Research Article

Process Managing the Study Abroad Experience: An Innovative Framework

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Abstract

In the fast-changing business landscape, the challenge to emulate breakthroughs to improve process efficiency and productivity while increasing organization value has become a priority of most organizations. Ultimately, the aim is to meet business objectives, staying competitive by building the worth of organizations to its customers, while minimizing costs. Managing business processes effectively has been a prime objective to maintain competitiveness and sustain peak performance, which can be improved by leveraging innovative technologies. Such technologies can include artificial intelligence (AI) and algorithms in machine learning (ML), while amalgamating business processes to provide a sophisticated form of optimization and visualization for identifying inefficiencies, enhancement opportunities and measuring the effectiveness of implemented business process improvement initiatives. This study generates a novel conceptual framework using a Business Process Management (BPM) solution by adopting AI and ML algorithms in the higher education sector. The scenario in this paper is a student study abroad application cycle of an Australian university. Leveraging ML and AI data driven decision and process mining capabilities to develop a novel BPM framework will lead to a university's strategic process improvement becoming more profitable, cost-effective and trustworthy, thereby enhancing the value of the organization and improving a student's international mobility experience.

Keywords: international education, business process management, process mining, business intelligence, process improvement.

Introduction

Recent advancement in technologies around artificial intelligence, machine learning, blockchains, the Internet of Things (IoT) and distributed systems affect how organizations execute and design business processes (Mendling *et al.,* 2018). Processes are perennial in any organization, enterprise, or business (Bandara *et al.,*

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2007). Effective implementation of Business Process Management (BPM) utilizes processes as a critical link to recent technologies to translate strategy into execution, while delivering sustainable value to an organization (Franz & Kirchmer, 2015). At the same time, the fundamental purpose of conventional BPM is to lower costs and produce more efficient processes (Harmon & Tregear, 2016). Concurrently, a new BPM wave is evolving to deliver business agility, an improved customer experience and digital automation (Kalmijn, 2019), which can foster regulatory compliance, risk mitigation, business continuity and sustainability (Harmon & Treager, 2016). Finally, advancements in machine learning, artificial intelligence and distributed systems can and will influence the design and business process execution of organizations in the future (Mendling *et al.,* 2018).

Through BPM, the entire cross-organizational value chain has the capacity for innovation to transform businesses continually (vom Brocke & Rosemann, 2014). BPM is a discipline where a variety of methods are used to identify (Dumas *et al.,* 2018), model, analyse, measure, and transform processes, improve inefficiencies, optimize, automate and even eliminate manual processes (Jeston *et al.,* 2008). Most business process definitions relate to business goals and value creation (Heindel &Weber, 2020). Copious quantities of data in organizations enable low level event data to be analysed using process models as a 'lens', which aids organizations to understand and solve performance and compliance related problems (vom Brocke, & Mendling, 2018). Data sources have also broadened with widespread adoption of mobile or portable devices such as smart phones, smart watches, or tablets (Bachiller *et al.,* 2018). In the business-IT divide, process enforcement technologies are widely acknowledged to have the capability to embrace the so-called "missing-middle" (Davenport, 2019). As technology develops, it can become overly complex (Kiela *et al.,* 2016), however, process-aware information systems (Kalenkova, 2017), or process mining providing holistic insight into actual processes allowing inefficiency

identification and uncovering of effort drivers, represent some of the most innovative digital tools supporting the digital transformation of a company (Reinkemeyer, 2020). Event data's omnipresence in combination with process mining capabilities enables organizations to diagnose a problem, not from fiction but facts (van der Aalst, 2016). Companies such as Walmart, UPS, and Uber leverage technology to create new profitable business models, which is one area where technology has the ability to improve performance without humans (Davenport *et al.,* 2019).

For a company to reap the benefits of BPM, it is vital a firm outlines the business drivers, articulates its process scope, and sets clear goals on deployment strategies. Likewise in the Australian higher education context, several substantial issues are emerging as higher education increasingly becomes diverse, complex, financially challenged and internationally dependent (Brett *et al.,* 2017). A high level of consensus in shared governance is the most important issue in most academic organizations, while international rankings, technology transfer, student accessibility, declining federal budget support and student financial aid are just some of the other issues identified. Regardless of which Australian university lobby group membership - the Group of Eight (Go8), the Australian Technology Network (ATN), the Regional Universities Network (RUA), the Innovative Research Universities (IRU) or the non-aligned, they all share key characteristics (Brett *et al.,* 2017) - namely sector leaders need to explore options to reposition institutions into new disruptive business models (Cawood *et al.,* 2017).

Australian Higher Education

The main drivers of the Australian economy are the healthcare, finance, and higher education sectors (Labour Force Australia, 2020), where higher education forms the focus of this study. In Australia's economy, education serves as a central pillar, being the heartbeat of communities with a major contribution socially, economically, culturally, and intellectually (Brett *et al.,* 2017). Over the last three decades,

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Australian universities have experienced significant changes and are at a pivotal time of evolution and development (Brett *et al.,* 2017). However higher education has around 70 years of reported success, such that it has become complacent to change (Fitzgerald *et al.,* 2013). A commitment to research, comprehensive course offerings and a high number of enrolments represent an expensive way to deliver higher education (Cawood *et al.,* 2018), hence no Australian university can survive 2025 with the current business model (Brett *et al.,* 2017). The education sector employs 8% of Australian workers and was the largest service export with total earnings of $20.3 billion in 2015/2016 in international education. The higher education sector alone contributes $30 billion to the country's Gross Development Product (GDP). In the Times Higher Education (THE) world rankings, thirty-five Australian universities feature, with six in the world's top 100 (Cawood *et al.,* 2018). In sixty-six years, student numbers increased from around 31,000 in 1949 to 1.4 million in 2015 (Brett *et al.,* 2017).

In the past three decades, major developments have focused on three fundamental academic functions of the university - research and knowledge generation, teaching and learning dissemination, and outreach and engagement (Brett *et al.,* 2017). People in Australia are reasonably innovative, however models that work in the UK, the Netherlands or elsewhere in Europe, may not be applicable here because the level of industry investment is simply not present (Brett *et al.,* 2017). One of the greatest opportunities to strengthen the Australian system is through international partnerships. While the UK and the US are two strong traditional partners, China, Germany and even India have great potential to be transformative for Australia. The growing desire of the current generation in undergraduate learning is a practical experience involving partnerships or service-learning opportunities and to be work ready. Higher education has become a global market; hence the international mobility of students is something university leaders grapple with. Australia is too small not to be international (Brett *et al.,* 2017),

hence a major focus is on expanding partnerships globally.

Aims And Objectives

The focus here is an international education study abroad application that has been proven to be one of the key influencers of a higher employability rate of graduates. The problem here is to formulate a novel conceptual framework for a study abroad application process, where establishing process performance is the core target, while identifying the best process scenario to be adopted in an application cycle. In the study abroad application process, several challenges hinder the smooth flow of the process and a quality student experience. Some of the parameters are a need to lodge an application one year before the actual overseas trip; the process requires several documents; there exists a low conversion rate of actual acceptance; a complex eligibility assessment process; a lengthy academic credit application; a complicated host institution application process; and an intricate pre-departure orientation. Hence there is an increasing need to optimize the process to achieve efficient applications, improve the student experience and achieve the organization's strategic aim to send 50% of students overseas for international education to strengthen employability upon graduation. Given the complexity of the existing process, traditional modelling takes longer to create, impeding analysis and improving the following application cycle. Additionally in the study abroad team, there exist different roles where salary varies. In a study abroad application in a 35-hour work week are 5 Exchange Advisers with a rate of $45.00/hour ($7,875.00/week) and 2 Exchange Coordinators at $52.00/hour ($3,640.00/week). Given an estimate of 20% process improvement, the annual estimated savings would be $118,300.00. Optimizing the process means resources can be re-allocated to higher value work, reducing process overheads. For students, the study abroad application process will be faster, resulting in a better student experience because of a quicker turnaround time. Hence the research questions posited here are:

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RQ1: How do ML and AI-based BPM frameworks vary from conventional business process management solutions in higher education, specifically in the study abroad process in terms of reliability, profitability, cost-effectiveness, and trustworthiness?

RQ2: What are the pre-requisites in using data-driven and process mining capabilities of ML and AI to effectively implement BPM frameworks in the higher education study abroad process?

The goal here is thus to create a novel conceptual BPM framework enabled by artificial intelligence (AI) and machine learning (ML). For AI in process mining to work enterprise wide, special techniques, methods, tools, and process form pre-requisites (Akirraju *et al.,* 2020); however recent breakthroughs in process mining enable process miners to uncover a process model automatically. Conformance to a process can be discovered through a predefined algorithm as to whether a process is reflected in the data, whilst uncovering deficiencies in performance, such as bottleneck detection (Schuster *et al.,* 2020) to enhance business processes (van der Aalst, 2016) through gaining insights relating to the actual performance of these processes (Augusto *et al.,* 2019). In this study, the event log from a study abroad application is used to analyse an end-to-end process, which is optimized to achieve the organizational target by improving the student experience through streamlining, removing bottlenecks and the adoption of the best possible process scenario to create an ideal process. The AI and ML novel BPM framework will be used after each study abroad application cycle to evaluate the process of a previous cycle and continuously improve the following cycle. Some of the distinct characteristics of the novel framework aims are its performance-based focus, rapid turn-around and output process-centric capabilities, that are not possible in the existing BPM lifecycle models.

Business Process Management

BPM is now considered a practice in organizations using numerous methods to design a process, perform analysis, measure performance, enhance inefficiencies and transform business processes. BPM is also a systematic approach to achieve coordinated and sustainable organizational goals that capture, shape, execute, document, measure, monitor and steer automated and non-automated processes (Paschek, Luminosu & Draghici, 2017), integrating people's behaviour, systems, information and entities that produce a business end result to uphold business strategy. Although optional, technologies are generally used in conjunction with BPM, as a crux to developing business strategy (Gartner, 2014), where process support in a wider perspective incorporates analysis such as simulation, verification, and process mining (Weske, 2012). BPM refers to comprehensively improving and managing an organization's end-to-end integrated enterprise-wide processes, to meet the fruition of three elements critical to performance-based goals driven by customer firms, which are to clarify strategic objectives, align resources and enhance regulation of day-to-day operations (vom Brocke *et al.,* 2017). BPM also enables the identification of problems visually in processes and enables businesses to elucidate business processes improvements and testing prior to implementation. Several value-driven capabilities that BPM delivers throughout the organization are: improvements in cost, productivity and quality, accelerated timelines, improved customer service levels and satisfaction, simplified business processes to drive efficacy and agility. BPM also supports improved risk management and helps achieve compliance, better governance, an enhanced visual perspective on the performance of an organization, reduces costs and improves revenue streams (Rock *et al.,* 2014).

The BPM lifecycle is considered to comprise six processes, namely identifying target processes, task discovery through qualitative or quantitative analysis, conducts process transformation, changes implementation and monitors and controls

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(vom Brocke *et al.,* 2017; Dumas *et al.,* 2018). At the same time, advancements in ML, AI and distributed systems, will likely influence the design and business process execution of organizations into the future (Mendling *et al.,* 2018). The BPM lifecycle includes extensive options of process change frameworks such as Lean (Modig & Ahlstroem, 2019), NESTT, Six Sigma, TQM (Total Quality Management), CPI and CPM and SOX compliance legislation (van der Aalst, 2016).

BPM has evolved and is now in its third wave. The first wave was conceived in the 1920s and summarized in the theory of management by Fredrick Taylor, where process management was considered an analytical method and procedure. The second wave specifies what manual reengineering of processes can do through one-time activity. The third wave is the on-the-fly creation capability of optimizing redesigned business processes in the organization (Smith & Fingar, 2003). The principal purpose of conventional BPM is to minimize costs and produce more efficient processes. A new BPM wave is evolving to deliver business agility, customer experience and digital automation (Kalmijn, 2019). Another level of business process management is hyper-automation, a business-driven disciplined approach rapidly identifying, automating, and vetting as many business processes as possible. An example of hyper-automation involving the orchestration of technologies, tools and platforms involving AI or ML, includes robotic process automation (RPA), event driven software architecture and iBPMS (Kazamouzis & Stoudt-Hansen, 2020).

Research Model

Our initial step was to conduct qualitative analysis incorporating literature including case studies on the topic of process mining to solve business problems. In qualitative research, the method is inductive. Concepts are created and measured simultaneously within the data gathering process (Neumann, 2014). This step commenced with a survey of academic literature of different case studies from 2016 to 2020 covering process automation applications in BPM and process mining incorporating AI

and ML. The analysis covered process mining applications found in books, conference papers, journals and unpublished papers, with a focus on peer reviewed publications. Filters used included the keywords 'process mining', 'BPM', 'business process management', 'process discovery', 'conformance checking', 'process reengineering' and 'process monitoring'. Every article gathered provided insights on commonly used methodologies, tools or even frameworks.

