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SUPERNOVA Application-to-Approval

A BPM Approach

João Manuel Travanca Prado

Project Work

presented as partial requirement for obtaining the Master Degree Program in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação

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SUPERNOVA APPLICATION-TO-APPROVAL: A BPM APPROACH

By

João Manuel Travanca Prado

Project Work presented as partial requirement for obtaining the Master's degree in Information Management, with a specialization in Information Systems and Technologies Management

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Lisbon, July 13th, 2023

DEDICATION

To my wife for her dedication and support in the most difficult moments.

To my children, so that I can be an inspiration to them for the future.

ABSTRACT

Universities, like most organizations today, have digital transformation programmes in their strategic plans so as not to lose competitive advantage over their competitors. In parallel, universities have been adopting various corporate tools, adapting them to the university environment, usually in the form of digital technologies. This Master's project was born from the combination of the innate desire to improve processes with the commissioning of a CRM in the University, a digital technology from the corporate world increasingly adopted by universities to focus on a student-centric education approach. Digital Transformation is a process that originates changes in organizations induced by digital technologies. Two relevant success criteria of digital transformation and process digitalization projects (PDP) in organizations are efficient and effective business processes. Business Process Management (BPM) is a management discipline that looks at the business processes as the most important asset of an organization and enables organizations to leverage Digital Transformation and Digital Technologies for process improvement and innovation, which is considered the most value-adding phase of the BPM lifecycle. This Master's project focuses on SUPERNOVA's Application-to-Approval (A2A) process with the main goal of overseeing how the work is performed to take advantage of improvement opportunities, leveraging digital technologies (CRM) and supporting NOVA's digital transformation.

KEYWORDS

BPM; BPMN; Digital Transformation; Information Management; Process Modelling; Process Redesign; Process Optimization; Higher Education

SUSTAINABLE DEVELOPMENT GOALS (SGD):

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LIST OF ABBREVIATIONS AND ACRONYMS

7PMG	Seven Process Modelling Guidelines
A2A	Application-to-Approval process
AMS	Academic Management System
ABPMP	Association of Business Process Management Professionals
AI	Artificial Intelligence
BI	Business Intelligence
BPF	Business Process Flow
BPM	Business Process Management
BPMN	Business Process Model and Notation
CRM	Customer Relationship Management
CT	Cycle Time
DT	Digital Transformation
DSR	Design Science Research
HEI	Higher Education Institutes
IS	Information System
KPI	Key Performance Indicator
LMS	Learning Management System
PDP	Process Digitalization Projects
RPA	Robotic Process Automation
SGD	Sustainable Development Goals
SRM	Student Relationship Management
TBD	To Be Defined
TQM	Total Quality Management
WIP	Work in Progress

1. INTRODUCTION

Business Process Management (BPM) is a management discipline that looks at the business processes as the most important asset of an organization (Dumas et al., 2018) and at the key business operations where there is added value (Zairi, 1997). BPM aims to discover, analyze, redesign and monitor business processes. This is a tremendous benefit for every company that wants to have a competitive advantage. Another important discipline needed in all organizations is Digital Transformation (DT). DT is one of the top-3 priorities for CIOs (*2022 CIO Priorities | CIO Dive*, 2022). For example, universities, like all types of organizations, are struggling with the social pressure for digitalization as one of the factors to keep competitive in the world rankings to attract the best talents (Mora & Sanchez, 2020).

NOVA University Lisbon (NOVA) is a young European university founded in 1973, located in Lisbon, Portugal, composed of nine teaching units and the Rectorate, which hosts several offices that support the Rector and the University, with more than 20.000 students, which 20% of them are international students of 110 different nationalities. One of NOVA's strategic goals is to attract and promote the best national and **international talent** from all over the world to create a multicultural environment under the motto "*NOVA is a global and civic university*", which NOVA believes contributes to expanding its international profile. Another NOVA's strategic goal is **Value Creation** which aims to contribute significantly to the social and economic development of the country. To achieve these goals, NOVA Rectorate will run concrete initiatives, such as the **SUPERNOVA** program as an approach to achieve the **Talent** goal and the **NOVA DIGITAL** program, whose mission is to embrace the challenge of digital transformation and value creation at NOVA (*UNL - Strategic Plan 2020-2030*, n.d.).

SUPERNOVA Foundation Programme is a Rectorate's programme for non-EU students who have completed high school and wish to apply for higher education in Portugal. SUPERNOVA unit has identified several problems in its current application process, which is leading to low conversion rates. The admissions process at a university, which begins when a student applies for admission to a program, is the process that falls under the Application-to-Approval (A2A) process category of BPM (Dumas et al., 2018).

In order to fill the existing gap and correct the current inefficiencies of the previous process, this work proposes to apply the BPM lifecycle approach to improve the SUPERNOVA application process and leverage Digital Transformation (DT).

The BPM lifecycle methodology (Dumas et al., 2018) is followed in this Master's project to improve the SUPERNOVA application process for further implementation into a new Business Process Flow (BPF) within the University's newly implemented Customer Relationship Management (CRM) system. Specifically, the project has the following objectives:

1. Identify, discover, and model SUPERNOVA's application process;
2. Define and quantify process performance metrics through qualitative and quantitative analysis of the process;
3. Identify and analyze potential solutions for the assessed and quantified problems;
4. Propose a redesign version of the process to improve process performance metrics (cost-related, time-related and/or error-related);
5. Propose the necessary changes for the implementation of the redesigned version of the process.

Researching scientific literature on improving the admissions process within the university context following a BPM approach is very scarce. This knowledge gap is reflected in the lack of standardization and consistency of the process across NOVA's schools.

A Master's project on the application process in universities and how it can be improved following a BPM approach becomes more relevant given that the admissions process is also the applicant's first contact with a Higher Education Institution (HEI), which typically generates income from two main sources: student fees and research income (Dempsey et al., 2020). It is, thus, crucial that this first contact provides an optimal experience for the applicant through an effective and efficient process (Verma, 2008).

After a context about NOVA University and the problem that was presented by the University that served as the basis for this Master's project, a framework and state of the art of the discipline and respective methodology used in the development of this project - BPM and BPM lifecycle - are described. Afterwards, the results obtained through the application of the methods and techniques of the methodology used are presented, followed by a critical analysis and the limitations identified throughout the execution of this Master's project. At the end, the conclusions drawn from the results and future work are presented and how they can contribute to the knowledge in the area.

2. THEORETICAL BACKGROUND

Dumas et al. (2018) argue that business processes are what companies do whenever they deliver a service or a product to customers. The way processes are designed and performed affects the quality of service that customers perceive and the efficiency with which services are delivered. Furthermore, it means that business processes impact directly and indirectly everyone who has a relationship with them within the organization, influencing the way customers, vendors and suppliers are perceived (Denner et al., 2018).

In today's rapidly evolving world, efficient management of business processes has become increasingly critical for organizations across various sectors. The field of Business Process Management offers valuable methods, techniques, and tools that enable organizations to optimize their operational processes, leading to enhanced productivity, improved customer satisfaction, and competitive advantage (Weske, 2007). Within the industry of higher education, where complex administrative procedures and approval processes are prevalent, adopting a BPM approach can bring substantial benefits, streamlining operations and ensuring effective decision-making (Seethamraju, 2012).

BPM has evolved as a vital discipline in modern organizations, aiming to enhance efficiency, streamline operations, and achieve strategic objectives and can play a significant role in improving the application-to-approval process within universities by automating and streamlining the various stages of the process (Mircea, 2010). For example, BPM techniques such as process modelling and simulation can be used to identify and eliminate bottlenecks and inefficiencies in the process (Dumas et al., 2005).

2.1. APPLICATION-TO-APPROVAL IN HIGHER EDUCATION INSTITUTES

The Application-to Approval process is a type of process that starts with an application for a benefit or privilege and ends with the grant or denial of the requested benefit or privilege (Dumas et al., 2018). The admissions process at a university, which begins when a student applies for admission to a program, is the process that falls under this category.

As noted in the introduction, there is very little to no scientific literature on improving the admissions process in the university context following a BPM approach, although studies related to other disciplines dealing with business processes, like Six Sigma and Total Quality Management (TQM) on the admissions process can be found (Hrnjic, 2016; Mulay & Khanna, 2020; Verma, 2008) and provide knowledge that can be leveraged for the Master's project contributing to its success.

The admissions process was found to have the most impact on quality and student experience at the Higher Education Institutions (HEI) (Hrnjic, 2016; Mulay & Khanna, 2020). Also, Higher Education Institutions (HEI) typically generate income from two main sources: students' fees and research income (Dempsey et al., 2020).

CRMs have been adopted by HEIs as they enable a customer-orientated approach, as well as customer-focused processes, where the student is seen as a customer and transforming the CRM into a Student Relationship Management (SRM). The customer service model is derived from the theory of TQM, which has been promoted as a tool that enables student-oriented effectiveness by HEI, increasing its competitive advantage (Hrnjic, 2016).

The choice of CRM technology for this project was based on the fact that with the implementation of this digital technology, the HEI will be able to obtain and analyze data for the creation of indicators such as student satisfaction and create student retention strategies by joining the performance of all three process categories, which for HEI includes activities related to classes, management and support processes (Dumas et al., 2018; Hrnjic, 2016).

2.2. BPM

According to W. M. P. van der Aalst (2013), BPM has had multiple origins that are difficult to identify; however, it is agreed that it should be the insertion of the division of labour. The concept of managing business processes can be traced back to the early 20th century when Frederick Taylor pioneered scientific management principles (Taylor, 2021). Taylor's work focused on optimizing industrial processes, emphasizing standardization, efficiency, and measurement. His time and motion studies laid the foundation for understanding and improving business processes. This approach remained in place until the 1980s, when considerable attention was paid to Total Quality Management (TQM) and Lean Manufacturing. TQM emphasized continuous improvement and customer satisfaction, while Lean Manufacturing focused on eliminating waste and improving value delivery. Both approaches recognized the significance of process-oriented thinking and paved the way for the formalization of BPM. The integration of computers and software systems enabled organizations to automate and manage their processes more effectively. However, as early as the 1970s, it was dominated by the focus on data rather than processes due to the complexity of this approach (W. M. P. van der Aalst, 2013).

This interest continued to increase in the 1990s, with the entry of Process Reengineering promoted by authors such as Davenport (Davenport, 1993) and Hammer (Michael Hammer, 1996), in which it has since become evident that it has not generated the expected positive effect on organizational performance (Paul Puah & Nelson Tang, 2000).

In the late 1990s and early 2000s, BPM emerged as a distinct management discipline and combined principles from management theories, information technology, and process improvement methodologies to address the challenges faced by organizations (Paul Puah & Nelson Tang, 2000). BPM aimed to align business processes with strategic goals, enhance agility, and foster innovation.

In recent years, the use of digital technologies such as Robotic Process Automation (RPA) to operate Digital Transformation in Higher Education Institutes can help automate manual and repetitive tasks using software robots (Mora & Sanchez, 2020). Artificial Intelligence (AI), by integrating AI algorithms into university chatbots, can leverage virtual desks and free up human resources from academic services for more important tasks. Machine learning models can be used to improve process efficiency and decision-making (Flores et al., 2022). By using data mining and process analytics techniques, process mining technologies give valuable insights into the performance of business processes and make data-driven decisions identifying areas for improvement (W. Van Der Aalst et al., 2012; W. M. P. van der Aalst, 2018).

These are all technology trends in BPM towards more intelligent, flexible and user-friendly solutions that can support Digital Transformation initiatives (Pridmore & Godin, 2021). The integration of BPM with emerging technologies has opened new possibilities for intelligent automation, predictive analytics, and customer-centric process design (W. M. P. Van Der Aalst et al., 2003; Weske, 2012).

2.3. PREVIOUS RESEARCH ON BPM IN EDUCATION

There was some previous research on how the Six-Sigma methodology has been applied to the admission process at HEI to improve the process (Coowar et al., 2006). However, Six-Sigma is a methodology originally developed by Motorola to systematically improve processes by eliminating defects, which is a limited approach (Verma, 2008).

BPM, in comparison to Six-Sigma, is a methodology with a holistic philosophy that, in addition to defect/waste analysis, also looks at customer value (value-add analysis), as it tries to align all aspects of an organization with customer needs (Claassen, 2016).

Previous research on the application of BPM in HEI has shown that BPM can be an effective tool for improving the processes and operations of these organizations (Cruz et al., 2021; Hrnjic, 2016; Pridmore & Godin, 2021). Generally, BPM has been shown to increase the efficiency of processes in HEI by reducing the time and resources required to complete processes, improving accuracy, and reducing errors (Cruz et al., 2021).

BPM has also been shown to improve student satisfaction by streamlining processes and reducing wait times, making it easier for students to access information and services (Dempsey et al., 2020; Hrnjic, 2016; Mora & Sanchez, 2020; Mulay & Khanna, 2020) and increase transparency by providing clear and consistent process documentation, which can help to eliminate confusion and misunderstandings (Cruz et al., 2021).

From an inner perspective, BPM has improved collaboration among different departments in HEI by providing a common understanding of processes and a shared language for communication (Cruz et al., 2021; Dumas et al., 2005) and improved decision-making in HEI by providing a structured approach to analyzing and improving processes, and by providing a wealth of data and information that can be used to inform decision making (Chee et al., 2016; Rozinat & van der Aalst, 2008; W. Van Der Aalst et al., 2012; W. M. P. van der Aalst, 2018). Hence, previous research suggests that BPM can be an effective tool for improving the processes and operations of HEI and that it can lead to a range of benefits.

3. FRAMEWORK – THE BPM LIFECYCLE

A master's project on the application process in the universities and how they can be improved following a BPM approach to become more effective and efficient becomes more relevant as this type of process can be lengthy and complex and involves multiple stages (Chow, 2021).

According to the Association of Business Process Management Professionals (2013), managing business processes in a closed-loop cycle is crucial for maintaining process integrity and promoting continuous improvement. This approach allows organizations to be flexible and adapt to changing market conditions (Liu et al., 2009). There have been various definitions and frameworks for the BPM lifecycle, but they all follow a continuous and iterative process with integrated activities.

The methodology used in this Master's project was the BPM lifecycle model proposed by Dumas (2018), which consists of six phases (see Figure 1 - BPM Lifecycle (Dumas et al., 2018)), each one with its own methods, techniques and tools to identify the inefficiencies in the current process and apply improvements that can add value to the organization.

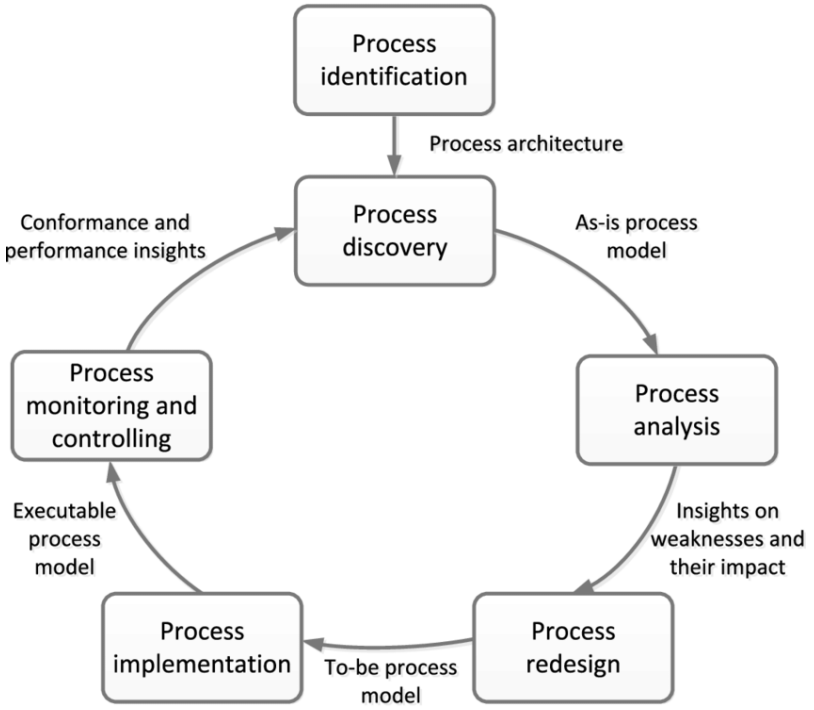


Figure 1 - BPM Lifecycle (Dumas et al., 2018)

The **process identification** phase is the first phase of the BPM lifecycle, and it involves identifying and documenting the business processes that are critical to the organization's success and helps ensure that the right processes are being improved and optimized. The process identification phase involves two steps: process designation to identify the existing business processes and process evaluation to select which processes to focus on for improvement. This decision should be based on factors such as the impact of the process on the organization, the level of complexity of the process, and the potential benefits of improving the process.

The **process discovery** goal is to gain a comprehensive understanding of the current process, and it involves identifying and documenting the existing business process within an organization. The process

discovery phase involves defining the setting to assemble a complementary team with process analysts and experts to work on the process, information gathering to collect data about the process typically through three types of discovery techniques (evidence-based, interviews and workshops), process modelling to represent the process in a clear and detailed manner using process modelling techniques, such as flow charts, data flow diagrams, and swim lane diagrams, and finally assure resultant as-is model(s) quality (syntactic, semantic and pragmatic) to ensure that they accurately reflect the existing process and to identify any missing or incorrect information.

The **process analysis** phase is a key phase in the BPM lifecycle, and the goal of this phase is to identify areas where the processes can be streamlined, errors can be reduced, and performance can be enhanced. The process analysis phase involves qualitative analysis (value-added analysis, waste analysis, issue register and root-cause analysis) of the as-is process and identifies process performance issues through quantitative analysis (quantitative flow analysis, queuing analysis and process simulation) to take the appropriate actions to solve the issues.

The **process redesign** phase is an important step in the BPM lifecycle, and it involves designing and purpose process improvements based on the results of the process analysis phase. The goal of this phase is to optimize the processes so that they are more efficient, effective, and aligned with the goals of the organization.

The **process implementation** phase involves putting the redesigned processes into operation. The goal of this phase is to ensure that the process is smoothly transitioned from the design stage to the production environment, ensuring that the necessary support and training are provided to all participants involved in the process with a structured approach – organizational change management and the implementation and deployment of new technology and automation solutions to support the To-Be process are put into place – process automation.

The **process monitoring and controlling** phase is an ongoing step in the BPM lifecycle, and it involves monitoring and controlling the performance of the processes to ensure that it is operating effectively and efficiently. The goal of this phase is to identify and address any issues that arise during the operation of the process, avoiding process degradation.

The BPM lifecycle model outlines the starting point of a BPM initiative within an organization and views it as an ongoing cycle with specific tasks and objectives in each phase. The conceptual model for the development of the project focused on the first four phases of the BPM lifecycle to achieve the objectives proposed for the Master's project aligned with the goals of the University and the Supernova team. The remaining two phases can and should be addressed in future work to provide continuity to the work done in this Master's project.

