CONFORMANCE CHECKING AND DISCOVERY OF INFORMATION SERVICE REQUEST PROCESS

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การทำเหมืองกระบวนการเป็นรูปแบบหนึ่งของการวิเคราะห์กระบวนการทางธุรกิจ แนวทางดังกล่าวสามารถสนับสนุนองค์กรในการค้นคืนสารสนเทศกระบวนการแบบมีโครงสร้าง โดยใช้ข้อมูลกระบวนการที่ถูกบันทึกไว้เพื่อค้นพบ ตรวจสอบติดตาม และปรับปรุงกระบวนการ ในงานนี้ เทคโนโลยีการทำเหมืองกระบวนการได้ถูกประยุกต์ใช้สำหรับการตรวจสอบความคงรูปและการค้นพบกระบวนการร้องขอบริการสารสนเทศที่เป็นจริงขององค์กรแห่งหนึ่งซึ่งใช้เป็นกรณีศึกษา ปัจจุบัน แบบจำลองที่ใช้อ้างอิงกระบวนการทำงานถูกวาดอย่างง่ายๆ โดยใช้ไมโครซอฟต์เวิร์ด ผู้วิจัยได้นำเสนอวิธีการโดยเริ่มต้นจากการเขียนสคริปต์วีบีเอในการดึงเส้นทางจากภาพวาด เพื่อจะได้สามารถแปลงให้อยู่ในรูปแบบไฟล์เอกซ์อีเอส สำหรับใช้จำลองแบบกระบวนการอ้างอิงเพทริเน็ต ซึ่งเป็นสัญกรณ์แบบจำลองกระบวนการที่สามารถประมวลผลได้ กระบวนการที่ใช้ทำงานจริงในปัจจุบันได้ถูกตรวจสอบบนพื้นฐานของบันทึกเหตุการณ์ที่รวมรวมไว้ในการระบุความเบี่ยงเบนจากแบบจำลองกระบวนการอ้างอิง เครื่องมือโอเพนซอร์สพรอมที่ทำงานร่วมกับปลั๊กอิน ได้แก่ ดิสโกและอินดักทิฟวิชวลไมเนอร์ ได้ถูกนำมาใช้เพื่อการทวนสอบ อาทิ การตรวจหาคอขวด รวมทั้งการวิเคราะห์สมรรถนะด้วยมุมมองอื่นเพิ่มเติม เช่น กราฟเครือข่ายสังคม ข้อค้นพบต่างๆจะมีประโยชน์เพื่อนำไปสู่การปรับปรุงกระบวนการธุรกิจขององค์กรต่อไป นอกจากนี้ แนวทางที่นำเสนอยังอำนวยความสะดวกการจำลองแบบกระบวนการอ้างอิงขององค์กรด้วยสัญกรณ์มาตรฐานบีพีเอ็มเอ็นที่สร้างอัตโนมัติจากไฟล์เอกซ์อีเอส จากเดิมที่แสดงด้วยกระแสงานแบบง่ายสร้างจากโปรแกรมไมโครซอฟต์

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Process mining is a form of business process analysis. The approach could support organizations in retrieving structured process information by using recorded process data to discover, monitor and improve the processes. In this work, the process mining technology is applied for conformance checking and discovering an organization's Information Service Request process in reality as a case study. Currently, the reference model was drawn as a simple flow using Microsoft Word. The proposed method starts with writing a VBA script to extract traces from the drawing that enables the generation of XES file used for modeling the reference process in Petri net which is an executable process modeling notation. Based on the collected event logs, the actual process is investigated to identify the deviations from the reference process model. The open-source ProM with the plug-in Disco and Inductive visual Miner is utilized for verification such as detecting bottlenecks, as well as performance analysis with additional perspectives such as social network graph. The findings would benefit further improvement of the organization's business process. In addition, compared to the previously simple workflow created from Microsoft Drawing, the presented approach facilitates modeling the organization's reference process with the standard BPMN notation generated from the XES file.

Field of Study: Computer Science Student's Signature ....
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Liam Khaosanoi

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CHAPTER 1
Introduction

1.1 Statement of problems

Information systems have become essential for business and play an important role in dealing with changes, customer needs and organization strategies. The information systems facilitate the business operations including storing the corporate data and information, logging the events or activities performed on the systems. For example, the service request system has been implemented to allow users from different departments for service requests from others. With a service request system, the public requests are visible to everyone, easy to track, monitor or follow up. Things look promising, but some complaints have been raised, such as lack of good communication or overload during peak periods.

Process mining is a technique that would help a process owner to analyze and track processes. The paradigm uses existing data available in corporate information systems to discover the current actual process that enables the realization of delays in production, overwork, and underseen extra steps.

Conformance checking is a technique of process mining used to compare event logs or the resulting (actual) process with the reference (target) model of the same process. The technique would help determine whether the current processes comply with the target processes.

The integration of process mining technology: ProM [1], Inductive visual Miner [2], and Disco [3], has been applied to gain complete visibility of the current service request process as a case study in this work, in addition to achieve more control over the organization’s automated program.

1.2 Objectives

1.2.1 Study process mining paradigm and technology.

1.2.2 Apply the technique of process mining for process discovery and analysis of deviations and performance of the selected real-world business process.

1.2.3 Facilitate the generation of the revised process model.

1.3 Scope of Study

1.3.1 Use Service Request System, focusing IS request, as a case study.

1.3.2 Experiments using ProM, Inductive visual Miner, and Disco.

1.4 Research Methodology

1.4.1 Study process mining paradigm and technology.

1.4.2 Review several related works in literature.

1.4.3 Gather and prepare data.

1.4.4 Design the experiments and analyze the results.

1.4.5 Conclude on the contribution of research.

1.4.6 Publish the research work

1.4.7 Compile the thesis.

1.5 Contribution

1.5.1 A prototype for conformance analyzing and process discovering of the current process from the event logs that could be applied with other event data.

1.5.2 An approach that would help process owners to identify improvement opportunities.

1.6 Publication

Parts of the thesis had been published in the conference as following:

L. Khaosanoi and Y. Limpiyakorn, “Conformance Checking and Discovery of Information Service Request Process”, in Proceedings of the 14th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI 2021), 2021, Shanghai, China.

CHAPTER 2
Literature Review

2.1 Process Mining

Process mining is an emerging research discipline that sits between computational intelligence and data mining on one hand, and process modeling and analysis on the other [4]. Process mining aims to extract information from recorded process data, which can gain insights into the process [2]. Recorded process data might store additional information such as the resource, activity, timestamp, or data elements. Organizations can discover, monitor, and improve processes based on facts rather than fiction from this record data. Three types of process mining exist:

1) Discovery extracts process models from event logs. It can discover actual processes based on given event logs. Thus, process discovery is a starting point for other types of analysis.

2) Conformance compares the existing process model with event logs to identify the deviations. Process mining techniques can quantify the level of conformance and diagnose differences. Conformance checking can determine if reality, as recorded in the log, conforms to the model and vice versa.

3) Enhancement extends or improves the model using the observed events. For example, process mining tools can extend a model to show bottlenecks, service levels, throughput times, and frequencies by using timestamps in the event logs.

2.2 Petri Net

Petri net [5, 6] is a graphical and mathematical modeling language for describing distributed systems. It is a directed bipartite graph that consists of places, transitions and arcs. Petri nets are executable and provide many analysis techniques. The network structure is *static*, but governed by the *firing* rules that cause tokens to flow through the network. Example Petri net is depicted in Figure 1 containing:

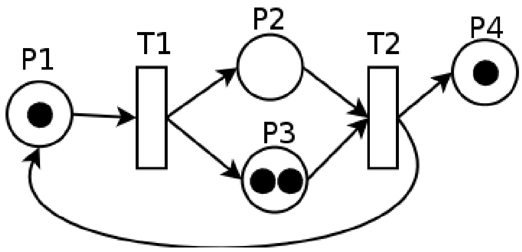

Figure 1 Petri Net [5]

1) **Place** is a buffer, a location, a state and is represented by a white circle. A place can contain any number of marks called tokens. A distribution of tokens over the place represents a configuration (*marking*) of the net.

2) **Transition** is an event, an action and is represented as a bar (rectangle). A transition is fired if it is enabled. When the transition fires, it consumes the required input tokens and creates token in its output places. A firing is atomic (single non-interruptible step). When transitions are enabled at the same time, any one of them may fire.

3) **Arc** is a connection between place and transition and is represented by a directed arrow. It points from a place to a transition or a transition to a place.

Process mining techniques make use of data attributes attached to events to analyze processes from multiple perspectives. However, applying multi-perspective process mining is a laborious task when the event data contains many different attributes. The Multi-perspective Process Explorer tool [9] was introduced in 2015. It supports multi-perspective process mining with integrations of discovery and conformance checking and aims to reduce the time of data exploration. Five perspectives have been considered in process mining:

1) **Control-flow** perspective describes the order of activity executions and corresponds to a possible sequence of activities. s which should be executed
2) **Resource** perspective describes the resources of process executions and the interaction with each other, and resources can be human, machine or material.

3) **Data** perspective describes data required as input for process execution and how data objects are created and updated during the execution of the process.
4) **Time** perspective is related to all times that occur in the process, executions time, waiting time, or transition time between activities.
5) **Function** perspective focuses on specific or series of activities of the process, how the activities affect others, the dependency activities or sub-process to be executed together.

2.3 Disco

Disco [3] is a complete process mining toolkit from Fluxicon. Disco stands for discovery, and it has been on the market since 2012. It is compatible with the ProM 6 by importing and exporting the event log standard formats MXML and XES. Moreover, users can switch and exchange between Disco and ProM. As shown in Figure 2, Disco provides friendly screens and is rich in features as follows.

- Import and Export
- Automated Process Discovery
- Process Statistics
- Variants and Individual Cases
- Filtering
- Performance Highlighting
- Animation

eXtensible Event Stream (XES) [7] is the standard eXtensible Markup Language (XML) format supported by most process mining tools including ProM 6 and Disco. XES was adopted in 2010 by the IEEE Task Force on Process Mining as the standard format for logging events. It has become an official IEEE standard in 2016.