The result of the data analysis was then used to conceptualize a framework. The initial step was filtering, and screening peer reviewed papers based on the content of the abstract, conclusion, and introduction. An additional prerequisite was that the paper be written in English and cover BPM applications of a specific organization. The next step was to filter papers concerning the specific application of BPM, process mining or process automation. Some 40 papers were selected - all peer reviewed and may be seen after our reference list. Of the 40 papers, 31 comprised book chapters discussing how business process management was used to solve a specific industry problem. The remaining 9 case studies were peer reviewed conference papers in management. The case studies excluded those not covering process management or process improvement initiatives. NVIVO 12 software was used for analysis, where deductive coding was applied to the content of the papers. Codes or nodes were uncovered and labelled as: Process Analysis, Process Discovery, Process Identification, Process Redesign, Process Monitoring and Control and Process Implementation. The steps taken in the qualitative analysis are illustrated in figure 1. As we sought to develop a model, we incorporated design science research (DSR) with its focus on artefacts as an output of the research process. Next, we briefly elaborate on the BPM case studies analysed, then discuss our design science approach to develop the framework for this paper.

BPM Lifecycle Case Studies

Again, qualitative analysis of peer reviewed BPM Case Studies across different

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industries was conducted. Thirty-one papers were BPM cases (vom Brocke & Mendling, 2018) in digital innovation and business transformation in practice, and an additional nine cases were BPM focused papers. The BPM lifecycle activities - process identification, discovery, analysis, redesign, implementation and monitoring and control (Dumas *et al.,* 2018) were the focus of each case study where details may be found in appendix 2 table 2.1. The NVivo 12 software was used to perform cluster analysis and hierarchical visualization as shown in figure 2 [A] and [B]. In process discovery, several methods can be adopted to capture the current condition of the business process of the organization as illustrated in figure 3 [A]. There exist various methods ranging in different levels of abstraction. Automated process discovery is an emerging approach. Other methods include event driven process chains, process architecture or object-oriented BPM, while other organizations leap directly to the process redesign phase. The main goal observed in most of the case studies was to improve the business process. It is also notable that there are varying models and frameworks adopted to achieve this target. In figure 3 [B], a summary of these frameworks, models and methods is mapped in the spectrum of business process redesign, which shows while most organizations trend towards analytical and transactional methods, there are cases exploring transformational and creative methods and more innovative approaches.
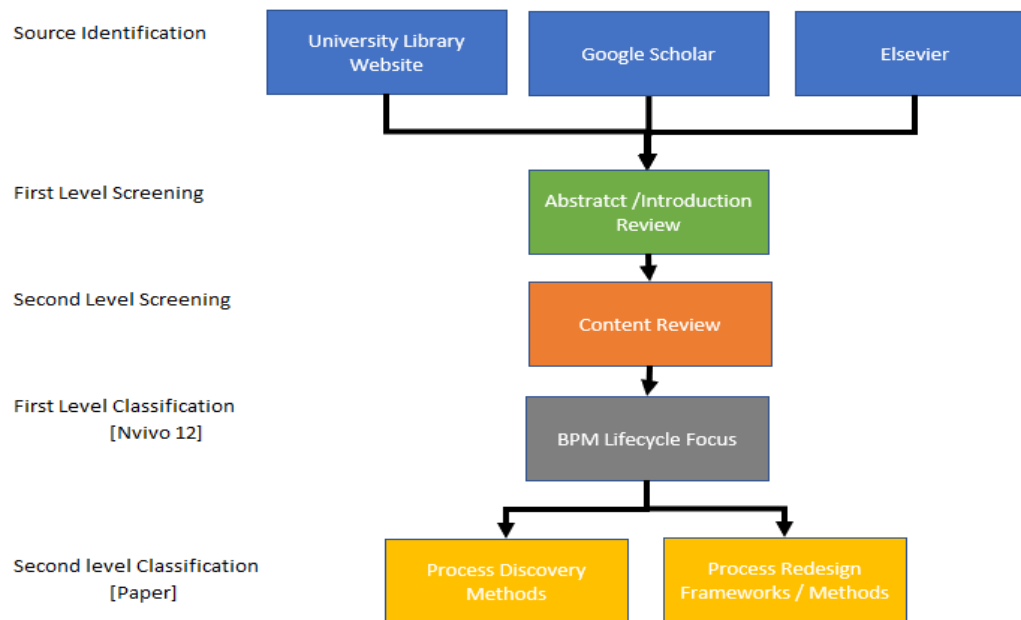
Figure 1: Qualitative Research Flow of BPM Case Studies

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[A]   [B]
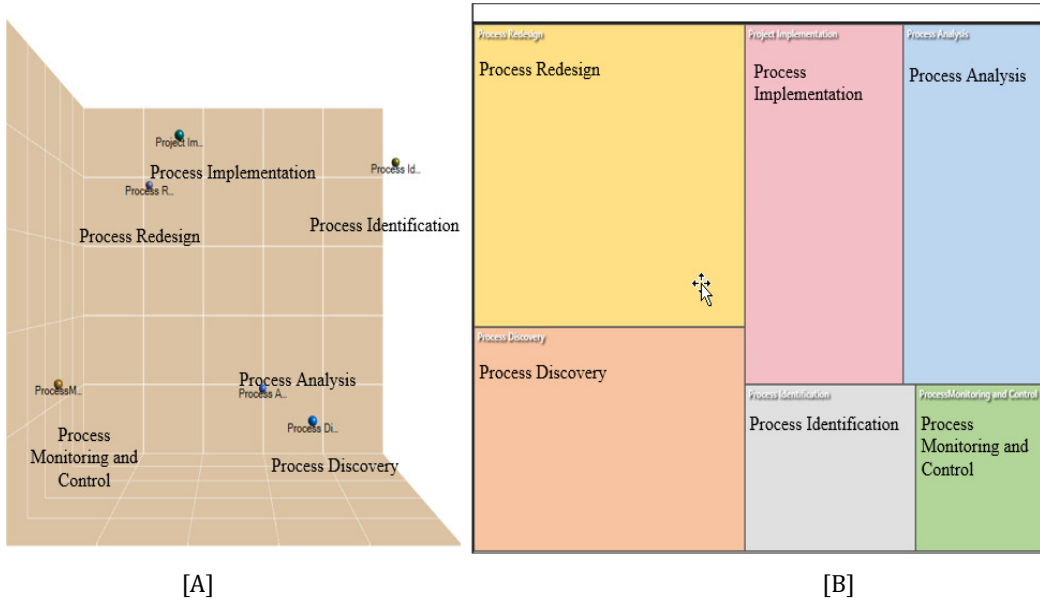
Figure 2: Case Study Analysis [A] and a Cluster [B] Hierarchical Chart using Nvivo 12

Design Science Research

In seeking human knowledge enhancement through the creation of innovative artifacts, design science research (DSR) seeks to enhance science and technology knowledge foundations through the creation of innovative artefacts that solve problems and enhance the environment in which they are instantiated (vom Brocke *et al.,* 2020). A design artefact can be used to address the quality model and external and internal metrics including quality-in-use metrics (Pries-Heje, Baskerville & Venable, 2008). Six steps are involved in DSR: identifying the problem and motivation, defining the objectives for a solution, analysis for design and development, demonstration, and evaluation (vom Brocke *et al.,* 2020).

[A]   [B]

Figure 3 [A] and [B]: Frameworks Adopted for Process Redesign (40 Case Studies)

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It is through design science research that procedures, principles and practices provide a nominal process model to provide researchers with a road map. In DSR motivating, designing, developing, demonstrating, communicating, and evaluating the artifact should be consistent (Peffers *et al.,* 2007), where motivating and designing is the initial phase. Developing, dem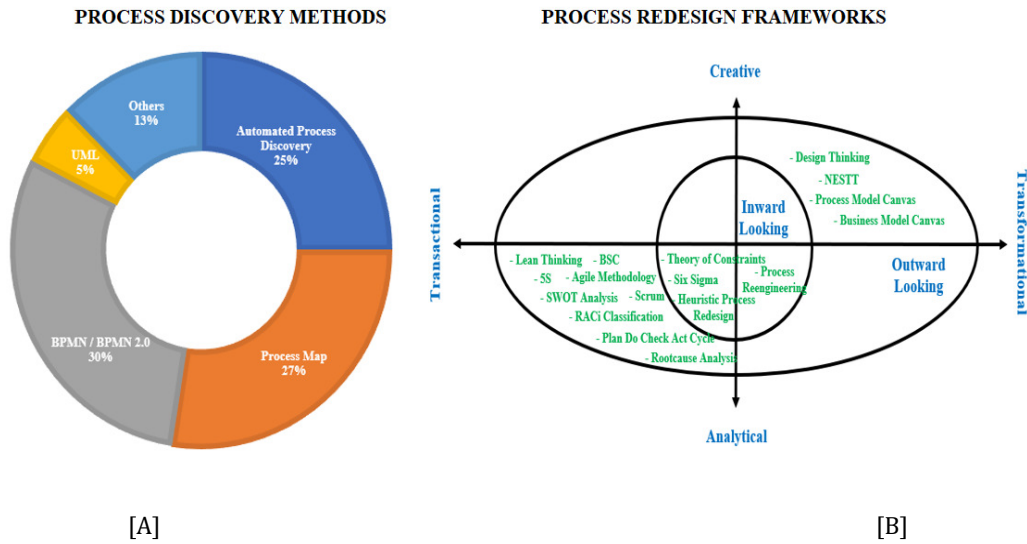onstrating, and communicating is conducted in the analysis and evaluation phases. Research questions generally evolve around increasing the operational metrics vis-à-vis novel design artifacts (Gregor & Hevner, 2013). Examples of design science research methodology in Information Systems (IS) can also be seen in Baskerville & Vaishnavi (2020) to create a novel approach for benchmarking performance data, and in Winter & Aier (2020) for developing evolution paths for enterprise-wide information systems (e-wIS) using BPM for better quality management (Becker *et al.,* 2020). In this study, we create a novel conceptual framework to introduce a solution to business problems in international education, specifically in the study abroad business process.

DSR played a significant role in performing activities in this study. During the *initialization* phase for gaining data for extraction, event log data were exported from a process aware information system. In the *analysis* stage, preparation was a critical step to choose data to be removed from the event log. At this stage, business rules were established. In the *process discovery* stage, different algorithms were used to explore the most logical process model. The succeeding step was *conformance checking*, where accuracy of process models generated was measured and validated through a fitness of the model. Finally in the *evaluation* and *performance,* checks of the different metrics in the process model were generated. Through

DSR, the following significant activity was identified: [1] relevance of performance metrics, [2] effective utilization of process aware information, [3] capability of AI/ ML enabled software, [4] process model extraction in the event log, and [5] identification of process improvement areas. A research framework was then conceptualized (figure 4). In process mining, the fundamental activities are automated process discovery, conformance checking and process enhancement (van der Aalst, 2016). It is through these categories that mining will ensure the model generated is sound, fit, precise, simple, and general, which are the main check items when using an automated process discovery tool. These five features will be measured during conformance checking, where each of the check items is simulated and their performance evaluated. The enhancement step is when process reengineering takes place, as it is conformance checking that enables the identification of bottlenecks in a process and the waiting time between activities which serves as the basis for enhancements.

Process Scenario

Let us now turn our attention to the scenario in this paper. The high-level process architecture of a study abroad application covers the core, support, and management process. The core processes include activities and the student administration team of a student study abroad application (figure 5 and 6). Management processes are responsible for strategy development, partnerships, funding, and internal stakeholders to achieve a study abroad university target, while support processes including systems and application support and business intelligence reporting for oversight on the progress on different projects across the team.