3.1. PROCESS IDENTIFICATION

This project emerged at a stage when no BPM initiative existed at the University yet, during a set of workshops where the goal was to understand gaps in technologies and information systems to better support the activities and business processes of NOVA's Rectorate.

During these workshops, throughout the description of the application process to the Foundation Programme by the SUPERNOVA team, it was realized the existing opportunities for improvement with the possibility of managing the application process of the program in the recently implemented CRM

system. The enthusiasm of the SUPERNOVA team with this opportunity leverages the start of the BPM initiative, which served as the trigger for this Master's project.

3.1.1. Designation

As previously stated, the process on which this project (and the Rectorate) will focus on this first initiative is well identified by the very origin underlying this Master's project – the SUPERNOVA Application-to-Approval process. Nevertheless, although considering that an exhaustive enumeration of the Rectorate's processes is beyond the scope of this project (see Limitations and Future Works), based on several interviews and workshops conducted by the author with the coordinators and heads of the various departments and divisions that compose NOVA's Rectorate, it was possible to enumerate the existing macro-processes (Figure 2 - NOVA's Rectorate: Process Landscape – Level 1).

3.1.2. Evaluation

Attending to the strategic objectives of NOVA to obtain an international profile and digital transformation for the creation of value to society and being the students currently considered the *customers* of the University and from where comes one of the largest sources of income, the admission process is considered a critical process within universities. In this specific case, since the organizational context is the Rectory of NOVA and not one of the schools of the University, the SUPERNOVA foundation program is the most relevant admission process of the Rectorate.

The choice of this process is also justified by the feasibility of managing this process through the support given to the initiative by top management and the process owners, who saw it as an opportunity to obtain an increase in their conversion rate allied to a more efficient process that will free resources from the teams working on the process to other tasks.

Some challenges identified by the author are common in the several schools and institutes that are part of NOVA and similar to the issues reported by SUPERNOVA, which can capitalize on the outcome of this Master's project:

- Lack of standardization and consistency in the admission process across NOVA;
- Inefficient and time-consuming processes that can lead to delays and frustration for applicants;
- Limited transparency in decision-making and a lack of clear communication with applicants;
- Concerns over fairness and impartiality in the assessment and recommendation stages;
- Resistance to change and a lack of investment in technology and automation to streamline the process.

The SUPERNOVA unit also conducts academic management activities after candidates are admitted, but the Academic Management System (AMS) is not yet fully implemented, which limits the feasibility of managing a successful BPM initiative that fully addresses the improvements identified as needed by the domain experts.

3.1.3. Process Architecture

Complementing the information gathered in the designation phase workshops with the Rectorate's organogram (Annex I - Rectorate Organogram) and its functions and categorizing the processes identified in Porter's value chain model, we obtain the following process architecture as an outcome:

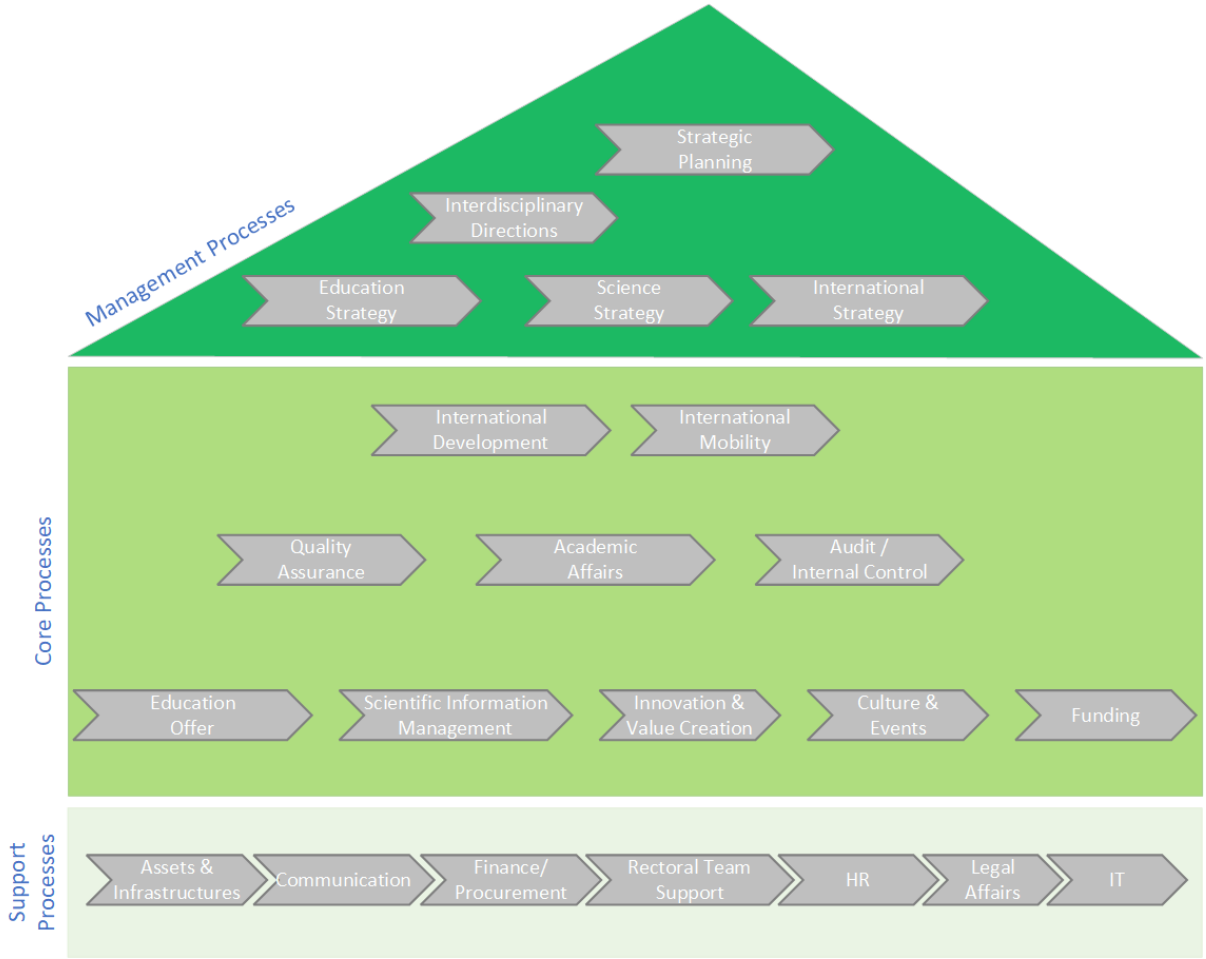


Figure 2 - NOVA's Rectorate: Process Landscape – Level 1

The Application-to-Approval process of the SUPERNOVA programme is framed as a sub-process of the Educational Offer macro-process, the latter being a process that aims to keep NOVA's educational offer attractive as a whole, both nationally and internationally to attract, retain, train and advance the best talents with high potential.

3.2. Process Discovery

The process discovery phase was a very time-consuming activity to manually gather the required information about the process to be modelled. To optimize the work done in this phase, the following iterative method was followed:

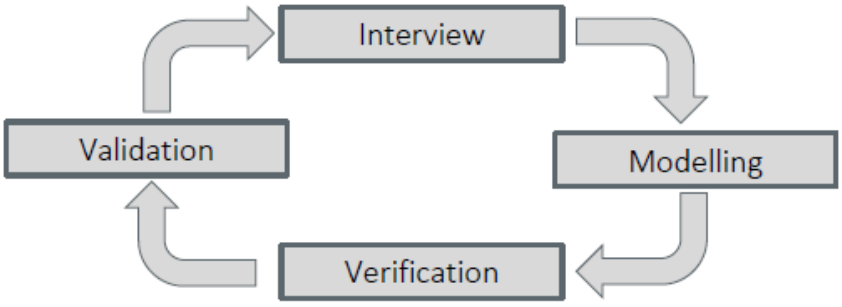


Figure 3 - Process Discovery: Iterative method

3.2.1. Defining the setting

First and foremost, it was necessary to identify the stakeholders of the project:

Stakeholder	Role
International Division Director	Management Team
SUPERNOVA Manager	Process Owner
SUPERNOVA Marketing & Recruitment Team	Process Participants
Author & supervisor, co-supervisor	Process Analysts
IT Division	System Engineers
TBD	BPM Group

Table 1 - Stakeholders

While there is no defined BPM group responsible for maintaining a BPM culture to support NOVA's strategic goals, the author suggests that the IT Division lead this function within the Rectorate since that was where the initiative was born.

After all the project's stakeholders had been identified, a setting was defined to work on the process discovery. The team was defined in a natural way as a consequence of the initiative from which the project was born:

Domain Experts	Process Analysts
SUPERNOVA Manager SUPERNOVA Marketing & Recruitment Team	The Author Supervisor and co-supervisor

Table 2 - The Project Setting

3.2.2. Information Gathering

To collect information about the process, various techniques and methods that are part of the discovery phase of this conceptual model were used.

3.2.2.1. Evidence-based discovery

At SUPERNOVA website is described the current application process (*Application Process - SUPERNOVA*, n.d.), divided into the following five steps, which were validated with the domain experts:

Step 1: Online Application

The application is done through an online form and requires the upload of the following documents:

- A motivation letter
- Recommendation letter (optional)

- High School diploma or an official declaration from the school attesting when the candidate will be finishing High school
- Transcript of records with a full list of courses and corresponding grades/or the ones completed by that time, including respective grades
- Passport copy.
- Certificate of Language Proficiency in English and/or Portuguese (optional)

After submission, the applicant will receive an email acknowledging receipt of documents and providing instructions for enrolment fee payment.

Step 2: Analysis

The Admissions Committee is constituted by one faculty member from each of the NOVA schools and is coordinated by the Vice-Rector for International Development and Education.

After reviewing all application elements, the Admissions Committee makes the final decision and informs candidates by email.

Applicants will be invited for an interview by the Admissions Committee to examine the information provided in the application. Interviews will be conducted online.

Step 3: Admission Tests

Candidates interested in following math-based courses must take a mathematical admission test in two phases. The first phase is either an online test. The second phase is an additional face-to-face evaluation at the beginning of the programme. Candidates with a specific interest in Economics, Management must take the final microeconomics and math exams face-to-face at the end of the programme, in Lisbon while candidates with a specific interest in Data Science, Information Management and Information Systems must take the final math exam face-to-face at the end of the programme, in Lisbon.

Step 4: Enrolment

After the interview, if accepted, applicants will receive an email from the Admissions Committee informing them about their application results.

Step 5: Registration

Once participation in the program is confirmed, students will be contacted by NOVA with instructions for paying the programme's final fee. After settling this fee, students will receive information about the start of classes, timetables, school calendars, etc.

During the workshops, the process analysts asked SUPERNOVA team to draw a flow of the process using whatever notation they wish, to have better insights of the process flow and activities in order to gain information for a more accurate model (Annex II – SUPERNOVA Application Process Flow by SUPERNOVA Team).

SUPERNOVA team made also available several documents that they use to operationalize the process throughout the interaction in this phase, both for registering the candidates' information in the programme (Excel file), and for tracking the status of each candidate and conducting the necessary interactions with the candidates throughout the application process. The latter is currently done in text editor (Word) shared by the marketing and recruitment team members, with titles to identify the various states of each candidate and the respective interaction dates. The team also shared a document that they use to onboard new team members to communicate the whole process to the new member. An anonymized sampled of the shared documents can be found in Annex III – Operational Documents (anonymized Samples).

There is plus another Excel document that the team uses to register process statistics and later calculate some process performance indicators (Annex IV – Lead Conversion), and that should serve as a basis for the construction of the KPIs and dashboards in the last phase of the cycle: **process monitoring and control**.

All the information in the shared documents was essential in this discovery phase for the correct understanding of the process and contributed positively to the construction of the As-Is model described in 3.2.5.

Besides document analysis, it was not possible to use any other evidence-based discovery technique because 1 - there was no automation of any activity of the process and 2 - no availability for observation due to professional limitations.

3.2.2.2. Workshop-based discovery

Given the culture of openness existing in the Rectorate of NOVA and taking advantage of being able to gather the whole team of domain experts to avoid fragmentation of knowledge of the process, it was decided to conduct workshops instead of individual interviews whenever possible to minimize the time spent by domain experts, adapting the application of the iterative method described in Figure 3 to workshops instead of interviews.

The domain experts' team was always very collaborative and available during the workshops (some being in interview model due to unavailability of schedules), which made the work performed, although voluminous, easily accomplished.

With the seamless interaction between the project teams, the iterative method worked very well to achieve the goal of modelling the current process, having had seven iterations until reaching a model validated by domain experts.

Most of the iterations were due to gaps in activities or the sequence in which they occurred in the model that only became obvious to the domain experts after the analysis to validate the model, who, despite having complete knowledge of the process, sometimes the number of times they do the same activities led them to forget they were doing them. There were also some rare cases where the iteration was due to the workshop having been done without the full team of domain experts, leaving incomplete information due to fragmentation of knowledge of some specific activities of the process.

3.2.3. Process Modelling

To model the existing process, the Bizagi modelling system with the BPMN 2.0 modelling language was used in the project.

The main challenge identified in this phase was the lack of familiarity with process modelling languages by domain experts, which was overtaken by using natural language as much as possible during the workshops and validations to improve communication between teams.

Since modelling a process is a complex task, the procedure recommended in the conceptual model in a systematic way was followed, which is described below to maximize the success in the model development:

1. Identify the process boundaries;
2. Identify activities and events;
3. Identify resources and their handovers;
4. Identify the control flow;
5. Identify additional elements;

To reach a level of detail of the process precise enough for the team of domain experts to validate the process, it was necessary to open the modelling up to level 4 of detail, considering Level 1 as the Process Landscape (Figure 2 - NOVA's Rectorate: Process Landscape – Level 1), which was not modelled in Bizagi:

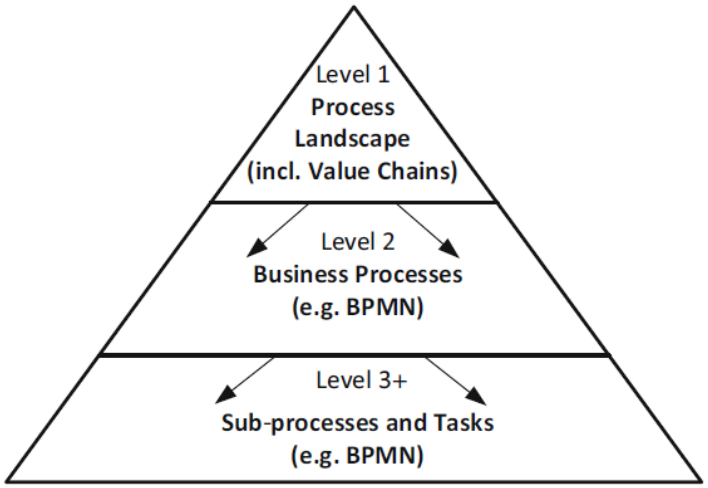


Figure 4 - Process Architecture: Level of Detail (Dumas et al., 2018)

For the quantitative analysis phase of the process in which it is necessary to run simulations in Bizagi, a specific simulation model was also created (Figure 7 - As-Is Simulation Model), given the limitations of Bizagi itself (see Limitations and Future Works).

3.2.4. Assure Model Quality

For the syntactic verification, Dumas (2018) proposed the Seven Process Modelling Guidelines (7PMG) and was the tool used to assure the model quality in syntactic terms (Dumas et al., 2018, p. 192-193), double checked by all process analysts of the project team.

Although the effort to follow all the guidelines, some of the guidelines, like G3 (*use one start event for each trigger and one end event for each outcome*) was not possible to follow on a detailed model (level 3) due to the way process was undergone by the SUPERNOVA team (*e.g.*, Appendix A – As-Is Process Models – Level 3).

The following table presents the number of events in each modelled process using a Bizagi tool to count the elements of each process, which served to validate G1 (*use few elements as possible*) and G7 (*decompose a model with more than 30 elements*) of 7PMG:

	Events	Gateways	Sub-Process	Tasks	Overall
A2A - Level 2 - NOVA University	2	0	4	0	**6**
AsIs - Issue Acceptance Letter Sub - Mkt & Recruitment Team	3	0	0	3	**6**
AsIs - Perform Admission Test Sub - Applicant	3	0	0	4	**7**
AsIs - Request Learning Method Sub - Mkt & Recruitment Team	5	2	0	2	**9**
AsIs - Request Honor Declaration Sub - Mkt & Recruitment Team	7	4	0	3	**14**
AsIs - Request Enrolment Fee Sub - Mkt & Recruitment Team	8	4	0	3	**15**
AsIs - Request Tuition Fee Sub - Mkt & Recruitment Team	8	4	0	4	**16**
AsIs - Suggest Another Program Sub - Mkt & Recruitment Team	8	5	0	3	**16**
AsIs - Review Application Elements Sub - Mkt & Recruitment Team	10	6	0	5	**21**
AsIs - Perform Admission Test Sub - SUPERNOVA Team	11	4	0	8	**23**
AsIs - Perform Interview Sub - SUPERNOVA Team	14	6	0	6	**26**
AsIs - Request Application Fee Sub - Mkt & Recruitment Team	8	8	0	10	**26**
AsIs - Level 3 - SUPERNOVA Team	6	10	11	2	**29**

Table 3 - 7PMG: G7 verification on Bizagi Modeler

The validate tool available on Bizagi (Bizagi Corporation, 2018) was also used to check against the behavioural correctness of the process model and BPMN 2.0 syntax used.

3.2.5. As-Is Process Model

After all the (seven) iterations between domain experts and syntactic verification among the process analyst team, the As-Is process models presented in the following chapters were validated by the project team as describing the current process.

For readability reasons, only the level 2 process models are presented. The level 3 models of the sub-processes can be found in the Appendix A – As-Is Process Models – Level 3section of this document.