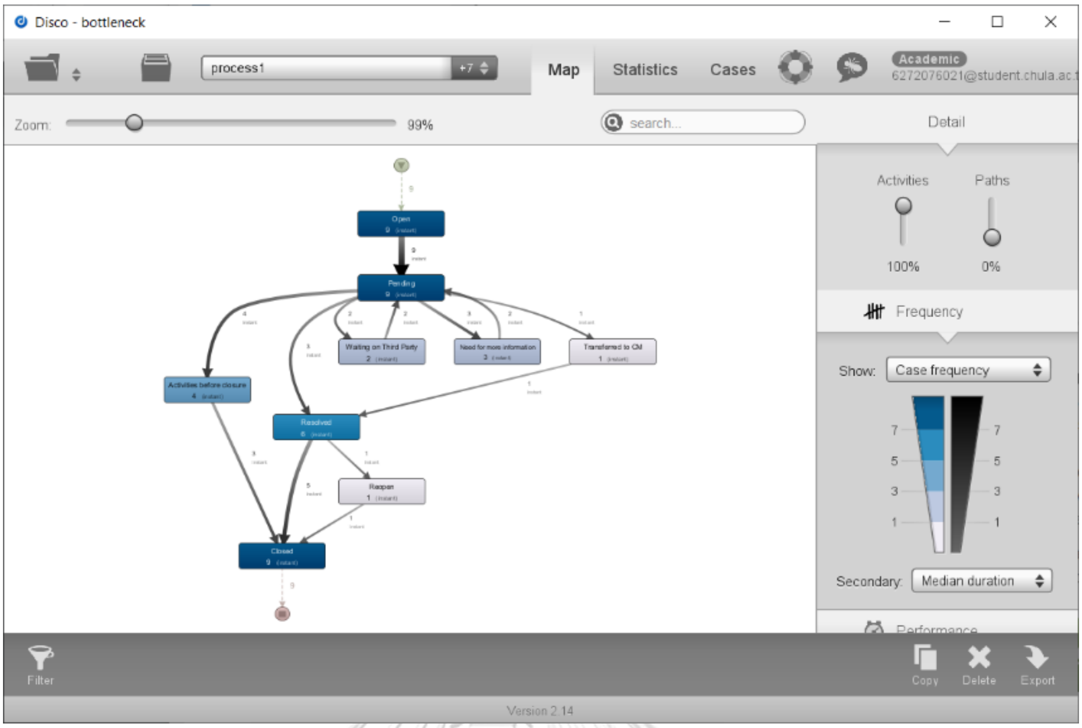

Figure 2 Example of modeling process from event data using Disco

2.4 ProM

ProM [1] is an extensible framework that supports a wide variety of process mining techniques in the form of plug-ins. ProM 6 has been developed from scratch and uses a completely redesigned architecture, the process mining algorithm and the GUI have been carefully separated, and the concepts of contexts have been introduced. Figure 3 illustrates the workspace of ProM 6 and the history of executions, associated with the available actions on a selected object, “XES Event Log”.

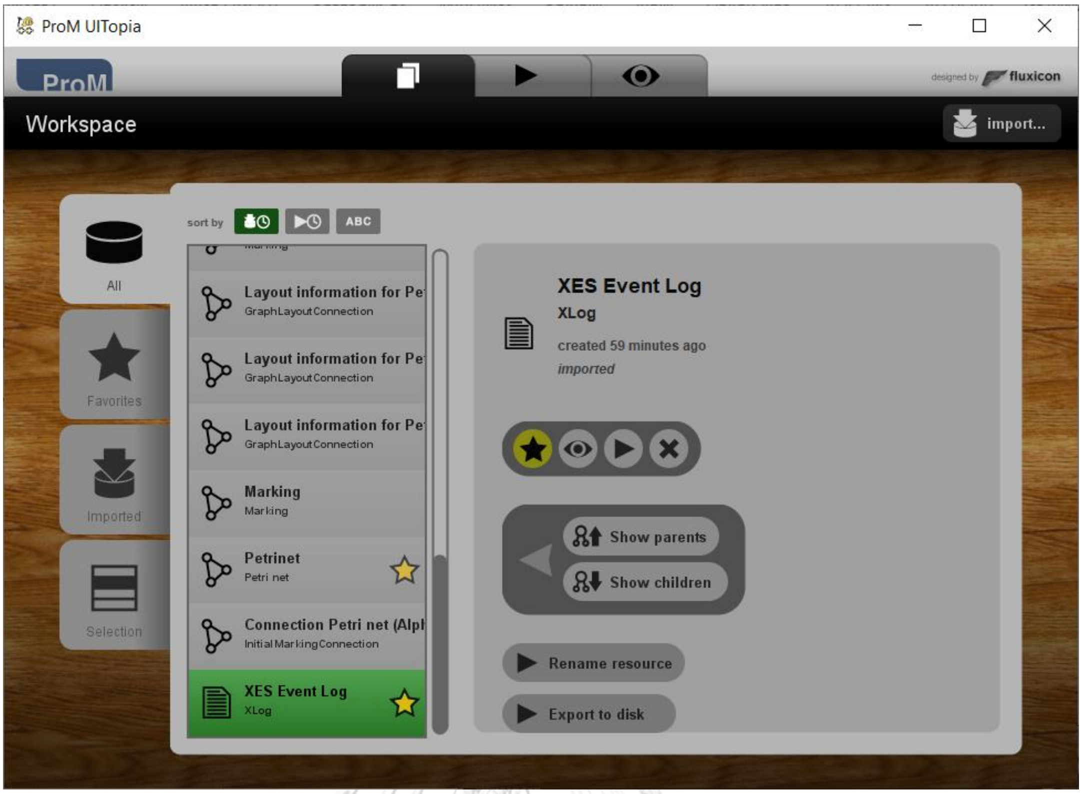

Figure 3 ProM 6 Look&Feel

2.5 Inductive visual Miner (IvM)

The Inductive visual Miner [2, 8] was introduced in 2014, aims to bridge the gap between existing commercial and academic process exploration tools. The commercial process exploration tools offer plenty of options to set the scope of the exploration but usually do not produce models having executable semantics, which thus cannot be used for automated evaluation or further use, while most academic tools lack features such as seamless zooming and animation, thus do not support the repetitive nature of process exploration well.

IvM has been implemented as a plug-in of the ProM framework. It resembles a chain of analysis and visualization tasks to show a model and the traces of the event logs animated on it, and where the log and model deviate from one another. IvM visualizes deviations using a dashed red edge to show which parts of the model fit well and which parts do not. It improves on evaluation by a new notation and the addition of animation and quick node selection filtering. Moreover, user can change parameters at any time with an easy-to-use. IvM will help to:

- discover a process model using Directly Follows Miner or Inductive Miner
- align the discovered process model with the event logs
- show where the discovered process model deviates from the event logs
- compute performance measures for the model and each activity
- animate the event log on top of the discovered process model

An example of the result of mining event logs with IvM is depicted in Figure 4.

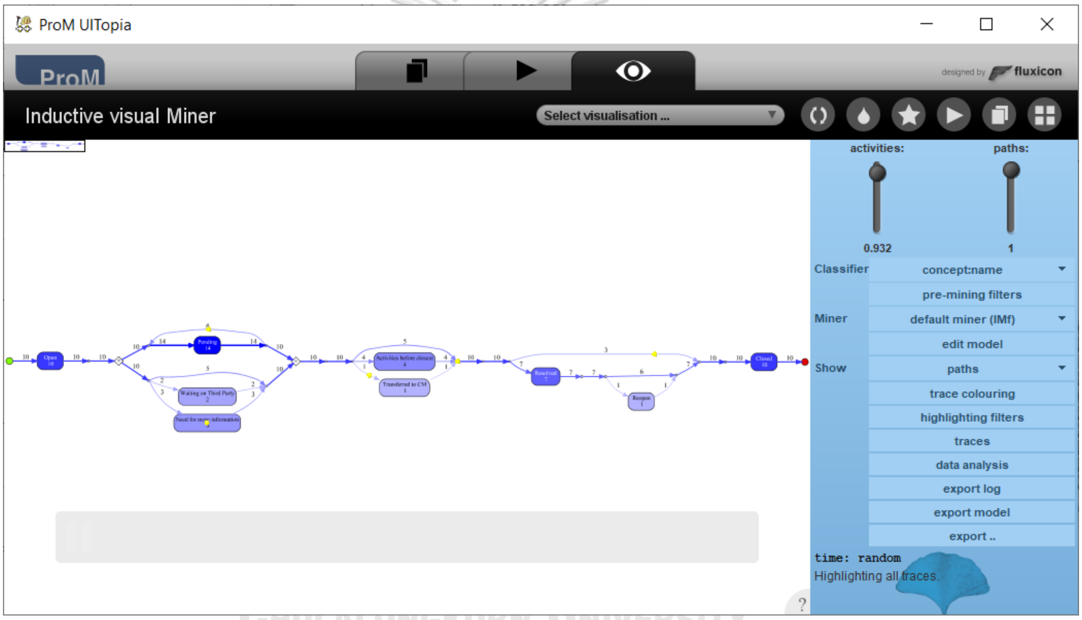

Figure 4 Example traces of event data generated by Inductive visual Miner

2.6 Business Process Modeling Notation (BPMN)

Business Process Modeling Notation [9] has recently become one of the most widely used languages to model business processes. BPMN is supported by many tool vendors and has been standardized by the OMG [10] . Figure 5 illustrates a small subset of all notational elements. Atomic activities are called tasks and they can be nested. Routing logic is not associated with tasks but with separate gateways. There are split and join gateways of different types: AND, XOR, OR as shown in Figure 5. The splits are based on data conditions. An event is comparable to a place in a Petri net. However, the semantics of places in Petri nets and events in BPMN are different. There is no need to insert events in-between activities and events. Start events have one outgoing arc, intermediate events have one incoming and one outgoing arc, and end events have one incoming arc. Unlike in Petri nests, one cannot have events with multiple incoming or outgoing arcs; splitting and joining needs to be done using gateways. Example BPMN model is depicted in Figure 6.

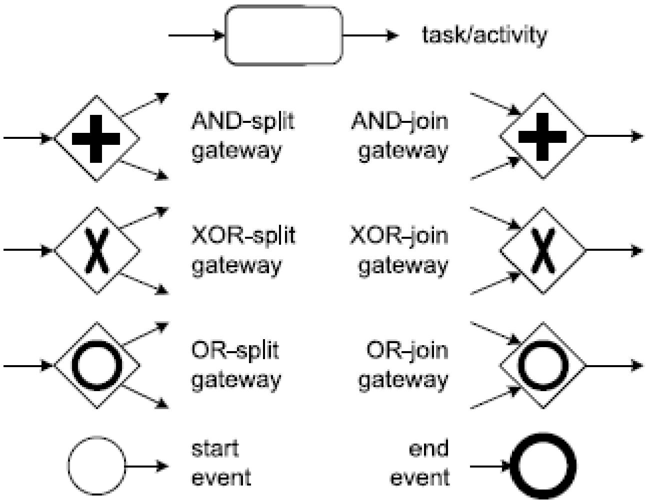

Figure 5 BPMN notation

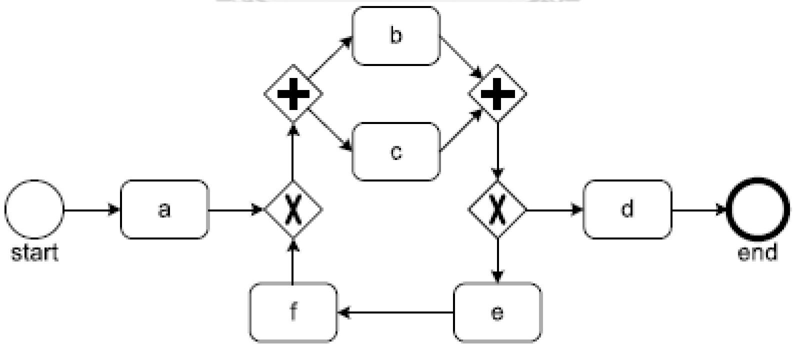

Figure 6 Example process modeling with BPMN

2.7 The Multi-perspective Process Explorer [11]

In 2018, Mannhardt et al. [11] proposed five multi-perspective process mining methods :

1) A conformance checking method that balances the importance of multiple perspectives to provide an alignment between recorded event data and a process model.

2) A precision measure for multi-perspective process models with regard to an event log.

3) A process discovery method that uses domain knowledge on the functional perspective of a process to improve the result of existing discovery methods.

4) A process discovery method that uses the data perspective of a process to distinguish certain infrequent paths from random noise.

5) A decision mining method for discovering, potentially, overlapping decision rules.

The authors developed two interactive tools Interactive Data-aware Heuristic Miner (iDHM) and Multi-perspective Process Explorer (MPE), and both are released as open-source software and implemented as plug-ins of the ProM framework, and have been successfully used.