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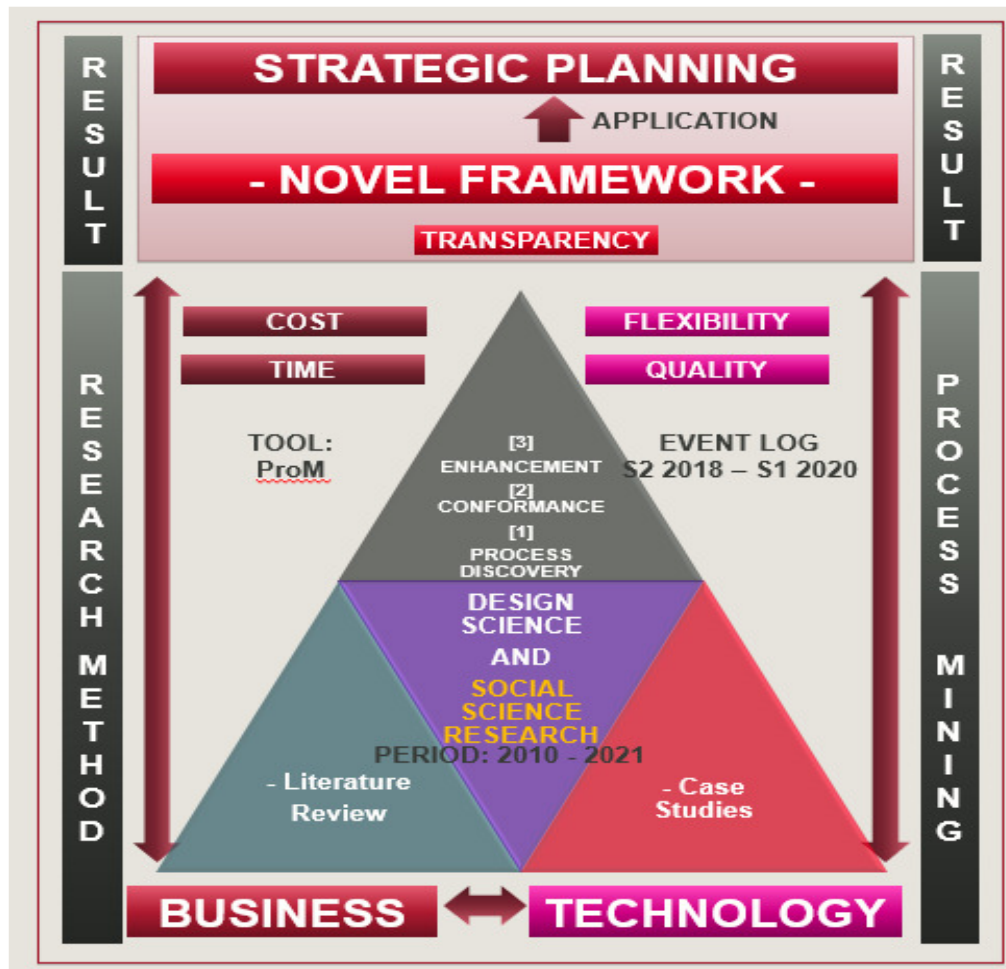
Figure 4: Research Model

Due to the level of abstraction of a process architecture, business processes can be difficult to share, hence it is imperative to construct process models based upon the process architecture as perceived by the modeller (Dumas *et al.,* 2018). Process models can be created through different modelling languages, such as Event-driven Process Chains (EPCs), Petri Nets and Business Processing Modelling Notation (BPMN) (Ishak & Choudhary, 2019). Petri nets are the earliest and most studied process modelling language allowing concurrency, simplicity, and an intuitive graphical notation. However, the longest-established language to model business processes is BPMN (van der Aalst, 2016). The activity to gather and organize information of existing processes and constructing the "As-Is" process model is process discovery. It has been proven that process discovery is a ponderous, tedious and time-consuming practice (Dumas *et al.,* 2018). It is during this phase that a comprehensive depiction of current business processes is specified as an "As-Is" process model (vom Brocke & Mendling, 2018). Figure 6 illustrates the high-level "As - Is" process model of the core processes as shown in figure 5, using BPMN. More detailed process figures are shown in appendix 1 (figures 1-1 to 1.4).

The "As-Is" business process model of a study abroad application is initiated through an information session with the student, organized to discuss the study

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abroad application process, the requirements, time lines and concerns the student may have (table 1). Application forms which include questionnaires, learning and signature contents are then submitted. Eligibility of the student is then assessed based on a weighted average mark (>50), progression status (a pass progression) and total completed credit points (>24 CP). All eligible students are forwarded to student administration for another assessment which includes available elective units in the course or endorsement from faculty.
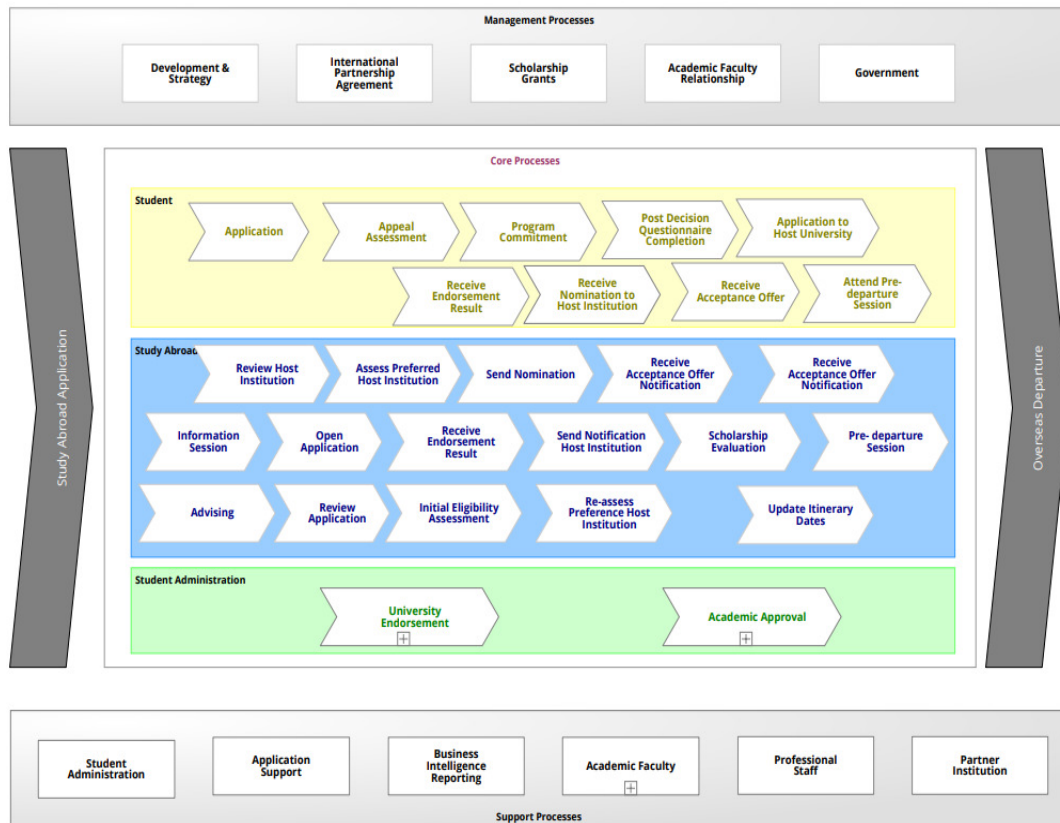
Figure 5: High Level Process Architecture of Study Abroad

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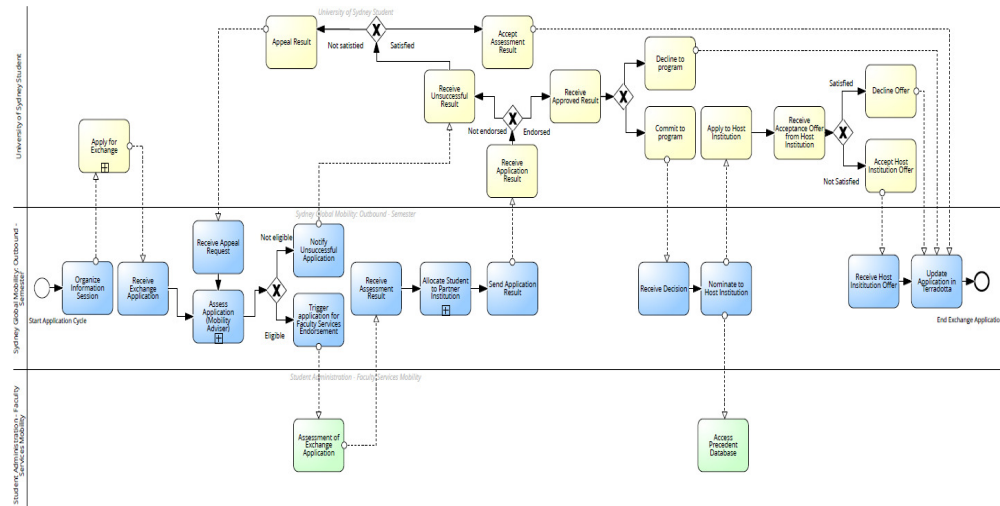
Figure 6: High Level Process Model of a Study-Abroad Application

When the student is endorsed, the study abroad team will then continue the assessment, nominating the student to the specific host institution. Students will apply to a host institution website. When students receive the acceptance letter from the host institution, the status in the study abroad application is changed to 'Accepted to Host Institution'. An exception process occurs when a student appeals for a failed exchange eligibility, whereupon a preferred host institution is considered as a variant in the ideal process model. Domain knowledge is often held by different stakeholders (Korherr, 2008). In most cases, three different staff are knowledgeable – a process analyst, a subject matter expert and the process owner. The various process discovery methods employed as a guide to gather information are evidence, interview, and workshop process discovery.

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Table 1: Steps in the Study Abroad Process (full list in Appendix 1 Table 1.1)

Main Task	Sub Task	Step	Performer	Classification
Organize Information Session				
		Create schedule for Information Session	Coordinator	BVA
		Confirm Information session schedule with the team	Coordinator	NVA
		Post Information Session in Study Abroad System	Media Officer	VA
Received Exchange Application				
		Confirm latest release schedule of academic results	Coordinator	VA
		Confirm students for late exams exceptions	Coordinator	NVA
Assess Application - Eligibility Criteria		Check enrolment status of the student in Student Information System	Coordinator	BVA
	Check Dual Enrolment	Open Study Abroad System	Coordinator	VA
		Search student exchange application	Coordinator	VA
		Check student profile in Study Abroad System - Student ID Course field	Coordinator	VA
	Confirm Course for Credit	Check course to credit exchange in Study Abroad System student application	Coordinator	VA
		Verify suitability of course for credit in exchange application	Coordinator	VA
	Update Course in Study Abroad System	Copy Student ID Course student profile in Study Abroad System	Coordinator	NVA
		Paste Student ID Course in Student Details questionnaire in Study Abroad System	Coordinator	NVA
	Start Academic Quals Assessment	Open Sydney Student Information System	Coordinator	BVA
		Open Progression Register of the student in Student Information System	Coordinator	BVA
	Check Progression	Verify student progression status in Student Information System	Coordinator	BVA
		Note student progression status in Student Information System	Coordinator	BVA
	Check WAM (Weighted Average Mark)	Open the exchange application in Study Abroad System	Coordinator	VA
		Check the student profile WAM field in Study Abroad System	Coordinator	BVA
		Note student WAM (>= 50 : Eligible for exchange / < 50 : Not eligible for exchange)	Coordinator	BVA

Data Collection

The set of data for process discovery was an event log from a study abroad application, anonymized and converted to XES using ProM Lite 1.3 software containing mandatory columns such as activity ID, activity name and timestamp. The parameters included the following:

1. Activity identification is a numeric field referring to each case in the record set.

2. Activity name is a text field describing the activity or event.

3. Activity timestamp is a text field containing a date and timestamp when the activity execution ended. The column format is "DD-MM-YYYY HH:MM: SS".

4. Resource column is a text field referring to the resource identifier performing the activity; this field has been converted to an equivalent role in the organization for anonymity purposes.

The study abroad application is a cloud-based platform used by students applying to study overseas and the staff that manage the application. The history log records all activities performed in the application from the creation of the application, acceptance by the overseas host institution while abroad and the return phase. In this research, the data are from application creation until acceptance by the host university only - and do not cover activities onwards since these activities have minimal added value in the business process. The source of the event log used is the

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application process of the study abroad application capturing the end-to-end

lifecycle of the student application, as illustrated in figure 7.

Figure 7: Status Transition of Study Abroad Application

The data were from 2018 semester 2 until 2020 semester 1 for semester applications, as well as the winter and summer semester 2018 - 2019 short-term cohort. These data were selected because study abroad applications use commenced last 2018 S2, so a complete application cycle started from 2018 semester 2 and contained a complete history log. While historical data before 2018 semester 2 only contain 1 record per student for tracking purposes. Furthermore, the study abroad program is

on hold from 2020 Semester 2 because of the COVID-19 pandemic, while we await Australian government permission to lift travel restrictions. The details in table 2 below represent the summary of data used. The quality of data selected requires reformatting of activity names as there exist irrelevant events, while concept drift, time and date are in separate columns and need to be concatenated into one column, as required by the software (ProM Lite 1.3).

