in the mailbox (service task).
        iii. End the process (application rejected)(end event).

While much of this process could be automated, certain tasks fall outside the scope of this project. For example, automating send and service tasks would require Java development, which is beyond the current focus on workflow automation. The remaining user tasks (reviewing the application, updating or adjusting it and assessing its approval status) are all performed by a single individual, namely the Management Desk Officer. These user tasks are relatively minor and often redundant. For instance, the review process could be enhanced by creating form features that prevent submission of incomplete or incorrect applications (e.g., ensuring that street names align with designated municipal areas). In reality, application approval often results in acceptance because it primarily involves integrating an asset into the management structure of another municipal department. Assigning and routing responsibilities is already automated based on the initial application form, leaving only minimal verification work. Since all tasks are performed by the same individual, automating this workflow has limited practical value within the current scope, as workflow automation typically focuses on processes involving multiple users.

That said, the process could be almost entirely automated to ensure maximum efficacy, a key priority according to expert feedback. Automated emails, service tasks for registration and assignment and archiving functions could replace most user interactions. This level of automation would ensure a user-friendly system where the Management Desk Officer has minimal manual input. However, this level of automation is beyond the scope of this project. See the implementation plan for a further detailed explanation in how to improve and eventually deploy this process.

5.4. Implementation Plan

With the BPMS and BPMN models created and deployed, the focus now shifts toward the future development and implementation of these systems. To achieve this, it is essential to consider subsequent stages of the BPM lifecycle and the MSPM. This ties directly to the research question:

> **SRQ 6: What steps should be included in an implementation plan to further develop and implement BPMN models for automation?**

5.4.1. Current State of the Models & Improvements

At present, both BPMN models run locally on a personal device (local server). For broader implementation, they need to be deployed on a server, either internal or external, to allow integration and scalability. The current database configuration utilizes an H2 database, which is adequate for testing purposes but unsuitable for production. Connecting to a robust database (e.g., PostgreSQL or MySQL) will enable easier data extraction and provide the foundation for data visualization (providing insights to performance indicators). The default configuration file, default.yml, used during development, also needs to be replaced with a production.yml file. This production setup must incorporate advanced settings such as authentication, cookies, security protocols and additional configuration options to ensure the system's reliability and safety in a live environment.

The models were developed at the process workflow level, assigning tasks to specific users. While this approach is suitable for the Proposal Process, the BAP (Registration & Routing) process has different requirements. This process can be almost entirely automated, rendering workflow automation insufficient. For the BAP process, several key adjustments are necessary to optimize automation:

- Service Tasks: Incorporate service tasks to update records, automatically assign users to projects (routing) and archive information.
- Automated Emails: Implement send tasks to automatically send notifications to relevant users.
- User Task Reduction: With successful automation of service and send tasks, the need for user tasks can be minimized. Eventually, these tasks can be eliminated entirely once settings and programs handle all functions.

Such full automation can be achieved using Camunda 7 Run, but other platforms like Microsoft Power Automate could also serve as viable alternatives. These changes ensure the process is efficient, user-friendly, and aligned with expert recommendations.

5.4.2. Testing implementation and later stages of the BPM Lifecycle

After implementing the BPM models into a BPMS, it is crucial to evaluate their performance and refine them further, aligning will later stages of the BPM lifecycle and MSPM. The implementation process includes running the businesses process for a while and observing its outcomes. This is followed by a dual focus on data analysis to ensure the models meet the objectives, eventually evaluating the performance (using performance indicators) and then continue improving the business process. This should give conformance and performance insights, opening possibilities for optimalisation and improvement. Two methods can be potentially used to do this:

Flow Analysis

Using a flow analysis, the overall performance of a process can be estimated based on knowledge of individual tasks (Dumas, *et al*.). By using this analysis, performance indicators such as the average cycle time and cycle efficiency can be calculated (Dumas, *et al*.). The cycle time represents the time that is required to complete an entire process from start finish. The cycle time efficiency measures the proportion of time that resources (people or machines) are actively processing work, versus idle or waiting time. Low cycle time efficiency often highlights areas for improvement, which can be addressed using techniques like the Critical Path Method (Dumas, *et al*.). This analysis can be done running a BPMN model and extracting data.

However, flow analysis does have limitations. It can be challenging to estimate the average processing time of each individual task (used for the calculations), this is a common obstacle in a quantitative data analysis. Additionally, flow analysis does not handle significant fluctuations in workload well. This is due to resource contention, meaning that there is a sudden increase in workload, meaning that demand for resources exceeds the availability (Dumas, *et al*.). Flow analysis is best suited for processes with relatively stable workloads over time, this aligns well with the models of Oxand and the Municipality of Amsterdam making it a valuable analysis.

TAM / UTAUT

This will assess how well the implementation of the system contributes to the improvement in business processes for both Oxand and the Municipality of Amsterdam. Together with the improvements found in the business processes, after the implementation of the system, the effectiveness will be tested and evaluated using a TAM (Technology Acceptance Model) or UTAUT (Unified Theory of Acceptance and Use of Technology), which will assess the overall acceptance by the stakeholders/users of the implemented models. This checks if the model aligns with the goals and needs of the stakeholders.

One limitation of this method is that the systems used are already pre-programmed, meaning that initially the BPMN models should already be well-designed. If not, the data gathered is unreliable and unlikely to represent the actual truth. Therefor the validity must be ensured through checking and reviewing the models, ensuring that the models meet the necessary requirements. Reliability will be ensured by running and comparing the BPMS several times across similar test cases, making it more consistent.

5.4.3. Summary

The implementation plan outlines the steps needed to transition from locally deployed BPMN models to fully automated, scalable solutions hosted on a server using Camunda 7 Run. These include optimizing database connections, refining configuration files and automating processes to enhance efficacy and user-friendliness. Subsequent stages involve testing, monitoring performance, data analysis, and stakeholder evaluation using TAM or UTAUT frameworks. While the Proposal Process benefits from workflow automation, the BAP process should transition to full automation. These steps ensure the models remain aligned with organizational goals opening the way for continuous improvement throughout the BPM lifecycle.

6. Discussion, Conclusion & Recommendations

This chapter discusses the main findings of the research and their implications. It first examines the strengths and limitations of the methods used. The chapter then presents key conclusions by answering the research questions. Finally, recommendations are provided to improve process automation and guide future implementations.

6.1. Discussion

This section evaluates the limitation, methodologies, tools, and theoretical frameworks applied in the research. It examines the strengths and limitations while considering their theoretical and practical implications and alignment with existing literature.

Existing Research

The Analytic Hierarchy Process (AHP) has been extensively studied, with entire books (e.g., Munier & Hontoria, 2021) dedicated to its applications and limitations. Similarly, Business Process Management (BPM) and its potential implementations are well-documented (e.g., Dumas et al., 2018), with globally accepted BPMN standards such as ISO 19510 (Object Management Group). Various studies have explored BPM techniques (including BPMN) and compared them using AHP (e.g., Al-Rakhami & Almashari, 2019). Additionally, a lot of quality criteria for BPMN models have been created in different kinds of research. Modeling guidelines have been systematically literature reviewed (Avila et al., 2020), setup by creating the seven modeling guidelines (7PMG, by Mendling et al., 2009) and business process quality aspects are researched a lot (e.g.: Leopold et al., 2015; Yahya et al., 2018; Corradini et al., 2017). Extensive research has already been conducted on transforming BPMN models into common executable formats. Some studies focus on automatically generating executable web services from BPMN models (Zafar et al., 2019). Others explore business process reliability modeling (Bocciarelli et al., 2020) and digitalization models for IT consulting (Bode et al., 2024).

While BPMN execution and automation has been extensively studied, prioritizing workflow automation criteria based on expert stakeholder input using AHP has not been explored in depth. Most studies focus on technical automation solutions rather than stakeholder-driven prioritization of automation needs. This research bridges that gap by integrating AHP with expert-stakeholder input to identify and validate process-specific automation criteria. A similar approach exists in service selection workflows (Viriyasitavat & Bi, 2020), but not explicitly in BPMN transformation. This research is unique in combining AHP with expert-driven prioritization, generating insights that help workflow automation.