The iDHM is an interactive data-aware heuristic process discovery tool. With ProM integration, the obtained results can be used for further analysis with other plug-ins in ProM framework. iDHM allows for quick data attributes for control-flow discovery, visualizes the result as models with clear semantics and provides conformance checking, but it is not allowed to adjust the layout and need to improve the on handling the complex C-Nets to be readable.

The MPE provides interactive data-aware visualizations and filtering facilities with three main features 1) integration of multi-perspective conformance checking, analysis of deviations and performance analysis techniques; 2) interactive efficient discovery of decision rules governing the process; 3) built-in filtering and event log exploration based on context-sensitive charts and a trace variants explorer. It has been used in several real-life case studies and has been successfully used but the automatic graph layout works well in simple cases but produces poor layouts for cyclic structures.

CHAPTER 3

Research Methodology

The Service Request system has been implemented to support different types of requests such as Purchasing Request, Finance Request, and Information System Request. In this work, we merely focused on Information System Request (ISR) and used ProM 6 as a primary tool to perform process mining and its plug-ins, which support various types of mining and analysis. IvM, Replay a Log on Petri Net for Conformance Analysis and Multi-perspective Process Explorer were used for process discovery and conformance checking. In addition, VBA script and MS SQL helped to deal with data processing and trace generation.

Figure 7 illustrates the overall process to discover the actual process and conformance checking of the service request process as the case study. The details will be described in the following subsections.

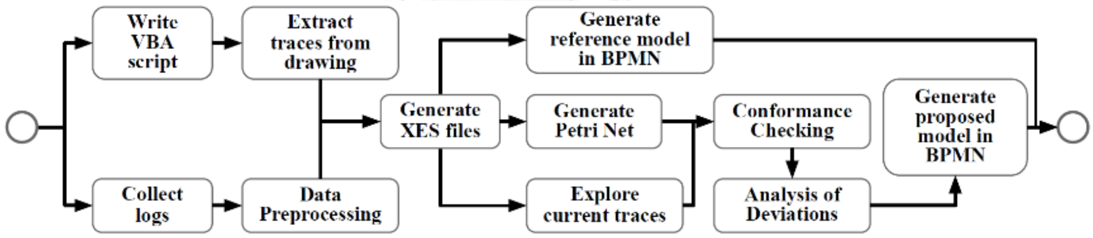

Figure 7 Overview of the proposed methodology

3.1 Reference Model

The organization has defined a business process to describe the workflow and the sequence of activities to be performed on the Information Service Request system as shown in Figure 8. Observing that the current reference model of the ISR process was created using Microsoft drawing.

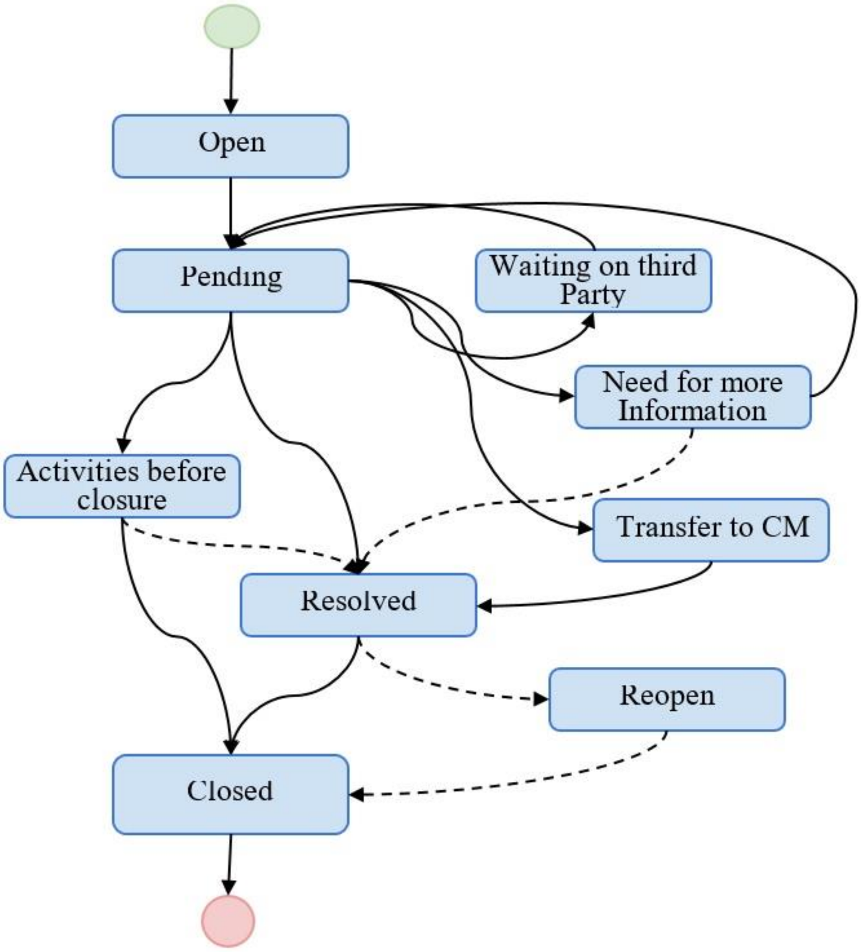

Figure 8 Current reference model of ISR process

The VBA script has been written to bridge the gap between an existing simple drawing of the reference model and a standard for business process modeling approach. First, the script extracted the objects inside the drawing in Figure 8, pulled the links and the process flow direction. Next, generating all the paths (traces) based on their relations by considering “Open” as the start of the process and “Closed” as the last activity. *Trace* is the sequence of events from start to end of one process execution (one request).

```
(General)                                    getStatesFromDrawing
For i = 1 To myShape.GroupItems.Count
    str1 = ""
    stateText = ""
    beginObj = ""
    endObj = ""
    If myShape.GroupItems(i).Type = msoAutoShape Then
        If InStr(1, myShape.GroupItems.Item(i).Name, "Connector") <> 0 Then
            str1 = "Connector,,"
            If myShape.GroupItems.Item(i).ConnectorFormat.BeginConnected = msoTrue Then
                Dim frm As String
                frm = getStatebyName(myShape.GroupItems.Item(i).ConnectorFormat.BeginConnectedShape.Name)
                str1 = str1 & frm & ","
                beginObj = frm
            Else
                 str1 = str1 & ","
            End If
            If myShape.GroupItems.Item(i).ConnectorFormat.EndConnected = msoTrue Then
                Dim toend As String
                toend = getStatebyName(myShape.GroupItems.Item(i).ConnectorFormat.EndConnectedShape.Name)
                str1 = str1 & toend & ","
                endObj = toend
            End If
        objType = "Connector"
        seq = frm & "," & toend
        Call updateListObject
        Debug.Print str1
        End If

    Else
        str1 = str1 & myShape.GroupItems.Item(i).Name & " =" & myShape.GroupItems(i).Type
    End If
```

Figure 9 Part of the script to extract traces from Figure 8

The script stored the listing of all sequences of objects as paths (traces), started with the "Open" state and ended with the "Closed" state, as shown in Table 1. Next, the traces have been rearranged into the list of activity sequences before importing into ProM and converted into XES format. Then, IvM was used to render the process model.

3.2 Data Preprocessing

The system stores logs of each activity performed. Only the activities related to the status movement and duration of the request will be collected. Table 2 presents event data after removing irrelevant data and incomplete traces.

The event logs have to be converted into a computation format, XES file as shown in Figure 10, before starting the mining activity with toolkits.

Table 1 All existing paths (traces) of the reference model

Traces
Open,Pending,Resolved,Closed
Open,Pending,Activities before closure,Closed
Open,Pending,Transferred to CM,Resolved,Closed
Open,Pending,Need for more Information,Resolved,Closed
Open,Pending,Activities before closure,Resolved,Closed
Open,Pending,Resolved,Reopen,Closed
Open,Pending,Waiting on third Party,Pending,Resolved,Closed
Open,Pending,Need for more Information,Pending,Resolved,Closed
Open,Pending,Transferred to CM,Resolved,Reopen,Closed
Open,Pending,Need for more Information,Resolved,Reopen,Closed
Open,Pending,Activities before closure,Resolved,Reopen,Closed
Open,Pending,Waiting on third Party,Pending,Activities before closure,Closed
Open,Pending,Need for more Information,Pending,Activities before closure,Closed
Open,Pending,Waiting on third Party,Pending,Transferred to CM,Resolved,Closed
Open,Pending,Need for more Information,Pending,Transferred to CM,Resolved,Closed
Open,Pending,Waiting on third Party,Pending,Need for more Information,Resolved,Closed
Open,Pending,Need for more Information,Pending,Need for more Information,Resolved,Closed
Open,Pending,Waiting on third Party,Pending,Activities before closure,Resolved,Closed
Open,Pending,Need for more Information,Pending,Activities before closure,Resolved,Closed
Open,Pending,Waiting on third Party,Pending,Resolved,Reopen,Closed
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Open,Pending,Need for more Information,Pending,Transferred to CM,Resolved,Reopen,Closed
Open,Pending,Waiting on third Party,Pending,Need for more Information,Resolved,Reopen,Closed
Open,Pending,Need for more Information,Pending,Need for more Information,Resolved,Reopen,Closed
Open,Pending,Waiting on third Party,Pending,Activities before closure,Resolved,Reopen,Closed
Open,Pending,Need for more Information,Pending,Activities before closure,Resolved,Reopen,Closed

Table 2 Example of event data after cleaning

Request id	Timestamp	Status
5653714	11-06-2021 09:00:29	Open
5653714	11-06-2021 09:34:02	Pending
5653714	14-06-2021 16:52:38	Activities before closure
5653714	18-06-2021 14:59:33	Resolved
5631915	04-06-2021 13:39:38	Open
5631915	04-06-2021 15:22:10	Pending
5631915	08-06-2021 05:49:50	Need for more information
5631915	08-06-2021 06:10:00	Pending
5631915	08-06-2021 06:40:16	Need for more information
5631915	08-06-2021 07:19:56	Pending
5631915	08-06-2021 16:30:40	Activities before closure
5631915	09-06-2021 09:28:01	Closed


```xml
<?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="5653714"/>
        <event>
            <string key="concept:name" value="Open"/>
            <string key="lifecycle:transition" value="complete"/>
        </event>
        <event>
            <string key="concept:name" value="Pending"/>
            <string key="lifecycle:transition" value="complete"/>
        </event>
        <event>
            <string key="concept:name" value="Activities before closure"/>
            <string key="lifecycle:transition" value="complete"/>
        </event>
        <event>
            <string key="concept:name" value="Closed"/>
            <string key="lifecycle:transition" value="complete"/>
        </event>
    </trace>
    <trace>
    <trace>
```


Figure 10 Excerpt of XES file of event logs

3.3 Actual Model

The actual process model was discovered by processing the XES file of an event log. The process and traces exploration has been performed using ProM, IvM, and Disco, and both used the same event log but gave different perspectives of the result. Therefore the flexibility of Disco gave ease of interaction and drilled down on focused behaviors, and IvM discovered the process and indicated the deviations simultaneously by choosing the path and adjustment parameters.

The discovered process model by IvM is presented in Figure 11 and the one created by Disco is shown in Figure 12.