Table 2: Events and Cases Summary of Study Abroad Event Log

Term	TOTAL		2018		2019		2020	
	Cases	Events	Cases	Events	Cases	Events	Cases	Events
Semester 1	634	6245			353	3573	281	2672
Semester 2	798	8372	409	4059	389	4313		
Year (S1 + S2)	32	365			27	287	5	82
Year (S2 + S1)	517	747	45	472	25	275		
Short-Term Winter	683	3542	200	912	483	2630		
Short-Term Summer	611	2716	234	846	377	1870		

Process Reengineering

With novel digital technologies, existing frameworks are challenged to adapt to the socio-technical impact on individual behaviours, collaborations at the intra and inter-company level, and the need for including automation (Kerpedzhiev *et al.,* 2020). The typical "As-Is" process model can be analysed with qualitative and quantitative methods to identify redundant process steps through value added analysis, examining the origin of waste through

waste analysis. Value added analysis involves task decomposition into steps. The step is then analysed and can classify a positive outcome as Value Adding (VA). Steps necessary to the organization, but providing no gain to the customer, may be classified as Business Value Adding (BVA). Steps not belonging to either VA or BVA become Non-Value Adding (NVA) (Dumas *et al.,* 2018). The value-added analysis and classification of steps for the study abroad process is shown in appendix 1 table 1.1 and

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the excerpt is shown in table 3 below. Waste analysis is the antithesis of value-added analysis and traces steps to identify waste which can be through a specific step or the entire process. Taiichi Ohno developed the Toyota Production System or TPS in the

1970s. One of the key techniques is the reduction of *muda* - meaning waste in Japanese. The concept is to find waste based on categories involving move, hold, and overdo in the process handoffs (Dumas *et al.,* 2018)

Table 3: List of wastes identified from a Study Abroad Process

Categories	Sub - category	Waste
Move	Transportation	Student appeal for the assessment result
		Student appeal for the endorsement result
		Number of email received by students can be confusing
		Use spreadsheet to list student application
	Motion	Changing of Adviser handling the student application
Hold	Inventory	Large number of students decline program
		Large number of students decline host institution offer
	Waiting	Waiting for Student Administration to endorse students
		Waiting for students doing late exams to verify eligibility
		Delayed information from students on notifying host institution acceptance offer
Overdo	Defect	Allocated host institution is not accepted by the student
		Incorrect endorsement of Student Administration
		Request on nominated host institution
	Over - processing	Exchange adviser has to go through 3 preferences if top 2 preferences are not available / suitable
		Accepts application for both Semester and Year terms but just withdraw
		Withdrawn application after nomination
	Over - production	Student never went on exchange after it was accepted in host university
		Student came back after few days overseas due to health issues
		Student came back after few days overseas due to natural disaster concerns

Figure 8 illustrates the revised process model which includes additional data such as cycle time, branching probability and processing time as a sample business process, resulting in total 64.14 of days for the cycle time for study abroad process

from the first to last process. In cases where the overall processing time would be relative throughout the cycle of the process, table 4 summarizes the cycle time in the activities of the Study Abroad team with their estimated cycle and process times.
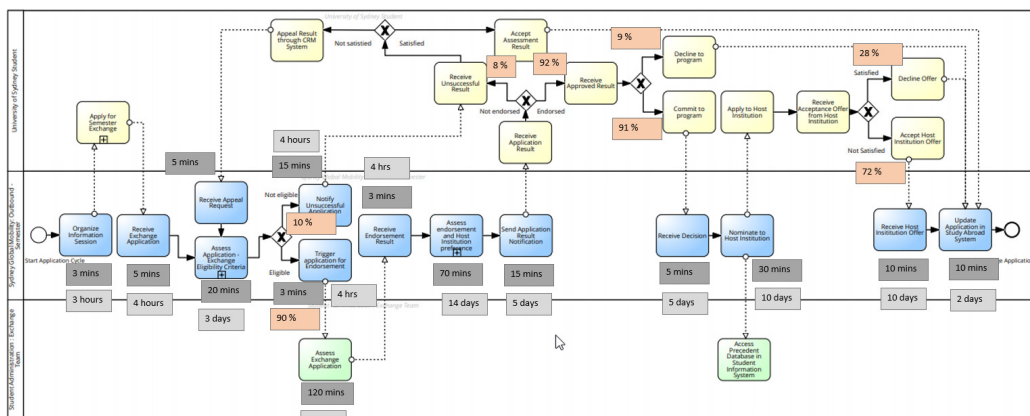

Figure 8: Study Abroad Cycle Times, Processing Times and Branching Probability

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Automated Process Model

Recent breakthroughs in process mining enable organizations to automatically discover process models and analyse conformance as to whether the process is reflected in the event log. Detection of deficiencies in performance such as bottlenecks (Schuster *et al.,* 2020), improved business processes using event data (van der Aalst, 2016) and the extraction of insights regarding the actual performance of these processes (Augusto *et al.,* 2019), are also possible.

Table 4: Summary of Cycle and Processing Times for the Study Abroad Process

Task	Cycle Time (Minutes) CT	Processing Time (Hours) TCT	Process Efficiency CTE
Organize Information Session	3	3	1.67%
Receive Exchange Application	5	4	2.08%
Assess Application Exchange Eligibility Criteria	20	21	1.59%
Notify Unsuccessul Application	15	4	6.25%
Trigger application for endorsement	3	4	1.25%
Receive Endorsement Result	3	4	1.25%
Assess Endorsement and Host Institution	70	35	3.33%
Send application result notification	15	70	0.36%
Receive Student decision	5	35	0.24%
Nominate to Host Institution	30	70	0.71%
Receive Host Institution offer	10	70	0.24%
Update Application in Study Abroad	10	70	0.24%

Process mining evolves around business process improvement in a data-driven way (Apromore, 2020), and is a process management approach allowing analytical understanding of business processes based on digital traces captured in event logs (Reinkemeyer, 2020) to extract information (Schuster *et al.,* 2020). An event log contains traces with timestamp-encoded activities undertaken for the execution of a corresponding process (Schuster *et al.,* 2020) or collation of events to execute a business process, where every event refers to a specific activity taking place at a specific timestamp allocated to a unique case (Reinkemeyer, 2020). As a minimum requirement, an event log includes a numeric identifier such as a case ID specifying the 'activity' taking place at a precise time - i.e., a 'timestamp' of every activity (Reinkemeyer, 2020).

In this digital age, AI is an emerging transformational technology (Chu *et al.,* 2018). The promising capability of ML and AI for prediction in conjunction with process mining results in accurate prediction of erratic processes (Welsing *et al.,* 2020), capable of automatically spotting business process deficiencies and uncovering root cause of issues, while delivering intelligent decisions to enhance process misapplications (Veit *et al.,* 2017). Adopting ML techniques provides consistency, robustness, and precision in predicting convoluted relationships of process sequences, features, or business case characteristics (Mehdiyev, Evermann & Fettke, 2020). Furthermore, explainable AI (XAI) lays the bedrock for prescriptive decision analysis in process mining to mitigate impediments in a data-driven business process intelligence for a significant added value in the organization (Mehdeyiv & Fettke, 2020).

It is process mining that can bridge the gap between analysis of conventional model-based process and data-centred analytical approaches such as ML and data mining.

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Process mining is not constrained to process discovery of tightly coupled event logs, which makes it viable to confirm conformance, predict delays, deviation detection, substantiate decision making and prescribe process redesign. Process mining techniques, contrary to inactive process models, breathe life into today's substantial data volumes (van der Aalst, 2016). Discovery uses event logs to construct a graphical illustration of the business process where outcomes are typically a process model, which can either be a classic Petri Net, widely used BPMN, or UML Activity diagrams, and can even be a social network. Conformance relates to the correlation of the event log and actual business process model. Lastly, enhancement identifies improvement points, by utilizing information generated in the event log. Discovered models are a calculated abstraction of real processes, usually focusing on various points of view such as control flows of tasks, data flow of activities, time, resources utilized, or costs spent. The tactical level has a medium-term impact and is based upon extant data where decisions at the operational level have prompted outcomes using running case event data (van der Aalst *et al.,* 2016). Event data are then used to create process models to understand the business further, identify improvement areas or audit, which is made possible through process discovery (Augusto *et al.,* 2018).

Event Logs

A collection of timestamped events or activities is an event log (van der Aalst, 2016), usually stemming from a process aware application. Every event identifies an execution of tasks or processes and can also indicate a message, escalation, or other applicable pertinent events in a specific background of identified process. The event log can be used in most mining techniques. The three attributes as a minimum requirement are a case identifier which is a unique identifier for a set of events, an event class or activity name and a timestamp which includes both date and time. In practice, additional attributes such as resource, cost or other domain specific data are also included. A case identifier is the identification in which case the event happened. An event class is the reference of the event, where the timestamp is the date and time the event occurred (Dumas *et al.,* 2018). The event log of a sample study abroad process is shown in table 5.

Table 5: Excerpt of an Event Log for Study Abroad Application

case	completeTime	event	resource
22815	21/05/2018 12:24	Update application - questionnaire updated	Adviser 4
22815	29/11/2017 8:35	Status update - Submitted Application	Student
22815	15/02/2018 4:16	Update application - questionnaire updated	Adviser 7
22815	23/05/2019 3:18	Status update - Accepted to Host University	Coordinator 2
22815	26/10/2017 8:12	Application created	Student
22815	29/11/2017 8:35	Status update - Submitted Application	Student
22815	12/03/2018 9:05	Status update - Committed	Student
22815	15/02/2018 4:16	Status update - Approved Exchange Application	Adviser 7
22815	12/03/2018 9:05	Status update - Committed	Student
22815	1/11/2018 8:38	Update application - questionnaire updated	Coordinator 2
22815	26/09/2018 6:41	Status update - Application to Host Insitution	Adviser 4
22815	15/02/2018 4:16	Status update - Approved Exchange Application	Adviser 7
22815	2/10/2018 3:53	Update application - questionnaire updated	Coordinator 2
22815	14/03/2018 2:05	Status update - Nominated to Host University	Adviser 7
22864	26/10/2017 10:16	Application created	Student
22864	23/11/2017 7:22	Status update - Submitted Application	Student
22864	24/11/2017 1:20	Update application - questionnaire updated	Adviser 1
22864	16/02/2018 9:05	Status update - Approved Exchange Application	Adviser 7
22864	22/02/2018 4:40	Update application - questionnaire updated	Adviser 7
22864	22/02/2018 4:41	Update application - questionnaire updated	Adviser 7
23216	30/11/2017 10:26	Status update - Submitted Application	Student
23216	30/11/2017 10:26	Status update - Submitted Application	Student
23216	30/10/2017 8:47	Application created	Student
23227	31/10/2017 7:10	Application created	Student
23270	31/10/2017 12:40	Application created	Student

A common format for an event log is a CSV or comma-separated-value. For a more complicated event log containing data attributes in the events, a flat comma delimited file is not an appropriate format, hence an extra functional converted file (the eXtensible Event Stream (XES)) is used to format event logs, which is an acknowledged process mining standard by the IEEE Task Force (Dumas *et al.,* 2018). An XES format is partially depicted in figure 9, which is the processed file of a Study Abroad Event Log. An XES file contains multiple traces, and every trace contains multiple events which contain different attributes in each event (Dumas *et al.,* 2018). The original file was generated directly from a study abroad application in a CSV file. The process mining ProM Lite 1.3 tool was used as the XES converter to generate the equivalent XES file of the study abroad event log.