Validity & Reliability

Several measures were taken to enhance validity and reliability, because it is crucial for research. During the creation of the models, continuous validation was carried out by involving multiple stakeholders and experts to review and check the business processes. For instance, the Oxand proposal process was validated through five consecutive sessions, ensuring consistency and accuracy in the models. Additionally, peer-reviewed articles were exclusively used for criteria and literature research, and findings were cross-verified with multiple sources to improve reliability. During the application of the AHP methodology, a Consistency Ratio of less than 10% was maintained, requiring experts to demonstrate consistency when prioritizing criteria. By involving various experts, including modelers, management, end-users, and enterprise architects, to review the processes and prioritize criteria from different perspectives, the research achieves more reliable outcomes. Despite these measures to ensure the validity and reliability of both quantitative and qualitative data in this research there are some limitations.

Limitations of Camunda 7 Run

Camunda 7 Run offers an easy-to-use, preconfigured environment that simplifies deployment and execution. However, its preconfigured setup restricts customization for complex use cases. While this is favorable for beginners or less technically complex workflows, it may not meet the needs of processes that are more complex. For scenarios requiring greater control, developing a (Camunda 7) Spring Boot application using an integrated development environment (IDE) like Eclipse could be a viable alternative. Spring Boot provides enhanced flexibility, enabling tailored automation and integration. However, it requires advanced technical expertise, making it less accessible researchers with limited programming knowledge.

There already is a Camunda 8, and the last update of Camunda 7 will be released October 2025, meaning changing to Camunda 8 offers advanced features, including enhanced scalability, multi-tenancy support and cloud working and deploying capabilities. Despite these advantages, it was not selected for this project due to its complexity. The focus was on achieving quick implementation with minimal training, making Camunda 7 Run a more accessible option. For organizations or projects that anticipate significant growth or require cloud-native solutions, transitioning to Camunda 8 could provide long-term benefits.

General Limitations

Due to the researcher’s limited computer science knowledge (and more business oriented scope), the thesis primarily focused on workflow automation rather than full-scale process automation. While this approach sufficed for the Proposal Process, the BAP process requires more advanced automation to achieve its objectives efficiently (full automation). This technical gap could be addressed through training or collaboration with technical specialists enabling a full automation solution.

The Analytic Hierarchy Process (AHP) provided a structured framework to prioritize criteria for process transformation. However there are some limitations. The effectiveness of the AHP method heavily relies on input from a diverse group of experts. In this thesis the pool of experts was limited to only 6 experts, potentially affecting the prioritization outcomes. Future studies could involve more stakeholders, however this would provide a lot more work. Although AHP quantifies preferences, the method is still subject to bias in criteria weighting and pairwise comparisons. This bias may influence the results and the prioritization of automation goals. Cross-validation with alternative prioritization techniques could provide additional reliability to the criteria evaluation process.

Theoretical implications

By utilizing the Analytic Hierarchy Process (AHP), key criteria (efficacy, user-friendliness, conformity, and flexibility) can be identified and prioritized to ensure that automation solutions align with stakeholder needs. Through an AHP survey, experts and stakeholders can systematically rank these criteria, which can then be integrated into the automation of business processes. Additionally, by following a structured approach to transitioning BPMN models from descriptive to common executable formats, the process can be optimized for automation. This methodology ensures that automation efforts are guided by expert and stakeholder priorities, ultimately resulting in a process that is both efficient and aligned with stakeholder expectations.

Practical implications

The primary challenge faced by Oxand and the Municipality of Amsterdam was their lack of experience in converting descriptive BPMN models into executable formats. This issue was addressed through a structured approach involving AHP-based prioritization, BPMS selection, and technical implementation. By adopting Camunda 7 Run, workflow automation was successfully implemented, improving process monitoring and administration. This research provides a practical roadmap for organizations seeking to transition from descriptive BPMN models to automated workflows, ensuring both efficiency and stakeholder satisfaction.

6.2. Conclusion

The main research question for this study is: ***How can business processes modeled at a descriptive/analytic BPMN level be transformed into a common executable format and automated (partially or fully) using a BPMS/WfMS, while considering prioritized criteria?*** This question will be answered by systematically addressing each sub-research question (SRQ), which together provide a comprehensive pathway to understanding and resolving the main research question. Starting with the SRQ1:

1. *What are the current business processes, and how are they structured?*
    i. *How are the processes modeled in BPMN?*
    ii. *What does the sales process (proposal phase) look like?*

The first SRQ provides a contextual analysis, offering insight into the current state of the business processes and their BPMN representations. For the BAP process, it is modeled at a descriptive BPMN level, detailing actors, tasks, and interactions. These models were created using Sparx Enterprise

Architect and are ready for enhancement to achieve workflow automation via a BPMS. Criteria for this enhancement must be clearly established, with input from experts to prioritize these for effective workflow automation. The Oxand Proposal Process lacked formal documentation initially. Through interactive sessions with stakeholders, inefficiencies were addressed and the process structure was refined. This resulted in a BPMN model (Figure 4.6) that maps the proposal process and is now ready to be transformed into a common executable format. Continuing with the second and third sub-research questions:

2. *Which criteria influence the transformation and implementation of business processes modeled with Business Process Model & Notation (BPMN) from a descriptive or analytical level to an executable level (to create a model)?*
    i. *How do these criteria apply to various stakeholders and phases in the BPM lifecycle?*
3. *Which criteria are most important (according to experts) when transforming and implementing the BAP process modeled in BPMN from a descriptive/analytical level to an executable level?*

When automating processes, it is crucial to consider the criteria that affect stakeholders and the workflow itself. Stakeholders' priorities guide the transformation and ensure that the models meet practical and organizational needs. To answer the second sub-research question, four main criteria with sub-criteria were identified:

- Efficacy: Achieving goals efficiently with minimal resource use, aligning with managers' priorities during design and implementation.
- User-Friendliness: Creating intuitive and accessible systems for ease of use, ensuring end-user satisfaction.
- Conformity: Adherence to BPMN standards, completeness, and seamless integration, critical during design and validation.
- Flexibility: Ensuring adaptability to changes, supporting scalability and modularity for long-term sustainability.

After conducting the survey, expert analysis using the AHP highlights two primary criteria for transforming the BAP process from a descriptive/analytic BPMN level to an executable format:

1. Efficacy (45%): Ensuring the automated workflow optimizes resource allocation, minimizes process steps, and effectively reduces time consumption and waste.
2. User-Friendliness (31%): Making the system accessible and intuitive to encourage adoption and satisfaction. Without ease of use, the automation risks being underutilized.

Other criteria, such as flexibility (15%) and conformity (9%), were ranked lower in priority. Experts prioritized immediate process efficiency over strict adherence to modeling standards or long-term adaptability. While flexibility can be beneficial for future adjustments, the current focus is on addressing existing inefficiencies in the BAP process. To ensure a successful transformation and implementation of the BAP process, the automation should prioritize efficacy and user-friendliness, ensuring that the workflow is both efficient and easy to use. Flexibility and conformity, while relevant, are secondary to solving the current challenges. Continuing with sub-research question 4:

4. *Which BPMS/WfMS are most effective for running BPMN models?*

Considering the scope and limitations, Camunda was identified as the most suitable BPMS for this project. Camunda's open-standard compliance, local engine deployment, and community support make it ideal for proof-of-concept development. Its modeler simplifies BPMN creation, while the Camunda 7 Run distribution offers preconfigured tools, reducing the need for advanced technical expertise.

5. *How can BPMN process models be transformed from descriptive into executable formats?*

The transformation involves engine and database configurations (Table 5.1) and the transformation from descriptive to common executable BPMN level (Table 5.2). For the BAP process the outcomes of SRQ3 were taken into account (focusing on efficacy and user-friendliness) and for the proposal process the mapped out process of SRQ1 was used.

6. *What steps should be included in an implementation plan to further develop and implement BPMN models for automation?*

The implementation plan focuses on transitioning BPMN models from local deployment to fully automated, scalable solutions hosted on servers using Camunda 7 Run. This includes:

- Optimizing database connections.
- Refining configuration files for production environments.
- Automating processes to enhance efficacy and usability.

Subsequent stages involve testing, data analysis, and stakeholder evaluation using frameworks like TAM and UTAUT. While the Proposal Process benefits from workflow automation, the BAP process is better suited for full automation tools. By addressing each SRQ, this study provides a structured framework for transforming BPMN models from a descriptive to an executable level. This transformation process uses prioritization criteria (using the AHP method), stakeholder engagement, and a BPMS to create automated workflows that align with organizational goals.