3.2.5.1. As-Is Process Model – Level 2

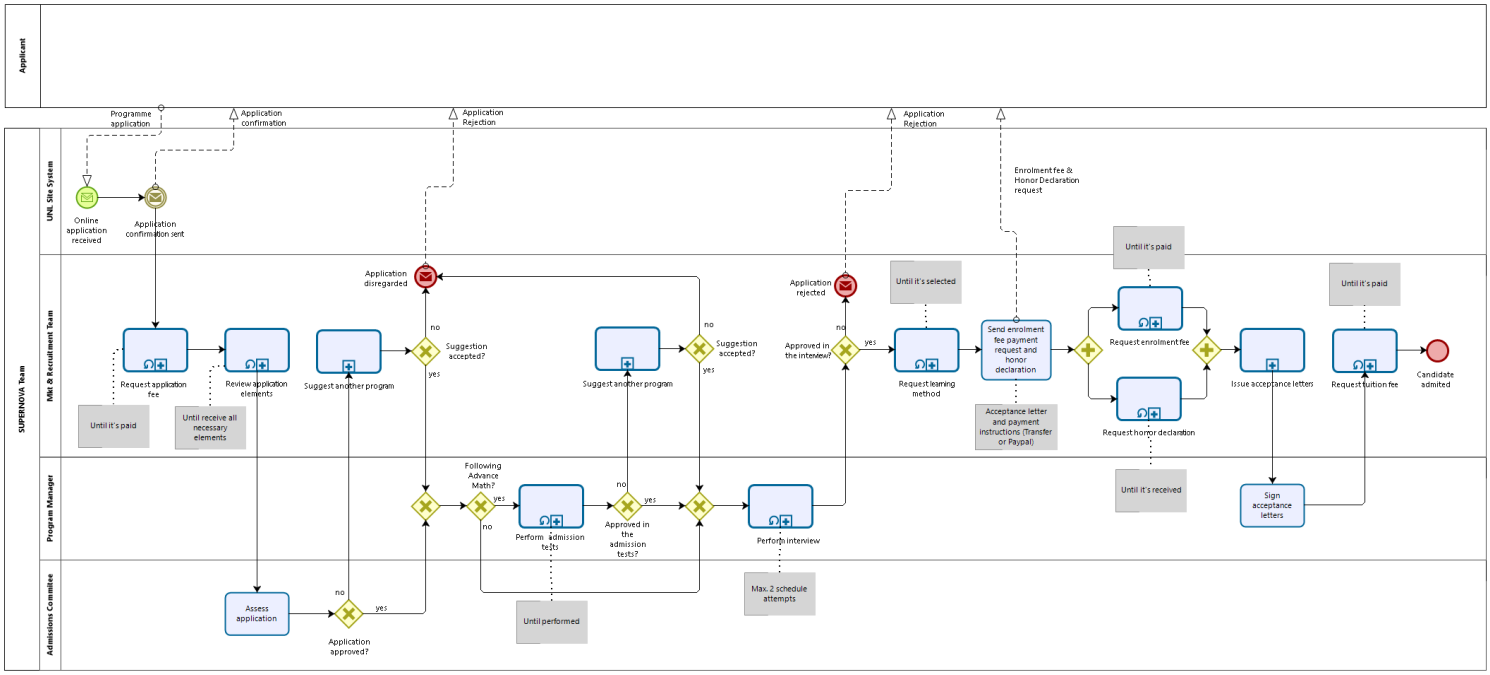


Figure 5 - SUPERNOVA A2A: As-Is Process Model - Level 2

3.3. PROCESS ANALYSIS

The process analysis provides the foundation for designing and implementing process improvements. Several methods and techniques were used to make an in-depth analysis and detailed analysis of the As-Is process to reach hypothetical scenarios that best suit the objectives of SUPERNOVA and the University.

3.3.1. Qualitative Analysis

This section presents a selected set of principles and techniques for qualitative process analysis. Those techniques are mainly used to identify unnecessary steps of the as-is process (value-added analysis) and sources of waste (waste analysis).

3.3.1.1. Value-added Analysis

The value-added analysis is a technique used to identify unnecessary steps in a process that may be candidates to be eliminated. In this Master's project, a step may be an activity, a task in the process or part of a task, and it may also be the case that one task involves several steps, where level 3 models were the basis for the decomposition of the As-Is process (Appendix A – As-Is Process Models – Level 3).

When performing the value-added analysis, three main steps were followed as procedure:

- decomposing each task into steps;
- identifying who is the customer of the process and what are the positive outcomes that the customer seeks from the process;
- analyzing each step with a focus on customers' value-added;

Since value-added analysis aims to identify positive outcomes for the customer of the process, to help with the analysis, the author kept in mind two main questions, among others:

- If the organization fails to make this step, will the customer of the process complaint?
- If the organization fails to make this step, will the customer pay the organization to do it?

The outcome of the value-add analysis is represented in the table below, classifying each step with the following classification:

- **Value Adding**: steps that directly contribute to positive outcomes.
- **Business Value Adding**: steps that the customer is neither willing to pay for; nor does not gain satisfaction from (not value-adding); however, they are necessary or valuable to the company where the process is performed.
- **Non-Value Adding:** Steps that are neither value Adding nor Business Value Adding.

Step	Performer	Classification
Receive application	UNL Site	Value Adding
Send application confirmation to applicant (automatic)	UNL Site	Value Adding
Download Application data	Mkt & Recruitment Team	Non-Value Adding
Log application data	Mkt & Recruitment Team	Business Value Adding
Check lead source	Mkt & Recruitment Team	Business Value Adding
Qualify lead (in Keystone)	Mkt & Recruitment Team	Business Value Adding
Log KPIs (application origin and lead source)	Mkt & Recruitment Team	Business Value Adding
Update number of applications	Mkt & Recruitment Team	Business Value Adding
Send fee payment request (1st time)	Mkt & Recruitment Team	Business Value Adding
Check fee payment (1st time)	Mkt & Recruitment Team	Business Value Adding
Update applicant status	Mkt & Recruitment Team	Business Value Adding
Send payment receipt internally	Mkt & Recruitment Team	Business Value Adding
Move email	Mkt & Recruitment Team	Non-Value Adding
Check application elements	Mkt & Recruitment Team	Business Value Adding

Send additional information request	Mkt & Recruitment Team	Non-Value Adding
Receive additional application information	Mkt & Recruitment Team	Business Value Adding
Assess application elements (1st time)	Mkt & Recruitment Team	Business Value Adding
Notify applicant (inc. eligibility, rejection and admitted)	Mkt & Recruitment Team	Value Adding
Assess application	Admissions Committee	Business Value Adding
Assess application for another programme	Mkt & Recruitment Team	Business Value Adding
Create Moodle users	Program Manager	Business Value Adding
Enroll applicant in course	Program Manager	Business Value Adding
Check test grade	Program Manager	Business Value Adding
Send test grade to Mkt & Recruitment Team	Program Manager	Non-Value Adding
Schedule interview	Program Manager	Business Value Adding
Send interview invite	Program Manager	Non-Value Adding
Send interview info & link	Program Manager	Business Value Adding
Perform interview	Program Manager	Business Value Adding
Assess interview	Program Manager	Business Value Adding
Request learning method	Mkt & Recruitment Team	Value Adding
Request enrolment fee	Mkt & Recruitment Team	Value Adding
Request honor declaration	Mkt & Recruitment Team	Business Value Adding
Send follow-up emails	Mkt & Recruitment Team	Business Value Adding
Issue acceptance letters	Mkt & Recruitment Team	Value Adding
Send acceptance letters to sign	Mkt & Recruitment Team	Non-Value Adding
Sign acceptance letters	Program Manager	Business Value Adding

Request tuition fee	Mkt & Recruitment Team	Business Value Adding
Send acceptance letter to candidate	Mkt & Recruitment Team	Value Adding

Table 4 - Value-Add Analysis

3.3.1.2. Waste Analysis

The waste analysis is the opposite of value-added analysis. While the value-added analysis views the steps from a positive perspective, the waste analysis looks from the opposing side.

Waste analysis has the objective of finding "waste" throughout processes which can be found within steps or between them, and is grouped into three categories:

- **Move**: wastes that are related to movement. There are two sub-types included in this category, transportation (send or receive materials or documents taken as input or output by the process activities) and motion (motion of resources internally within the process).
- **Hold**: wastes arising from holding something. There are two sub-types included in this category, which are inventory (materials inventory and work in process) and waiting (task waiting for materials or input data).
- **Overdo**: wastes arising from doing more than is necessary to deliver value to the customer or the business. There are three sub-types included in this category which are defects (correcting or compensating for a defect or error), overprocessing (tasks performed unnecessarily given the outcome of the process) and overproduction (unnecessary process instances are performed, producing outcomes that do not add value upon completion).

The following table presents the waste analysis category with the respective sub-type:

Step	Waste Category - Sub-type
About 94% of applications are handled concurrently (WIP)	Hold - Inventory
Download Application data	Move - Transportation
Waiting for fee payment	Hold - Waiting
Re-send fee payment request	Overdo – Over-processing
Re-check fee payment	Overdo – Over-processing
Move email	Move - Transportation
Send additional information request	Overdo - Defects
Re-check application elements	Overdo - Defects
Waiting for additional information	Hold - Waiting
Batch of applications waiting for admissions committee to meet	Hold - Inventory
Assess application for another program	Overdo - Defects

Waiting for applicant feedback for another program	Hold - Waiting
Batch of users waiting to be created in Moodle	Hold - Inventory
Applicant waiting for test credentials	Hold - Waiting
Waiting for test completion notification	Hold - Waiting
Send test grade to Mkt & Recruitment Team	Move - Transportation
Applicant waiting for interview invitation	Hold - Waiting
Waiting for interview schedule feedback	Hold - Waiting
Re-schedule interview	Overdo - Defects
Applicant waiting for interview info & link	Hold - Waiting
Waiting for interview assessment	Hold - Waiting
Send interview assessment	Move - Transportation
Waiting for learning method selection	Hold - Waiting
Re-send learning method request	Overdo – Over-processing
Waiting for honor declaration signed	Hold - Waiting
Re-send request to sign honor declaration	Overdo – Over-processing
Send acceptance letters to sign	Move - Transportation
Waiting for acceptance letters to sign	Hold - Waiting
Applicant waiting for acceptance letter	Hold - Waiting
Applicant drops after admitted	Overdo – Overproduction

Table 5 - Waste Analysis (sub-types)

The wastes identified in the process should be eliminated from the process. However, eliminating all the wastes at once can lead to undesirable resistances and entropies deriving from the transformation level needed to eliminate all the activities identified as waste.

3.3.1.3. Issue Register

SUPERNOVA team did not have any issue registering the document, which made it impossible to perform a quantitative analysis on it. Nevertheless, the team had an empirical knowledge of the issues, which still allowed them to build up the following table for a qualitative impact, complemented by the value-added/waste analysis:

Issue	Description	Qualitative Impact
Multiple information and leads' sources	Information spread by several documents and Leads are qualified in several platforms	Employees dissatisfaction Poor monitoring leads to missing opportunities
Missing updates & Follow-ups	Management based on Word and Excel files leads to very time-consuming activities	Employees dissatisfaction Low process efficiency Applicant dissatisfaction and loss (concurrent applications)
No issues register	Issues are not registered, which leads to unsolved and repeatable	Applicant dissatisfaction
Low conversion rate (20% - 25%)	The conversion rate is very low	Low revenue can indirectly affect NOVA's ranking

Table 6 - Issue Register

3.3.1.4. Why-why diagram

To identify and understand the root cause of low conversion rate of the process, which was the main issue identified by SUPERNOVA team, the why-why diagrams technique was used to try to find the root causes of this issue:

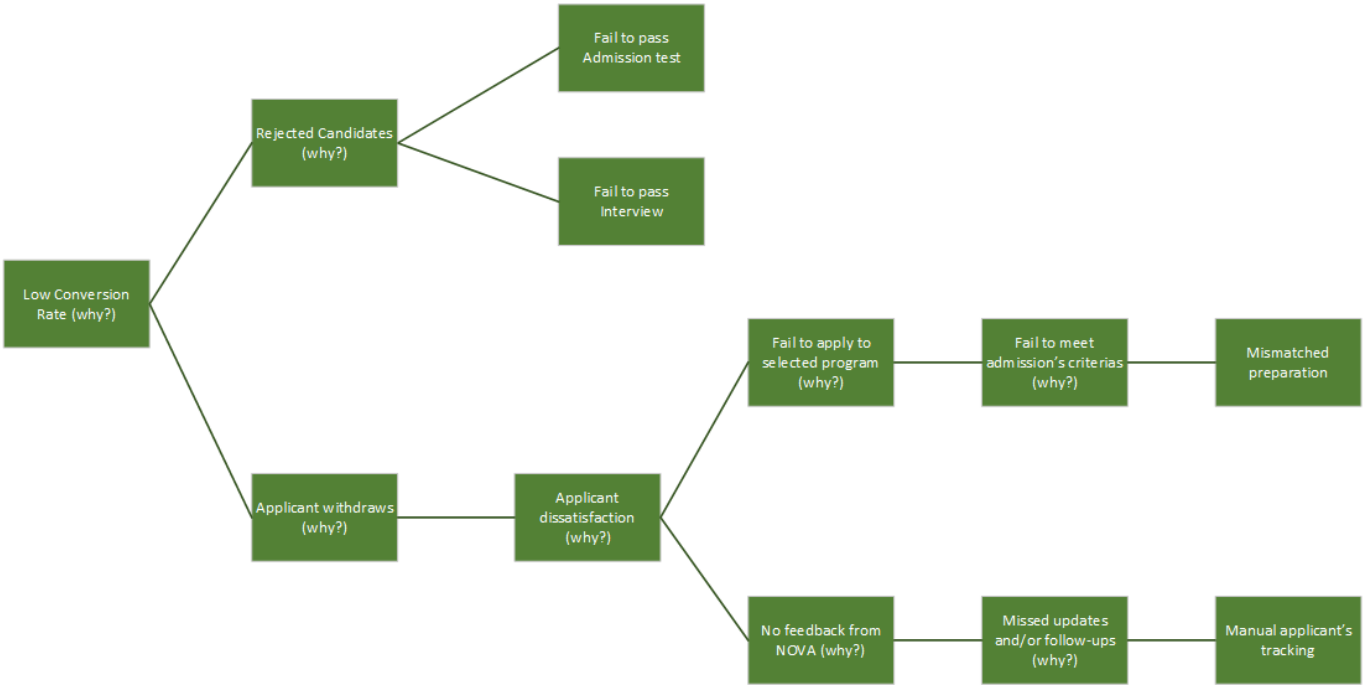


Figure 6 - Why-why diagram: Low Conversion Rate - Root Cause

3.3.2. Quantitative Analysis

For the quantitative analysis purpose, a simplified model of the process was used, aggregating all existing activities in the same lane using subprocesses:

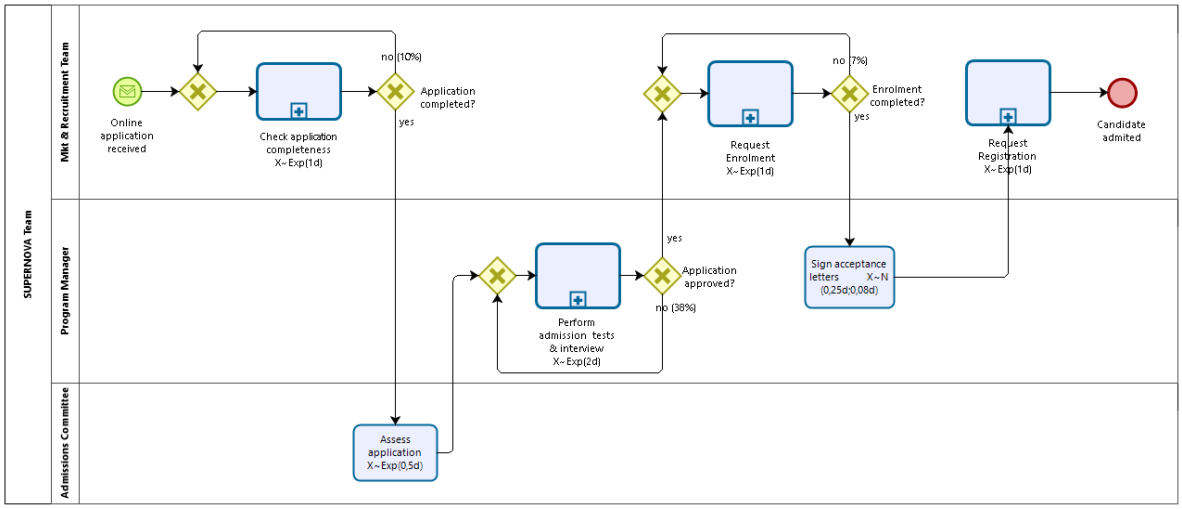


Figure 7 - As-Is Simulation Model

3.3.2.1. Input Data

Based on the data obtained in the process discovery (3.2Process Discovery), it was possible to define the input data for simulation, where for five months, 267 applications were registered.

Thus, the mean arrival rate (number of new cases per time unit) of applications was:

$$Mean\ arrival\ rate = \lambda = \frac{267\ applications}{150\ days} = 1{,}78\ [applications/day]$$

And the average time between applications was:

$$Mean\ inter-arrival\ rate = \frac{1}{\lambda} = \frac{1}{1{,}78} = 0{,}56$$

This means that every 13h26m, an application to the SUPERNOVA program is submitted.

Data	Value / Probability (calculation)
Duration	150 days
Mean arrival rate (λ)	1,78 applications/day (267 applications)
Mean inter-arrival time (1/ λ)	0,56
Application fee paid	Yes: 53% ; No: 47% (142/267)
Application elements fulfilled	Yes: 79% ; No: 21% (116/146)
Application completed	No: 47% x 21% = 10%

Application Approved *	Yes: 62% ; No: 38% (90/146)
Learning option selected	Yes: 40% ; No: 60% (55/61)
Enrolment fee paid	Yes: 89% ; No: 11% (49/55)
Honor declaration received	Yes: 96% ; No: 4% (53/55)
Enrolment completed	No: 60% x 11% = 7%
Tuition fee paid	Yes: 14% ; No: 86% (7/49)

Table 7 - As-Is Simulation Input Data

* Extrapolated value (as it was not possible to calculate probability based on the available data, it was assumed the "Accepted" ratio).

For the Time Analysis, since all the activities are manual handled, there was no systems' data available to fulfil data simulation. However, SUPERNOVA team estimates the times in table below based on empiric knowledge:

Process	Time – Distribution
Check application	Mean=1,2d – Negative Exponential Distribution
Assess application	Mean=0,5d – Negative Exponential Distribution
Perform admission tests & interview	Mean=2d – Negative Exponential Distribution
Request Enrolment	Mean=1d – Negative Exponential Distribution
Sign acceptance letters	(μ=0,25d ; σ=0,08d) – Truncated Normal Distribution
Request registration	Mean=1d – Negative Exponential Distribution

Table 8 – As-Is Processing Times

During the workshops and confirmed later with the SUPERNOVA team during quantitative analysis, due to the fact that all the processes are handled manually, with document analysis and verification, the domain experts could not define a reasonable interval to handle the tasks, with the exception of the "sign acceptance letters" task. Therefore, an "Exponential Distribution" was defined for all sub-processes for the simulation since the time spent varies a lot from one application to another.

In the following table are the resources available in the SUPERNOVA As Is process:

Resources	Quantities
Marketing & Recruitment team	2
SUPERNOVA Program Manager	1
Admissions Committee	1

Table 9 – As-Is Resource Data

Each task or activity is done by only 1 resource (of each team if applicable).

3.3.2.2. As-Is Simulation

Since the major issue identified by the SUPERNOVA team was the low conversion rate of applications, we will look at 150 days of the process (five of the six months) to evaluate the number of candidates admitted at the end of the application period and compare against data set in the same period.