Framework Formulation

The novel conceptual BPM framework using ML and AI is to be based upon automated process discovery activities to solve business problems. BPM is generally structured through frameworks, describing relevant capability areas for process implementation in organizations (Kerpedzhiev *et al.,* 2020). Again, the process mining tool and operational support application used is ProM Lite v1.3 - a state-of-the-art process mining tool containing plugins for automated process discovery, conformance checking and event enhancement evaluation by means of various algorithms including heuristic, inductive and fuzzy miners that provide data visualization capability. The automated "As-Is" process model (process discovery) will then be used for analysis.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- This file has been generated with the OpenXES library. It conforms -->
<!-- to the XML serialization of the XES standard for log storage and -->
<!-- management. -->
<!-- XES standard version: 1.0 -->
<!-- OpenXES library version: 1.0RC7 -->
<!-- OpenXES is available from http://www.openxes.org/ -->
<log xes.version="1.0" xes.features="nested-attributes" openxes.version="1.0RC7">
        <extension name="Time" prefix="time" uri="http://www.xes-standard.org/time.xesext"/>
        <extension name="Lifecycle" prefix="lifecycle" uri="http://www.xes-standard.org/lifecycle.xesext"/>
        <extension name="Concept" prefix="concept" uri="http://www.xes-standard.org/concept.xesext"/>
        <classifier name="Event Name" keys="concept:name"/>
        <classifier name="(Event Name AND Lifecycle transition)" keys="concept:name lifecycle:transition"/>
        <string key="concept:name" value="XES Event Log"/>
        <trace>
                <string key="concept:name" value="22493"/>
                <event>
                        <string key="CourseName" value="Bachelor of Commerce and Bachelor of Science"/>
                        <string key="Program Name" value="University of California (Super Exchange Partner)"/>
                        <string key="FacultyName" value="Business (Business School)"/>
                        <string key="Application History Time" value="1:05:04"/>
                        <string key="concept:name" value="Update application - questionnaire updated"/>
                        <int key="Year" value="2018"/>
                        <string key="DegreeLevelName" value="Bachelor"/>
                        <string key="resource" value="Student"/>
                        <string key="Term" value="Semester 2"/>
                        <string key="lifecycle:transition" value="complete"/>
```

Figure 9: Extract of converted XES format of Study Abroad Event Log

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Process mining is a data-driven holistic approach answering questions related to the business process. In this study we seek to answer the following questions about the behaviour of the event log:

- What is the Case ID taking the longest duration from status "Application created" to "Accepted to Host University"?

- What is the Case ID with the shortest duration from status "Application created" to "Accepted to Host University"?

- What activities cause bottlenecks?

- What is the average duration of applications from "Application created" to "Accepted to host University"?

- What are the top three most frequent activities occurring in the process model?

Automated Process Discovery

A plethora of algorithms exist in process mining capturing different levels of abstraction to generate a sound process model, as event logs are typically spaghetti-like with several traces, arcs and events, making them arduous to interpret.

Automated process discovery techniques use event logs converted to XES. Using the ProM Lite 1.3 tool, the XES file details of the event log are summarized in table 6. The core processes are the application status indicated in figure 10, which entail the main milestones of the students' study abroad application, while supplementary processes represent activities added intentionally or ignored. As indicated in table 6, the data set is separated by application cohort to understand the behaviour of every application cycle which has a specific application time frame. By separating different cohorts, the process used in each cohort can be analysed. Details can be drilled down for analysis and then compared to best practice. The algorithms used are the *heuristic*, *inductive*, *fuzzy* and *ILP* Miners. All algorithms have visualization capability and an animation feature. These highly sophisticated algorithms show how effective this state-of-the-art tool can be used. Let us briefly examine the outputs from each miner.

Heuristic Miner

Use was made here of a heuristic miner and relevant parameters include dependency, conditional, binding and conformance heuristics, where a conditional heuristic has a Cohen Kappa.

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Table 6: Summary of Relative Process Occurrences of Study Abroad Process

		2018				2019						2020	
		Semester 2	Year S2 - S1	Summer	Winter	Semester 1	Year S1 - S2	Semester 2	Year S2 - S1	Summer	Winter	Semester 1	Year S1 - S2
Event Log	Total process instances	409	45	234	200	353	27	389	25	377	483	281	5
	Total events	4059	472	846	912	3753	287	4313	275	1870	2630	2672	82
	Total number of classes	17	14	15	17	19	10	18	15	12	16	19	13
Core Processes	Application Created	10.076%	9.534%	27.660%	21.930%	9.406%	9.408%	9.019%	9.091%	20.160%	18.365%	10.516%	6.098%
	Application Submitted	20.251%	19.280%	20.686%	30.702%	19.078%	18.467%	18.386%	18.545%	25.775%	32.548%	21.819%	17.073%
	Nominated to Exchange	13.870%	13.559%	1.182%	3.728%	18.652%	17.770%	14.862%	16.000%	0.267%	1.863%	6.362%	4.878%
	Nominated to Non - Exchange			0.118%	0.110%						0.380%		
	Nominated to Study Abroad			2.837%	2.193%						1.559%		
	Comitted	19.808%	18.220%	9.220%	12.500%	18.385%	18.118%	17.783%	16.727%	0.374%	5.894%	18.001%	12.195%
	Application to Host University	2.242%	1.483%	0.118%	0.110%	3.810%	2.787%	3.594%	5.455%		0.076%	5.202%	3.659%
	Nominated to Host university	9.707%	9.322%			9.459%	9.059%	8.347%	5.455%		0.038%	7.859%	13.415%
	Accepted to Host University	10.150%	9.534%	28.369%	22.368%	9.512%	9.408%	9.576%	9.091%	20.428%	18.631%	11.040%	17.073%
	TOTAL	86.104%	80.932%	90.190%	93.751%	88.302%	85.017%	81.567%	80.364%	67.004%	79.354%	80.799%	74.391%
Supplementary Processes (Discovered)	Assign to Host Institution	11.505%	16.737%			9.699%	13.937%	10.364%	13.091%			11.714%	9.756%
	Conditional Nomination	0.985%	0.424%	1.418%	2.083%	0.639%	0.697%	5.541%	4.000%	0.160%	0.114%	4.528%	1.220%
	Re-preferenced Institution	0.394%	0.424%			0.160%		0.162%	0.364%			0.374%	
	Status change to Pending	0.246%	0.636%	2.009%	0.219%	0.373%		0.812%	0.727%	2.834%	2.091%	0.412%	2.439%
	Application Re-instated	0.222%	0.424%	1.773%	0.219%	0.266%		0.441%	0.364%		1.407%	0.374%	2.439%
	Application Un-Submitted	0.172%				0.053%		0.046%	0.364%	4.492%		0.225%	
	Withdrawn - Pre decision	0.246%	0.212%	2.719%	0.548%	0.293%		0.626%	0.364%	2.460%	1.407%	0.337%	2.439%
	Withdrawn - Did not Submit							0.023%					
	Withdrawn - Post nomination											0.037%	
	Withdrawn - Post decision	0.025%	0.212%	0.473%	0.329%	0.027%				0.107%	0.152%	0.112%	
	Withdrawn - Decline offer					0.027%							
	Withdrawn - While abroad							0.116%				0.299%	
	Rejected - Not Eligible	0.074%						0.023%	0.364%				
	Rejected - Not Endorsed	0.025%				0.053%	0.348%	0.278%				0.037%	
	Rejected - Host university					0.027%							
	Change status to Exchange			1.300%	2.522%					0.428%	1.407%		
	Exchange Endorsement											0.749%	7.317%
	Academic Approval									22.513%	14.068%		
	Waitlisted			0.118%	0.110%								
	Application Approved			0.219%	0.080%								
	TOTAL	13.894%	19.069%	9.810%	6.249%	11.697%	14.982%	18.432%	19.638%	32.994%	20.646%	19.198%	25.610%
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
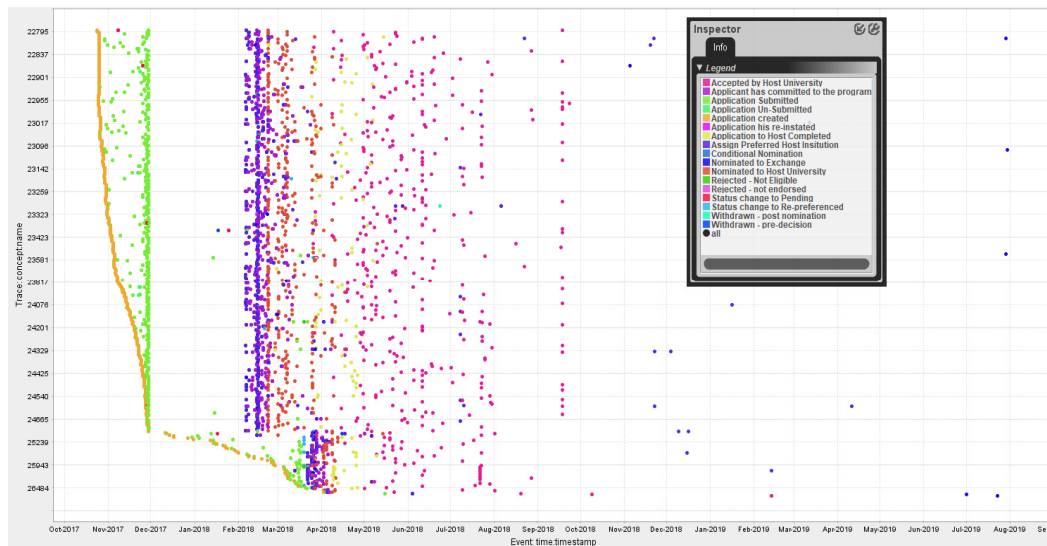
Figure 10: Dot Chart Output of the Study Abroad Process (2018 S2)

An F1 score option is available - including frequency thresholds. The two process models generated by this algorithm are shown in appendix 2 figure 2.1, with directly-follows and dependency graphs. The activity that is mostly executed in the process can be identified easily as "Application Submitted" instead of "Application Created", meaning study abroad advisers create an application on behalf of the student.

Inductive Miner

The Inductive Miner is a robust process discovery algorithm capable of generating a petri net, a process tree and a BPMN

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diagram. The state-of-the-art automated process discovery tool satisfies all process model checklists; it has animation capability that shows waiting times, deviations, service, or sojourn times, as indicated in figure 11. The configuration on Inductive Miner – infrequent (IMF) has a 0-noise threshold and a 95% visible path. In addition to the visualization capability of the inductive visual miner, data analysis can be used to dive deep into statistical values of the entire cohort result, which is summarized in appendix 2 - table 2.2 for minimum, average, median, maximum, and standard deviation values. The higher the path settings (in this case 95%), the lower the standard deviation for fitness, which makes it a reliable process model. In the trace duration, the maximum days are 890 days for 2020 Semester, 1, 570 days for Year S1-S2, and 899 days for the winter and summer cohorts.

Figure: 11 Excerpt from Inductive Miner Showing Path and Sojourn Times (2019 Summer)

Fuzzy Miner

The Fuzzy miner plugin creates process graphs but not petri nets. The implementation is regarded as practical where insights can be generated, however parallelism or choice is not considered in this algorithm. Generating fuzzy model parameters, such as attenuation, can be set if it is an nth root with radical or linear attenuation and maximal event distance. In appendix 2 - figure 2.2, the fuzzy model for the 2018 Semester 1 cohort is shown; this fuzzy model has a zero-significance node filter, with a fuzzy edge filter of 0.2 cut off and 0.75 utility rate ignoring self-loops. Also used is a concurrency filter set at 0.6 preserve and 0.7 ratio filter concurrency. All 17 traces are shown in the model with 3 orphan activities, making it difficult to understand the precedent activity.