6.3. Recommendations

Most recommendations are discussed in detail in the implementation plan (Section 5.4). However, due to the scope and time constraints of this research, one key recommendation is to reassess the selection of the BPMS. Section 5.4 outlines specific implementation steps using Camunda 7 Run, but for a more comprehensive BPMN automation, a reevaluation of the BPMS should be conducted. Below is a summary of key recommendations:

- Reselecting the BPMS: This research used Camunda 7 Run due to its ease of use, local execution (on a personal computer), and suitability for the project's limited timeline and technical expertise. However, for a full-scale implementation, this BPMS may not be ideal, particularly for complex, large-scale processes like the BAP process. If Camunda 7 Run is still chosen, improvements should include:
  - Transitioning from local execution to a dedicated server for enhanced stability.
  - Replacing the H2 database with a production-grade solution (e.g., PostgreSQL or MySQL) for better data management.
  - Using the production.yml file instead of the default.yml configuration to improve security and customization options.
- Enhancing process automation for the BAP process by implementing service and send tasks. These tasks are crucial for achieving higher automation levels, improving both efficacy and user experience.
- Reducing (and eventually eliminating) user tasks to move towards full automation in the BAP process.
- Continuously monitoring performance indicators of both processes.

This research contributes to business process automation by bridging the gap between descriptive BPMN models and executable workflows, integrating AHP-based prioritization to stakeholder needs. While proof-of-concept workflow automation was successfully implemented for the proposal process, for the BAP process full automation requires further technical development.

6.4. Future Scope

Future research should move beyond workflow automation towards full automation by incorporating service and send tasks, minimizing human intervention, and enhancing overall efficiency. Additionally, emerging technologies such as AI integration and cloud-based computing offer promising avenues for optimizing BPMN-based automation. AI can improve process intelligence by predicting bottlenecks and optimizing workflows, while cloud-based solutions can provide scalability, flexibility, and enhanced collaboration for distributed teams.

As described in Section 5.4 further research could also focus on flow analysis to detect and address inefficiencies in automated processes. Additionally, applying frameworks like TAM (Technology Acceptance Model) and UTAUT (Unified Theory of Acceptance and Use of Technology) can help assess system acceptance and effectiveness, ensuring the solution aligns with user expectations. By integrating these advancements, future studies can refine automation strategies, making business processes more adaptive, efficient, and aligned with evolving technological capabilities.

References

Ahmed, S. K. (2024). The pillars of trustworthiness in qualitative research. *Journal of Medicine, Surgery, and Public Health, 2*, 100051. https://doi.org/10.1016/j.glmedi.2024.100051

Al-Rakhami, M., & Almashari, M. (2019). *Business Process Modeling Notations Techniques: A comparative study using AHP*. AIS Electronic Library (AISeL). https://aisel.aisnet.org/ukais2019/7/

Avila, D. T., Santos, R. I. D., Mendling, J., & Thom, L. H. (2020). A systematic literature review of process modeling guidelines and their empirical support. *Business Process Management Journal*, *27*(1), 1–23. https://doi.org/10.1108/bpmj-10-2019-0407

Bocciarelli, P., D'Ambrogio, A., Giglio, A., & Paglia, E. (2020). Modeling resources to simulate business process reliability. *ACM Transactions on Modeling and Computer Simulation*, *30*(3), 1–25. https://doi.org/10.1145/3381453

Bode, M., Daneva, M., & Van Sinderen, M. J. (2024). A digitalization phase model for IT consulting services. In *Lecture notes in business information processing* (pp. 227–243). https://doi.org/10.1007/978-3-031-54712-6_14

Born, M., Dörr, F., & Weber, I. (2007). User-Friendly semantic annotation in business process modeling. In *Lecture notes in computer science* (pp. 260–271). https://doi.org/10.1007/978-3-540-77010-7_25

Cheligeer, C., Yang, L., Nandi, T., Doktorchik, C., Quan, H., Zeng, Y., & Singh, S. (2022). Natural language processing (NLP) aided qualitative method in health research. *Journal of Integrated Design and Process Science*, *27*(1), 41–58. https://doi.org/10.3233/jid-220013

CMMI Institute - CMMI Levels of Capability and Performance. (n.d.). https://cmmiinstitute.com/learning/appraisals/levels

Cooper, D. R., & Schindler, P. S. (2014). *Business research methods* (12th ed.). McGraw-Hill/Irwin.

Corradini, F., Ferrari, A., Fornari, F., Gnesi, S., Polini, A., Re, B., & Spagnolo, G. O. (2017). A Guidelines framework for understandable BPMN models. *Data & Knowledge Engineering*, *113*, 129–154. https://doi.org/10.1016/j.datak.2017.11.003

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of Business Process Management* (2nd ed.). Springer. https://doi.org/10.1007/978-3-662-56509-4

Dumas, M. (2008). Case Study : BPMN to BPEL Model Transformation. https://www.semanticscholar.org/paper/Case-Study-%3A-BPMN-to-BPEL-Model-Transformation-Dumas/48baadaf43abad8647a75bad80421940c890746e

Garrison, D. R. (1997). Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly, 48*(1), 18–33. https://doi.org/10.1177/074171369704800103.

Gulshad, K., Szydłowski, M., Yaseen, A., & Aslam, R. W. (2024). A comparative analysis of methods and tools for low impact development (LID) site selection. Journal of Environmental Management, 354, 120212. https://doi.org/10.1016/j.jenvman.2024.120212

Heerkens, H. & Van Winden, A. (2017). *Solving Management Problems Systematically*. Groningen: Noordhoff Uitgevers.

Kakar, Z. U. H., Rasheed, R., Rashid, A., & Akhter, S. (2023). Criteria for assessing and ensuring the trustworthiness in qualitative research. *York College Publications and Research*. https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=1386&context=yc_pubs

Koliadis, G., & Ghose, A. (2006). Relating Business Process Models to Goal-Oriented Requirements Models in KAOS. In *Lecture notes in computer science* (pp. 25–39). https://doi.org/10.1007/11961239_3

Leopold, H., Mendling, J., & Gunther, O. (2015). Learning from Quality Issues of BPMN Models from Industry. *IEEE Software*, *33*(4), 26–33. https://doi.org/10.1109/ms.2015.81

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.

Mendling, J., Reijers, H., & Van Der Aalst, W. (2009). Seven process modeling guidelines (7PMG). Information and Software Technology, 52(2), 127–136. https://doi.org/10.1016/j.infsof.2009.08.004

Munier, N., & Hontoria, E. (2021). Uses and Limitations of the AHP Method. In *Management for professionals*. https://doi.org/10.1007/978-3-030-60392-2

Oxand. (2024, May 29). Oxand. https://www.oxand.com/

Robinson JD, Persky AM. Developing Self-Directed Learners. Am J Pharm Educ. 2020 Mar;84(3):847512. https://doi.org/10.5688/ajpe847512 . PMID: 32313284; PMCID: PMC7159015.

Rohac, T., & Januska, M. (2015). Value Stream Mapping Demonstration on real case study. *Procedia Engineering*, *100*, 520–529. https://doi.org/10.1016/j.proeng.2015.01.399

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences,* 1, 83-98.

Saaty, T. L. (2012). *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World*. Third Revised Edition. Pittsburgh: RWS Publications.

Sampson, M. (2003). Electronic mail. In *Elsevier eBooks* (pp. 57–70). https://doi.org/10.1016/b0-12-227240-4/00052-6

Sarkar, S., Chauhan, S., & Khare, A. (2019). A meta-analysis of antecedents and consequences of trust in mobile commerce. *International Journal of Information Management*, *50*, 286–301. https://doi.org/10.1016/j.ijinfomgt.2019.08.008

Soliman, M., Esteves, O. O., Trevisan, M., & Segatto, G. F. (2022). A tentative integration of value stream mapping (VSM) and BPMN for improved process mapping. *Knowledge And Process Management*, *29*(4), 371–382. https://doi.org/10.1002/kpm.1729

Strauss, M. E., & Smith, G. T. (2009). Construct validity: Advances in theory and methodology. Annual Review of Clinical Psychology, 5, 1–25. https://doi.org/10.1146/annurev.clinpsy.032408.153639

Tay, M. (2023, May 19). *BPMN Process Model: Descriptive, Analytic, and Executable*. Orbus Software. https://www.orbussoftware.com/resources/research-library/detail/bpmn-process-model-descriptive-analytic-and-executable

Vermaas, P., Kroes, P., Van De Poel, I., & Franssen, M. (2010). *A philosophy of technology: From Technical Artefacts to Sociotechnical Systems*. Morgan & Claypool Publishers.