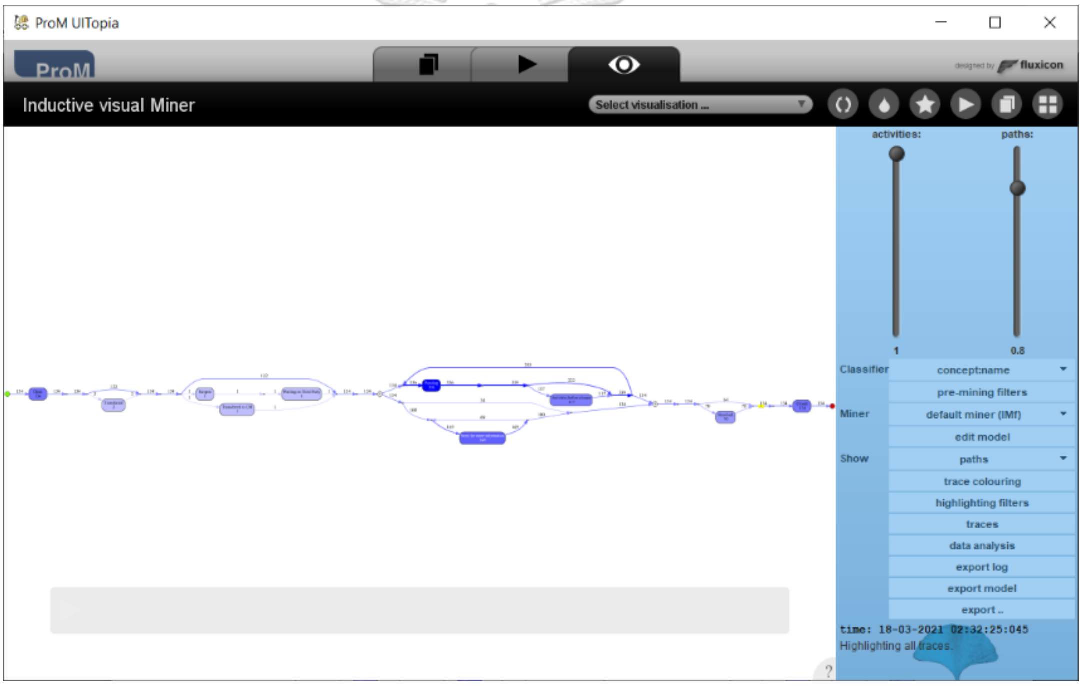


Figure 11 Process model created by IvM

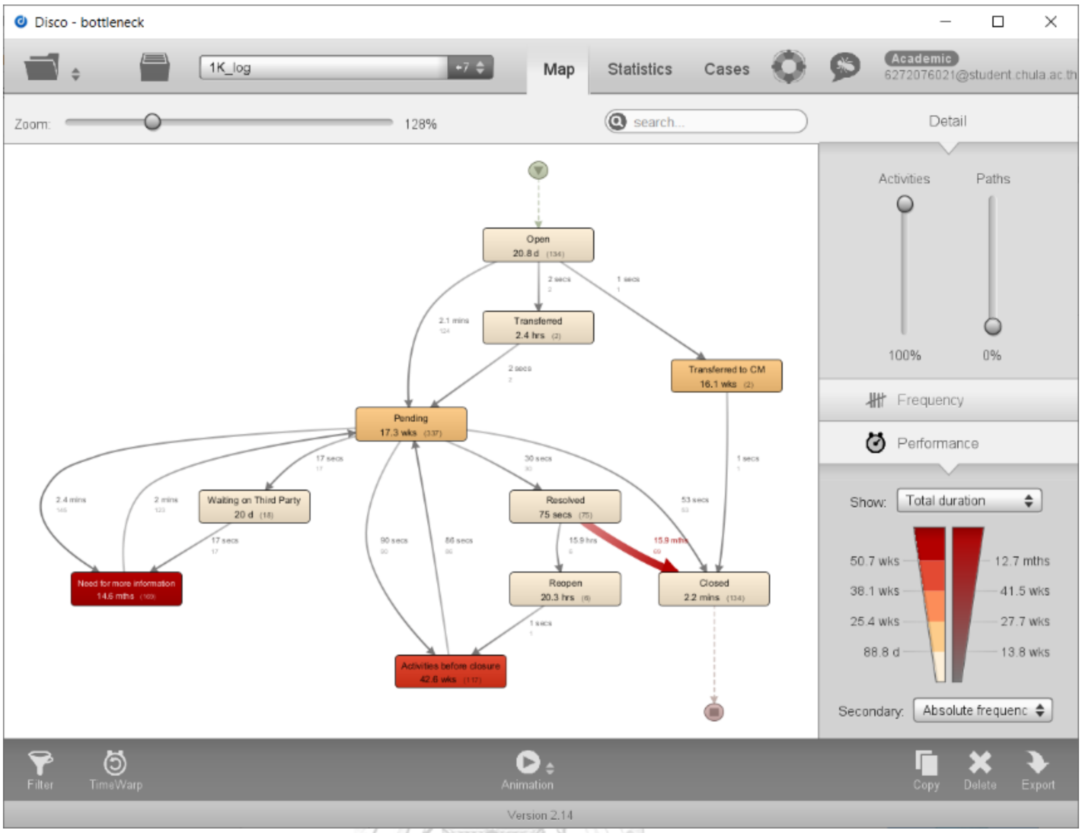


Figure 12 Visualization of process performance by Disco

3.4 Conformance Checking

The discrepancies between the reference process model and the real execution performed on the ISR used the reference process Petri Net and event logs imported to ProM with Multi-perspective Process Explorer plug-in. The result presented how the event log moves on the Petri Net model and many logs moved synchronize with a model, the wrong move on an event and missing move of event.

An alignment is a mapping between the modeled behavior in terms of a process model and the observed behavior from a real process execution recorded in an event log [11]. Events in the log trace are mapped to process steps in the reference model traces, some of the events may not align to reference process transitions. The alignment moves can be considered with these three:

1) Log Move – the activity in the event log. cannot be mapped to the process model.

2) Model Move – the activity on the process model cannot be mapped to the event log.

3) Synchronous Move – the activity in the event log. can be mapped to the process model.

A model with good fitness allows for most of the behavior seen in the event log. A model has a perfect fitness if all traces in the log can be replayed by the model from beginning to end [12]. The process model and log traces (LTS) will be measured with a fitness function provided in equation (1).

$$\text{fitness}(\sigma, \text{LTS}) \in [0, 1] \quad (1)$$

- fitness(σ, LTS) = 1, if the trace σ can be replayed by the model from the beginning to the end with no discrepancies; conversely,
- fitness(σ, LTS) = 0 denotes the poorest level of conformance.

The local fitness is considered to be used for detailed diagnostics on transition and place. A transition fitness (local fitness) process based on the number of model moves (countModelMoves_t) and incorrect moves ($\text{countIncorrectMoves}_t$) observed in the alignments moves of transition t compared to the overall number of alignment moves (countAllMoves_t) observed for that transition, the measure is calculated as in equation (2).

$$1 - \frac{\text{countModelMoves}_t + \text{countIncorrectMoves}_t}{\text{countAllMoves}_t} \quad (2)$$

The local fitness statistic for a place p (place fitness) is based on the number of log moves observed while place p was marked with at least one token (countLogMoves_p) compared to the overall number of alignment moves observed while place p contained at least one token (countAllMoves_p), the measure is calculated as in equation (3).

$$1 - \frac{\text{CountLogMoves}_p}{\text{countAllMoves}_p} \quad (3)$$

CHAPTER 4
Experimentation

4.1 Reference Model Generation

In this step, two types of the reference model, BPMN and Petri Net were generated. Afterward, the standardization of process model notation with BPMN will be proposed for modeling the business processes in the organization, whereas Petri net will be used for conformance checking, replay a log and measuring the quality of the proposed model, as demonstrated in the next step.

At ProM workspace, the XES file of the reference model was imported then selected the proper plug-ins, BPMN Analysis (using Casual Net Miner), and generated BPMN as shown in Figure 13.

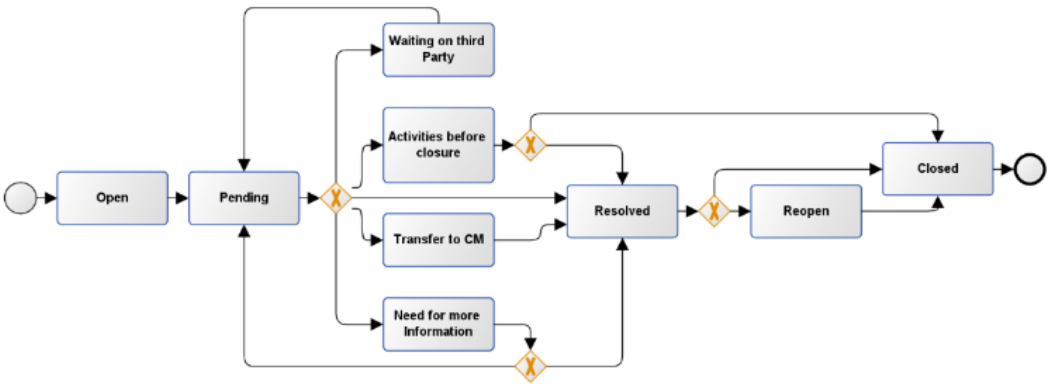


Figure 13 BPMN of the reference model

Figure 14 presents the Petri Net generated from the same XES file imported to ProM and used Mine Petri net with Inductive Miner

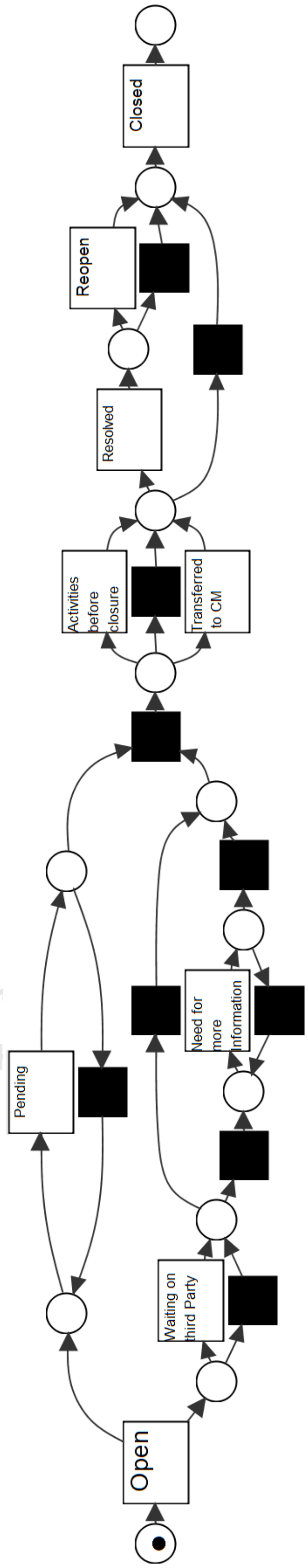


Figure 14 Petri Net of the reference model

4.2 Process Discovery

The XES of the event logs that we extracted, cleaned, and prepared from the earlier step was imported into tools and revealed ISR's real action performed.

ProM and IvM were used for discovering the actual process from the given event. As shown in Figure 15, the flow is slightly different from the defined process and contains more paths and connections than the reference process.