Bizagi tool has some limitations like stochasticity and assumptions that resources never stop working or make batch work (which happens in this process) and that there are no deviations to the defined process. A simplified model of the process was used in simulations to minimize the system's limitations (Figure 7 - As-Is Simulation Model), and the simulation was set with the input data defined in 3.3.2.1.

3.3.2.3. Simulation Analysis

After running several simulations to minimize stochasticity limitation, the following table shows that the Marketing & Recruitment Team is overloaded with the activities in the process:

Resource	Utilization
Mkt & Recruitment Team	100 %
SUPERNOVA Manager	88,9 %
Admissions Committee	37,9 %

Table 10 – As-Is Resource Utilization

In the following table is the output of the time analysis in the As-Is scenario:

Name	Instances completed	Avg. time (d)	Total time (d)	Total time waiting resource (d)
SUPERNOVA Team	7	79.2	9431.9	9250.1

Table 11 - As-Is Time Analysis Simulation

The simulation output reinforced the confidence in the data quality accuracy (DAMA UK Working Group, 2013) calculated in Annex V – Flow Analysis, with the same number (seven) of candidates admitted to the data set, although with an average time of 79,2 days to be processed in each activity/sub-process, with the difference being explained by flow analysis limitations for probability distributions (Peters et al., 2022).

3.3.3. Analysis Conclusions

Flow analysis (Annex V – Flow Analysis) confirmed value-add and waste analysis, where it was made evident that waiting times that lead to high level of rework have a big impact on the process Cycle Time. The NVA activities are having a negative impact on the process, particularly on the dimensions of time and quality. Also, the fact that 232 over 267 (87%) of the applications are Work in Progress instances it's a symptom that there are too many waiting times, specifically waiting for applicant inputs, leading to long Cycle Time.

The why-why diagram showed process analysts the factors that are the root cause of the main issue identified in the process (low conversion rates), and it became evident that all the rework to track applications is manually handled, which leads to missing updates and follow-ups, that in turn leads to

long cycle times leads to applicant dissatisfaction and loss of focus or loss of the applicant for concurrent applications with faster responses. With 6% of process efficiency, a system automating these activities can have a big impact on improving the process in quality and time dimensions.

The why-why diagram also highlights that the admission tests and interviews are responsible for many knockouts, and the re-sequence of these activities should be analyzed.

The As-Is scenario analysis allowed the process analysts to identify the issues the process suffers and to better understand where improvement opportunities should be applied, where NVAs tasks should be eliminated, and BVA should be automated to decrease waiting times and increase the number of instances that can be completed.

3.3.4. What-If Scenarios

The author simulated several choices of improvements in what-if scenarios, starting from the as-is model to address the issues identified in the as-is model.

Based on the conclusions of the As-Is simulation, process analysts simulated two what-if scenarios which are in line with the findings drawn from the conclusions, namely the need to reduce Cycle Time, both through automation and by eliminating handover NVAs, as the number of applications is expected (and desirable) to increase without this implying a substantial increase in resources in the team.

What-if Scenario 1: In this scenario, the SUPERNOVA Manager element is removed from the application process (eliminating handovers) and is exclusively allocated to the academic management process after the candidate's admission, with a new element added to Marketing & Recruitment Team

What-if Scenario 2: In this scenario, it simulated the implementation of the admission process in a Business Process Flow within NOVA's CRM system, where it was calculated that more than 80% of the tasks could switch to automatic, particularly follow-ups.

What-if Scenario 3: In this scenario, scenarios 1 & 2 were simulated, with the variance that no element was added to Marketing & Recruitment team, only process automation through the CRM system and SUPERNOVA Manager removed from the process.

The scenarios and outcomes of the respective simulations are listed in the table below:

Scenario	Mkt & Recruit. Team	SUPERNOVA Manager	Admissions Committee	Instances Completed	Min. Time (d)	Max. Time (d)	Avg. Time (d)	Total time (d)	Total time waiting resource (d)
As Is	100%	88,9%	37,9%	7	31,7	107,3	79,2	9431,9	9250,1
What-If 1	100%	0%	51,08%	9	23,3	138,9	74,4	10977	10647
What-If 2	86,28%	98,74%	92,68%	81	3,4	101,4	56,1	10467,4	10108,9
What-If 3	100%	0%	77,95%	82	3,4	116,9	62	13166,1	12814,6

Table 12 - What-If Scenarios

Removing handovers between the Mkt & Recruitment team and a SUPERNOVA Manager (what-if scenario 1) resulted in a lower Cycle Time, reduced by five days, representing a 7% Cycle Time reduction.

Automation (what-if scenario 2) greatly impacts the number of instances completed. Marketing and sales theory recognizes that the success of follow-ups increases exponentially after the third iteration and that the conversion rate of leads and opportunities is probabilistic (McCloskey, n.d.). Increasing the number of completed instances will increase the probability of converting applicants into admitted students.

In what-if scenario 3, although with one less member in the SUPERNOVA team, the automation through BPF in CRM and handover elimination resulted in a similar number of instances completed and Cycle Time as in What-if scenario 2, but with a big improvement of Cycle Time and instance completed over What-if scenario 1.

3.4. PROCESS REDESIGN

The process redesign phase delivers the tangible improvements to the process that are necessary to achieve the goals of the organization.

The business performance objective is to raise the conversion rate of applicants into admitted candidates, measured in percentage ($Conversion\ Rate\ (CR) = \%\ of\ applicants\ admitted$)

Based on the data set collected, the current conversion rate is **2,6%** (7 candidates admitted from 267 applications). The conversion rate shared by the SUPERNOVA team (20%-25%) seems to be calculated not from the number of applications but rather from the number of approved applications, which does not cover the entire process.

Based on the results of the simulations in the previous chapter, where the what-if scenarios demonstrated that by digitizing the process through the implementation of a BPF in the CRM system, which will allow automation of part of the process activities, the number of complete instances will increase substantially.

The simulations also indicated a resource utilization of around 100%, although the simulator limitations may be biasing the resource utilization derived from holding times. However, occupation rates above 90% should be avoided due to increase waiting times steeply.

To achieve the target set, process analysts set several redesign goals to improve the process and conversion ratio. By applying the Devil's Quadrangle to the identified improvement opportunities, process analysts aim to reduce waste **cost**, reduce waiting **time** and in turn, cycle time, and improve **quality** with customer feedback and on-time follow-ups and updates through automation.

Through an exploitative redesign with an incremental approach, redesign heuristics were applied to address the problems previously identified, which served as the based analysis of the process redesign phase:

			Dimension			
Issue	**Solutions**	**Heuristics**	**Time**	**Cost**	**Quality**	**Flexibility**
Reduce Handovers	Remove SUPERNOVA Manager from the process	**H1**: Task Elimination **H7**: Resource Optimization	↑	↑	o	o
Management based on Excel and Word	Digitize process into CRM BPF to eliminate manual activities to log, download, update and move data	**H1**: Task Elimination **H9**: Automation	↑	o	↑	o
Missing Follow-ups	Implement automatic follow-ups	**H1**: Task Elimination **H8**: Communication Optimization **H9**: Automation	↑	o	↑	o
Multiple information and lead sources	Integrate and centralize leads and opportunities data into CRM	**H8**: Communication Optimization **H9**: Automation	↑	↓	↑	↓
Manual tasks in LMS to perform admission test	Integrate LMS with CRM to create users, send credentials and get grades automatically	**H9**: Automation	↑	↓	o	↓
Manual generation of acceptance letters	Implement acceptance letter template and function to automatically generate, sign and send	**H9**: Automation	↑	↓	o	↓
No issue register	Digitize process into CRM to log all activities and issues	**H8**: Communication Optimization **H9**: automation	↑	o	↑	↓
Suggest another program management	Separate process for another program suggestion	**H6**: Process Specialization	o	↓	↑	↓
Perform Admission Tests & Interview as 1st activity	Switch to 1st activity since leads to higher knock outs	**H4**: Re-sequencing	↑	↑	o	o
Request Learning Method timing	Eliminate task and add question in the application submission form	**H1**: Task Elimination	↑	o	↑	o
Request Enrolment Fee & Request Honor Declaration	Merge two requests	**H2**: Task Composition	↑	↑	o	o

Table 13 – Redesign Solutions & Heuristics Analysis

In the Figure below, we can see the heuristics applied to the As Is level 2 model, although the proposed solutions have been designed considering the detail of the model up to level 3 (Appendix A – As-Is Process Models – Level 3):

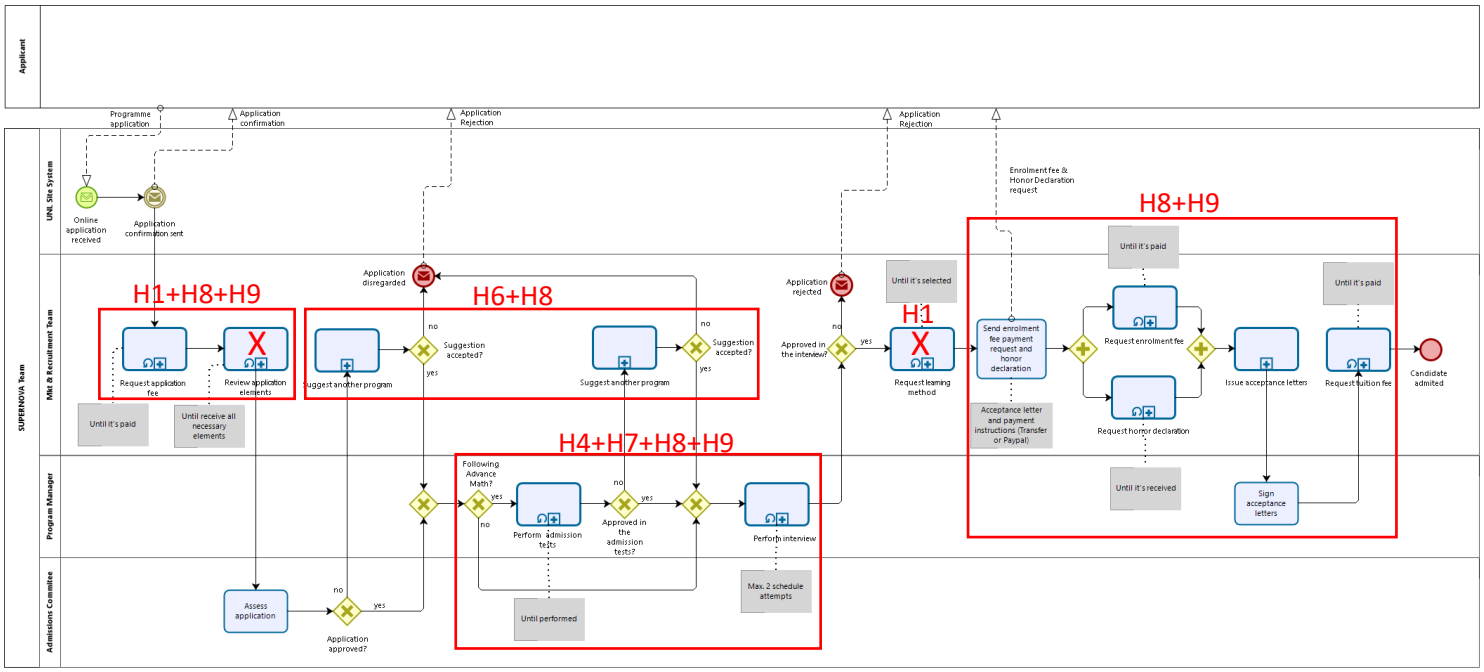


Figure 8 - Heuristics applied to As Is Model – Level 2

Based on the heuristic analysis and redesign prioritization according to SUPERNOVA inputs and the organic changes predicted in Rectorate's organization, the outcome is the new model proposed by the process analysts to SUPERNOVA Application-to-Approval process, represented in the Figure below:

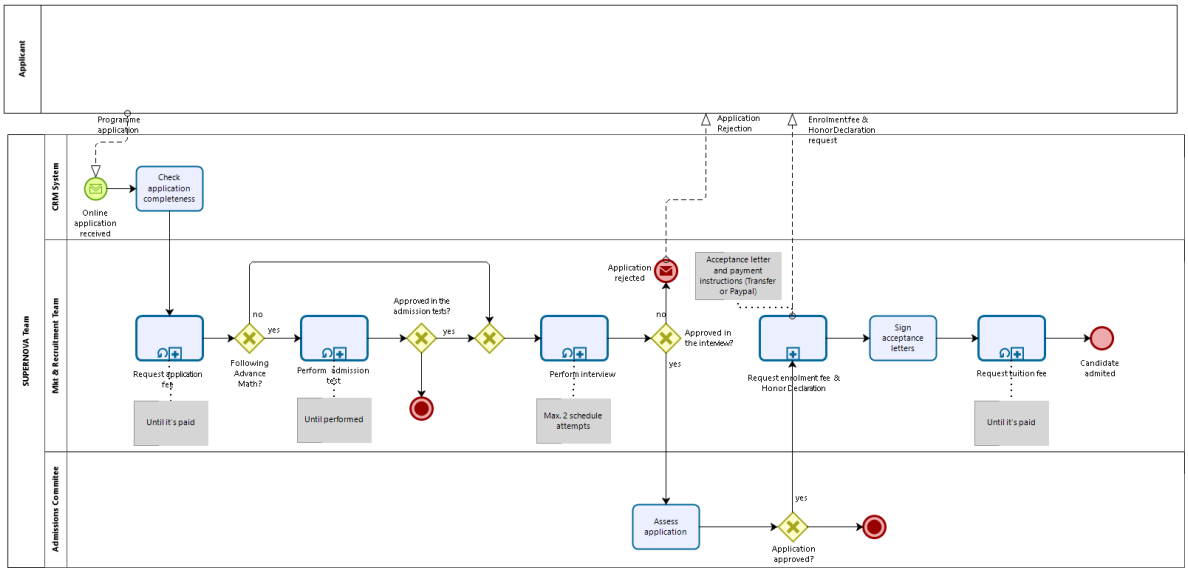


Figure 9 - SUPERNOVA A2A: To-Be Process Model - Level 2

As in As-Is modelling, only the level 2 process models are presented for readability reasons. The level 3 models of the To-Be sub-processes can be found in the Appendix B – To-Be Process Models – Level 3 section of this document.

3.4.1. To-Be Simulation

As with the simulation of the As-Is model, a simplified model was used for the simulation of the To-Be model:

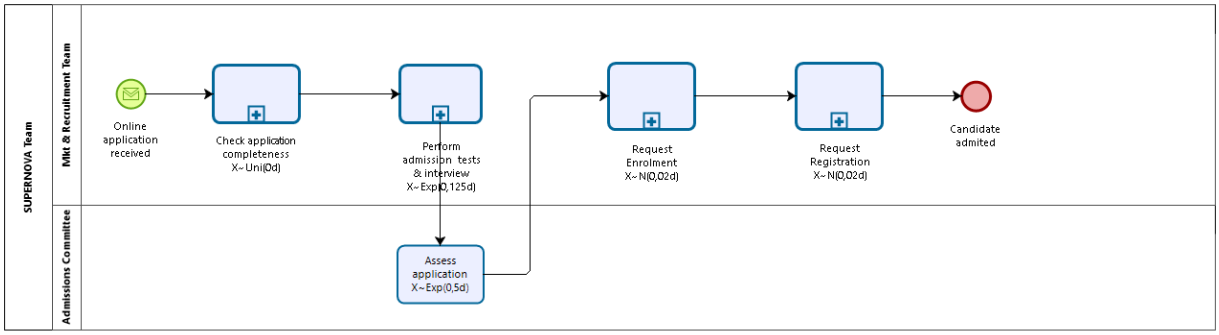


Figure 10 - SUPERNOVA A2A: To-Be Simulation Model

3.4.1.1. Input Data

With the proposed To-Be process model, the CRM system plays an important role in automating the process, and much of the follow-up rework that was previously done manually by the team is now handled automatically by the system, so the input data for simulation does not now have the loops of this follow-up rework.

Data	Value / Probability (calculation)
Duration	150 days
Mean arrival rate (λ)	1,78 applications/day (267 applications)
Mean inter-arrival time (1/ λ)	0,56

Table 14 - To-Be Simulation Input Data

With the redesign of the process and the level of automation that the new model allows to be achieved, where the process analysts estimated an average automation of 75% of the sub-processes with the implementation of the new model in CRM, the time data was defined with the following data:

Process	Time – Distribution
Check application completeness	(Min: 0; Máx:0,03) – Uniform Distribution (system)
Perform admission tests & interviews	Mean=0,125d – Negative Exponential Distribution
Assess Application	Mean=0,5d – Negative Exponential Distribution
Request Enrolment	(μ=0,02d ; σ=0,005d) – Truncated Normal Distribution
Request registration	(μ=0,02d ; σ=0,005d) – Truncated Normal Distribution

Table 15 - To-Be Processing Times

Taking into account the planned reorganization of the SUPERNOVA team by the University and the results of the simulations of the what-if scenarios and respective conclusions, the new model proposes the reduction of a human resource (Supernova Manager), which allows not only a reduction of financial costs, but also a reduction of handovers, which translates into a reduction of time and a probable increase of quality, since a reduction of errors is always expected with the reduction of handovers:

Resources	Quantities
Marketing & Recruitment team	2
Admissions Committee	1

Table 16 - To-Be Resources Data

3.4.1.2. Simulation Analysis

Analyzing the result of the simulations and their main KPIs, the process analysts validated that the proposed solution meets the NOVA's objectives and optimizes the process, verifying the decrease in resource usage, lower average and cycle times and mainly, the significant increase in the number of completed instances:

Scenario	Mkt & Recruit. Team	SUPERNOVA Manager	Admissions Committee	Instances Completed	Avg. Time (d)	Total time (d)	Total time waiting resource (d)
As-Is	100%	88,9%	37,9%	7	79,2	9431,9	9250,1
To-Be	15,3%	0%	89,1%	253	12,7	3226,1	3065,4

Table 17 - As-Is vs. To-Be Analysis

3.4.1.3. To-Be Simulation Conclusions

The simulations clearly demonstrate the gains in the key metrics defined for the process. With the solutions proposed, the process will increase in three main dimensions: **Efficiency**, where the ability to integrate with other systems relevant to the process and send automatic follow-ups and notifications increases the efficiency of the process; **Speed and Agility**, where the automation achieved with CRM and BPF implementation of the process, together with more efficient control and monitoring, will lead to shorter cycle and averages times, essential prerequisites for more excellent reliability and thus for high customer satisfaction and **Quality and fulfilment**, where a streamlined process also means less work, which leads to lower and shorter resource utilization with a positive impact on costs and current assets. Efficient, fast and less error-prone processes ultimately also drive employee and customer satisfaction.