Viriyasitavat, W., & Bi, Z. (2020). Service selection and workflow composition in modern business processes. *Journal of Industrial Information Integration*, *17*, 100126. https://doi.org/10.1016/j.jii.2020.100126

Von Rosing, M., Von Scheel, H., & Scheer, A. (2014). *The Complete Business Process Handbook: Body of Knowledge from Process Modeling to BPM, Volume 1*. Morgan Kaufmann.

Yahya, F., Boukadi, K., & Ben-Abdallah, H. (2018). Improving the quality of Business Process Models: Lesson learned from the State of the Art. *Business Process Management Journal*, *25*(6), 1357–1376. https://doi.org/10.1108/bpmj-11-2017-0327

Yaqin, M. A., Sarno, R., & Fauzan, A. C. (2017). Scalability measurement of business process model using business processes similarity and complexity. *EECSI*, 1–7. https://doi.org/10.1109/eecsi.2017.8239129

Zafar, I., Azam, F., Anwar, M. W., Maqbool, B., Butt, W. H., & Nazir, A. (2019). A Novel Framework to Automatically Generate Executable Web Services From BPMN Models. *IEEE Access*, *7*, 93653–93677. https://doi.org/10.1109/access.2019.2927785

Zhu, M., Bonk, C.J. & Doo, M.Y. Self-directed learning in MOOCs: exploring the relationships among motivation, self-monitoring, and self-management. *Education Tech Research Dev* **68**, 2073–2093 (2020). https://doi.org/10.1007/s11423-020-09747-8

Appendix

A. (English version) AHP survey

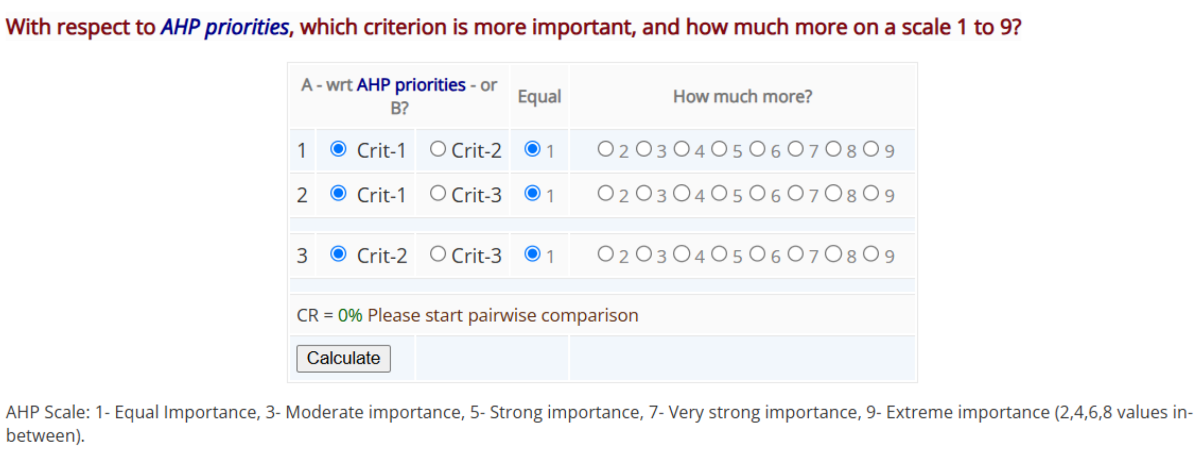
Introduction:

The Analytic Hierarchy Process (AHP) is a decision-making tool that helps analyze multiple criteria by breaking the problem down into a hierarchy and prioritizing the criteria through comparisons based on expert input.

The purpose of using AHP in this survey is to rank the criteria that influence the successful transformation and implementation of business processes modeled with Business Process Model & Notation (BPMN) from a descriptive or analytical level to an executable level. This ensures that these processes can, for example, be implemented in a BPMN-compliant Business Process Management System (BPMS) or Workflow Management System (WfMS).

This analysis specifically focuses on phases 1 and 2 (registration and routing) of the Management Acceptance Process (BAP) as carried out within the Urban Management department of the Traffic and Public Space Directorate of the Municipality of Amsterdam.

It is important to keep these phases in mind while completing the survey, as the results will provide insights into which aspects/criteria are considered most important by experts (you). The final outcome will be a ranking of the main criteria and subcriteria that play a key role in decisions regarding the (partial) automation and potentially effective elaboration and implementation of the BAP in a BPMS/WfMS.



Screenshot: Explanation of how priority is determined between two criteria (Site: https://bpmsg.com/ahp/)

Thank you in advance, and good luck completing the survey!

Criteria for the (partial) automation of phases 1 & 2 of BAP Urban Management (Stedelijkbeheer)

1. **Efficacy (Doelmatigheid)**

Explanation: Efficacy concerns the balance between the use of resources and achieving desired results. It evaluates how well a BPMN business process model achieves its goals without unnecessary waste of time, money, or other resources.

Example: An e-commerce company uses a BPMN model to process orders. Goal-orientation lies in fast delivery for satisfied customers. Effectiveness is demonstrated by a 99% success rate in timely processing. Efficiency is improved through automation, which saves costs. Controllability ensures real-time adjustments in case of delays and provides a clear explanation of authorities.

a. **Goal-Orientation (Doelgerichtheid)**
    i. Goal-orientation refers to the extent to which the process's objective is clear and the degree to which the process creates value for stakeholders (parties affected positively or negatively by the process execution and/or its result, or those who perceive it to be so) by meeting their needs, interests, and concerns as best as possible. This includes a clear understanding of who the process serves and what results/goals must be achieved.
    ii. *Example*: A hospital develops a model for scheduling surgeries that considers both the needs of patients (minimal waiting time) and the needs of health insurers (minimal costs through optimal use of operating rooms).

b. **Effectiveness (Effectiviteit)**
    i. Effectiveness concerns the extent to which the intended results are achieved. This includes how well the process can handle exceptions and errors, such as alternative paths or recovery options in case of process failures. It focuses on the consistency with which the desired result is achieved.
    ii. *Example*: An online store uses a process(model) in which 98% of orders are successfully processed and delivered. The model also includes steps for managing exceptions, such as stock shortages or delivery delays.

c. **Efficiency (Efficiëncie)**
    i. Efficiency concerns the amount of resources required to execute, monitor, manage, and maintain a process. This includes the costs of time, personnel, and materials, as well as integration with existing IT systems.
    ii. *Example*: The cost (e.g., personnel) in a process can be reduced by automating parts of order processing.

d. **Controllability (Bestuurbaarheid)**
    i. Controllability refers to the ability to monitor and adjust a process and the extent to which ownership and responsibilities at all levels (task, business process, management system/enterprise architecture) are clearly and

unambiguously assigned and traceable over time to specific individuals/entities. This also includes forecasting/planning resources and adapting processes based on changing circumstances or new insights.

ii. *Example*: During package delivery, an unexpected traffic jam occurs. The system suggests an alternative route to ensure the package is delivered on time. Additionally, it is clear who within the team is responsible for adjusting routes and communicating with customers. It is also clear how new predictive route navigation should be integrated into the process (including its management).

2. User-Friendliness

User-friendliness concerns the extent to which the process is easy and pleasant to use, understand, and maintain. It also involves the degree to which the information and (ICT) systems are accessible and intuitive for users with varying levels of expertise and backgrounds (executives, managers, and administrators) to manage and maintain them easily after implementation.