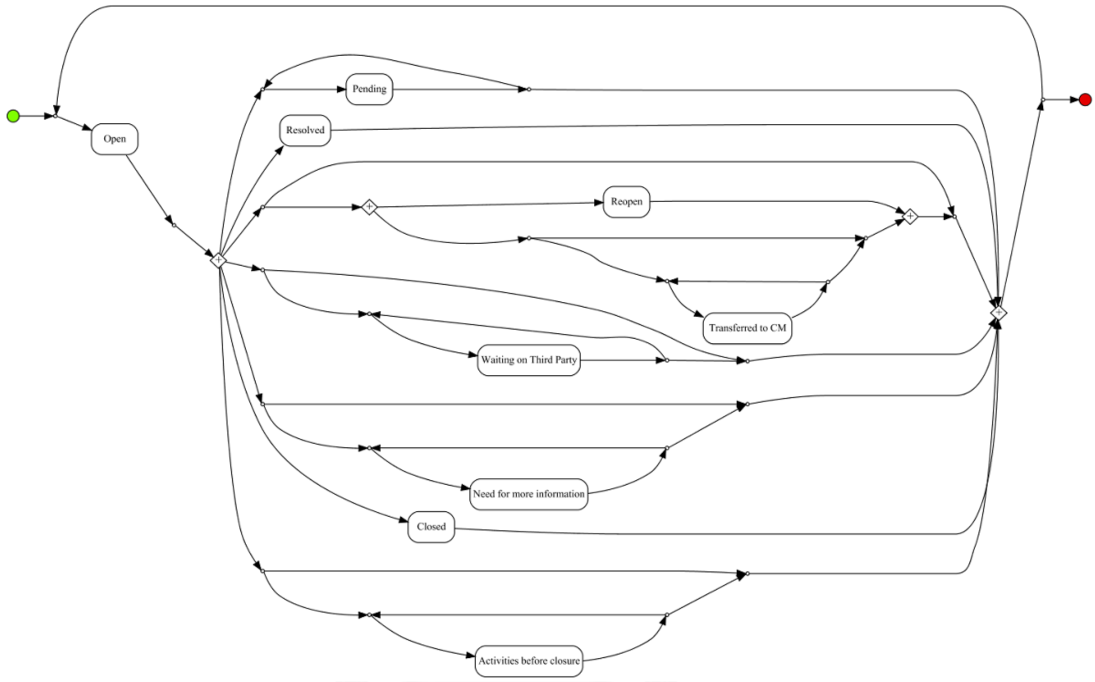


Figure 15 The actual process discovered by IvM

Disco was also involved in process discovery and provided the overview of activities performed in the system from the same event logs. We made use of the Disco features to thicken the path and filled the activities with darker color by its frequency as shown in Figure 16.

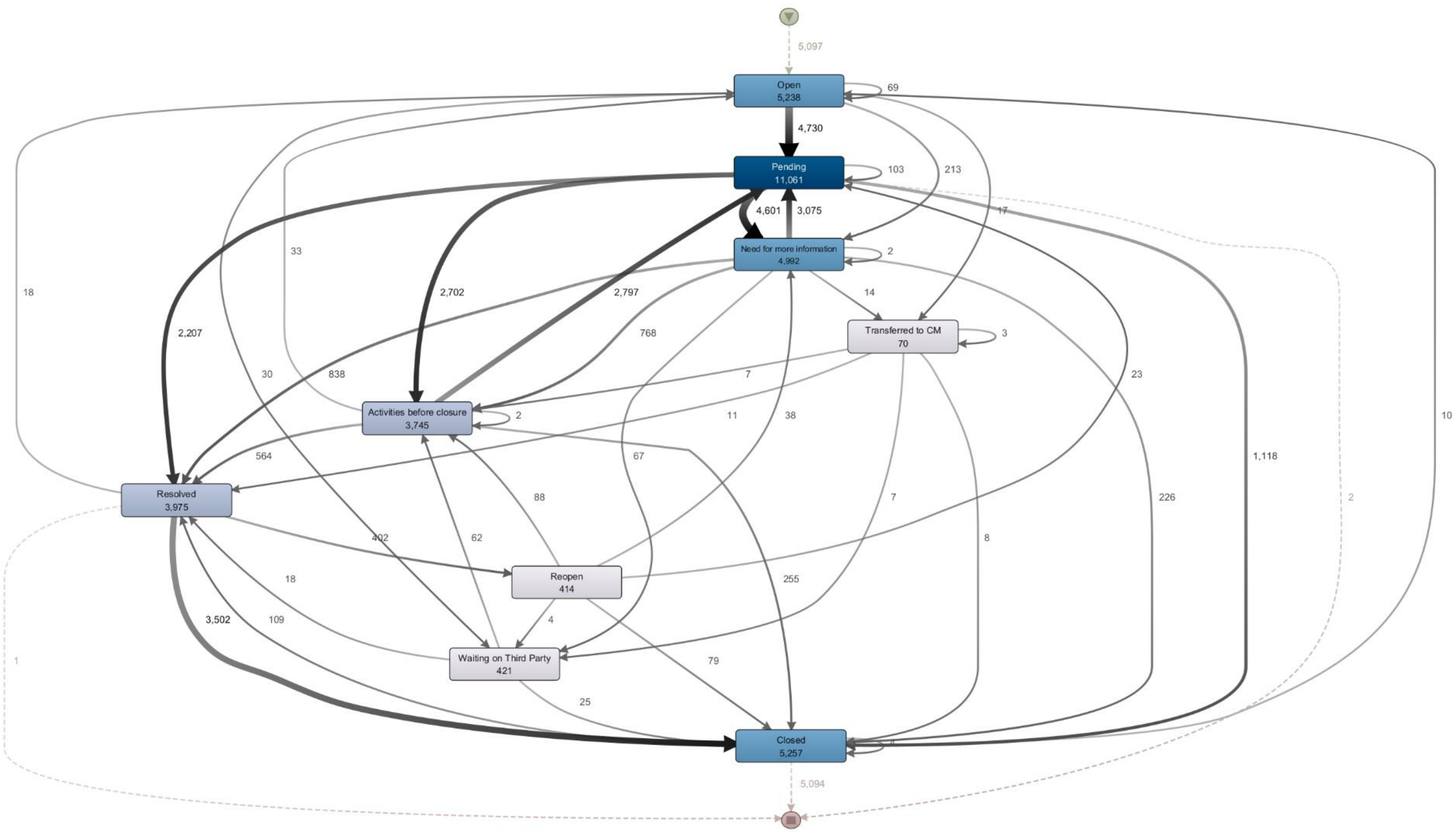


Figure 16 Actual process generated from event log by Disco

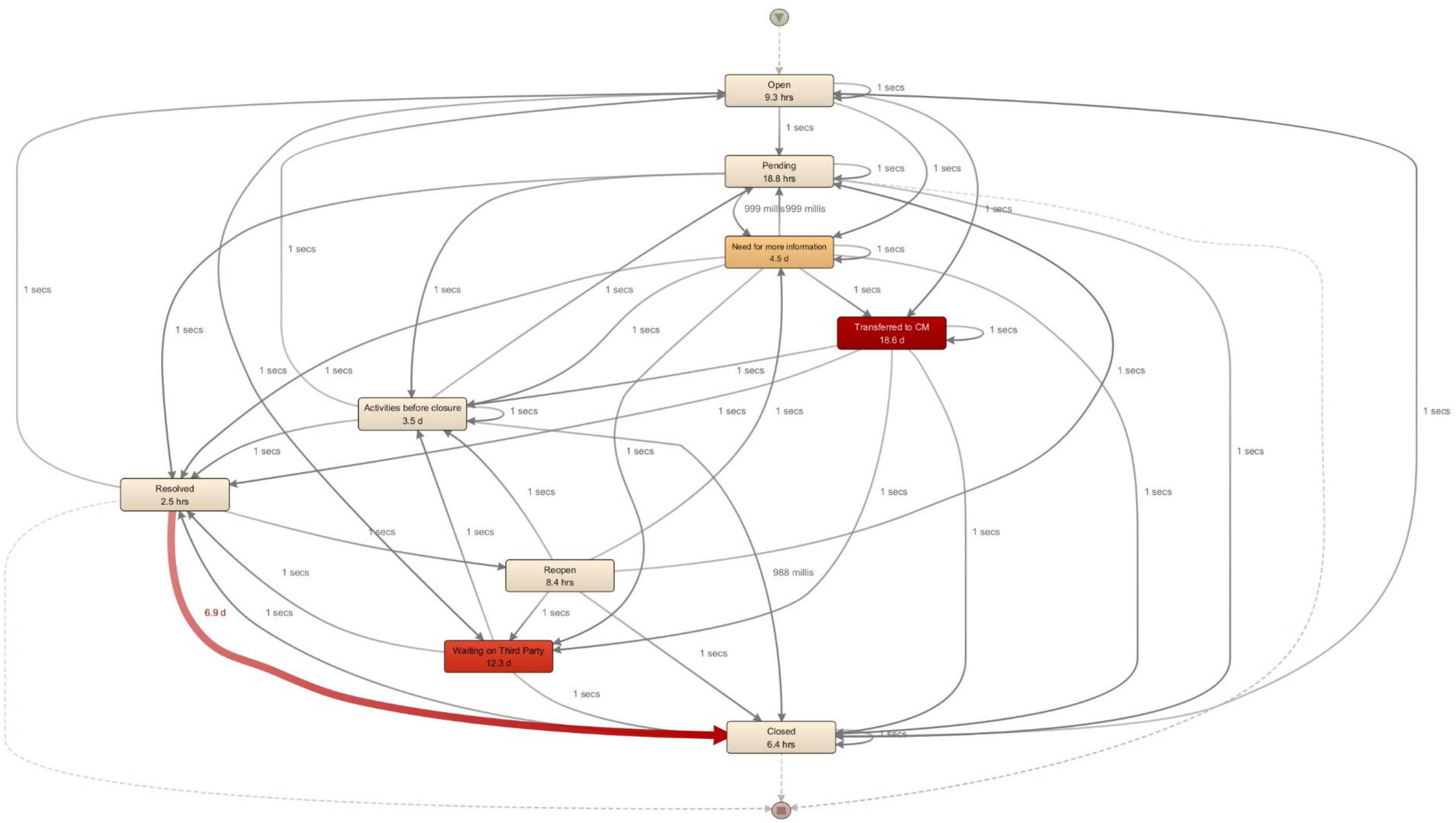


Figure 17 Actual process generated from event log by Disco with the performance highlight

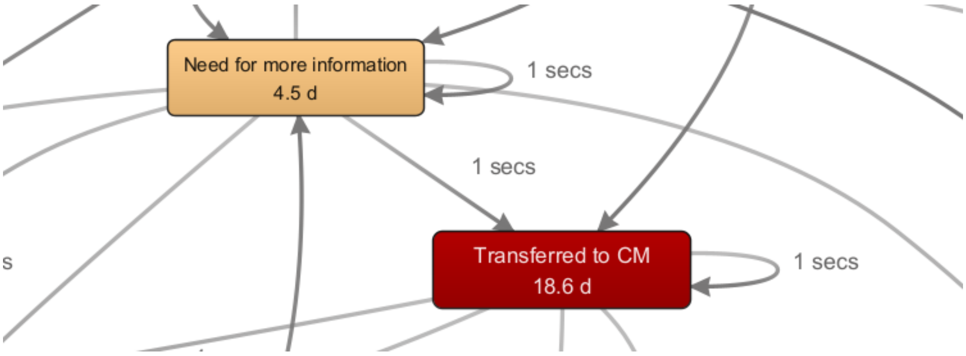
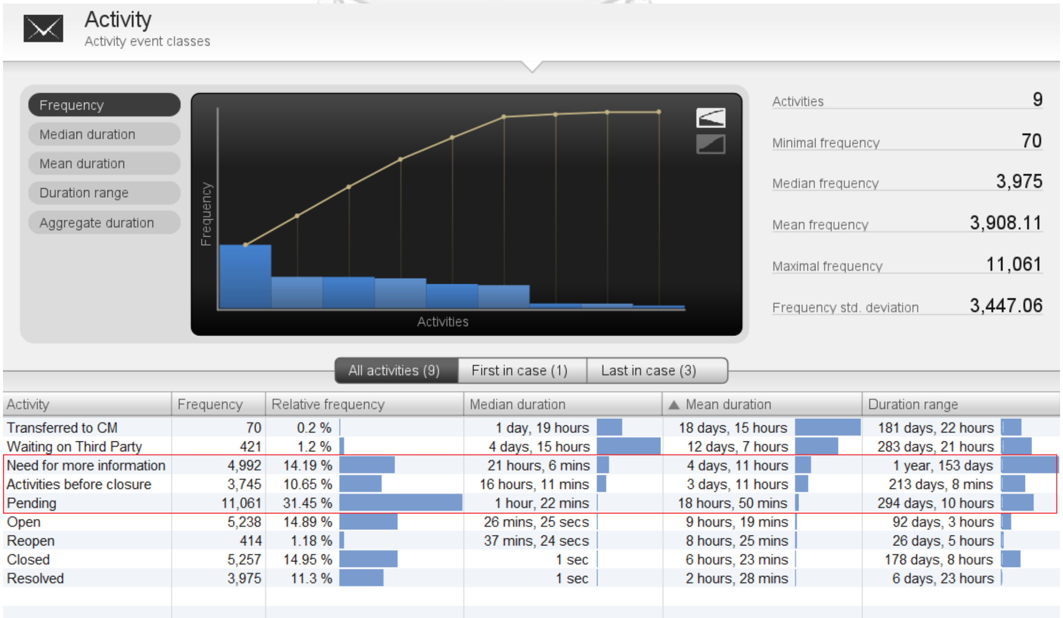