4. BUSINESS IMPLICATIONS

In organic terms, the implementation of this project implies a change in the SUPERNOVA team in which the Program Manager is no longer part of the admission process, but exclusively allocated to the academic management process after the candidate's admission.

In terms of costs, the following tables provide a 5-year analysis of the costs with resources of the current process:

Description	Quantity	Unit Cost	Total Amount
Marketing & Recruitment Resource	2	€ 1 500,00	€ 3 000,00
Program Manager Resource	1	€ 2 000,00	€ 2 000,00
Admission Committee Resources	1	€ 3 000,00	€ 3 000,00
Total Monthly Expenses			**€ 8 000,00**
Total Expenses - 1st Year			**€ 112 000,00**
Total Expenses - 5-year period			**€ 560 000,00**

Table 18 - As-Is Human Resources Costs

The following tables provide a 5-year analysis of the costs with the resources on the To-Be process resulting from the implementation of the new model:

Description	Quantity	Unit Cost	Total Amount
Marketing & Recruitment Resource	2	€ 1 500,00	€ 3 000,00
Program Manager Resource	0	€ 2 000,00	€ -
Admission Committee Resources	1	€ 3 000,00	€ 3 000,00
Total Monthly Expenses			**€ 6 000,00**
Total Expenses - 1st Year			**€ 84 000,00**
Total Expenses - 5-year period			**€ 420 000,00**

Table 19 - To-Be Human Resources Costs

By analyzing both human resources cost maps, with the proposed model, a 25% cost reduction is achieved, which after five years results in a total of €140k saved.

Project implementation costs will also need to be incurred for the project, which is estimated to last ten weeks, although no license or system acquisition is required since the CRM system is already in place:

Description	Quantity	Unit Cost	Total Amount
Senior Consultant Professional Resource	0,75	€ 3 250,00	€ 2 437,50
Senior Developer Professional Resource	1	€ 2 750,00	€ 2 750,00
Senior Tester Professional Resource	0,5	€ 1 500,00	€ 750,00
Two Weeks Waranty Period	1	€ -	€ -
Total Monthly Cost			**€ 5 937,50**
Total Project Cost (2,5 months duration)			**€ 14 843,75**

Table 20 – To-Be Project Implementation Costs

At a cost of approximately €15k, the implementation of the new model represents about 15% of the total cost in 1 year. In 5 years, this cost is diluted to about 3,5% of the total cost since it is a non-recurring cost.

4.1. Financial Analysis Summary

This section describes the financial analysis summary of the As-Is Scenario vs. To-Be Scenario. Additionally, it also breakdown each component in terms of project costs, human resources, and the total amount saved per year in a five-year return of investment plan.

	As-Is	To-Be
Total HR Costs (1st year)	112.000,00€	84.000,00€
Total Project Implementation Cost	-	14.843,75€
Total Investment (1st year)	**112.000,00€**	**98.843,75€**
Total Investment (5-year period)	**560.000,00€**	**434.843,75€**
Total Saved (per year)		**-25.031,25€**
Total Saved (5-year period)		**-125.156,25€**

Table 21 - Financial Analysis

Turning the table into a visual, we can better see that the ROI is achieved in the very first year:

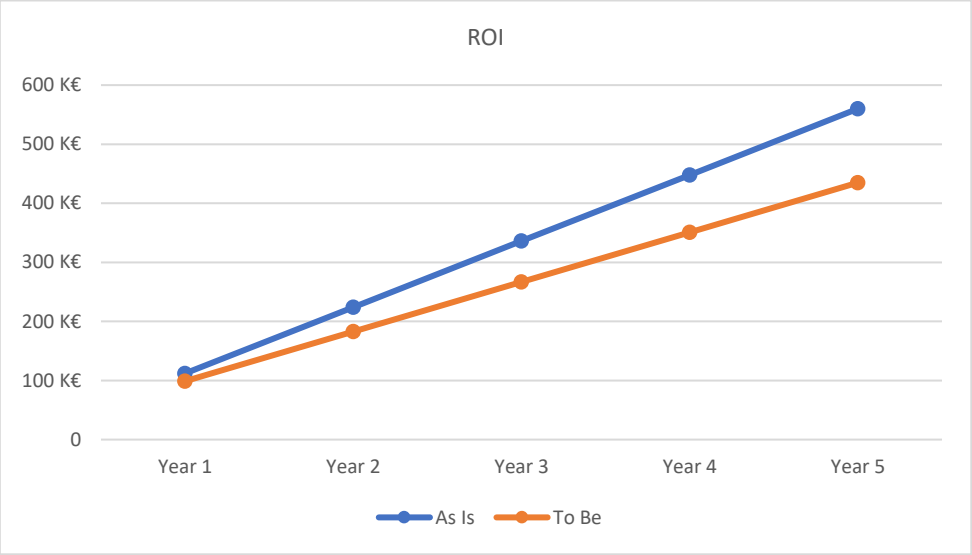


Figure 11 – ROI

Considering that the cost reduction achieved by the reduction in human resources compensates by a large margin the total cost of the project right from the first year (22% less), thus obtaining a Return on Investment even before the end of the first year, as can be seen in Figure 11, the investment for implementing the new model is fully justified, not only by the financial dimension, but by the gains that the new model will bring to the University in terms of process efficiency, both in time and quality.

If these gains in business process efficiency, we add the predictable increase in revenue with the increase in the conversion of applicants into students, which was the main objective of SUPERNOVA tam. We have that the investment in a BPM methodology proved to be an effective management

strategy and an efficient technology management strategy for implementing technological solutions, as stated by Pridmore & Godin (2021).

5. LIMITATIONS AND FUTURE WORKS

5.1. LIMITATIONS

Despite attempts to minimize simulation techniques and the simulator itself limitations by running several simulations, it will be necessary to validate the simulations made during the course of the implementation of the new process. It is also necessary to validate the costs of the human resources assumed, as it was not possible to obtain the real cost of each resource used, although the pay scales were used to arrive at the values of the salary bands and obtain confidence intervals.

Another limitation related to human resources was the identification of the resources themselves. For example, the admissions committee is formally composed of senior staff from the Rectory, although in practice, it is often not feasible to convene the committee in a timely manner with its formal composition, so the more operational staff often replace the formal staff. This volatility makes it difficult to estimate the cost of human resources.

5.2. FUTURE WORKS

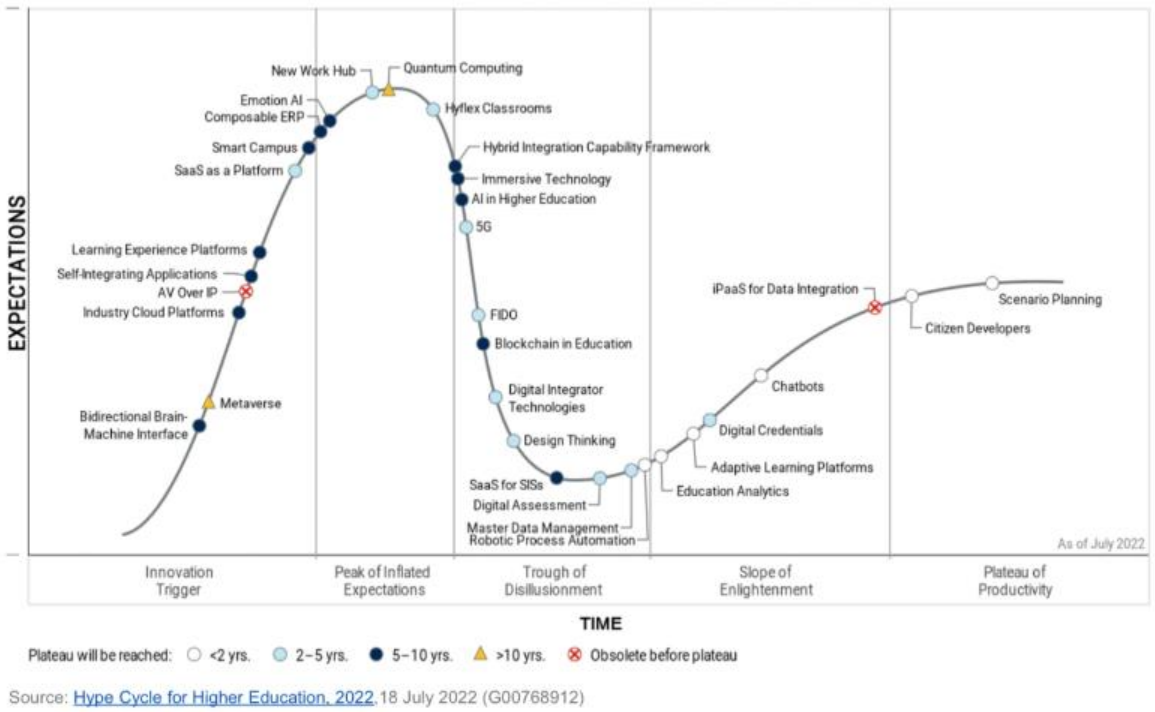
The implementation of the designed solution will require change management associated with the Digital Transformation inherent to the implementation of the project. It is recommended that best practices in both Project Management (PM) and change management be used so that the adoption of the new process running on top of an information system has a greater chance of success. As Baier et al. (2022) argue, BPM, PM, and DT are relevant disciplines in the literature for the success of a Process Digitalization Project. Besides BPM relevance, which was already covered in Chapter 2, Digital Transformation has shown its relevance as the integration of technology into areas of a business resulting in fundamental changes to how the business functions and how they deliver value to customers (Baiyere et al., 2020). Project Management has also shown its relevance in how the project and the management of the project support the business strategy.

With the start-up of this BPM initiative in the Rectory of NOVA, it will be important as future work to review in detail the process architecture (level 1) proposed in this project in the process identification phase (Figure 2), since this initiative has already started with the process to be improved already identified and process identification and the identification of processes carried out in this project was limited by the time required to carry it out and by the lack of structured information on the business processes of the Rectory.

The designation phase of all the existing processes is time-consuming and complex, but this future work will allow the Rectory to evaluate priorities with greater rigour and which may bring greater benefits to the Rectory, as well as better management of the business processes that exist in the Rectory and the processes already optimized throughout the course of the initiative.

An important future work also to be carried out is to plan the implementation of phase 6 of the BPM lifecycle to build relevant analytical dashboards to support the monitoring and control of the metrics of the process. Business Intelligence (BI) is increasingly being seen as **the** organizational decision support framework, and the CRM system available at NOVA enables integration with BI tools such as Power BI, which will enable to determine how well the process is performing with respect to its performance measures and performance objectives during this phase (Stefanovic et al., 2008).

Finally, we leave the hype cycle for higher education (Figure 12), where we highlight the introduction of AI, digital assessment and blockchain technology that together can make the admission process much more effective and efficient, with the veracity of academic certificates secured by blockchain and evaluation of applications and candidates using digitization and AI.



Source: Hype Cycle for Higher Education, 2022, 18 July 2022 (G00768912)

Figure 12 - Hype Cycle for Higher Education (Gartner.com, 2022)

6. CONCLUSIONS

The application-to-approval process is an important and complex process that requires ongoing improvement and innovation to ensure that it is efficient, effective, and fair for all stakeholders.

The adoption of CRM to improve NOVA's relations with its students and other stakeholders also implies a transformation from teacher orientation to student-orientation strategy, which has implications for the University's own CRM adoption strategy, so that it can be effective in processing continual improvements in particular, the process under study in this Master's project.

This Master's project also hopes to contribute to BPM initiatives as a driver to support digital transformation programs in higher education. Thus, in addition to the main objective of identifying improvement opportunities in the admission process of the SUPERNOVA programme as described in the introduction, which we consider to have been fully achieved, this Master's project turns out to have a wider scope than the University should consider at a strategic level, considering the Rectorate's holistic vision of all NOVA's schools and institutes:

1. Sediment and extend the BPM initiative to the whole NOVA;
2. Define a student-oriented CRM strategy, meaning an SRM;
3. Define a digital transformation process that supports continuous process improvement.