Conformance Checking

To guarantee the conformance of a process model generated from the event log, a different set of data is evaluated by comparing the observed behaviour with the modelled behaviour using an inductive visual miner (IMF Miner) with a 90% path and 100% activities setting, where the result of process model fitness, number of events, and number of log moves, is summarized in table 7. In conformance checking, the replay fitness of the process model is measured. Given that 90% of the path is visible, the model generated has a higher average fitness and a lower standard deviation, making it fit to use. The inductive visual miner was executed using the same parameter with a 90% visible path. The direct-follows miner shows perfect fitness, while the lifecycle miner and all-operators' miners have the same fitness result as the IMF Miner where the plugin inductive miner – infrequent is used with a 10% noise threshold.

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Performance Checking

The data set was evaluated using a petri net with a 0-noise threshold utilizing the MXML legacy classifier and an A* ILP-based manifest replay algorithm.

Table 7: Summary of Standard Deviation for Conformance Checking

Study Abroad Cohort		Fitness				
		Minimum	Average	Median	Maximum	Standard Deviation
2018	Semester 2	0.538	0.947	0.941	1.000	0.064
	Year S2 - S1	0.833	0.960	0.900	1.000	0.043
	Short Term Winter	0.000	0.986	1.000	1.000	0.035
	Short Term Summer	0.000	0.912	1.000	1.000	0.122
2019	Semester 1	0.695	0.976	1.000	1.000	0.043
	Year S1 - S2	0.904	0.978	1.000	1.000	0.035
	Semester 2	0.700	0.970	1.000	1.000	0.048
	Year S2 - S1	0.925	0.990	1.000	1.000	0.022
	Winter	0.631	0.972	1.000	1.000	0.057
	Summer	0.300	0.910	1.000	1.000	0.128
2020	Semester 1	0.666	0.962	1.000	1.000	0.060
	Year S1 - S2	0.933	0.978	1.000	1.000	0.030

Based on event log completed time, the throughput time is calculated where a bottleneck exists, while further analysis can be done to drill down the element statistics of each task's throughput, waiting or sojourn time to further compare its performance in the overall duration of the process model. In addition, the level of bottleneck can be identified visually. The summary of throughput time is shown in table 8 which includes best case (minimum) and worst case (maximum) models including the case property. The summary of bottleneck processes found are shown in appendix 2 table 2.3.

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Table 8: Summary of Case Throughput Time (A* ILP – Based Manifest Replay Algorithm)

Study Abroad Cohort		Case Property			Case Throughput Time			
		Cases	Perfectly fitting cases	Non Fitting cases	Average	Minimum	Maximum	Standard Deviation
2018	Semester 2	409	166	243	6.65 Months	1.36 Months	11.11 Months	1.75 Months
	Year S2 - S1	45	21	24	9.63 Months	5.15 Months	15.79 Months	2.87 Months
	Short Term Winter	200	169	31	4.73 Months	-	30 Months	8.38 Months
	Short Term Summer	234	157	77	2.65 Months	8 Months	22.5 Months	4.37 Months
2019	Semester 1	353	247	106	14.06 Months	1.51 Months	20.44 Months	1.90 Months
	Year S1 - S2	27	19	8	14.05 Months	11.44 Months	15.61 Months	1.14 Months
	Semester 2	389	251	138	9.51 Months	2.14 Months	24.90 Months	2.59 Months
	Year S2 - S1	25	24	4	11.67 Months	4.13 Months	18.53 Months	3.33 Months
	Winter	483	326	157	3.06 Months	10 Months	17.86 Months	4.08 Months
	Summer	377	226	151	2.03 Months	9 Months	14 Months	1.69 Months
2020	Semester 1	281	189	92	6.53 Months	27 Months	14.17 Months	1.70 Months
	Year S1 - S2	5	3	2	17.53 Months	15.98 Months	19 Months	1.20 Months

Event Log Probe Questions

One reason for a conventional process map is to grasp the performance of the current process as perceived by subject matter experts and identify areas of improvement, such as automated process discovery. The process model generated through automated process discovery algorithms must address all research questions. All 100% - i.e., all five questions were addressed with sufficient detail. The case ID with the longest and shortest duration can be identified by checking the trace details or through a performance algorithm, determining the bottleneck activities and were summarized in appendix 2 table 2.3. The three most frequent activities can be identified in table 8 where every task shows the ratio is often recurring in each cohort. Several performance metrics of the process can also be further examined, such as service times and waiting times, if further details are required. The succeeding activity would then be a comparison of these data to standard performance metrics of the organization. Discussion of activities desired for addressing problems can then be identified. Subject matter experts played a significant role in extrapolating details to understand the event log and separate the different study abroad cohorts.

Data Quality Assurance

The study abroad application event log contains comprehensive details of activities not directly related to the major milestone of the process. If all activities are included in the data and the actual activity name is used, it will create too much noise which can hamper the event log quality and analysis, because of factors such as [a] the clarity of the output process model; [b] the level of process conformance; [c] analysis of performance results; and [d] difficulty in identifying the correct parameters to be used. Hence as the first author is a subject matter expert embedded in the organization with direct contact to all resources, business rules have been applied to produce a clean event log as noted by Van Eck et al., (2015) that includes information directed to the major activities of a study abroad application. The business rules specifically apply to an activity name where a standard naming convention is used, removing irrelevant activities in the log and anonymizing the resource of each activity. In the case study by Andrews et al., (2017) employing automated process discovery, process mining challenges in this multi-faceted study included legislative changes, key personnel changes, and the semi-structured nature of the business process. Similar challenges also hampered the study abroad team, where an exception had to be

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considered (Wang *et al.,* 2014) to exclude the Covid-19 affected cohort or to capture organizational process change in every cohort.

Discussion

BPM is already considered a mature domain, whereas process mining is seen as an emerging technology. Nonetheless process mining shows promising results to automatically discover process algorithms, while evaluating conformance and performance. To achieve success in BPM, the performance of the process must be initially measured (Kis *et al.,* 2017). Process performance indicators are typically used for target-oriented analysis of actual process performance (Urnauer *et al.,* 2020). For greater business growth, the potential gain of data driven analyses is through better understood business performance (Wynn & Sadiq, 2019). The rising volatility of current markets results in complex processes where end-to-end definitions of process performance are crucial (Schmitz *et al.,* 2020). Our proposed AI and ML based BPM model is shown in figure 12. The model has 5 levels focusing on performance metrics, process aware information systems, process mining, process innovation and a target output model. It is imperative organisational goals are clear regarding process change implementation for the target process to meet performance metrics. The initial step is to establish performance metrics. The final step is the target process model in the proposed framework to make sure it will not deviate from the target metrics. Establishing

performance metrics is the first step, then using process aware information systems containing the event log, followed by process mining activities, will generate the process model automatically through algorithms incorporating a process modeller. Next is process innovation where the process requirement paradigm is used to identify change priorities needed in the process. Lastly, the output process model satisfies the performance metrics established in the initial step.

In a study abroad application, an application cycle is repeated in different terms and has specific targets in every cohort, so setting of performance metrics in a recurring cycle though the previous actual process can be established in the performance metrics and set for the following cycle. In addition, the performance metrics can include the waiting, cycle, processing times as well as the deviation, throughput or resource allocation derived from the devil's quadrangle (Jansen-Vullers *et al.,* 2007). The devil's quadrangle is a way of understanding the interaction of different projects' competing constraints such as time, cost, scope and quality (Jansen-Vullers *et al.,* 2007). Other metrics can also be added if they deliver value to the organization. The study abroad application is temporal, so service, processing or waiting times form a significant part of the performance metrics to be included. One essential component of the framework is a process aware information system (Kalenkova *et al.,* 2015), where the event log is generated and extracted.
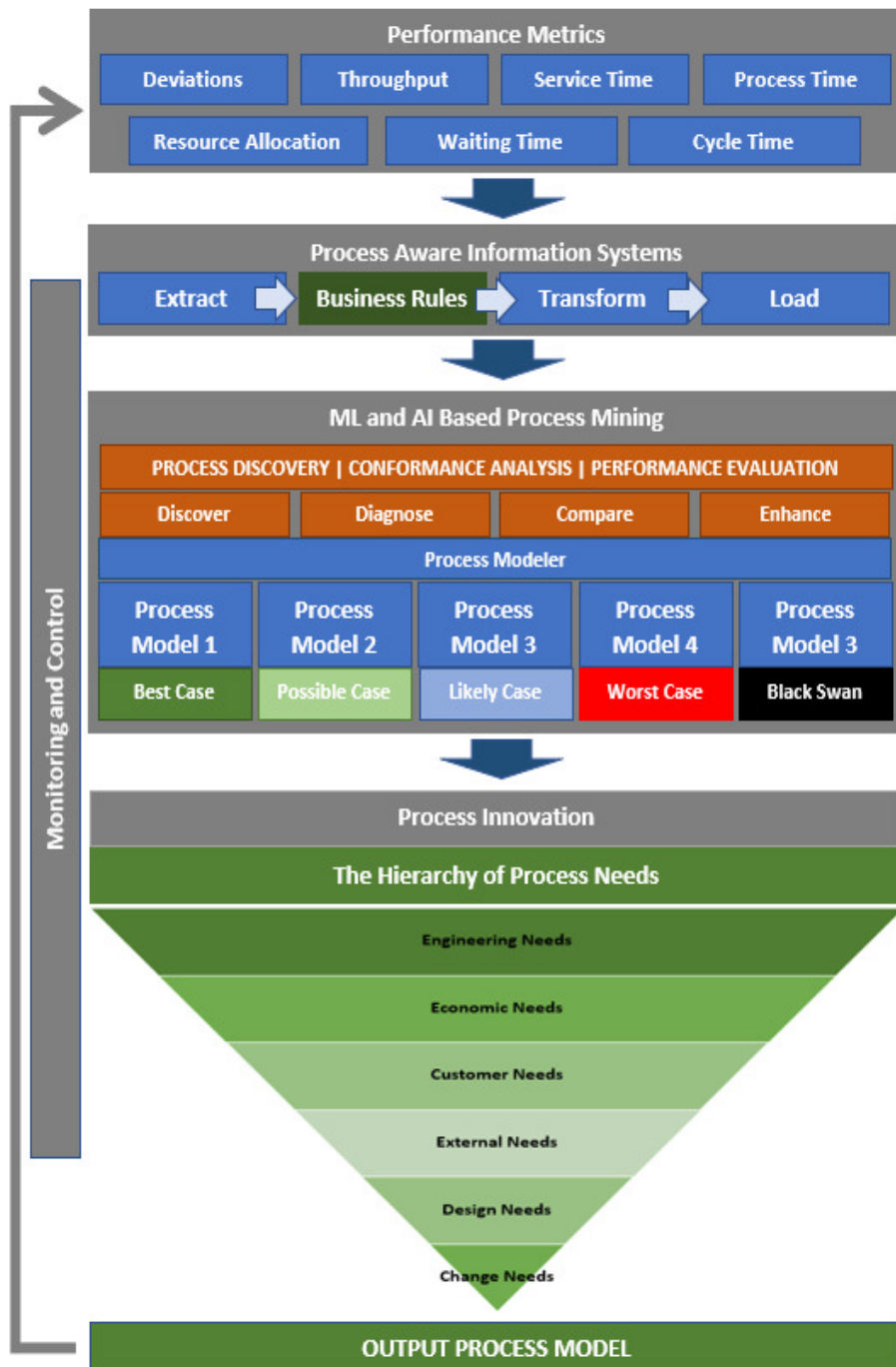
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Figure 12: Proposed AI and ML Enabled BPM Framework

The generic procedures of data warehousing for copying data from one source to another - Extract Transform Load (ETL) (Griesemer, 2011), includes an additional business rule definition after Extract; the business rule represents the structured guideline on how the data will be transformed, as raw event logs, directly extracted straight from the system, contain noise or unnecessary activities (Van Eck *et*

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al., 2015). Backtracking the process through activities in information systems has massive potential (Menges *et al.,* 2020). A secure, robust business process integration that maintains consistent data is a prime driver of success, where pervasive implementation of process-aware information systems eases the acquisition of digital footprints of a business process (Mehdeyiv & Fettke, 2020).