Figure 18 Close up of Figure 17

Figure 19 Close up of performance highlight of Figure 17



Activity	Frequency	Relative frequency	Median duration	Mean duration	Duration range
Transferred to CM	70	0.2 %	1 day, 19 hours	18 days, 15 hours	181 days, 22 hours
Waiting on Third Party	421	1.2 %	4 days, 15 hours	12 days, 7 hours	283 days, 21 hours
Need for more information	4,992	14.19 %	21 hours, 6 mins	4 days, 11 hours	1 year, 153 days
Activities before closure	3,745	10.65 %	16 hours, 11 mins	3 days, 11 hours	213 days, 8 mins
Pending	11,061	31.45 %	1 hour, 22 mins	18 hours, 50 mins	294 days, 10 hours
Open	5,238	14.89 %	26 mins, 25 secs	9 hours, 19 mins	92 days, 3 hours
Reopen	414	1.18 %	37 mins, 24 secs	8 hours, 25 mins	26 days, 5 hours
Closed	5,257	14.95 %	1 sec	6 hours, 23 mins	178 days, 8 hours
Resolved	3,975	11.3 %	1 sec	2 hours, 28 mins	6 days, 23 hours

Figure 20 Statistics of event data

The second process metric chosen to represent the performance of the process is shown in Figure 17 and displayed with a similar strategy, i.e., the darker and thicker indicates a longer duration of activities and paths.

Process discovery visualized activities performed on the system. The frequency metric showed system flow and indicated the most frequency activities are “Pending”, “Need for more information” and “Activities before Closure” as darker color filled in Figure 16 and they took 18 hours, 4 days and 3 days as an average on these states as shown in Figure 20. While the performance metric in Figure 17 pointed out “Transferred to CM”, “Waiting on Third Party” and “Need for more information” are longest duration time spent on states as 18, 12 and 4 days respectively. “Transferred to CM” and “Waiting on Third Party” are less occur on the system and understandable to spend more time since “Waiting on Third Party” will need to the involvement of the third party who could be in an organization or the vendor outside. “Need for information” is a member on both the most frequencies and the most prolonged durations, it could be considered as a bottleneck of the process. The performance and improvement of this state will significantly affect overall process performance.

In addition, the BPMN of the actual process model was produced to allow direct comparison with other ones we generated. Although this was different from the previous BPMN generation because it was impossible to use the event logs directly, the researcher understands that due to the mess and complexity of the event logs, this BPMN was created from Petri Net via ProM Convert Petri Net to BPMN as illustrated in Figure 21.

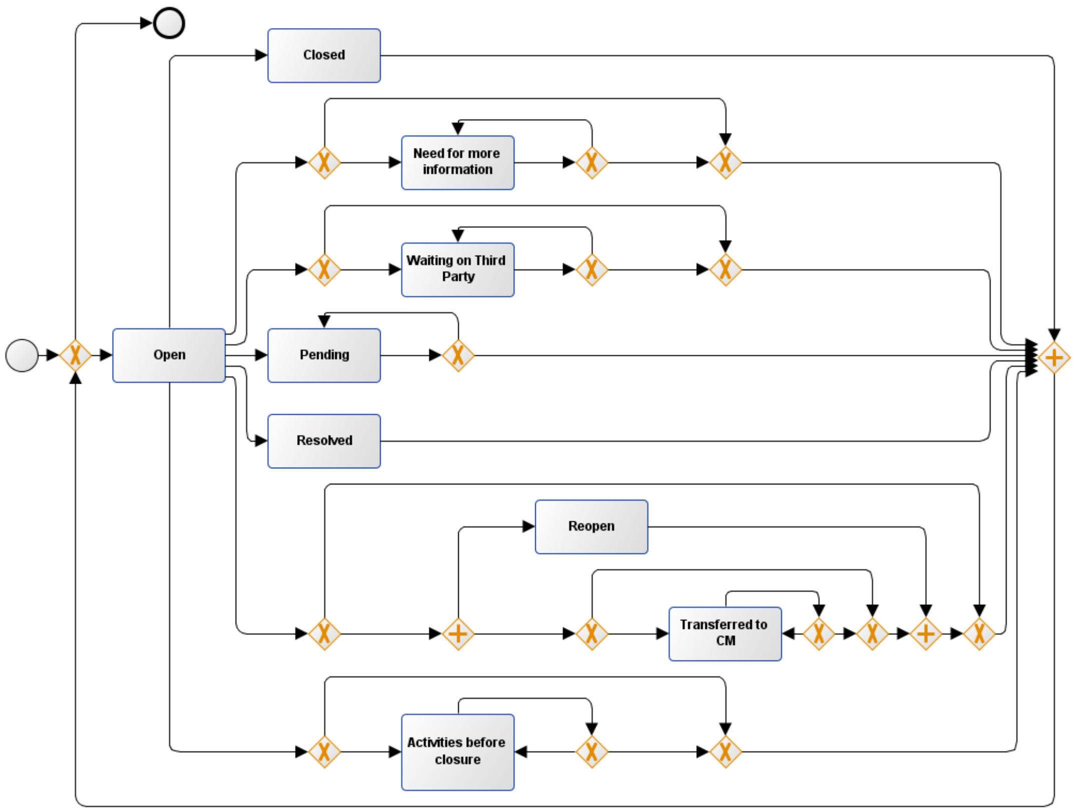


Figure 21 BPMN of actual process model.

4.3 Conformance Checking

The Petri Net of reference process model was used as the base model to identify the discrepancies. With ProM, we imported Petri Net of a reference process model and XES of event logs as input, then selected Multi-perspective Process Explorer and started checking to analyze how well the input process model represents the observed process behavior. Figure 22 shows the fitness diagnostics on the reference process model along with the used color scale.

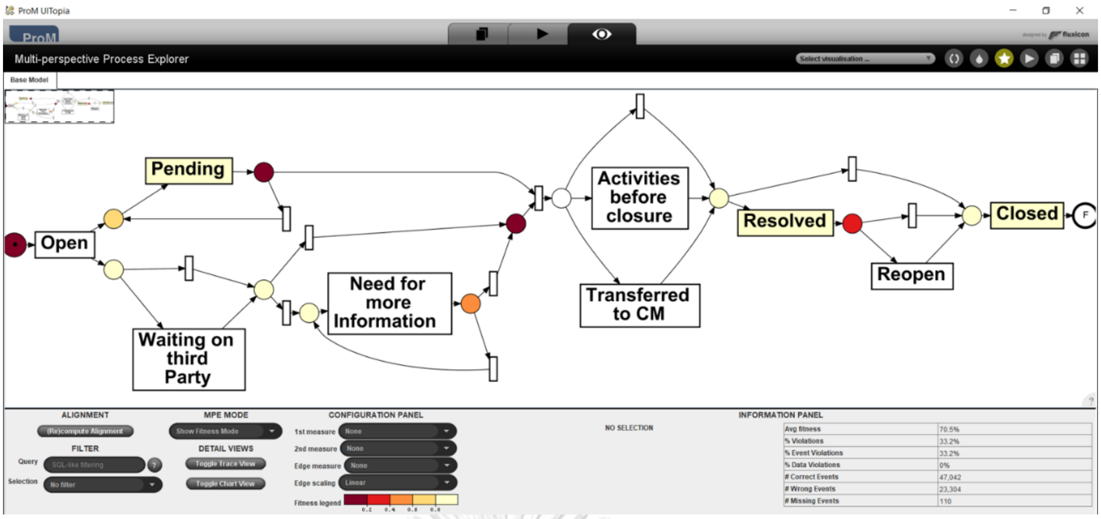


Figure 22 Fitness of reference model Mode on Multi-perspective Process Explorer

Table 3 Results of conformance checking against the reference model

Metric	Value
Avg fitness	70.5%
% Violations	33.2%
% Event Violations	33.2%
% Data Violations	0.0%
# Correct Events	47,042
# Wrong Events	23,304
# Missing Events	110

Table 4 Transition fitness of the reference model from Figure 22

States	Transition fitness	# Correct Events	# Wrong Events	# Missing Events
Open	100.0%	5,097	0	0
Pending	99.5%	22,084	0	108
Need for more information	100.0%	9,980	0	0
Waiting on Third Party	100.0%	146	0	0
Activities before closure	100.0%	767	0	0
Transferred to CM	100.0%	17	0	0
Resolved	100.0%	3,588	0	1
Reopen	100.0%	267	0	0
Closed	100.0%	5,096	0	1

Table 5 Place fitness of the reference model from Figure 22 with selected darkest color places.

	#1	#2	#3	#4
Place fitness	-129.1%	-55.4%	42.3%	29.3%
% Data Violations	0.0%	0.0%	0.0%	0.0%
% Event Violations	20.2%	26.7%	18.3%	50.1%
# Good events	46,222	21,783	13,116	3,589
# Wrong events (data)	0	0	0	0
# Missing events	0	0	0	0
# Wrong events (log)	11,676	7,920	2,942	3,603

The result presents in Figure 22, and the model fitness is shown in Table 3. The reference model reached 70.5% of average fitness and 33.2% of violations with 23,304 wrong events. On the other hand, transition fitness in Table 4 displays almost all the transitions reaching almost 100% except “Pending” which reached 99.5% of transition fitness with only 108 wrong events. The third detail of the result in Table 5 is place fitness, and the worst fitness is place #1 (the dark red circle after “Pending” in Figure 22) with -129.1% of place fitness, 46,222 of good events and 11,676 of wrong events. Another lookout place is #4 (the red circle behind “Resolved” in Figure 22) caught 50.1% of event violations, 3,589 good events, and 3,603 wrong events.

With these results, the researcher understood that the performers often skipped “Resolved” states once they finished the work on requests while only allowing either “Activities before closure”, “Resolved” or “Reopen” before moving to close and the system contained half of the wrong event at place #4. From the business perspective, a request sent to “Resolved” before “Closed” allows the requester to validate the resolution provided and reopen the request if further support is needed. Therefore, the system did not prevent users from updating the closed requests could be the reason for non-conform behavior. They can continue working and moving the requests backward if additional work is required.