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APPENDIXES

APPENDIX A – AS-IS PROCESS MODELS – LEVEL 3

a) As-Is: Request Application Fee Sub-Process

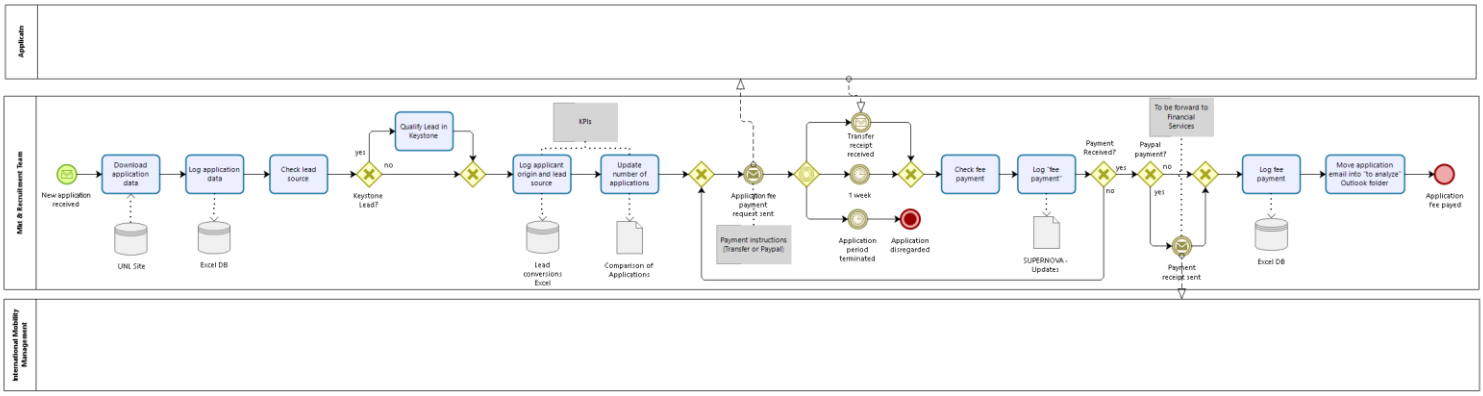

Figure 13 - As-Is: Request Application Fee Sub-Process Model

b) As-Is: Review Application Elements Sub-Process

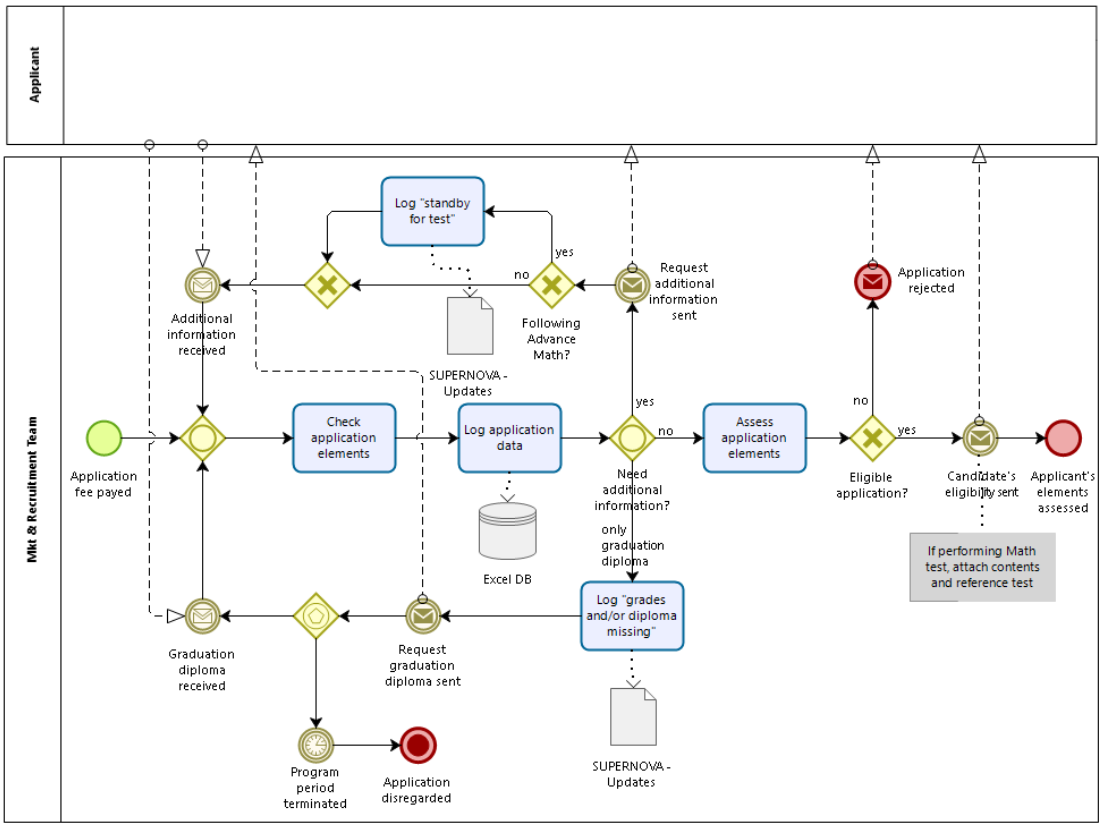

Figure 14 - As-Is: Review Application Elements Sub-Process Model

c) As-Is: Suggest Another Program Sub-Process

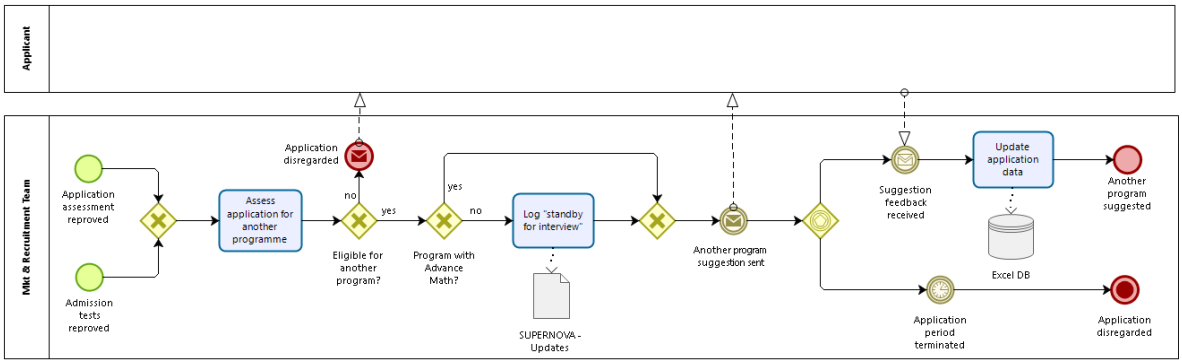

Figure 15 - As-Is: Suggest Another Program Sub-Process Model

d) As-Is: Perform Admission Tests Sub-Process

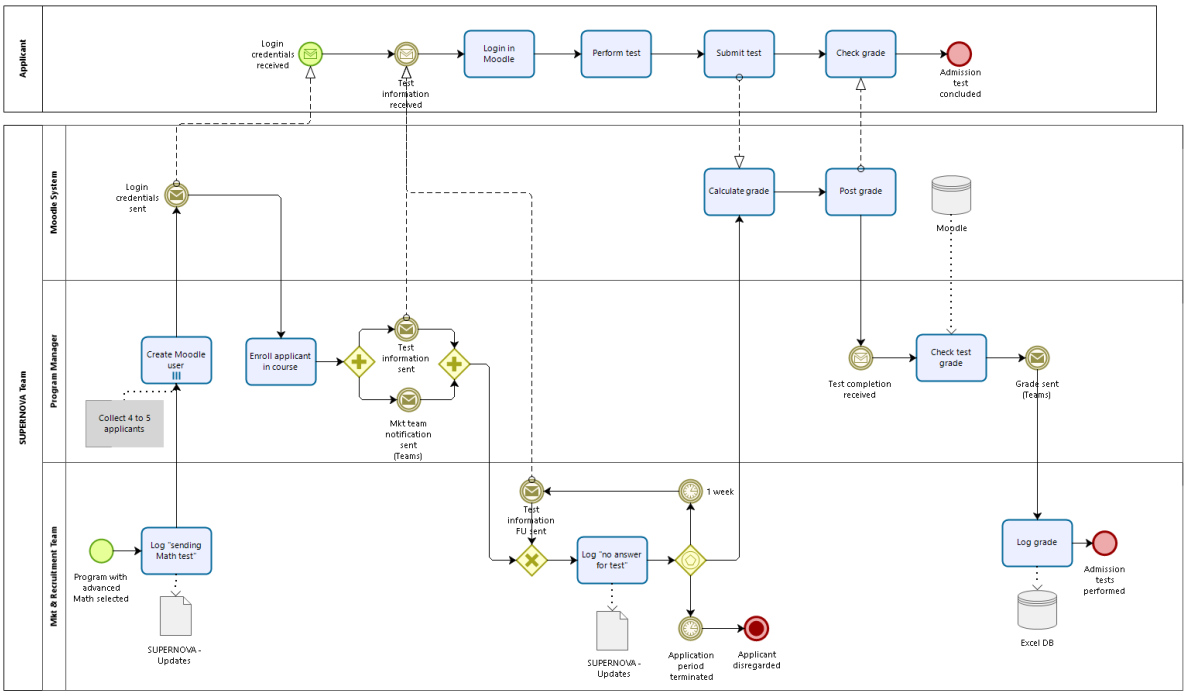

Figure 16 - As-Is: Perform Admission Test Sub-Process Model

e) As-Is: Perform Interview Sub-Process

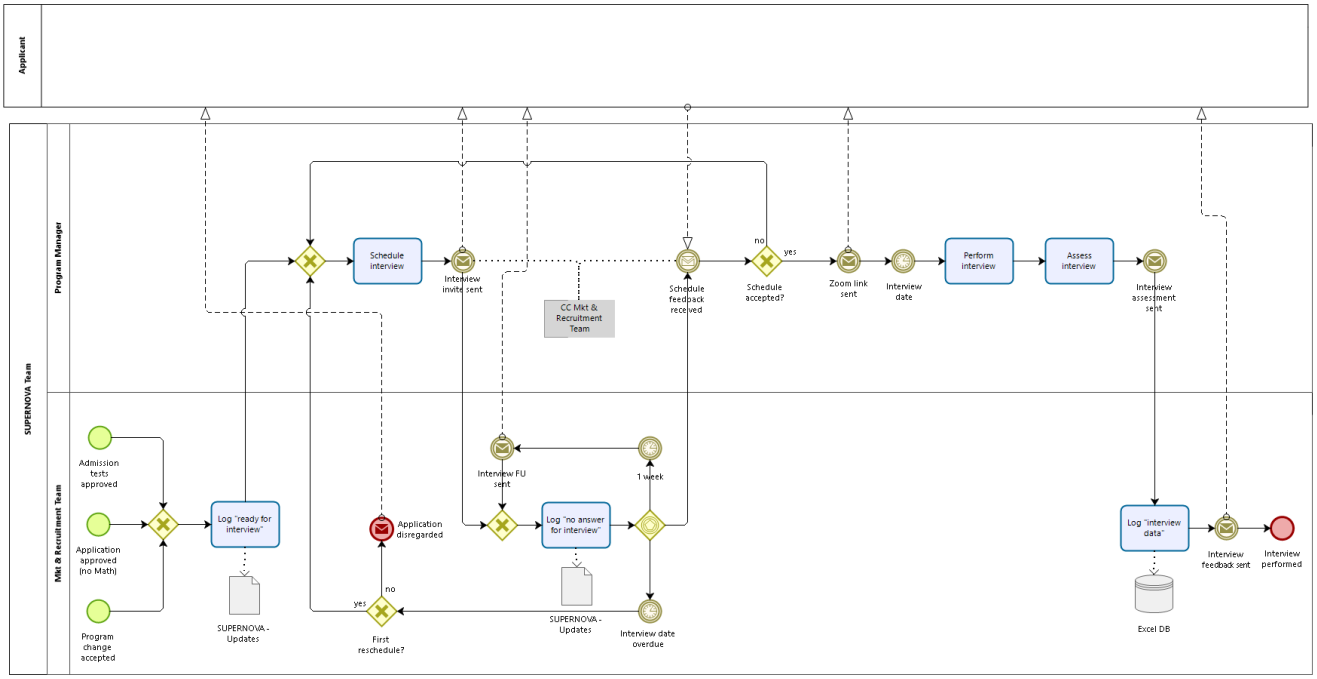

Figure 17 - As-Is: Perform Interview Sub-Process Model

f) As-Is: Request Learning Method Sub-Process

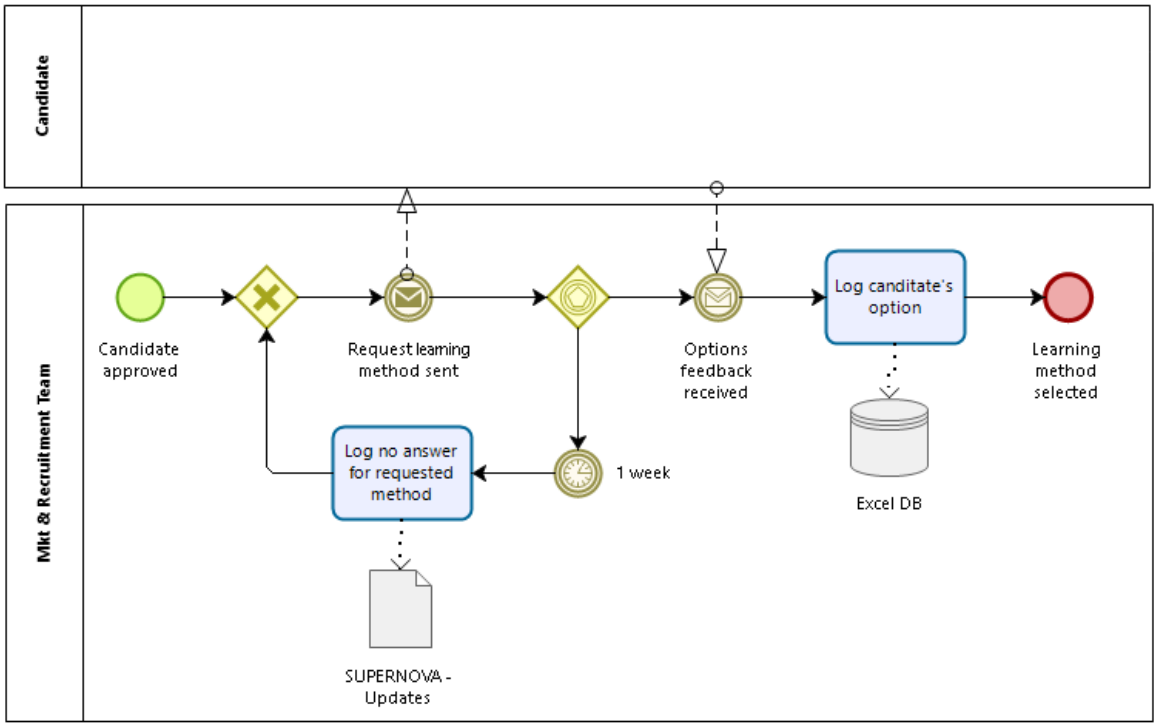

Figure 18 - As-Is: Request Learning Method Sub-Process Model

g) As-Is: Request Enrolment Fee Sub-Process

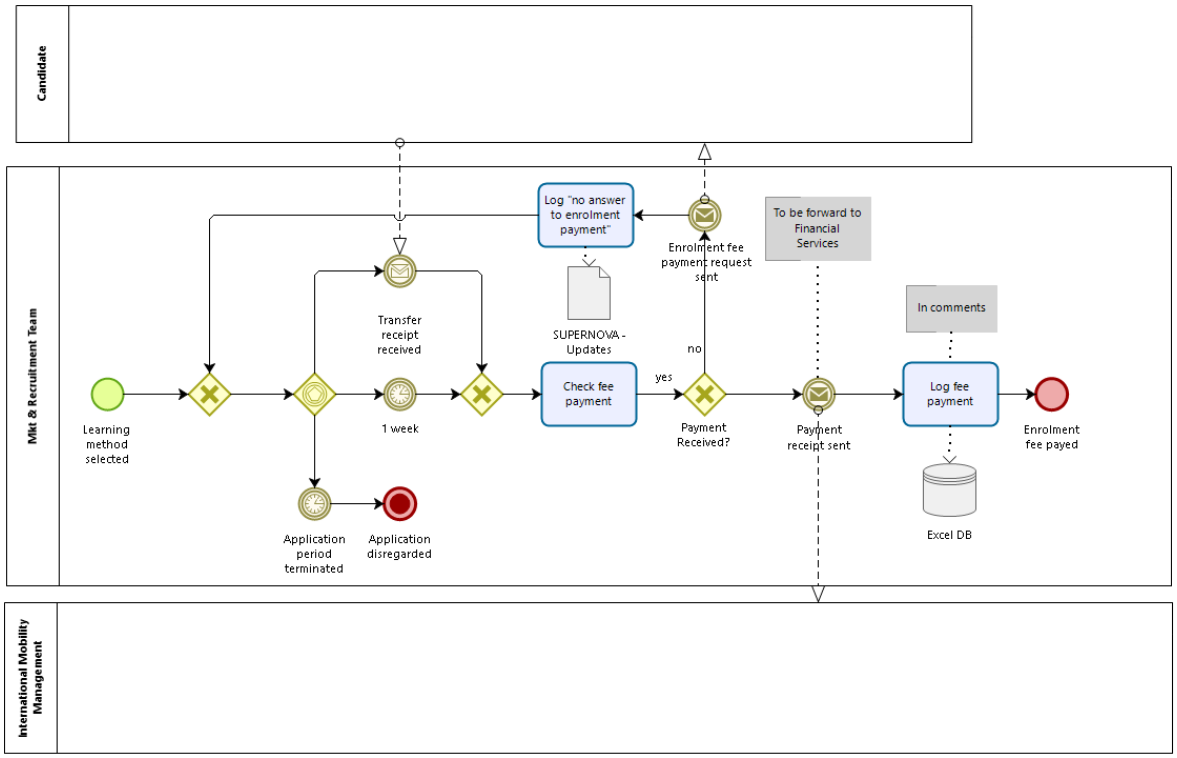

Figure 19 - As-Is: Request Enrolment Fee Sub-Process Model

h) As-Is: Request Honor Declaration Sub-Process

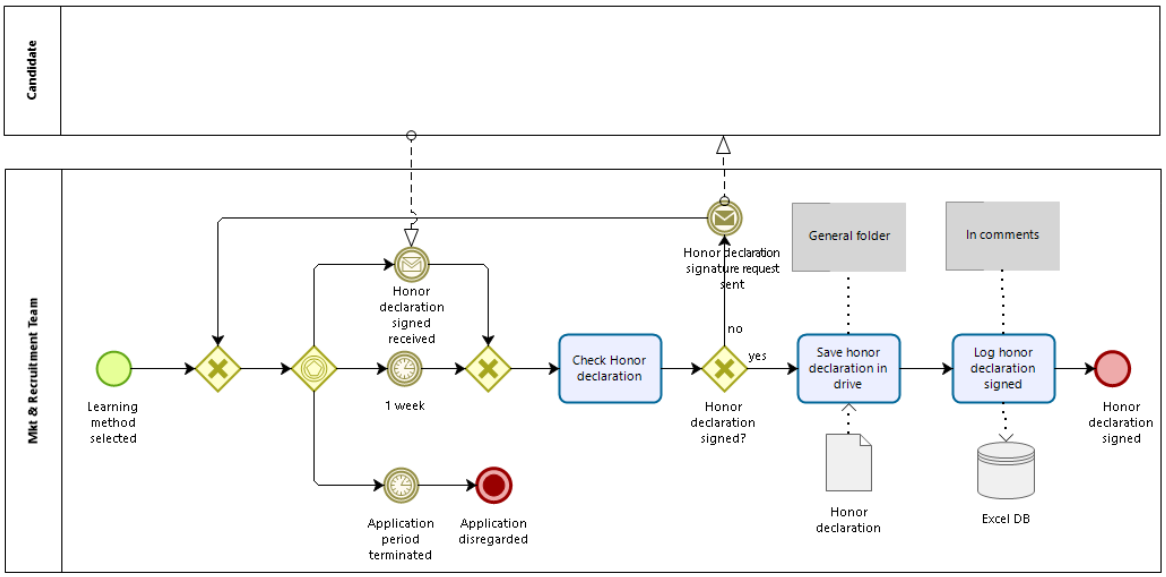

Figure 20 - As-Is: Request Honor Declaration Sub-Process Model

i) As-Is: Issue Acceptance Letters Sub-Process

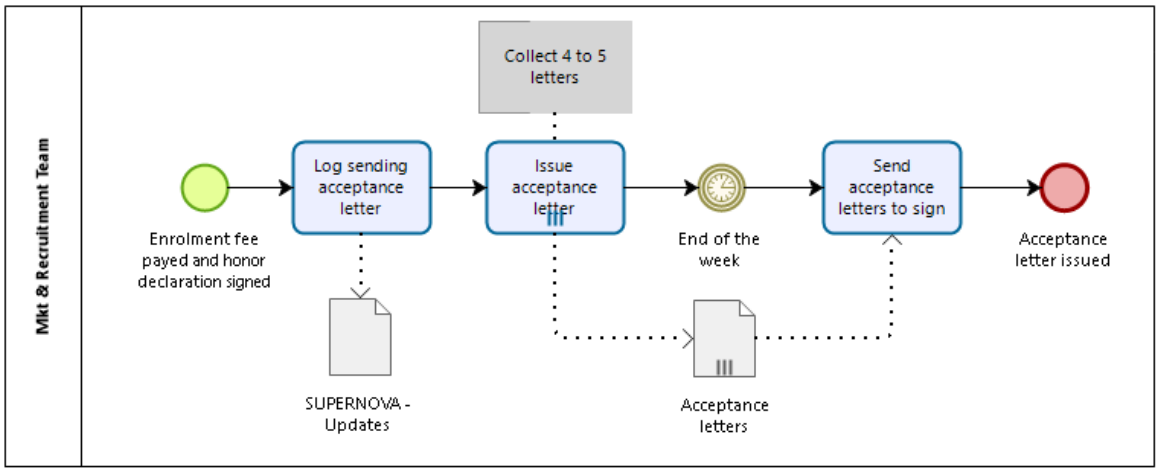

Figure 21 - As-Is: Issue Acceptance Letters Sub-Process Model

j) As-Is: Request Tuition Fee Sub-Process

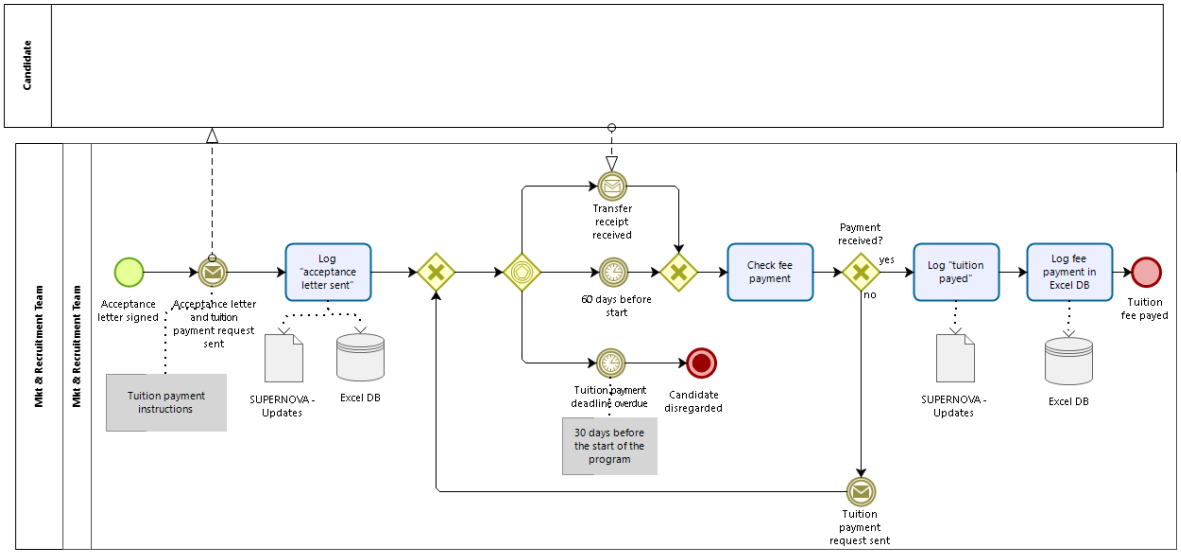

Figure 22 - As-Is: Request Tuition Fee Sub-Process Model

APPENDIX B – TO-BE PROCESS MODELS – LEVEL 3

a) To-Be: Request Application Fee Sub-Process

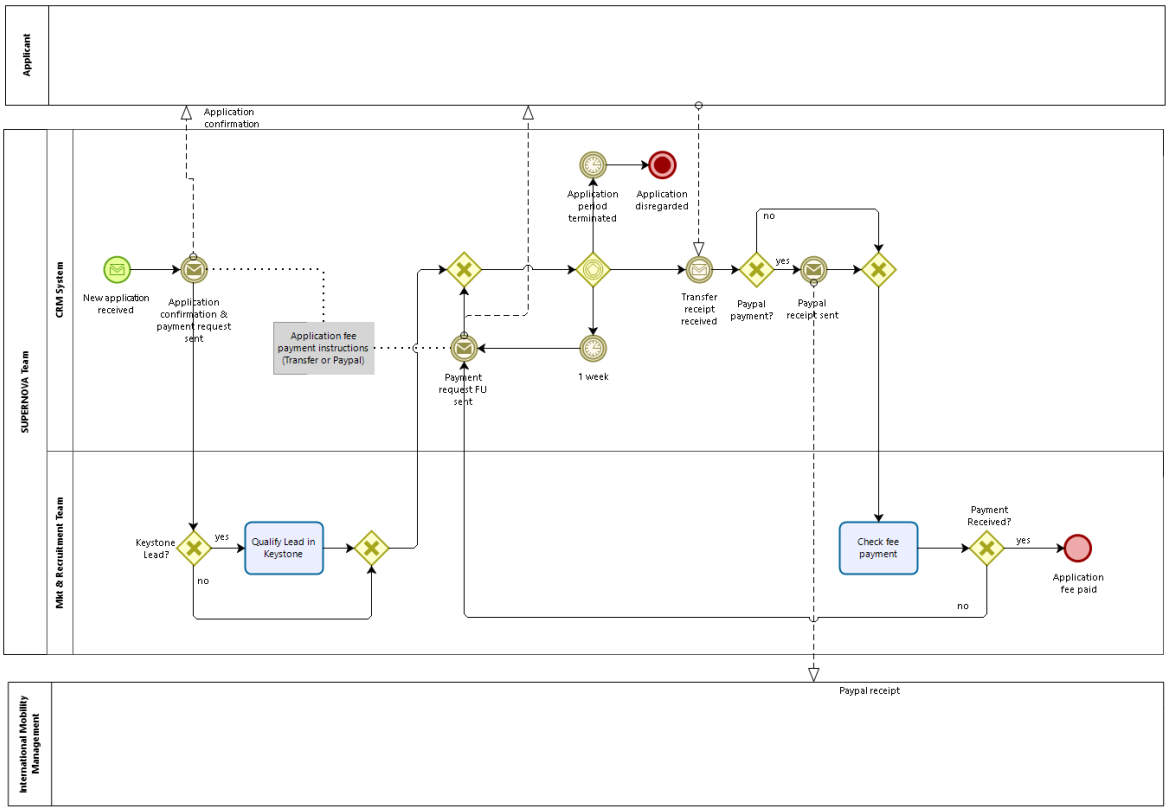

Figure 23 - To-Be: Request Application Fee Sub-Process Model

b) To-Be: Perform Admission Tests Sub-Process

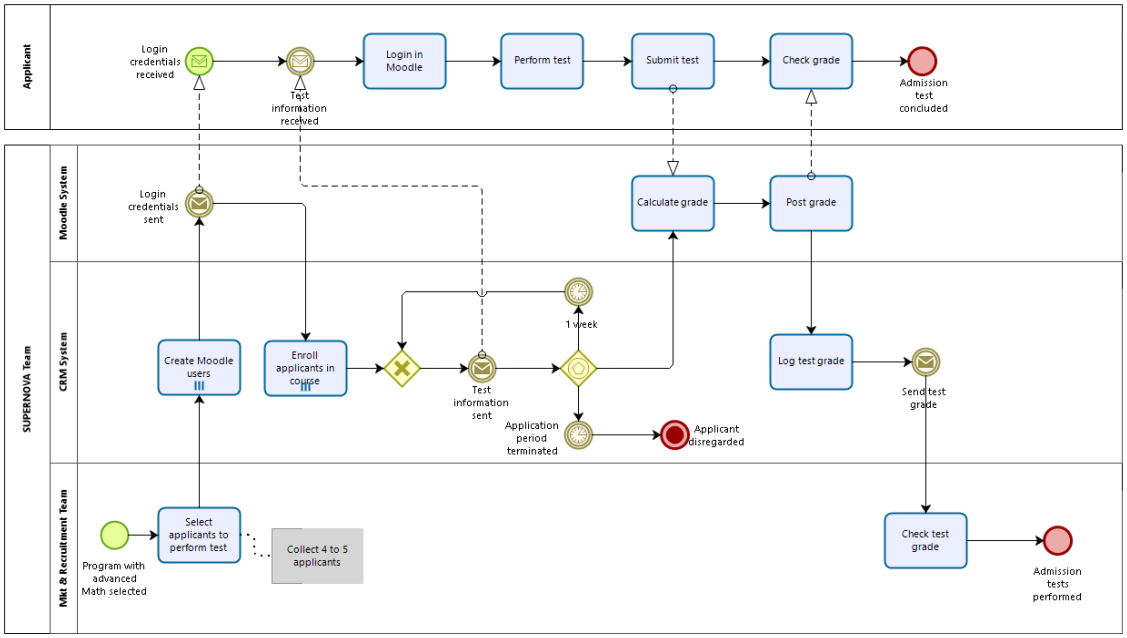

Figure 24 - To-Be: Perform Admission Tests Sub-Process Model

c) To-Be: Perform Interview Sub-Process

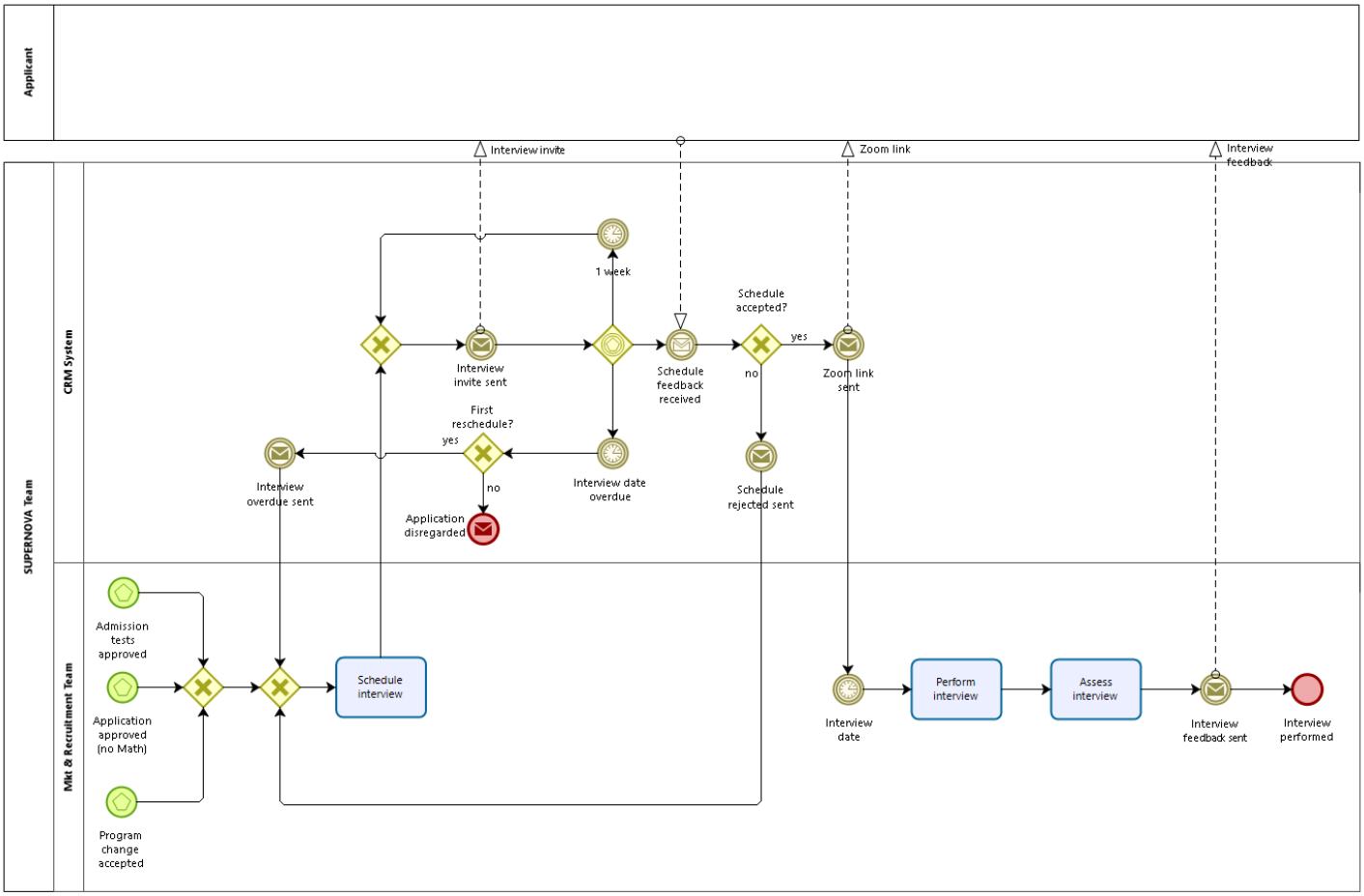

Figure 25 - To-Be: Perform Interview Sub-Process Model

d) To-Be: Request Enrolment Fee and Honor Declaration Sub-Process

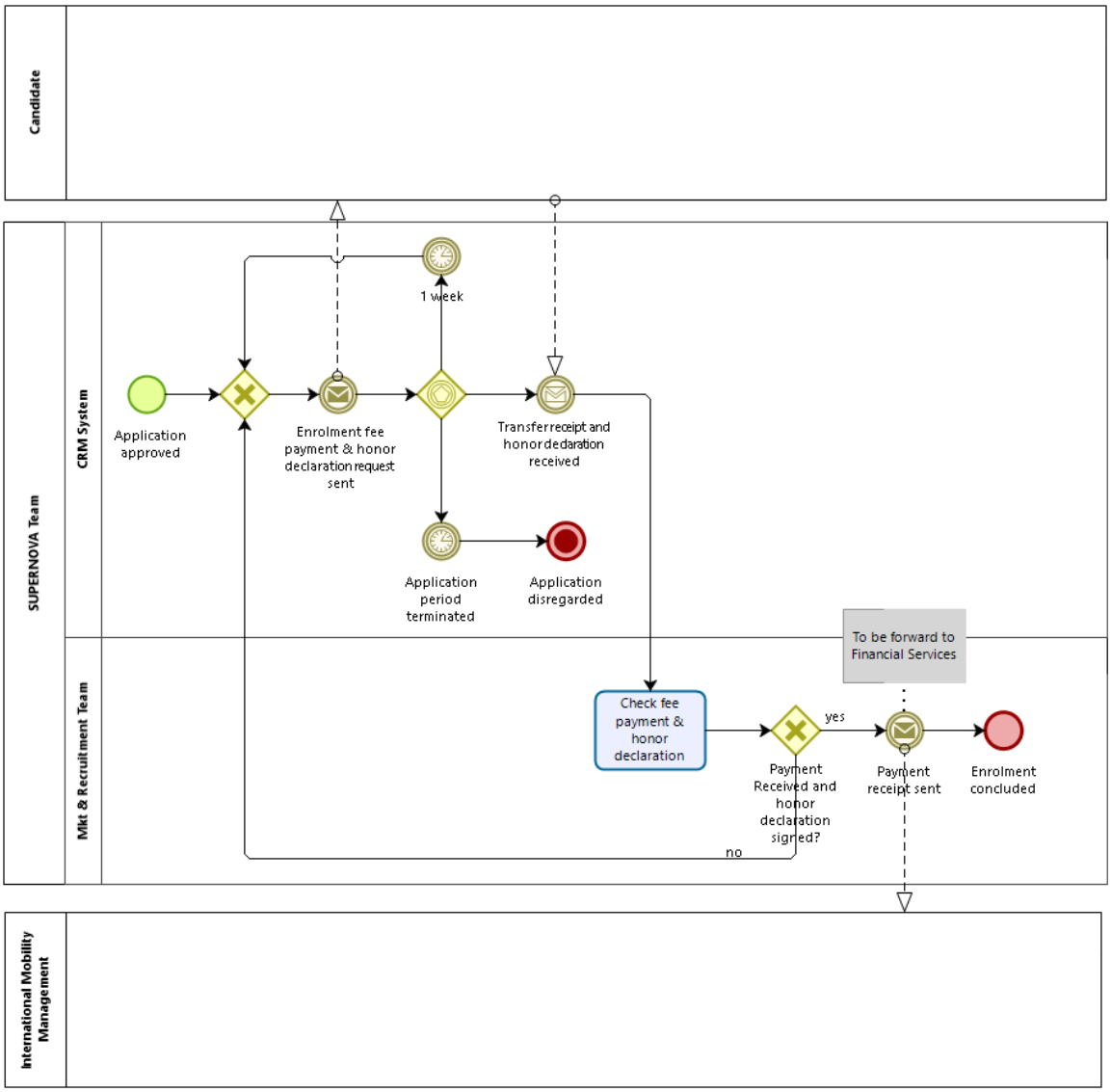

Figure 26 - To-Be: Request Enrolment Fee & Honor Declaration Sub-Process Model

e) To-Be: Request Tuition Fee Sub-Process

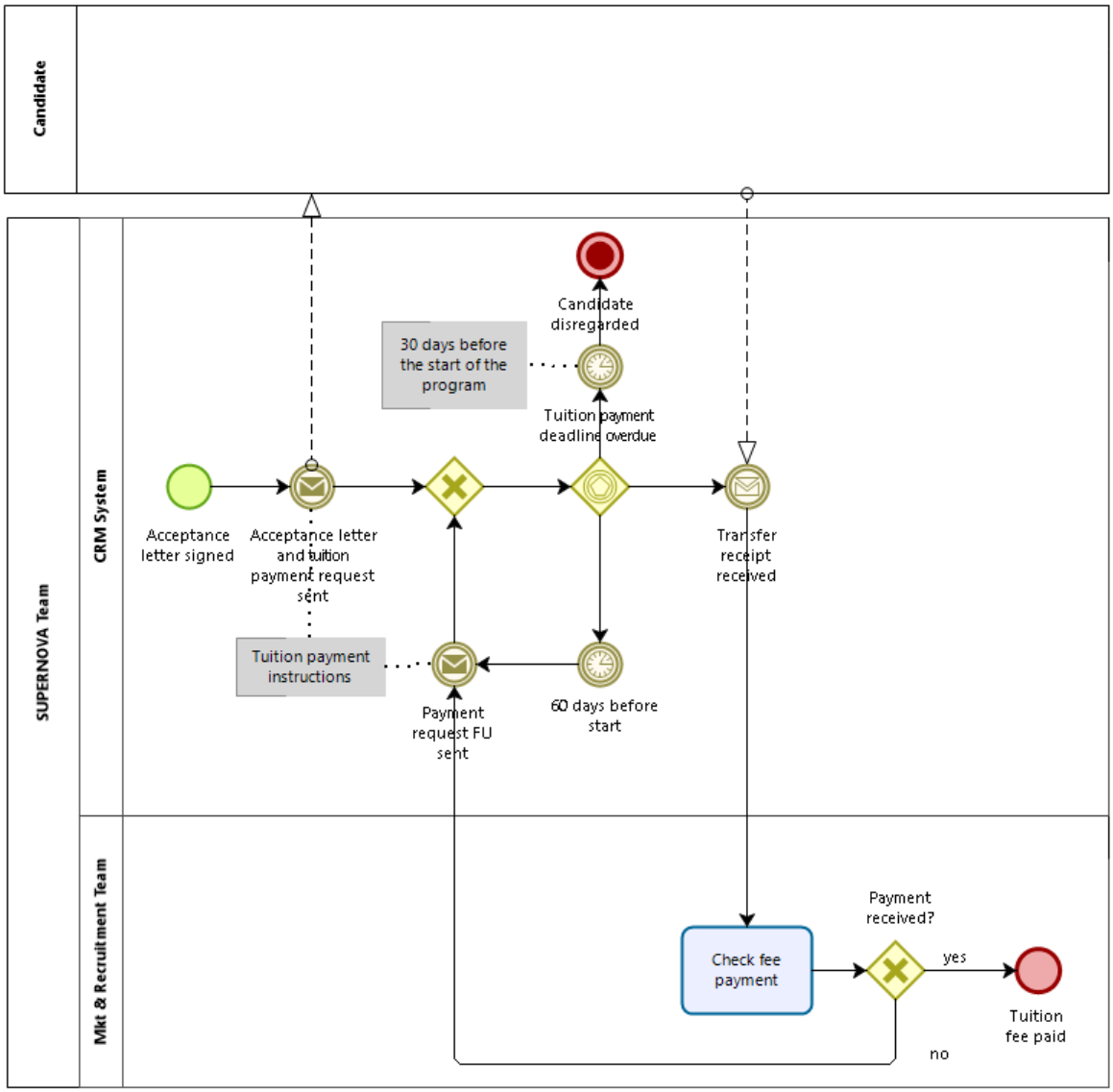

Figure 27 - To-Be: Request Tuition Fee Sub-Process Model

ANNEXES

ANNEX I - RECTORATE ORGANOGRAM

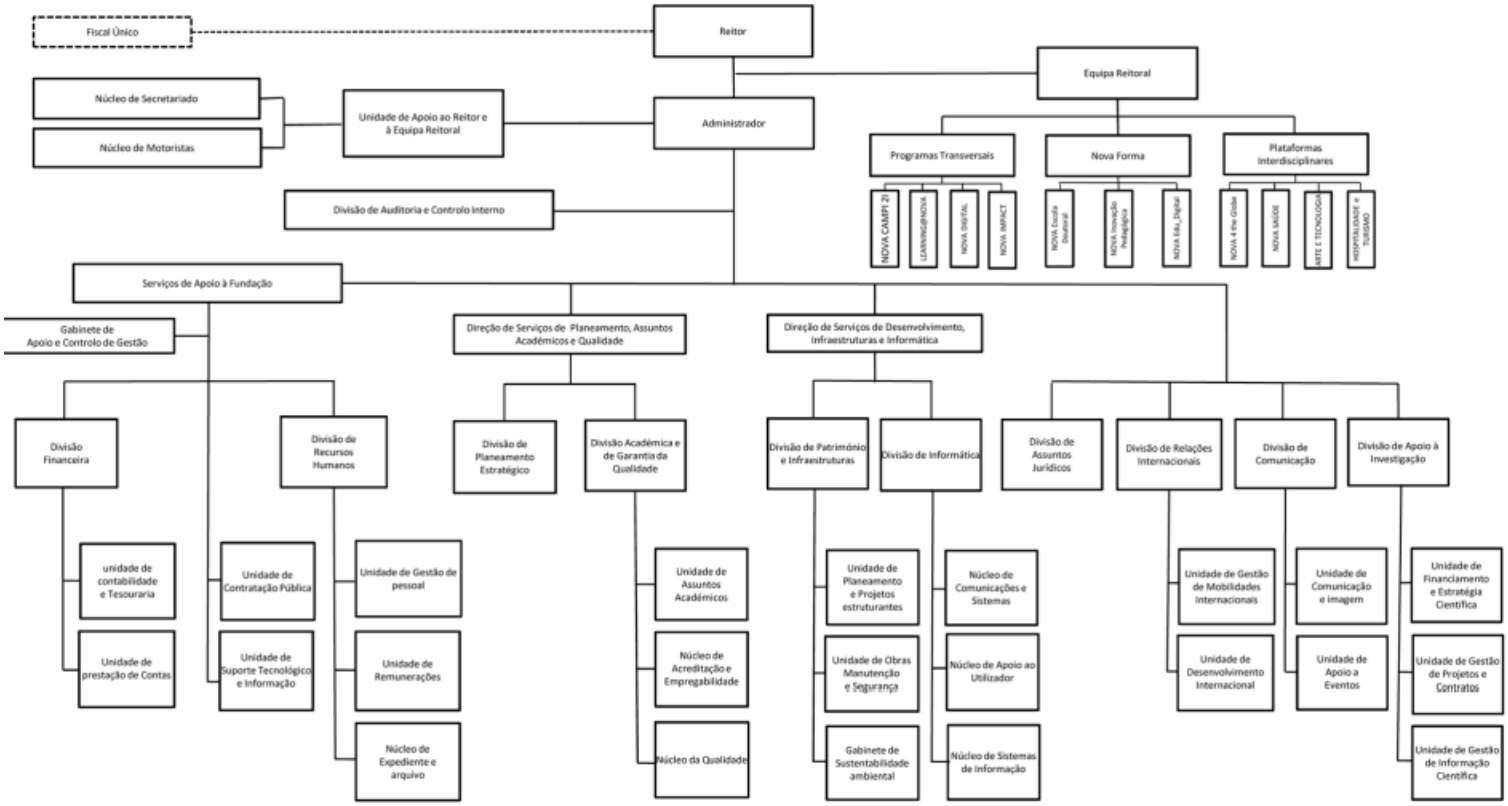

Figure 28 - NOVA's Rectorate Organogram

ANNEX II – SUPERNOVA APPLICATION PROCESS FLOW BY SUPERNOVA TEAM

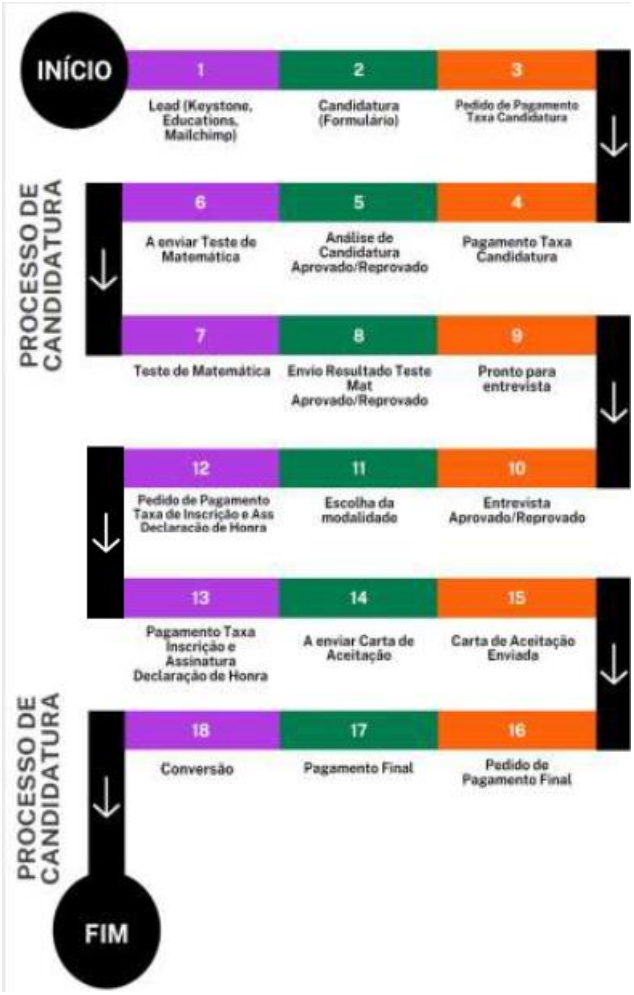

Figure 29 - A2A Process Flow by SUPERNOVA

ANNEX III – OPERATIONAL DOCUMENTS (ANONYMIZED SAMPLES)

a) SUPERNOVA "Database"

Submitted Time	Passport No.	Passport Expiration Date	Title	Name(s)	Surname(s) / Last Name(s)	Date of Birth	Nationality	Other Nationality	E-mail	Address	Phone number
04/07/2021 11:56	1564651464[illegible]	20/12/2024	Sra	Margari	Vagos	07/10/2002	Angola		4651465	Luanda,	2 449155 112

Table 22 - SUPERNOVA "Database"

b) Onboarding Guide: Steps and Activities

Processo de Análise de candidatura

1- Receber candidatura
2- Descarregá-la para a BD
3- Verificar origem (Keystone, Mailchimp)
4- Colocar no updates
5- Colocar origem candidatura no word conversões
6- Atualizar n de candidaturas no word compração de candidaturas
7- Enviar email como pedido de pagamento
8- APÓS TAXA DE CANDIDATURA PAGA
9- Após pago, enviar comprovativo ao João (nome, edição programa, e valor pago)
10- Responder que vamos avaliar a candidatura (resposta nos emaisl follow up)
11- Colocar a candidatura na pasta "para analisar)
12- Analisar candidatura
13- Atualizar word updates
14- Enviar email com feedback candidatura
15- Joana envia teste de matemática ao aluno (caso ele queria ir para a SBE, FCT E IMS)
16- Colocar na BD que teste foi enviado no dia X nos comentários ex. 28/03 teste mat enviado
17- Receber email com o teste feito e atualizarmos no updates secção "teste realizado"
18- Joana vai informar da nota e temos que colocar na BD "math test" menos de 10 recusado, mais de 10 aceite
19- Colocar nome no pronto para entrevista (word updates)
20- Joana envia info da entrevista ao aluno connosco em CC
21- Colocar na BD a data da entrevista
22- Recebemos mail da joana com feedback da entrevista