Example: An online application process for a permit is designed so that users are guided step-by-step through the process with clear instructions and example forms. This allows both experienced and less experienced users to easily provide the correct information and understand what is expected of them.

a. Usability (Bruikbaarheid)

i. Usability refers to the extent to which (end) users can easily, pleasantly, and intuitively use the process. An intuitive model requires minimal training and makes it easy and enjoyable to achieve specific results.

ii. *Example*: A logistics company implements a process(model) for package delivery where employees can, with minimal training, see which steps they need to follow, such as scanning a package, planning a route, and confirming the delivery, without requiring extensive training.

b. Understandability (Begrijpelijkheid)

i. Understandability refers to the clarity, unambiguity, and readability with which the process is documented and presented to users. This includes avoiding unnecessary elements and ensuring readability so that users can understand, use, maintain, and modify the process.

ii. *Example*: A process for handling customer complaints is visually represented with clear symbols, simple terminology, and clearly defined steps. This ensures that everyone in the company, from customer service to managers, can quickly understand how the process works.

c. Accessibility (Toegankelijkheid)

i. Accessibility refers to the ease with which users can access and use information and (ICT) systems related to the process. It also concerns the low threshold for obtaining the information needed to work with the process(model).

ii. *Example*: A hospital uses a digital, visual process(model) where doctors and nurses can access relevant patient data with a single click. The system is designed so that even staff without a technical background can use it easily and quickly.

d. Maintainability (Onderhoudbaarheid)

i. Maintainability refers to how easily the process model can be adjusted or updated by administrators, as well as how well the (ICT) systems supporting the execution, monitoring, adjustment, and improvement of the business process can be updated (e.g., when adding new users) and adapted (e.g., when making changes). The process(model) must be suitable for quickly and efficiently processing changes in the process without significant risks or errors.

ii. *Example*: A software company uses a process(model) for handling bug fixes and implementing software updates. When a new version of the software is released, the process(model) can be easily adjusted to add extra steps, such as new testing procedures or integrating user feedback, without redesigning the entire process.

3. Conformity (Conformiteit)

This criterion assesses how well the process(model) is designed and modeled. It involves adherence to standards, completeness of representation, and ensuring the integrity and security of the model.

Example: A hospital implements a process(model) for managing patient appointments. The process(model) follows the correct sequence of steps (accuracy), potentially also as required by (external) laws and regulations or (internal) organizational policies/requirements, such as checking availability, scheduling the appointment, and sending a confirmation. It also covers alternative scenarios (completeness), such as processing cancellations or changes, at least to the extent determined to be minimally necessary for the proper execution of the business process and the operation of supporting (ICT) tools. All systems, such as patient records and scheduling tools, are designed cohesively at the architectural level, the chosen solutions work flawlessly together (integrity), and the data is only accessible to authorized staff via secure login procedures (security).

a. Correctness (Juistheid)

   i. Accuracy refers to the extent to which BPMN 2.0 standards are followed and the correct use of syntax, symbols, and modeling rules. The process(model) must be technically accurate and straightforward to execute. It also includes the correct implementation of requirements and rules in the model.
   ii. *Example*: When designing a process model in a webshop, the order of activities is verified: first, an order is placed, then inventory is checked, and finally, an order confirmation is sent.

b. **Completeness (Volledigheid)**
   i. Completeness refers to the extent to which the process model represents the entire business process. This includes validation with stakeholders and documenting all relevant information, including exceptions and alternative routes (exception handling). General modeling conventions can be used to ensure consistency and completeness. It may also involve choosing not to handle exceptions but to return an error instead.
   ii. *Example*: In an insurance process, not only are the standard procedures for approved claims included, but also exception routes, such as what happens if a claim lacks sufficient documentation or is denied. However, some processes are better suited to generating an error message, leaving it to a person to resolve.

c. **Integrity (Integraliteit)**
   i. Integrity refers to the extent to which all parts of the process(model) align and form a logical and integrated whole. The process(model) should be designed in conjunction with the (enterprise) architecture and should work flawlessly with chosen solutions (e.g., other (ICT) systems or components) while following clear (integrated) agreements to prevent confusion and problems.
   ii. Example: In a logistics process, the process model ensures that data on shipping, storage, and delivery is processed consistently. If an address change is made, this must automatically be passed on to the delivery planning without manual adjustments. The model supports the design, execution (solution), and management of processes in line with the organizational architecture.

d. **Security (Beveiligbaarheid)**
   i. Security refers to the extent to which the model protects data from unauthorized access and manipulation. It includes access control and ensuring data integrity.
   ii. *Example*: In a hospital system, patient data is protected through access control, ensuring that only authorized doctors and nurses can view sensitive information.

4. **Flexibility (Flexibiliteit)**

Flexibility concerns how well the process(model) can grow with the organization and how easily changes can be made after implementation. It assesses whether the process(model) can be adjusted when requirements change, without requiring significant restructuring.

Example: A company grows internationally and needs to add new currencies, adjust current payment rates, and keep processes modular to remain organized.

a. **Adaptability (Aanpasbaarheid)**
    i. Adaptability encompasses the ease with which processes can be adjusted after implementation. This also includes the ability to adapt to new technologies, such as AI, or changing market demands.
    ii. *Example*: A supermarket decides to change or adjust products on a shelf to provide alternative options.

b. **Scalability (Schaalbaarheid)**
    i. Scalability refers to the ability to expand processes as needed. The model must be flexible enough to support growth without significant restructuring.
    ii. *Example*: A supermarket adds a new department (e.g., meat) alongside fish, while regular sales continue without interruption.

c. **Modularity (Modulariteit)**
    i. The extent to which the process(model) is divided into smaller modules or sub-processes. This ensures that adjustments can be made per module without altering the entire model. It helps reduce complexity and the likelihood of errors.
    ii. *Example*: In a hospital, each department is designed separately (e.g., emergency & surgery), allowing adjustments per module without impacting processes in other departments.

d. **Reusability (Herbruikbaarheid)**
    i. Reusability considers the extent to which parts of the process model can be reused in other systems or new models. This promotes consistency and efficiency when developing new processes.
    ii. *Example*: An HR system uses a standardized module for approving leave requests. This module is also applied in another system for submitting expense claims without requiring modifications.

B. (Dutch version) AHP enquête

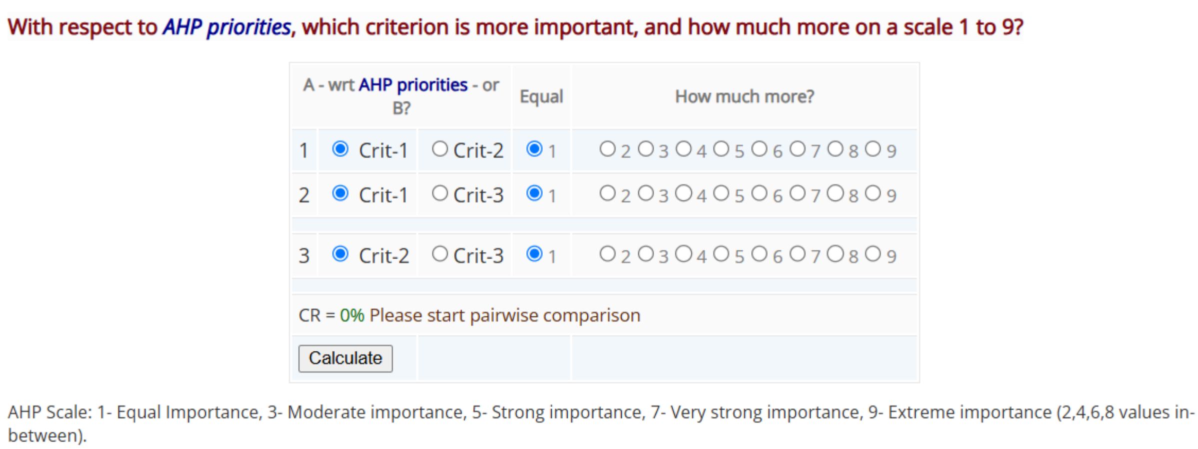
Enquête fasen 1 & 2 BAP Stedelijk Beheer

Uitleg:

De Analytic Hierarchy Process (AHP) is een beslissingshulpmiddel dat helpt om meerdere criteria te analyseren, door het probleem op te delen in een hiërarchie en de criteria te prioriteren via vergelijkingen op basis van input van experts.

Het doel van het gebruik van AHP in deze enquête is om de criteria te rangschikken die invloed hebben op de succesvolle transformatie en implementatie van bedrijfsprocessen gemodelleerd met Business Process Model & Notation (BPMN) op beschrijvend of analytisch uitwerkingsniveau naar uitvoerbaar uitwerkingsniveau, zodat deze bijvoorbeeld in een BPMN-comformant Business Process Management System (BPMS) c.q. Workflow Management System (WfMS) kan worden geïmplementeerd. Deze analyse richt zich specifiek op fasen 1 & 2 (aanmelding en routering) van het Beheeracceptatieproces (BAP) zoals dat uitgevoerd wordt binnen afdeling Stedelijk Beheer van directie Verkeer en Openbare Ruimte van de gemeente Amsterdam.