4.4 Proposed Model Generation

The proposed model was generated from the event logs with criteria as following

1) Only completed traces included for generating a proposed model; traces must start with “Open” and the last activity as “Closed”.

2) The repetition on “Pending” and “Need for more information” states was less than four times.

3) Select the top ten frequencies from all completed traces and the top three frequencies of each state. In addition, we included the reference model trace by considering them as must-have traces to keep the current defined process.

The script was created at Microsoft SQL Server to connect with the event logs directly, tables of violations and required trace patterns have been created in the database to be fed as the criteria in the script and saved as store procedure in the database to allow modification of script or re-executed once parameter changes.

```
/* generate traces of all cases, get variaints */
SELECT CAST(ticket_id AS VARCHAR(50)) AS ticket_id, [traces] = STUFF((
    SELECT ',' + [status] FROM #t WITH (NOLOCK)
    WHERE ticket_id = x.ticket_id ORDER BY RowN
    FOR XML PATH(''), TYPE).value('.[1]', 'nvarchar(max)'), 1, 1, '')
    INTO #tbTraces
        FROM #t  AS x
        GROUP BY ticket_id
```

```
/* get frequency of each valid trace*/
SELECT count(*) AS CNT,[traces]
INTO #tbTracesCNT
FROM #tbTraces t
INNER JOIN tb_violateTrace v ON t.[traces] NOT LIKE v.[text]
INNER JOIN tb_allowTrace a ON t.[traces] LIKE a.[text]
GROUP BY [traces]
ORDER BY count(*) DESC
```

```
/* rotate,unpivot selected traces into table format to be convert to XES */
 SELECT A.caseid,
     Split.a.value('.', 'VARCHAR(100)') AS [activity]
     ,seq=ROW_NUMBER() OVER (ORDER BY caseid)
 FROM  (SELECT caseid='case '+RIGHT(CAST(1000+ROW_NUMBER() OVER (ORDER BY [traces]) AS VARCHAR(10)),3) ,
         CAST ('<M>' + REPLACE([traces], ',', '</M><M>') + '</M>' AS XML) AS String
     FROM  #tbSelectedTraces) AS A CROSS APPLY String.nodes ('/M') AS Split(a);
```


Figure 23 Excerpt of a script for generation traces of proposed model

Stored procedure, generateProposedModel has been created from a script shown in Figure 23 to allow modification of script logic, re-executed, or criteria changing in the future. The result shown in Figure 24 contains the traces generated from the store procedure to be used in the next step on the proposed process model creation.

Proposed model traces were converted into XES as a required step, then fed into ProM BPMN Analysis (using Casual Net Miner). The generated BPMN process model is illustrated in Figure 25 and the corresponding Petri Net created with ProM Mine Petri net with Inductive Miner is displayed in Figure 26.

```sql
EXEC [dbo].[generateProposedModel]
```

100 %

Results | Messages

	caseid	activity	seq
1	case 001	Open	1
2	case 001	Pending	2
3	case 001	Activities before closure	3
4	case 001	Closed	4
5	case 002	Open	5
6	case 002	Pending	6
7	case 002	Activities before closure	7
8	case 002	Pending	8
9	case 002	Activities before closure	9
10	case 002	Pending	10
11	case 002	Resolved	11
12	case 002	Closed	12
13	case 003	Open	13
14	case 003	Pending	14
15	case 003	Activities before closure	15
16	case 003	Pending	16
17	case 003	Resolved	17
18	case 003	Closed	18
19	case 004	Open	19

Figure 24 Result of log generation for the proposed model

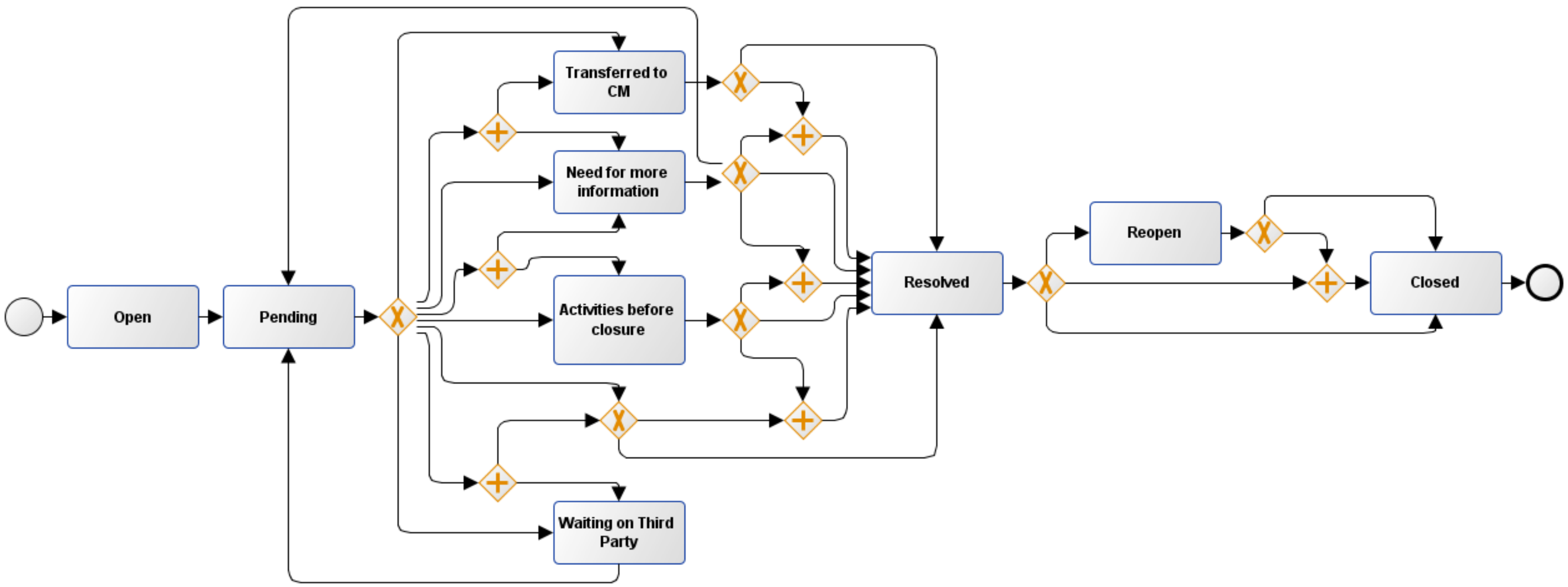


Figure 25 BPMN of the proposed model

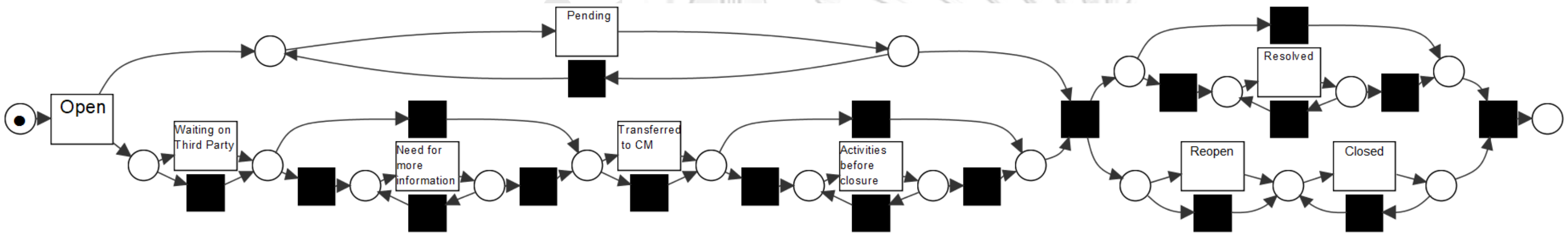


Figure 26 Petri Net of the proposed model

The Petri Net from Figure 26 was used to measure the proposed model's quality against the existing event logs by importing the Petri Net model and event logs into ProM then selecting Multi-perspective Process Explorer., the result is shown in Figure 27, and details are provided in Table 6, 7 and 8. The proposed model obtained 82.2% average fitness, 56,832 correct events, 13,514 wrong events, 412 missing events, and 19.7% of event violations.

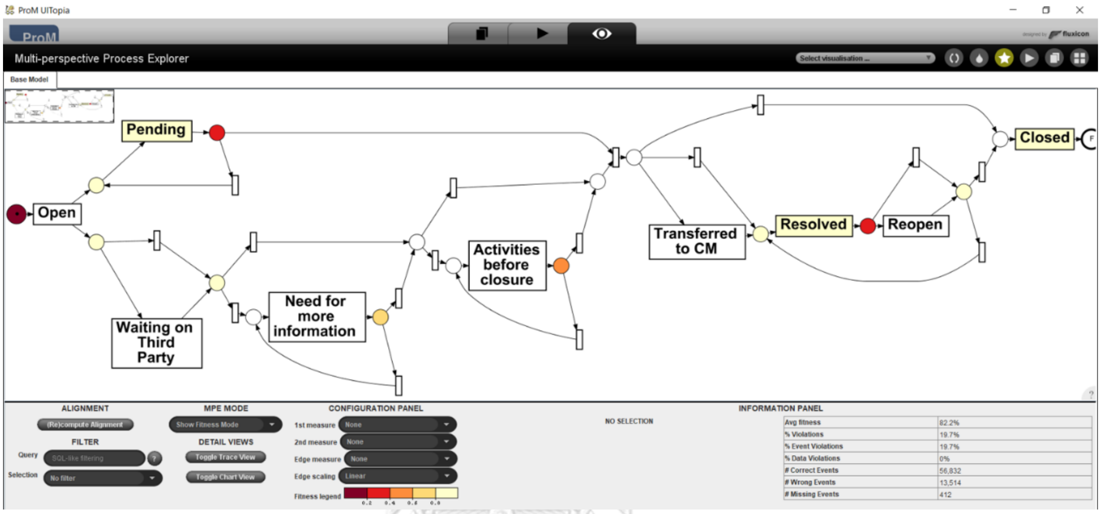


Figure 27 Fitness of proposed model Mode on Multi-perspective Process Explorer

Table 6 Summary of statistics for evaluation of proposed model

Metric	Value
Avg fitness	82.2%
% Violations	19.7%
% Event Violations	19.7%
% Data Violations	0.0%
# Correct Events	56,832
# Wrong Events	13,514
# Missing Events	412

Table 7 Transition fitness of the proposed model

States	Transition fitness	# Correct Events	# Wrong Events	# Missing Events
Open	100.0%	5,097	0	0
Pending	99.5%	22,100	0	108
Need for more information	100.0%	9,214	0	0
Waiting on Third Party	100.0%	132	0	0
Activities before closure	100.0%	6,998	0	0
Transferred to CM	100.0%	17	0	0
Resolved	96.2%	7,588	0	301
Reopen	100.0%	592	0	0
Closed	99.9%	5,094	0	3

Table 8 Placed fitness of the proposed model from highlight places in Figure 27

	#1	#2	#3
Place fitness	29.6%	54.3%	30.5%
% Data Violations	0.0%	0.0%	0.0%
% Event Violations	7.7%	12.2%	31.0%
# Good events	42,821	16,787	7,889
# Wrong events (data)	0	0	0
# Missing events	0	0	0
# Wrong events (log)	3,587	2,327	3,541

Table 9 Overall fitness of reference model and proposed model

Overall	Reference model	Propose model
Avg fitness	70.5%	82.2%
% Violations	33.2%	19.7%
% Event Violations	33.2%	19.7%
% Data Violations	0.0%	0.0%
# Correct Events	47,042	56,832
# Wrong Events	23,304	13,514
# Missing Events	110	412