23- CANDIDATO ACEITE
24- Colocar na BD faculdade à qual foi aceite (meter nos comentários cm o "nome faculdade"
25- Colocar nos updates "candidatura aceite"
26- Enviar email ao candidato de que foi aceite (email follow up) (É neste email que eles têm de escolher a modalidade presencial ou online
27- Quando eles escolherem a modalidade colocamos na BD e updates
28- Enviamos email de pedido de pagamento de taxa de inscrição (follow up) nesse mesmo email também enviamos a declaração de honra
29- **(Para avançar precisamos da taxa de inscrição paga e da declaração de honra aceite)** Quando recebermos esses documentos enviamos email a informar que a carta de aceitação será produzida
30- Colocar declaração de honra na pasta general
31- Colocar na BD que pagou taxa e assinou declaração de honra nos comentários
32- Fazer carta de aceitação
33- Atualizar nos updates que está pronta para enviar
34- Enviar cartas o final da semana à Joana (acumular cartas)
35- Com as cartas de aceitação assinadas enviar ao candidato as mesmas, com o pagamento das propinas incluído
36- Colocar na BD e nos updates que a carta foi enviada
37- Excel "Via rápida" para os alunos conseguirem visto
38- Alunos pagam propina, colocamos na BD e updates

c) “SUPERNOVA – Updates” Document

SUPERNOVA – Spring 23

Updates dos Candidatos

Enviado pedido de pagamento, mas ainda não respondeu:

- XXXX (19/07) **FU 08/08 FU 24/08 FU 06/09 FU 22/09 FU 07/10 FU 20/10 FU 03/11**

A enviar teste de matemática:

- XXXX (02/11) - ENVIAR A PARTIR DE 21/11
- XXXX (15/11)

Em stand by para teste

- XXXX (05/08) **FU 24/08 FU 06/09 FU 13/10 FU 28/10 FU 10/11**
- XXXX (30/09) **FU 10/11**

Não respondeu ainda ao envio do teste

- XXXX (12/08) **FU 06/09 FU 07/10 FU 20/10 FU 03/11**
- XXXX (18/08) **FU 06/09 FU 07/10 FU 20/10 FU 03/11**

Pronto para entrevista:

- XXXX (14/11)
- XXXX (15/11)

Em stand by para Entrevista:

- XXXX (22/08) - ESTAMOS À ESPERA DE INFORMAÇÕES **FU 13/10 FU 28/10 FU 10/11**
- XXXX (27/10) - ESTAMOS À ESPERA DE INFORMAÇÕES **FU 10/11**

Ainda não respondeu a entrevista

- XXXX (23/09) **FU 07/10 FU 20/10 FU 10/11**
- XXXX eno (19/10) **FU 10/11**
- XXXX (07/10) **FU 20/10** - EM STAND-BY

Certificado de secundário/histórico de notas ainda em falta:

- XXXX (26/07)
- XXXX (08/08) - ainda ñ acabou
- XXXX (11/08) - ainda ñ acabou + faltam diploma e notas

Confirmação de certificados com as escolas:

Enviado email de candidatura aprovada, mas ainda não respondeu

- XXXX (12/09) **FU 07/10 FU 20/10 FU 03/11 FU 10/11**
- XXXX (22/09) **FU 07/10 FU 20/10 FU 03/11 FU 10/11**

ANNEX IV – LEAD CONVERSION

a) Lead Qualification by Nationality

	Qualidade das leads						
Nacionalidade	Recebidas	Taxa de candidatura paga	Isentos de taxa de Candidatura	Aceites	Recusadas	Taxa de inscrição paga	Propina paga
Afeganistão	1	0	0	0	0	0	0
Algeria	2	1	0	1	0	0	0
Angola	32	21	0	18	3	8	1
Austria	2	2	0	2	0	0	0
Bangladesh	24	8	0	3	5	1	0
Brazil	23	19	0	18	1	7	0
Chile	1	1	0	1	0	0	0
Cabo-Verde	1	1	0	1	0	0	0
Cameroon	2	0	0	0	0	0	0
Canada	1	1	0	1	0	0	0
China	4	3	0	2	1	0	0
Colombia	2	2	0	2	0	1	0
Ecuador	1	0	0	0	0	0	0
Etiópia	1	0	0	0	0	0	0
Gambia	2	0	0	0	0	0	0
Germany	1	0	0	0	0	0	0
Guinea	1	0	0	0	0	0	0
Ghana	2	2	0	1	1	0	0
Haiti	1	0	0	0	0	0	0
India	9	1	0	1	0	0	0
Iran	2	0	0	0	0	0	0
Italy	1	1	0	0	1	0	0
Japan	1	1	0	1	0	0	0
Kazakhstan	1	0	0	0	0	0	0
Kenya	2	2	0	1	1	0	0
Lebanon	3	3	0	2	1	0	0
Libya	1	0	0	0	0	0	0
Morocco	5	3	0	3	0	1	0
Mozambique	8	2	0	2	0	1	0
Nepal	3	1	0	1	0	0	0
Nigeria	14	3	0	3	0	3	1
Pakistan	61	18	0	6	12	0	0
Philippines	1	1	0	1	0	1	0
Portugal	6	5	0	5	0	0	0
Russia	8	8	0	8	0	2	0
South Africa	3	0	1	1	0	1	0
Swaziland	1	1	0	1	0	0	0
Syria	3	1	0	1	0	0	0
Timor-Leste	1	1	0	0	1	0	0
Tunisia	1	1	0	1	0	1	0
Ukraine	6	4	0	3	1	0	0
United States	5	3	0	2	0	0	0
Vietnam	1	0	0	0	0	0	0
Zimbabwe	3	2	0	2	0	0	0
TOTAL	**254**	**123**	**1**	**95**	**28**	**27**	**2**

Table 23 - Lead Qualification by Nationality

b) Keystone Lead Qualification

Candidaturas Keystone						
Recebidas	Taxa de candidatura paga	Aceites	recusadas	Desistências	Taxa de inscrição paga	Propina paga
74	37	28	9	0	12	2

Table 24 - Keyston Lead Qualification

c) Whatsapp Leads

Mês	Nº de leads	
Julho	8	
Agosto	3	
Setembro	1	
Outubro	14	
Total		26

Table 25 - Whatsapp Leads

ANNEX V – FLOW ANALYSIS