Het is belangrijk om deze fasen in gedachten te houden tijdens het invullen van de enquête, omdat de resultaten inzicht zullen geven in welke aspecten/criteria door experts (u) als het belangrijkst worden beschouwd. Het eindresultaat zal een rangschikking zijn van de hoofdcriteria en subcriteria die een sleutelrol spelen bij de keuzes met betrekking tot het (gedeeltelijk) automatiseren en mogelijk effectief uitwerken en implementeren van het BAP in een BPMS / WfMS.



Screenshot: Uitleg hoe prioriteit bepaald worden tussen twee criteria (Site: https://bpmsg.com/ahp/)

Bedankt alvast en succes met invullen!

Criteria voor het (gedeeltelijk) automatiseren van fasen 1 & 2 BAP Stedelijk Beheer

1. **Doelmatigheid**

Uitleg: Doelmatigheid gaat over het evenwicht tussen de inzet van middelen en het behalen van de gewenste resultaten. Het beoordeelt hoe goed een BPMN-bedrijfsprocesmodel de doelen bereikt zonder onnodige verspilling van tijd, geld of andere middelen.

Voorbeeld: Een e-commercebedrijf gebruikt een BPMN-model om bestellingen te verwerken. Doelgerichtheid ligt in snelle levering voor tevreden klanten. Effectiviteit blijkt uit een 99% succesrate bij tijdige verwerking. Efficiëntie wordt verbeterd door automatisering, wat kosten bespaart. Stuurbaarheid zorgt voor real-time bijsturing bij vertragingen en een duidelijke uitleg over bevoegdheden.

a. ***Doelgerichtheid***
    i. Doelgerichtheid betreft de mate waarin het doel van het proces helder is, en de mate waarin het proces *waarde* creëert voor *stakeholders* (partijen waarop de *uitvoering* en/of het *resultaat* van het proces een positieve en/of negatieve impact heeft, of die de perceptie hebben dat dit zo is) door zo goed mogelijk invulling te geven aan hun *behoeften, belangen en zorgen*. Dit omvat een helder begrip van wie het proces bedient en welke resultaten/doelen moeten worden bereikt.
    ii. Voorbeeld: Een ziekenhuis ontwikkelt een model voor inplannen van operaties waarbij zowel naar de behoefte van de patiënt (minimale wachttijd) en de behoefte van zorgverzekeraars (minimale kosten door optimaal gebruik van operatiekamers) wordt gekeken.

b. ***Effectiviteit***
    i. Effectiviteit betreft de *mate waarin de beoogde resultaten worden behaald*. Dit omvat hoe goed het proces om kan gaan met uitzonderingen en fouten, zoals alternatieve paden of herstelopties bij procesfouten. Het draait om de consistentie waarmee het gewenste resultaat wordt bereikt.
    ii. Voorbeeld: Een online winkel gebruikt een proces(model) waarbij 98% van de orders succesvol worden verwerkt en bezorgd. Het model bevat ook stappen voor het beheren van uitzonderingen, zoals een voorraadtekort of een vertraging in de bezorging.

c. ***Efficiëntie***
    i. Efficiëntie betreft de *hoeveelheid middelen die nodig is om een proces uit te voeren, bewaken, beheren en onderhouden*. Dit omvat onder andere de kosten van tijd, personeel en middelen, evenals integratie met bestaande IT-systemen.

ii. Voorbeeld: De hoeveelheid kosten (bv. personeel) kan verminderd worden in een proces door een deel van orderverwerking te automatiseren.

d. Bestuurbaarheid

i. Bestuurbaarheid betreft de mogelijkheid om een *proces te monitoren en bij te sturen* en de mate waarin het *eigenaarschap en de verantwoordelijkheden op alle betrokken niveaus* (taak, bedrijfsproces, managementsysteem/ enterprisearchitectuur) helder en eenduidig belegd zijn en door de tijd heen getraceerd kunnen worden naar specifieke personen/ entiteiten. Dit omvat ook het prognosticeren/plannen van middelen en het aanpassen van processen op basis van veranderende omstandigheden of nieuwe inzichten.

ii. Voorbeeld: Tijdens het bezorgen van pakketten ontstaat er een onverwachte file. Het systeem stelt een alternatieve route voor, zodat de bestelling alsnog op tijd wordt afgeleverd. Bovendien is duidelijk wie binnen het team verantwoordelijk is voor het aanpassen van routes en het communiceren met klanten. Daarnaast is het duidelijk hoe nieuwe voorspellende routenavigatie binnen het proces geïntegreerd moet worden (incl. het beheer hiervan).

2. Gebruiksvriendelijkheid

Gebruiksvriendelijkheid betreft de mate waarin het proces eenvoudig en prettig te gebruiken, begrijpen en onderhouden is. Ook betreft dit de mate waarin de informatie en (ICT-)systemen toegankelijk en intuïtief zijn voor gebruikers met verschillende niveaus van expertise en achtergrond (uitvoerende, managers en beheerders) om het eenvoudig te beheren en onderhouden na implementatie.

Voorbeeld: Een online aanvraagproces voor een vergunning is zo ontworpen dat gebruikers stapsgewijs door het proces worden geleid met duidelijke instructies en voorbeeldformulieren. Hierdoor kunnen zowel ervaren als minder ervaren gebruikers gemakkelijk de juiste gegevens invullen en begrijpen wat er van hen wordt verwacht.

a. Bruikbaarheid

i. Bruikbaarheid betreft de *mate waarin (eind)gebruikers eenvoudig, prettig en intuïtief het proces kunnen gebruiken*. Een intuïtief model vereist minimale training en maakt het eenvoudig en prettig om specifieke resultaten te bereiken.

ii. Voorbeeld: Een logistiek bedrijf implementeert een proces(model) voor pakketbezorging waarbij medewerkers met minimale training kunnen zien welke stappen ze moeten volgen, zoals het scannen van een pakket, het plannen van een route, en het bevestigen van de levering, zonder dat ze hier veel training voor nodig hebben.

b. Begrijpelijkheid

i. Begrijpelijkheid betreft de *mate van duidelijkheid, eenduidigheid en overzichtelijkheid waarmee het proces is gedocumenteerd en aan gebruikers wordt getoond*. Dit omvat het vermijden van overbodige elementen en de *mate van leesbaarheid,* zodat gebruikers het proces een kunnen begrijpen, gebruiken, onderhouden en aanpassen.

ii. Voorbeeld: Een proces voor het afhandelen van klantklachten wordt visueel weergegeven met duidelijke symbolen, eenvoudige terminologie, en eenduidig gedefinieerde stappen. Hierdoor kan iedereen binnen het bedrijf, van klantenservice tot managers, snel begrijpen hoe het proces werkt.

c. Toegankelijkheid

i. Toegankelijkheid betreft de mate waarin het *eenvoudig het is voor gebruikers om toegang te krijgen tot en gebruik te maken van informatie en (ICT-)systemen met betrekking tot het proces*. Het gaat ook over de *laagdrempeligheid van het krijgen van de informatie* die nodig is om met het proces(model) te werken.

ii. Voorbeeld: Een ziekenhuis gebruikt een digitaal, visueel proces(model) waarin artsen en verpleegkundigen met één klik toegang hebben tot relevante patiëntgegevens. Dit systeem is zodanig ontworpen dat ook medewerkers zonder technische achtergrond het eenvoudig en snel kunnen gebruiken.

d. Onderhoudbaarheid

i. Onderhoudbaarheid betreft hoe *eenvoudig het procesmodel aangepast of bijgewerkt kan worden door beheerders*, maar ook hoe goed de (ICT-) systemen die de uitvoering, bewaking, (aan/bij)sturing en verbetering van het bedrijfsproces ondersteunen geactualiseerd (bv. bij het toevoegen van nieuwe gebruikers) en aangepast (bv. bij doorvoeren van wijzigingen) kunnen worden. Het proces(model) moet geschikt zijn om veranderingen in het proces snel en efficiënt te verwerken zonder grote risico's of fouten.

ii. Voorbeeld: Een softwarebedrijf gebruikt een proces(model) voor het afhandelen van bugfixes en het doorvoeren van software-updates. Wanneer een nieuwe versie van de software wordt uitgebracht, kan het proces(model) eenvoudig worden aangepast om extra stappen toe te voegen, zoals nieuwe testprocedures of het integreren van feedback van gebruikers, zonder het hele proces opnieuw te ontwerpen.