For study abroad, the process aware information system records all activities undertaken without any filter or exception. In this study, the focus are the major activities relevant to a student application and such activities can be easily identified by a subject matter expert, or semester and short-term coordinators. Through the defined business rules, the transformed event log will be structured and consistent and possess standardized naming conventions and be ready to be loaded as input to a process mining algorithm for automated process discovery. The filtering of relevant activities is descriptive. Output activities are in either BPMN, transition diagrams, process trees or petri nets which are easier to understand and follow, making analysis straightforward. Process mining algorithms, applied in the study abroad application cycle to create process models through automated process discovery and visualize process performance, have shown promising results and can be used instead of manual methods. Configurable parameter options to obtain tolerable conformance levels can be set flexibly. The structure presented in figure 12 is a performance metric focused BPM framework, where process mining algorithms are aligned, as performance metrics play a pivotal role in organization goals and usually trigger business process change initiatives. Process innovation is the end goal of these preliminary activities and ultimately identifies the component of the process most in need of improvement.

The research questions were addressed by comparing a manually created process model with process and cycle times with a probability ratio. Using ML and AI based plugins with state-of-the-art innovative algorithms, we can generate various performance metrics of existing process models using event logs from a process-aware information system. More options are also available in the latter, in terms of visualization and process discovery representation as indicated in appendix 2, which shows a significant difference in terms of the following areas as indicated in RQ1: *How do ML and AI-based BPM frameworks vary from conventional business process management solutions in higher education, specifically in a study abroad process in terms of reliability, profitability, cost-effectiveness, and trustworthiness?* The automated process discovery is data-driven in that it depicts actual activities and is free from any pre-conceived bias and individual judgment. Process efficiencies are easily identifiable through various actionable visualization options. The automated process discovery output can be checked through conformance algorithms, and configurable parameter options to ensure the output process model is trustworthy. With different performance metrics available, all areas in the process can be met through event logs which represent real time activities in a process aware information system with human intervention. One of the challenges here is creating business rules that make sense of complex activities in the event log. RQ2: *What are the pre-requisites in using data-driven and process mining capabilities of ML and AI to effectively implement BPM frameworks in higher education study abroad process?* A process aware information system is the main requirement, which is the source of an event log or XES functioning as the input element in the process mining software tool (Kalenkova, 2017). Performance metrics are important to serve as a compass for identifying best or worst-case process models in the event log number of traces. Basic knowledge in using ProM Lite 1.3 is also required.

Conclusion

Creating a process model for different organizations and various domains can be challenging, and requires a specific skill set with additional information requiring investigation during process discovery, analysis, or redesign. The time spent that can be saved when automating process

discovery capability is far less than creating a conventional mapping of the process; however, it also requires skill to use a software tool and navigate through the application to capture the information needed. The AI and ML enabled BPM Framework encapsulates a new way of thinking in process-centric change initiatives, where performance objectives form a significant step in any target organization. The phases in the framework (figure 12) are directed specifically at achieving the performance goals at the metrics level. This first step in the framework indicates several metrics can be used as a key performance indicator. In the process mining application stage, the framework shows the process nomenclature where the preferred process model is selected as the ideal process for innovating the existing process. When change is implemented utilizing an ordering of process needs, the output process satisfies the performance goal established. The interesting insight here is that the framework in figure 12 is relatively agile, such that process changes can be justified and implemented in a short period of time, so that performance can be improved to meet the target as often as required.

Limitations and future work

The scope of this study was a study abroad application starting with application commencement until the student is accepted to a host institution. However, the journey of the student mobility experience is only starting at this stage as there are activities involved during student departure, while the student is overseas, when the student completes the exchange program and then returns home. All such activities are considered out of scope and are a limitation of this study; however, they are part of the event log recorded in the system and were thus filtered out. The activity after the student is accepted to host university affects the staff-hours of an exchange adviser. There are special cases where staff support is also needed, and this can consume much time. There are also supplementary activities in the event log, but these were excluded in this study. It would be interesting to examine the end-to-end mobility experience cycle performance

compared to a presumed process. The event log used also needs to undergo data cleansing to eliminate noise correctly, meaning good quality data are structured. In addition, the ProM 1.3 machine learning algorithm is not capable of building mathematical models from sample data to make decisions, and hence not capable of prescriptive analytics. Studying overseas as part of a higher education degree has become more attractive to students because of likely higher employability outcomes after graduation. Intake of study abroad applications is expected to increase, particularly with certain countries which are highly preferred by students - such as the USA, UK or the Netherlands. There are also cases where students withdraw from a program while overseas, which could prove helpful to understand trends. One idea is to continue to build an interactive seamless business intelligence application tool using the novel BPM framework integrating different levels. This tool may include a business rules library capable of automatically converting event logs into interactive dashboards to show comparative results between target performance metrics and the deviation of actual data, along with a process modeller library capable of automatic decision making.

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- **Case study 25**: Schindlbeck, B., Kleinschmidt, P., (2017), 'Integrate Your Partners into Your Business Processes Using Interactive Forms: The Case of Automotive Industry Company HEYCO'

in *Business Process Management Cases*, (1)1, pp. 485–501, Springer International Publishing, Cham.
- **Case study 26**: Kloppenburg, M., Kettenbohrer, J., Beimborn, D., Bögle, M., (2017), 'Leading 20,000+ Employees with a Process-Oriented Management System: Insights into Process Management at Lufthansa Technik Group' in *Business Process Management Cases*, vol.1(1), pp. 505–520, Springer International Publishing, Cham.
- **Case study 27**: Imgrund, F., Janiesch, C., Rosenkranz, C., (2017), '"Simply Modeling": BPM for Everybody-Recommendations from the Viral Adoption of BPM at 1&1' in *Business Process Management Cases*, vol.1(1), pp. 521–540, Springer International Publishing, Cham.

APPENDIX 1

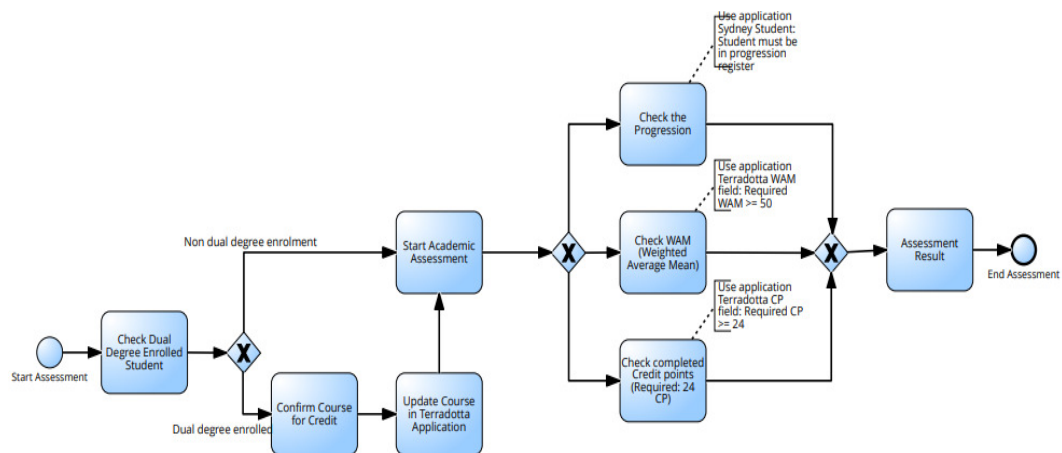**STUDY ABROAD PROCESS DETAILS**

Figure 1.1: Semester Exchange: Expanded "Assess Application – Eligibility Criteria" Process
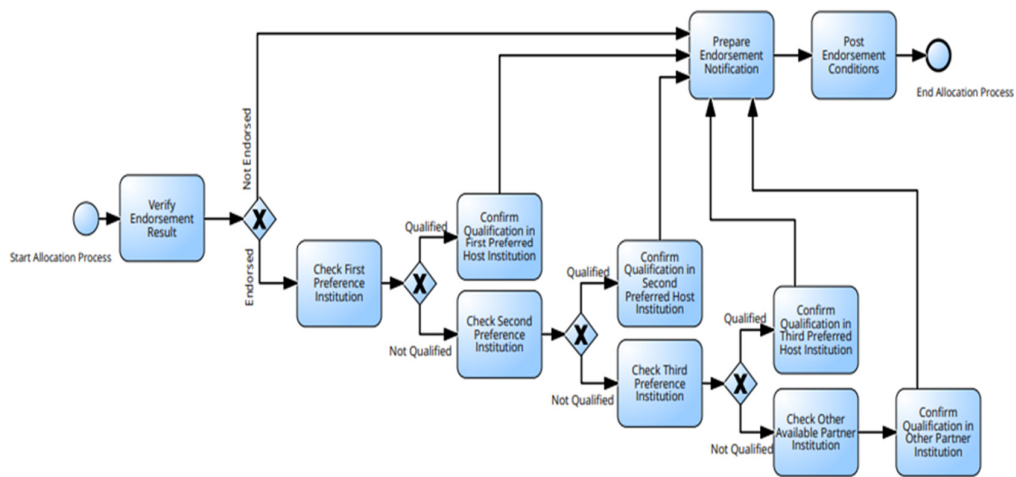
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Figure 1.2: Semester Exchange: Expanded process for "Assess endorsement and Host Institution Preference" Process
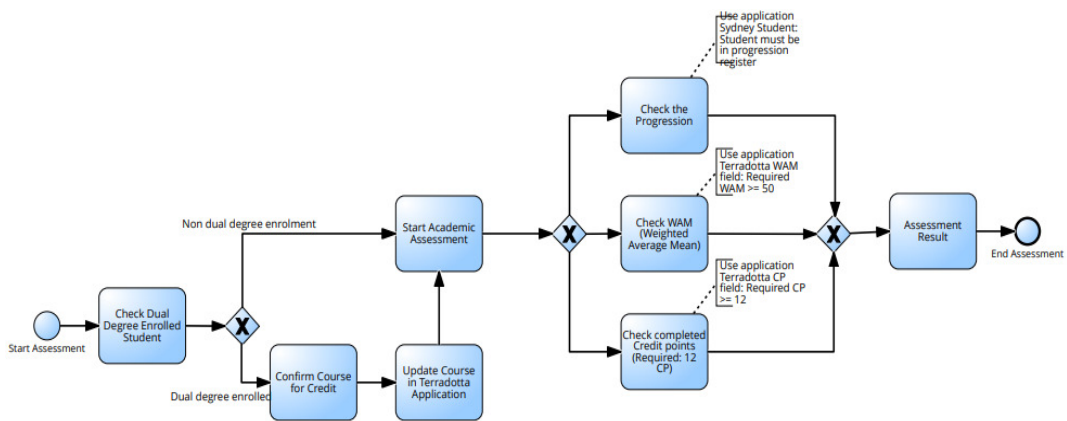

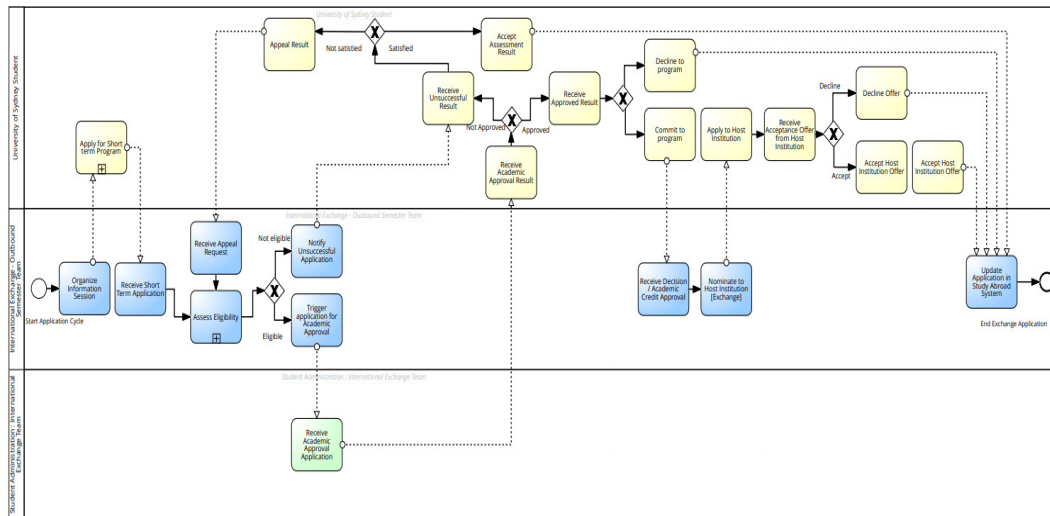**Figure 1.3: Short Term Program Process Map**

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Figure 1.4: Short Term Program. Expanded process for "Assess Eligibility"

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Table 1.1: Detailed Activity Steps and Value Classification for Process Map

Main Task	Sub Task	Steps	Performer	Classification
Organize Information Session		Create schedule for Information Session	Coordinator	BVA
		Confirm Information session schedule with	Coordinator	NVA
		Post Information Session in Study Abroad	Media Office	VA
Received Exchange		Confirm latest release schedule of academic	Coordinator	VA
		Confirm students for late exams exceptions	Coordinator	NVA
Assess Application – Academic Quals		Check enrolment status of the student in Student Information System	Coordinator	BVA
	Check Dual Enrolment	Open Study Abroad System	Coordinator	VA
		Search student exchange application	Coordinator	VA
		Check student profile in Study Abroad System – Student ID Course field	Coordinator	VA
	Confirm Course for Credit	Check course to credit exchange in Study Abroad System student application	Coordinator	VA
		Verify suitability of course for credit in	Coordinator	VA
	Update Course in Study Abroad System	Copy Student ID Course student profile in Study Abroad System	Coordinator	NVA