Flow analysis is a technique that provides process analysts information about the global performance of a process. This technique was used to calculate process Cycle Time (CT), which is the average time between the process starts and its end (including waiting times), processing time, to finally achieve process efficiency.

To have better insights about the process, the following model was used to perform flow analysis:

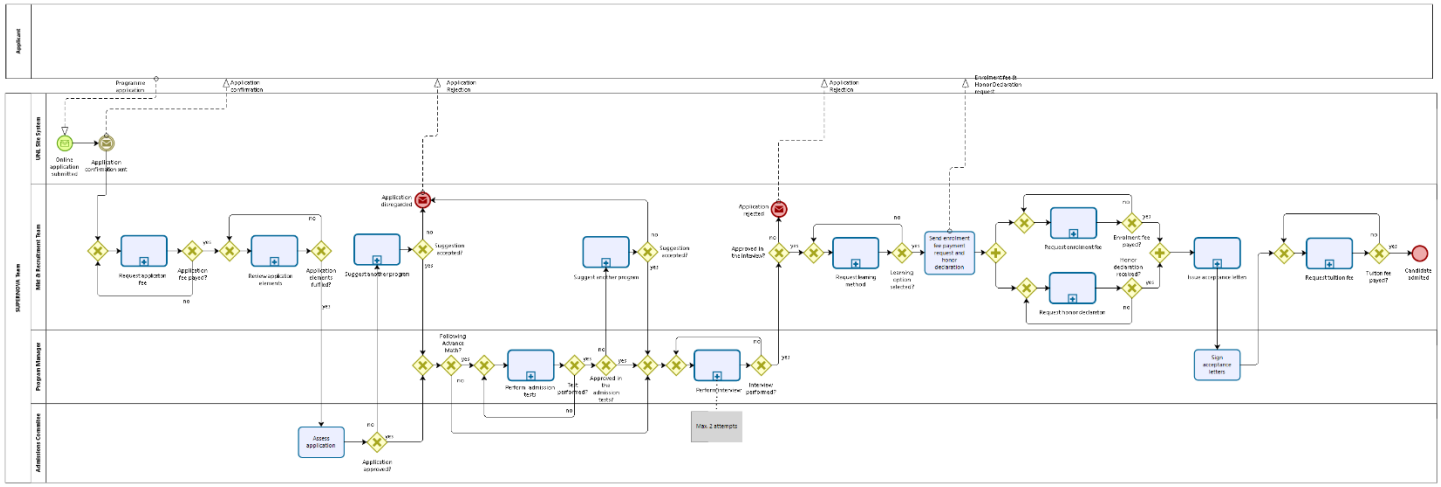

Figure 30 - As-Is Simulation Model - Level 2

As previously referred, no system data was available, so SUPERNOVA team was asked to estimate activities cycle times:

Process	Time / Distribution
Request application fee	10d – Truncated Normal Distribution
Review application elements	2d – Truncated Normal Distribution
Assess application	1d – Negative Exponential Distribution
Suggest another program	5d – Truncated Normal Distribution
Perform admission tests	10d – Truncated Normal Distribution
Perform interview	5d – Truncated Normal Distribution
Request learning method	5d – Truncated Normal Distribution
Send enrolment fee payment request and honor declaration	1d – Truncated Normal Distribution
Request enrolment fee	5d – Truncated Normal Distribution
Request honor declaration	5d – Truncated Normal Distribution
Issue acceptance letters	1d – Truncated Normal Distribution

Sign acceptance letters	3d – Truncated Normal Distribution
Request tuition fee	5d – Truncated Normal Distribution

Table 26 - Activities Cycle Times

Process analysts calculated gateways' activation probabilities based on the data collected from SUPERNOVA and team inputs:

Data	Value / Probability (calculation)
Application fee paid	Yes: 47% ; No: 53%
Application elements fulfilled	Yes: 79% ; No: 21%
Application approved	Yes: 77% ; No: 23%
Suggestion accepted*	Yes: 77% ; No: 23%
Following advance Math	Yes: 28% ; No: 72%
Math test performed	Yes: 15% ; No: 85%
Approved in admission test	Yes: 49% ; No: 51%
Interview performed	Yes: 17% ; No: 83%
Approved in the interview*	Yes: 77% ; No: 23%
Learning option selected	Yes: 40% ; No: 60%
Enrolment fee paid	Yes: 57% ; No: 43%
Honor declaration received	Yes: 43% ; No: 57%
Tuition fee paid	Yes: 26% ; No: 74%

Table 27 - Activation Probabilities

* Extrapolated value (as it was not possible to calculate probability based on the available data, it was assumed the "Accepted" ratio).

Based on the data obtained in the process discovery (3.2), it was possible to observe that at a given time (fifth month of application period), the Work in Progress (WIP) was 232 applications of 267 applications for another application period (Spring' 23). Process Cycle Time can be calculated knowing Mean arrival time and WIP from Little's Formula:

$$CT = \frac{WIP}{\lambda} = \frac{232\ applications}{1{,}78\ app./day} = \mathbf{130}\ [\boldsymbol{days}]$$

Based on the inputs given by SUPERNOVA team (Table 26 and Table 27), the estimated Cycle Time is:

$$CT = \frac{12}{(1-0{,}47)} + \frac{2}{(1-0{,}21)} + 1 + (0{,}38 \times 5) + (0{,}28 \times \frac{10}{(1-0{,}85)}) + (0{,}51 \times 5) + \frac{5}{(1-0{,}83)} + (0{,}77 \times \frac{5}{(1-0{,}6)}) + 1 + \max(\frac{5}{(1-0{,}43)}; \frac{5}{(1-0{,}29)}) + 1 + 3 + \frac{5}{(1-0{,}86)} \Leftrightarrow$$

$$CT = 22{,}64 + 2{,}53 + 1 + 1{,}9 + 18{,}67 + 2{,}55 + 29{,}41 + 9{,}63 + 1 + 8{,}77 + 1 + 3 + 35{,}71 \Leftrightarrow$$

$$CT = \mathbf{137{,}81}\ [\boldsymbol{days}]$$

Assessing data quality of the data set against the estimates given by the process analysts, for accuracy dimension (DAMA UK Working Group, 2013), we achieve 94% of accuracy of Cycle Time, which allow to have a good degree of confidence in the data set:

$$Data\ Quality\ Accuracy = \frac{130}{137{,}81} = \mathbf{94{,}3}\%$$

Processing time can also be calculated based on the process analysts estimates:

$$CT = \frac{1{,}2}{0{,}9} + 0{,}5 + \frac{2}{0{,}62} + \frac{1}{0{,}93} + 0{,}25 + 1$$

$$CT = 1{,}33 + 0{,}5 + 3{,}23 + 1{,}08 + 0{,}25 + 1 = 7{,}4\ [days]$$

With cycle time and processing time, the process efficiency is:

$$CT\ Efficiency = \frac{7{,}4\ days}{130\ days} = \mathbf{5{,}7}\%$$

The cycle time value can give process analysts valuable insights regarding process efficiency, which in this specific case is very low due to very long holding times.

One should have in mind flow analysis limitations since this technique has no support for probability distributions and only works with structured models and fixed arrival rates.