3. Conformiteit

Dit criterium kijkt in hoeverre het proces(model) goed is ontworpen en gemodelleerd. Het gaat om het correct volgen van standaarden, de volledigheid van de weergave, en het waarborgen van integriteit en beveiliging van het model.

Voorbeeld: Een ziekenhuis implementeert een proces(model) voor het beheer van patiëntafspraken. Het proces(model) volgt nauwkeurig de juiste volgorde van stappen (juistheid), evt. ook zoals via (externe) wet -en regelgeving dan wel vanuit (intern) organisatiebeleid/-eisen opgelegd, zoals het controleren van beschikbaarheid, het vastleggen van de afspraak, en het verzenden van een bevestiging. Het dekt ook alternatieve scenario's (volledigheid), zoals het verwerken van annuleringen of wijzigingen, in ieder geval in de mate zoals dat bepaald is dat minimaal benodigd is voor de juiste uitvoering van het bedrijfsproces en de werking van ondersteunende (ICT) middelen. Alle systemen, zoals patiëntendossiers en planningstools, worden zowel op architectuurniveau in samenhang ontworpen en de gekozen oplossingen werken foutloos samen (integraliteit), en de gegevens zijn alleen toegankelijk voor bevoegde medewerkers via beveiligde loginprocedures (beveiligbaarheid).

a. ***Juistheid***
    i. Juistheid betreft de *mate van het naleven van de BPMN 2.0-standaarden en het correcte gebruik van syntax, symbolen en modelleringsregels*. Het proces(model) moet technisch accuraat zijn en eenvoudig uitvoerbaar. Het omvat ook het correct implementeren van vereisten en regels in het model.
    ii. Voorbeeld: Bij het inrichten van een procesmodel in een webshop controleert men of de volgorde van activiteiten klopt: eerst wordt een bestelling geplaatst, daarna wordt de voorraad gecontroleerd, en vervolgens wordt een orderbevestiging verzonden.
b. ***Volledigheid***
    i. Volledigheid betreft de *mate waarin het procesmodel het volledige bedrijfsproces weergeeft*. Dit omvat *validatie met stakeholders* en het vastleggen van alle relevante informatie, inclusief uitzonderingen en alternatieve routes (*exception handling*). Hierbij kan gebruik worden gemaakt van algemene modelleringsafspraken om consistentie en volledigheid te garanderen. Er kan ook voor gekozen worden om juist géén uitzondering uit te voeren, maar een error terug te geven.
    ii. Voorbeeld: In een verzekeringsproces zijn niet alleen de standaardprocedures voor goedgekeurde claims opgenomen, maar ook uitzonderingsroutes, zoals wat er gebeurt als een claim onvoldoende documentatie bevat of geweigerd wordt. Er zijn echter ook processen die beter een foutmelding kunnen geven, om vervolgens door een persoon opgelost te worden.
c. ***Integraliteit***

i. Integraliteit betreft de *mate dat alle onderdelen in het proces(model) op elkaar aansluiten en samen een logisch en (integraal) geheel vormen*. Het proces(model) moet in *samenhang* met de (enterprise)architectuur worden ontworpen, en moet zonder fouten samenwerken met de gekozen *oplossingen* (bv. andere (ICT-)systemen of onderdelen) en duidelijke (integrale) afspraken volgen om verwarring en problemen te voorkomen.

ii. Voorbeeld: In een logistiek proces moet het procesmodel ervoor zorgen dat gegevens over verzending, opslag en levering consistent worden verwerkt. Als een adreswijziging wordt doorgevoerd, moet dit automatisch worden doorgegeven aan de leveringsplanning, zonder handmatige aanpassingen. Het model ondersteunt hiermee zowel het ontwerp, de uitvoering (oplossing) als het beheer van processen in samenhang met de organisatiearchitectuur.

d. Beveiligbaarheid

i. Beveiligbaarheid betreft de mate waarin het model *data beschermt tegen ongeautoriseerde toegang en manipulatie*. Het omvat toegangscontrole en het waarborgen van data-integriteit.

ii. Voorbeeld: Bij een ziekenhuissysteem worden patiëntgegevens beschermd door middel van toegangscontrole, zodat alleen bevoegde artsen en verpleegkundigen gevoelige informatie kunnen inzien.

4. Flexibiliteit

Uitleg: Hier draait het om hoe goed het proces(model) kan meegroeien met de organisatie en hoe eenvoudig het is om veranderingen door te voeren na implementatie. Is het mogelijk om het proces(model) aan te passen wanneer de eisen veranderen, zonder dat er grote herstructureringen nodig zijn.

Voorbeeld: Een bedrijf groeit internationaal en moet nieuwe valuta toevoegen, huidige betalingstarieven aanpassen en processen modulair houden zodat ze overzichtelijk blijven.

a. Aanpasbaarheid

i. Aanpasbaarheid omvat de eenvoud waarmee processen *na implementatie kunnen worden aangepast*. Dit omvat ook het vermogen om zich aan te passen aan nieuwe technologieën, zoals AI, of veranderende markteisen.

ii. Voorbeeld: Een supermarkt besluit de producten in een schap te veranderen/aanpassen voor andere opties.

b. Schaalbaarheid

i. Schaalbaarheid verwijst naar de *mogelijkheid om processen uit te breiden* naarmate dit nodig is. Het model moet flexibel genoeg zijn om groei zonder grote herstructurering te ondersteunen.

ii. Voorbeeld: Een supermarkt waar een extra afdeling bijkomt (wordt opgeschaald), naast vis nu ook vlees, dit terwijl de huidige verkoop gewoon doorgaat.

c. ***Modulariteit***

i. De mate waarin het proces(model) is *opgesplitst in kleinere modules of sub-processen*. Dit zorgt ervoor dat aanpassingen eenvoudig per module kunnen plaatsvinden, zonder dat het gehele model hoeft te worden gewijzigd. Het helpt complexiteit te verminderen en de kans op fouten te verkleinen.

ii. Voorbeeld: In een ziekenhuis wordt elke afdeling los ontworpen (bv. spoedeisende hulp & chirurgie) en kunnen aanpassingen per module gedaan worden, zodat het niet processen beïnvloed van een andere afdeling.

d. ***Herbruikbaarheid***

i. Herbruikbaarheid kijkt naar de mate waarin *onderdelen van het procesmodel opnieuw kunnen worden gebruikt in andere systemen of nieuwe modellen*. Dit bevordert consistentie en efficiëntie bij de ontwikkeling van nieuwe processen.

ii. Voorbeeld: Een HR-systeem gebruikt een gestandaardiseerde module voor het goedkeuren van verlofaanvragen. Deze module wordt ook toegepast in een ander systeem voor het indienen van declaraties, zonder dat aanpassingen nodig zijn.

C. (Dutch) Answer form / antwoordenformulier

Enquêteformulier Analytic Hierarchy Process (AHP):

Organisatie: Gemeente Amsterdam

Organisatieonderdeel: directie Verkeer en Openbare Ruimte, afdeling Stedelijke Beheer

Bedrijfsproces: Beheeracceptatieproces fasen 1 & 2 (aanmelding & routering)

Naam:...

Functie / Rol:..

Betrokkenheid i.r.t. onderwerp:..

Datum:..

Let op! AHP-schaal: 1 - Gelijke belangrijkheid, 3 - Matig belangrijker, 5 - Sterk belangrijker, 7 - Zeer sterk belangrijker, 9 - Extreme belangrijker (waarden 2, 4, 6, 8 als tussenwaarden).

Hoofdcriteria: Welk criterium is belangrijker, en hoeveel op een schaal van 2-9?

	Links	Rechts	Gelijk (1)	2	3	4	5	6	7	8	9
1 vs 2											
1 vs 3											
1 vs 4											
2 vs 3											
2 vs 4											
3 vs 4											

1. Doelmatigheid: Welk subcriterium is belangrijker, en hoeveel op een schaal van 2-9?

	Links	Rechts	Gelijk (1)	2	3	4	5	6	7	8	9
a vs b											
a vs c											
a vs d											
b vs c											
b vs d											
c vs d											

2. Gebruiksvriendelijkheid: Welk subcriterium is belangrijker, en hoeveel op een schaal van 2-9?

	Links	Rechts	Gelijk(1)	2	3	4	5	6	7	8	9
a vs b											
a vs c											
a vs d											
b vs c											
b vs d											
c vs d											

3. Conformiteit: Welk subcriterium is belangrijker, en hoeveel op een schaal van 2-9?

	Links	Rechts	Gelijk(1)	2	3	4	5	6	7	8	9
a vs b											
a vs c											
a vs d											
b vs c											
b vs d											
c vs d											

4. Flexibiliteit: Welk subcriterium is belangrijker, en hoeveel op een schaal van 2-9?

	Links	Rechts	Gelijk(1)	2	3	4	5	6	7	8	9
a vs b											
a vs c											
a vs d											
b vs c											
b vs d											
c vs d											

Opmerkingen / Extra criteria die missen?