		Paste Student ID Course in Student Details questionnaire in Study Abroad System	Coordinator	NVA
	Start Academic Quals	Open Sydney Student Information System	Coordinator	BVA
		Open Progression Register of the student in Student Information System	Coordinator	BVA
	Check Progression	Verify student progression status in Student Information System	Coordinator	BVA
		Note student progression status in Student Information System	Coordinator	BVA
	Check WAM (Weighted Average	Open the exchange application in Study Abroad System	Coordinator	VA
		Check the student profile WAM field in Study Abroad System	Coordinator	BVA
		Note student WAM (>= 50 : Eligible for exchange / < 50 : Not eligible for exchange)	Coordinator	BVA
	Check completed credit points	Check the student profile completed credit points in Study Abroad System	Coordinator	BVA
		Note student completed credit points (CP >= 24 CP / CP < 24)	Coordinator	BVA
	Assessment Result	Confirm student is eligibility for exchange (In progression register and WAM >= 50 and completed CP >= 24)	Coordinator	BVA
		Confirm Student is non eligibility: (Not in progression register or WAM < 50 or	Coordinator	BVA
		Update student application status in Study Abroad System	Coordinator	BVA
Notify Unsuccessful Application		Select Unsuccessful email template in Study Abroad System	Adviser	NVA
		Send unsuccessful email notification through Study Abroad System	Adviser	NVA
Receive Appeal Request		Receive enquiry email from student through ServiceNow application	Adviser	NVA
		Assess appeal request details	Adviser	NVA
		Reply to student appeal result	Adviser	NVA
Forward application for Student Administration		Open Study Abroad System	Coordinator	VA
		Search exchange application of the student	Coordinator	BVA
		Add tag "FS Endorsement" in Study Abroad	Coordinator	BVA
Receive Endorsement Result		Receive email from Student Administration Exchange Team	Coordinator	NVA
		Open Study Abroad System application	Adviser	VA
		Open Endorsement Result questionnaire in Study Abroad Application	Adviser	BVA
		Verify endorsement condition details	Adviser	VA

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Main Task	Sub Task	Steps	Performer	Classification
Assess Endorsement and Host Institution Preference	Verify Endorsement Result	Verify Endorsement status: Approved for Endorsement for endorsed student	Adviser	BVA
		Verify Endorsement status: Not Endorsed for unsuccessful student	Adviser	NVA
	Check Quals for First Preference Institution	Verify course and major compatibility of student in first preference institution	Adviser	BVA
		Verify applicant numbers and ranking in first preference institution	Adviser	BVA
	Confirm Quals in First Preferred Institution	Confirm applicant suitability to first preference institution	Adviser	BVA
		Place applicant to first preference institution	Adviser	BVA
	Check Quals for Second Preference	Verify course and major compatibility of student in second preference institution	Adviser	VA
		Verify applicant numbers and ranking in second preference institution	Adviser	VA
	Confirm Quals in Second Preferred	Confirm applicant suitability to second preference institution	Adviser	VA
		Place applicant to second preference	Adviser	VA
	Check Quals for Third Preference Institution	Verify course and major compatibility of student in third preference institution	Adviser	VA
		Verify applicant numbers and ranking in third preference institution	Adviser	VA
	Confirm Quals in Third Preferred Host	Confirm applicant suitability to third preference institution	Adviser	VA
		Place applicant to third preference institution	Adviser	VA
	Check Other Available Partner Institution	Confirm applicant qualification if it doesn't match to first, second or third preference	Adviser	NVA
		Verify course and major compatibility of student to other available partner institution	Adviser	NVA
		Verify applicant numbers and ranking in other available partner institution	Adviser	NVA
	Confirm Quals in Other Available Partner	Confirm applicant suitability to other available partner institution	Adviser	NVA
		Place applicant to other available partner	Adviser	NVA
	Prepare Endorsement Notification	Select email template for the application endorsement and institution allocation	Adviser	BVA
		Send email notification of the application endorsement details through Study Abroad	Adviser	BVA
Send Application Result Notification	Post Endorsement Conditions	Open Student Information System	Adviser	VA
		Open International Education application	Adviser	VA
		Post endorsement condition of the student	Adviser	VA
Receive Student Decision		Received notification that the applicant committed to the program	Adviser	BVA
		Open study abroad application	Adviser	VA
		Confirm application status of the student in Study Abroad System	Adviser	BVA
Nominate to Host		Open host institution website allocated to the	Adviser	BVA
		Enter student details of the exchange	Adviser	BVA
		Submit nomination to host institution	Adviser	BVA
		Inform student to apply to host institution application website	Adviser	BVA
		Update student application status in study abroad system	Adviser	BVA
Receive Host Institution		Receive information from student on the offer	Adviser	VA
		Confirm host institution acceptance offer	Adviser	NVA
Update Application		Open Study Abroad System	Adviser	VA
		Search applicant in Study Abroad System	Adviser	VA
		Confirm attachment of Host Institution	Adviser	VA
		Update student application status in Study Abroad System	Adviser	BVA

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APPENDIX 2 RESULTS

Table 2.1: Summary of Case Studies and BPM Lifecycle Main Focus

Case	Author	BPM Lifecycle					
		Process Identification	Process Discovery	Process Analysis	Process Redesign	Process Implementation	Process Monitoring and Control
1	Reisert, Zelt & Wacker, 2017		✔	✔		✔	
2	Blasini, Leist & Werner, 2017		✔			✔	✔
3	Viaene & van den Bergh, 2017	✔				✔	
4	Bandara et al. 2017					✔	
5	Czarnecki, 2017				✔		
6	Kovacic et al. 2017				✔	✔	✔
7	Wollinski & Bala, 2017				✔		
8	Kim et al. 2017				✔		
9	Rosemann, 2017				✔		
10	van Looy & Rotthier, 2017				✔		
11	Cereja, Santoro & Gorbacheva, 2017		✔			✔	
12	Karle & Teichenthaler, 2017		✔		✔		
13	Marengo et al. 2017				✔	✔	
14	Andrews et al. 2017	✔	✔	✔			
15	Thaler et al. 2017	✔	✔				
16	Andrews et al. 2017		✔	✔			
17	Matzner et al. 2017			✔	✔		
18	Duelli et al. 2017				✔	✔	
19	Rau et al. 2017		✔			✔	
20	Debois et al. 2017	✔			✔		
21	Becker et al. 2017		✔	✔			
22	Schrepfer et al. 2017		✔	✔			✔
23	Leitz et al. 2017				✔	✔	✔
24	Suchy et al. 2017		✔	✔			
25	Schindlbeck & Kleinschmidt, 2017				✔	✔	
26	Kloppenburg et al. 2017					✔	
27	Imgrund, Janiesch & Rosenkranz, 201	✔		✔		✔	
28	Russack & Menges, 2017				✔	✔	
29	Krogstie, Heggset & Wesenberg, 2017			✔	✔	✔	
30	Bührig et al. 2017	✔			✔		
31	Alves et al. 2017	✔					
32	Bach, Vukšić & Vugec, 2017			✔			
33	Syed, Bandara, & French, 2018			✔	✔		✔
34	Bogéa et al. 2020			✔	✔		
35	Gibson et al. 2019		✔	✔			
36	Helbig, Römer & Mellouli, 2015		✔		✔		
37	Bogodistov, Moormann & Sibbel, 2019			✔	✔		
38	Fleig, Augenstein & Maedche, 2018		✔	✔			
39	Lehto, Hinkka & Hollmen, 2016			✔			✔
40	Saarsen & Dumas, 2016		✔	✔			
	TOTAL	7	15	17	20	15	6

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Table 2.2: Summary of Fitness, Duration and Timestamp using Inductive Miner

		2018				2019						2020	
		Semester 2	Year S2 - S1	Summer	Winter	Semester 1	Year S1 - S2	Semester 2	Year S2 - S1	Summer	Winter	Semester 1	Year S1 - S2
Event Log	Total traces	409	45	234	200	353	27	389	25	377	483	281	5
	Total events	4059	472	846	912	3753	287	4313	275	1870	2630	2672	82
Duration (Trace Attribute)	Minimum	40 Days	154 Days	0 Days	0 Days	45 Days	343 Days	64 Days	123 Days	0 Days	0 Days	0 Days	479 Days
	Average	208 Days	288 Days	79 Days	141 Days	422 Days	421 Days	286 Days	350 Days	60 Days	92 Days	205 Days	525 Days
	Median	200 Days	276 Days	47 Days	54 Days	431 Days	428 Days	285 Days	310 Days	47 Days	50 Days	194 Days	517 Days
	Maximum	642 Days	473 Days	674 Days	899 Days	613 Days	468 Days	747 Days	555 Days	419 Days	535 Days	890 Days	570 Days
	Standard Deviation	70 Days	86 Days	131 Days	251 Days	57 Days	34 Days	78 Days	99 Days	50 Days	122 Days	83 Days	36 Days
Fitness (Trace Attribute)	Minimum	62.00%	83.80%	71.40%	78.50%	69.50%	90.90%	70.00%	92.50%	78.50%	0.00%	71.40%	100.00%
	Average	98.10%	98.80%	98.70%	99.00%	98.10%	98.80%	97.00%	99.00%	97.70%	97.60%	97.40%	100.00%
	Median	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Maximum	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Standard Deviation	4.40%	3.30%	4.10%	3.40%	4.20%	2.30%	4.60%	2.30%	4.70%	5.80%	5.80%	n/a
Timestamp (Event Attribute)	Minimum	25/10/17	26/10/17	12/07/18	01/02/18	26/10/17	29/11/17	17/04/18	17/09/18	24/05/19	22/05/18	25/09/18	08/04/19
	Average	14/02/18	24/02/18	20/10/18	15/05/18	11/09/18	20/09/18	14/02/19	25/02/19	01/11/19	19/04/19	13/08/19	16/11/19
	Median	16/02/18	16/02/18	18/10/18	27/04/18	22/08/18	22/08/18	08/02/19	07/02/19	28/10/19	15/04/19	12/08/19	15/08/19
	Maximum	31/07/19	12/02/19	20/07/20	20/07/20	29/11/19	01/08/19	17/03/20	02/04/20	19/11/20	20/07/20	04/03/21	30/10/20
	Standard Deviation	68 Days	91 Days	82 Days	131 Days	122 Days	132 Days	98 Days	110 Days	41 Days	73 Days	69 Days	163 Days

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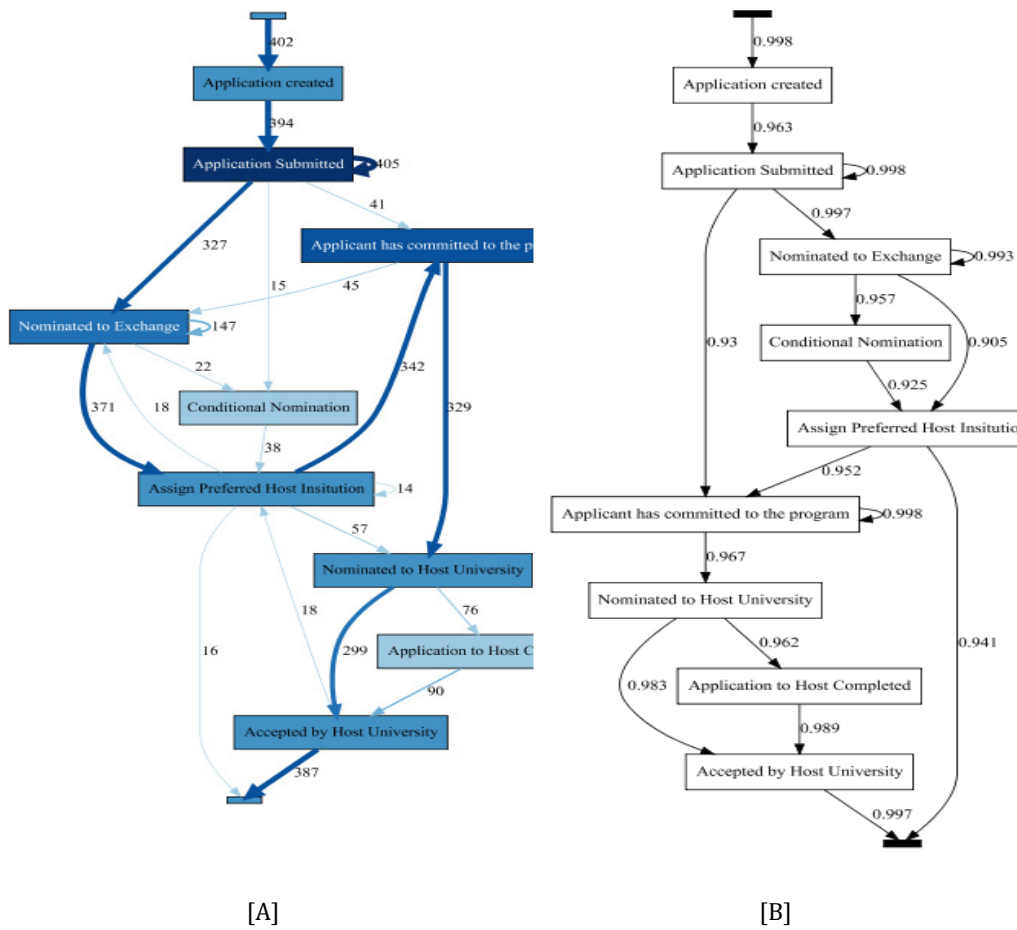[A]   [B]

Figure 2.1: Heuristic Miner [A] Directly-Follows Graph [B] Dependency Graph of Study Abroad Event Log (2018 S2)
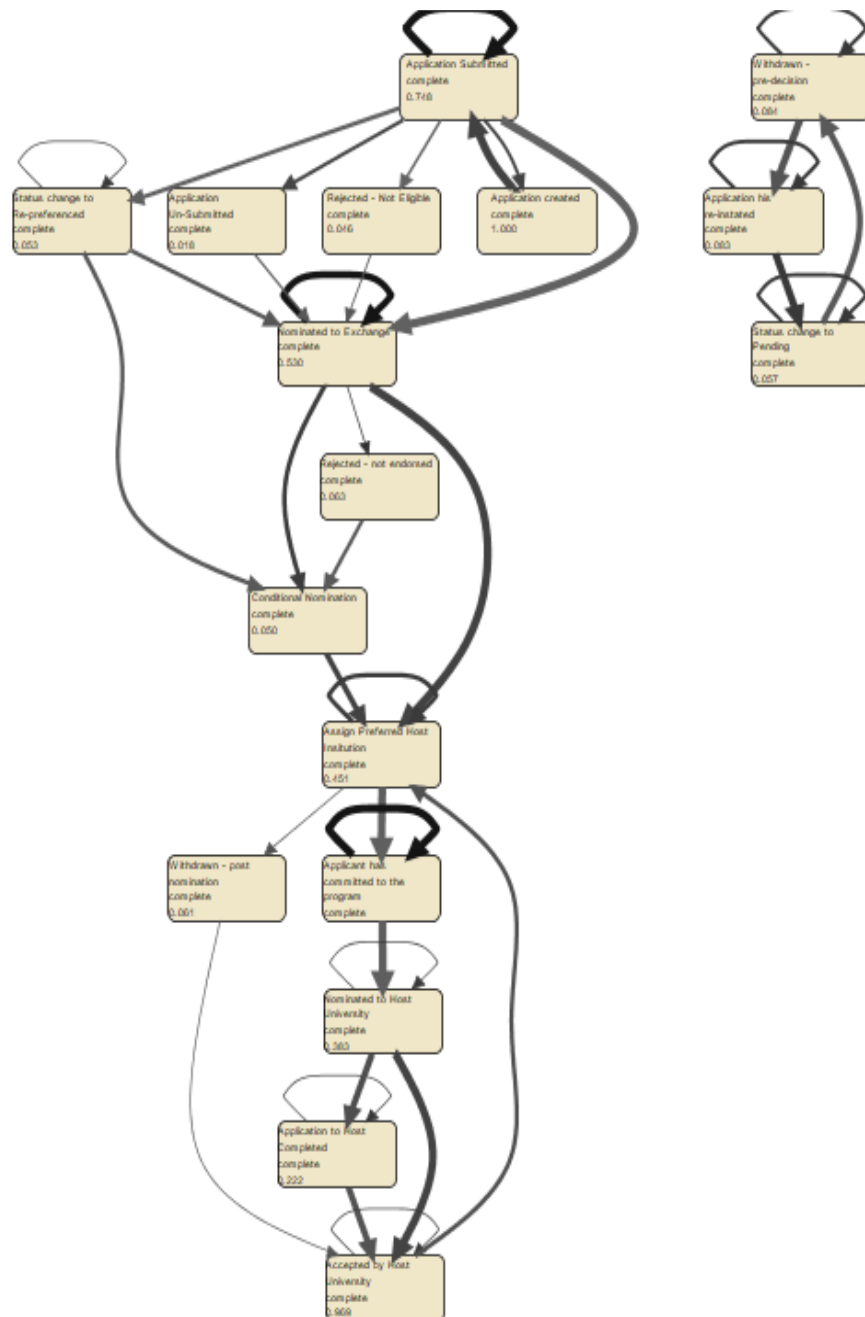
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Figure 2.2: Fuzzy Model For (2018 S2)

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Table 2.3: Summary of Bottleneck Activities Identified in Performance Checking

Study Abroad Cohort		Bottleneck Process							
		Assign Preferred Host Institution	Application to Host Institution	Change to Exchange Status	Nominated to Exchange	Rejected - Not Eligible	Nominated to Host University	Accepted to Host Insitution	Withdrawn - While Abroad
2018	Semester 2	✔	✔					✔	
	Year S2 - S1							✔	
	Short Term Winter			✔					
	Short Term Summer			✔					
2019	Semester 1				✔				
	Year S1 - S2	✔			✔			✔	
	Semester 2	✔			✔		✔	✔	
	Year S2 - S1				✔	✔		✔	
	Winter			✔					
	Summer			✔					
2020	Semester 1				✔			✔	✔
	Year S1 - S2	✔					✔	✔	