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D. Results of AHP (for every expert)

Table D.1: Results E1-Dennis van 't Ende

Categories	Weights (wc)	Rank	Sub categories	Weights (wsc)	Final(wc*wsc)	Ranking
Efficacy	0,606	1	Goal-Orientation	0,376	0,227856	1
Efficacy	0,606	1	Effectiveness	0,331	0,200586	2
Efficacy	0,606	1	Efficiency	0,102	0,061812	6
Efficacy	0,606	1	Controllability	0,191	0,115746	4
User-Friendliness	0,273	2	Usability	0,348	0,095004	5
User-Friendliness	0,273	2	Understandability	0,101	0,027573	8
User-Friendliness	0,273	2	Accessibility	0,449	0,122577	3
User-Friendliness	0,273	2	Maintainability	0,101	0,027573	8
Conformity	0,062	3	Accuracy	0,383	0,023746	10
Conformity	0,062	3	Completeness	0,383	0,023746	10
Conformity	0,062	3	Integrity	0,175	0,01085	12
Conformity	0,062	3	Security	0,06	0,00372	16
Flexibility	0,059	4	Adaptability	0,7	0,0413	7
Flexibility	0,059	4	Scalability	0,1	0,0059	13
Flexibility	0,059	4	Modularity	0,1	0,0059	13
Flexibility	0,059	4	Reusability	0,1	0,0059	13

Table D.2: Results E2-Martijn van Barlingen

Categories	Weights (wc)	Rank	Sub categories	Weights (wsc)	Final (wc*wsc)	Ranking
Efficacy	0,495	1	Goal-Orientation	0,409	0,202455	1
Efficacy	0,495	1	Effectiveness	0,289	0,143055	2
Efficacy	0,495	1	Efficiency	0,096	0,04752	8
Efficacy	0,495	1	Controllability	0,205	0,101475	5
User-Friendliness	0,31	2	Usability	0,374	0,11594	3
User-Friendliness	0,31	2	Understandability	0,346	0,10726	4
User-Friendliness	0,31	2	Accessibility	0,198	0,06138	7
User-Friendliness	0,31	2	Maintainability	0,082	0,02542	11
Conformity	0,061	4	Accuracy	0,338	0,020618	13
Conformity	0,061	4	Completeness	0,413	0,025193	12
Conformity	0,061	4	Integrity	0,146	0,008906	15
Conformity	0,061	4	Security	0,104	0,006344	16
Flexibility	0,134	3	Adaptability	0,476	0,063784	6
Flexibility	0,134	3	Scalability	0,211	0,028274	10
Flexibility	0,134	3	Modularity	0,097	0,012998	14
Flexibility	0,134	3	Reusability	0,216	0,028944	9

Table D.3: Results E3-Bilal Sari

Categories	Weights (wc)	Rank	Sub categories	Weights (wsc)	Final (wc*wsc)	Ranking
Efficacy	0,263	2	Goal-Orientation	0,249	0,065487	6
Efficacy	0,263	2	Effectiveness	0,57	0,14991	3
Efficacy	0,263	2	Efficiency	0,124	0,032612	10
Efficacy	0,263	2	Controllability	0,058	0,015254	13
User-Friendliness	0,511	1	Usability	0,46	0,23506	1
User-Friendliness	0,511	1	Understandability	0,067	0,034237	9
User-Friendliness	0,511	1	Accessibility	0,149	0,076139	4
User-Friendliness	0,511	1	Maintainability	0,325	0,166075	2
Conformity	0,066	4	Accuracy	0,268	0,017688	12
Conformity	0,066	4	Completeness	0,529	0,034914	8
Conformity	0,066	4	Integrity	0,134	0,008844	15
Conformity	0,066	4	Security	0,068	0,004488	16
Flexibility	0,16	3	Adaptability	0,459	0,07344	5
Flexibility	0,16	3	Scalability	0,073	0,01168	14
Flexibility	0,16	3	Modularity	0,299	0,04784	7
Flexibility	0,16	3	Reusability	0,17	0,0272	11

Table D.4: Results E4- Johannes Houttuijn Bloemendaal

Categories	Weights(wc)	Rank	Sub categories	Weights (wsc)	Final (wc*wsc)	Ranking
Efficacy	0,28	1	Goal-Orientation	0,278	0,07784	6
Efficacy	0,28	1	Effectiveness	0,4	0,112	5
Efficacy	0,28	1	Efficiency	0,144	0,04032	11
Efficacy	0,28	1	Controllability	0,178	0,04984	10
User-Friendliness	0,481	2	Usability	0,25	0,12025	1
User-Friendliness	0,481	2	Understandability	0,25	0,12025	1
User-Friendliness	0,481	2	Accessibility	0,25	0,12025	1
User-Friendliness	0,481	2	Maintainability	0,25	0,12025	1
Conformity	0,09	4	Accuracy	0,613	0,05517	9
Conformity	0,09	4	Completeness	0,208	0,01872	13
Conformity	0,09	4	Integrity	0,089	0,00801	15
Conformity	0,09	4	Security	0,089	0,00801	15
Flexibility	0,149	3	Adaptability	0,42	0,06258	7
Flexibility	0,149	3	Scalability	0,388	0,057812	8
Flexibility	0,149	3	Modularity	0,06	0,00894	14
Flexibility	0,149	3	Reusability	0,132	0,019668	12

Table D.5: Results E5- Leon de Jonge

Categories	Weights(wc)	Rank	Sub categories	Weights (wsc)	Final (wc*wsc)	Ranking
Efficacy	0,39	1	Goal-Orientation	0,09	0,0351	7
Efficacy	0,39	1	Effectiveness	0,618	0,24102	1
Efficacy	0,39	1	Efficiency	0,046	0,01794	11
Efficacy	0,39	1	Controllability	0,246	0,09594	5
User-Friendliness	0,168	2	Usability	0,259	0,043512	6
User-Friendliness	0,168	2	Understandability	0,594	0,099792	4
User-Friendliness	0,168	2	Accessibility	0,047	0,007896	15
User-Friendliness	0,168	2	Maintainability	0,101	0,016968	12
Conformity	0,053	4	Accuracy	0,046	0,002438	16
Conformity	0,053	4	Completeness	0,209	0,011077	13
Conformity	0,053	4	Integrity	0,56	0,02968	10
Conformity	0,053	4	Security	0,186	0,009858	14
Flexibility	0,39	3	Adaptability	0,083	0,03237	8
Flexibility	0,39	3	Scalability	0,417	0,16263	2
Flexibility	0,39	3	Modularity	0,417	0,16263	2
Flexibility	0,39	3	Reusability	0,083	0,03237	8

Table D.6: Results E6-Juun van Ophuizen

Categories	Weights(wc)	Rank	Sub categories	Weights (wsc)	Final (wc*wsc)	Ranking
Efficacy	0,508	1	Goal-Orientation	0,238	0,120904	3
Efficacy	0,508	1	Effectiveness	0,603	0,306324	1
Efficacy	0,508	1	Efficiency	0,117	0,059436	6
Efficacy	0,508	1	Controllability	0,043	0,021844	11
User-Friendliness	0,151	2	Usability	0,53	0,08003	4
User-Friendliness	0,151	2	Understandability	0,058	0,008758	14
User-Friendliness	0,151	2	Accessibility	0,118	0,017818	12
User-Friendliness	0,151	2	Maintainability	0,293	0,044243	7
Conformity	0,265	4	Accuracy	0,052	0,01378	13
Conformity	0,265	4	Completeness	0,588	0,15582	2
Conformity	0,265	4	Integrity	0,255	0,067575	5
Conformity	0,265	4	Security	0,104	0,02756	9
Flexibility	0,075	3	Adaptability	0,463	0,034725	8
Flexibility	0,075	3	Scalability	0,342	0,02565	10
Flexibility	0,075	3	Modularity	0,109	0,008175	15
Flexibility	0,075	3	Reusability	0,086	0,00645	16