Table 10 Place fitness of reference model and proposed model

	Reference model				Propose model		
	#1	#2	#3	#4	#1	#2	#3
Place fitness	-129.1%	-55.4%	42.3%	29.3%	29.6%	54.3%	30.5%
% Data Violations	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Event Violations	20.2%	26.7%	18.3%	50.1%	7.7%	12.2%	31.0%
# Good events	46,222	21,783	13,116	3,589	42,821	16,787	7,889
# Wrong events (data)	0	0	0	0	0	0	0
# Missing events	0	0	0	0	0	0	0
# Wrong events (log)	11,676	7,920	2,942	3,603	3,587	2,327	3,541

Table 11 Transition fitness of reference model and proposed model

Transition fitness	Reference model				Propose model			
States	**Transition fitness**	**# Correct Events**	**# Wrong Events**	**# Missing Events**	**Transition fitness**	**# Correct Events**	**# Wrong Events**	**# Missing Events**
Open	100.0%	5,097	0	0	100.0%	5,097	0	0
Pending	99.5%	22,084	0	108	99.5%	22,100	0	108
Need for more Information	100.0%	9,980	0	0	100.0%	9,214	0	0
Waiting on third Party	100.0%	146	0	0	100.0%	132	0	0
Activities before closure	100.0%	767	0	0	100.0%	6,998	0	0
Transferred to CM	100.0%	17	0	0	100.0%	17	0	0
Resolved	100.0%	3,588	0	1	96.2%	7,588	0	301
Reopen	100.0%	267	0	0	100.0%	592	0	0
Closed	100.0%	5,096	0	1	99.9%	5,094	0	3

The comparison of overall fitness between the reference model and proposed model display in Table 9 can be seen the slight improvement of the model, average fitness increased from 70.5% to 82.2% and violations reduced from 33.2% to 19.7%, except the missing event increased from 110 to 412 which will be explained by transition fitness. The place fitness in Table 10 gave an obvious result that we have one less attention place (dark red) in the proposed model and Table 11 provided detail of transition fitness comparison. Both models reached almost 100% of transition fitness except the "Resolved" and "Closed" transition fitness have been decreased to 96.2% and 99.9% respectively. The "Resolved" state caught more missing events which led to reduction of transition fitness, when looking in the detail found that "Resolved" has increased the number of correct events from 3,588 to 7,588.

The proposed model observed more events than that the reference model from numbers of correct events and missing events from both models, the overall average fitness increased even transition fitness in some states has been decreased. This convinced the researcher to use this proposed model as initial revision proposes for process improvement discussion.

4.5 Additional Perspective

We extracted and prepared the event logs as displayed in Table 12 with the support team attribute, aimed to explore who handled the requests and how they worked together with the hierarchy of support routing.

Table 12 The event logs with Support team attribute

Request id	Timestamp	Support Team
5653714	11-06-2021 09:00:29	L0-Contact
5653714	11-06-2021 09:34:02	L2-WEB
5658371	14-06-2021 09:47:25	L0-Contact
5658371	21-06-2021 17:12:33	L1-NONSAP
5658371	22-06-2021 08:15:49	L2-WEB
5659050	14-06-2021 12:53:35	L1-NONSAP
5659152	14-06-2021 13:10:23	PtP
5659152	14-06-2021 13:11:24	PtP
5659152	14-06-2021 13:13:34	L0-Contact
5659152	14-06-2021 15:06:03	L1-NONSAP

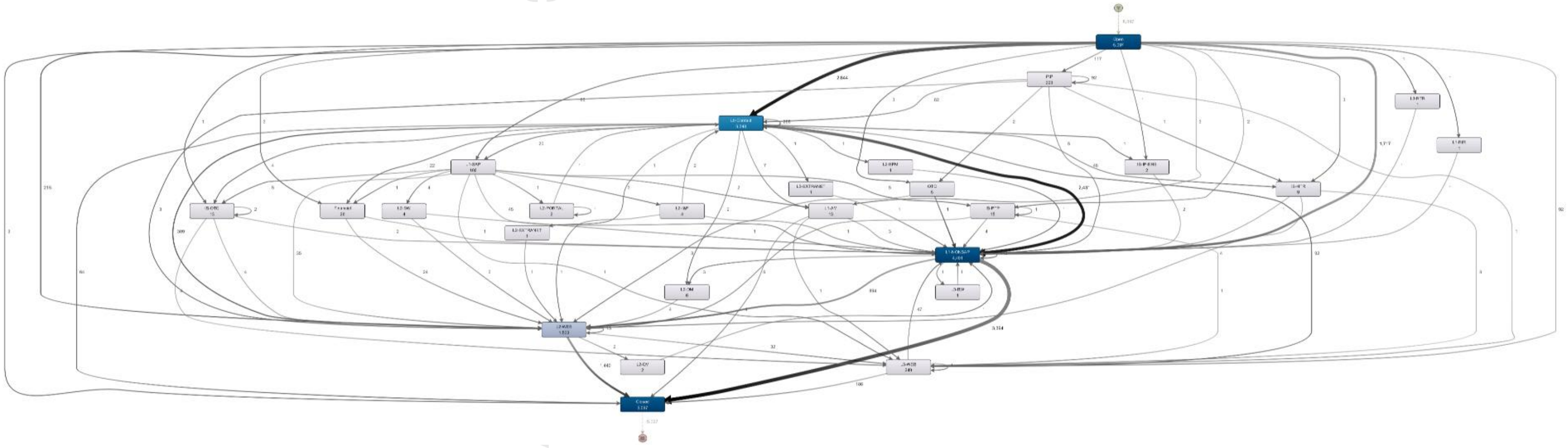


Figure 28 The process flow of the team supported the requests

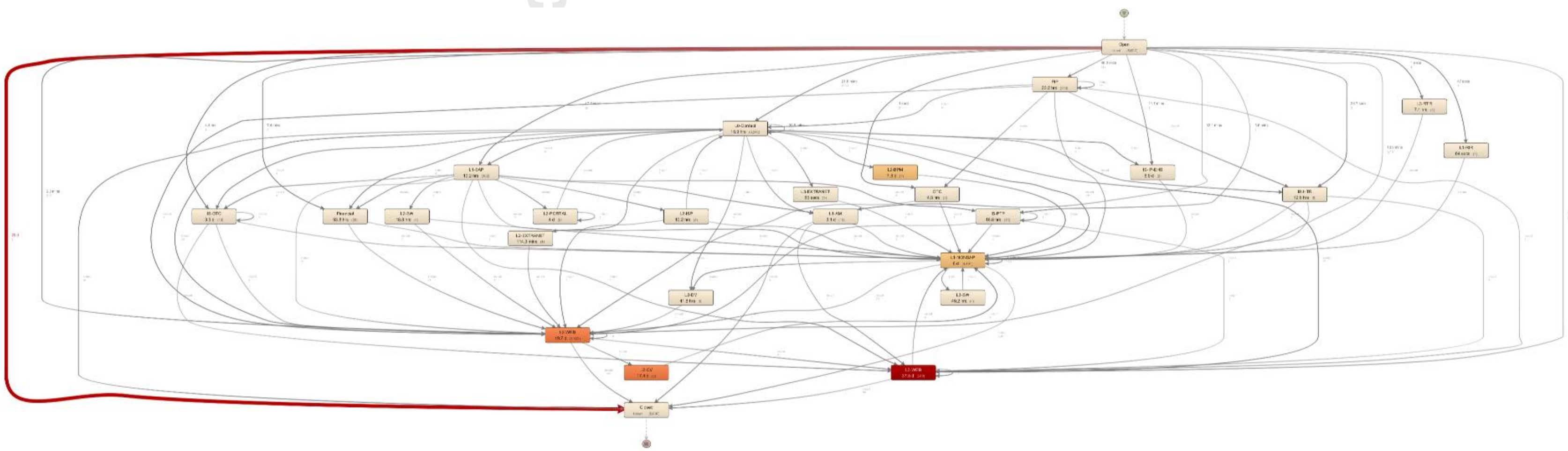


Figure 29 The process flow of the team supported the requests

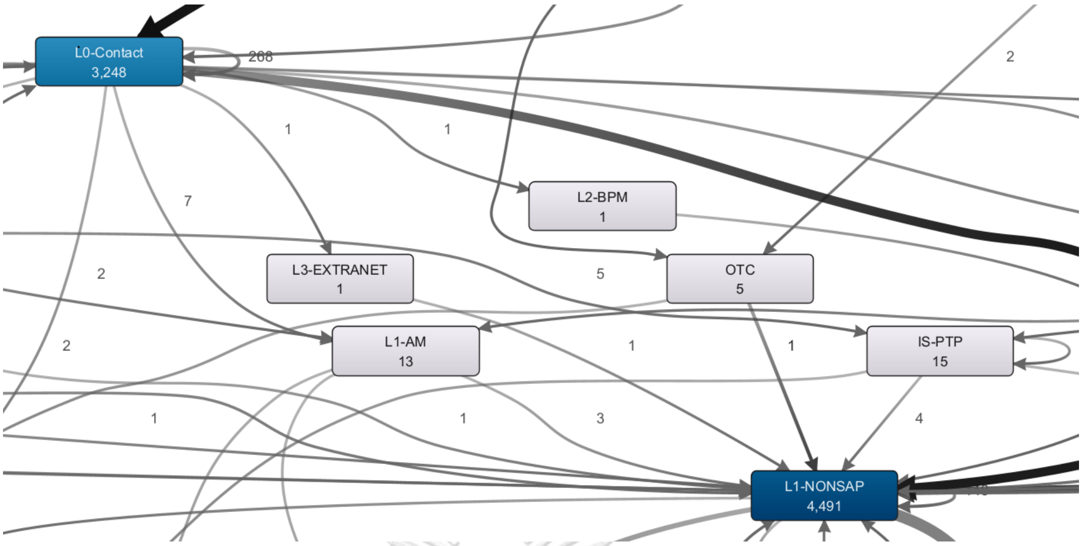


Figure 30 Focus on the resource workload from Figure 28

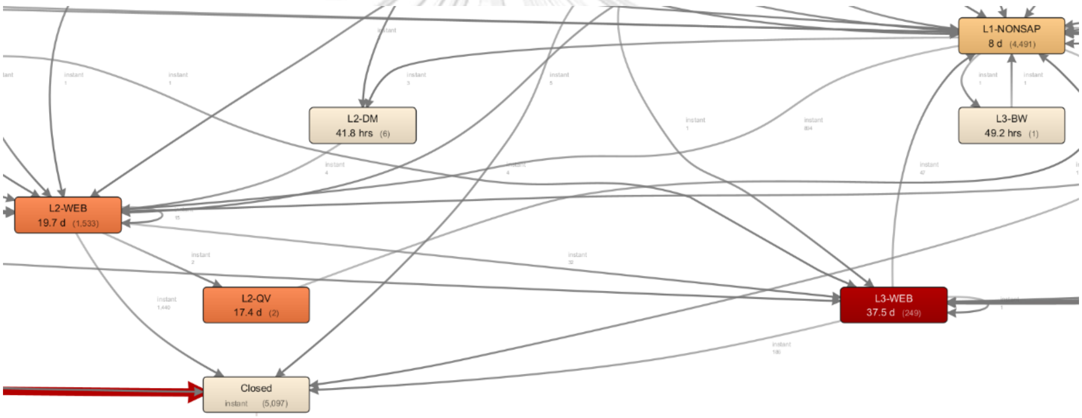
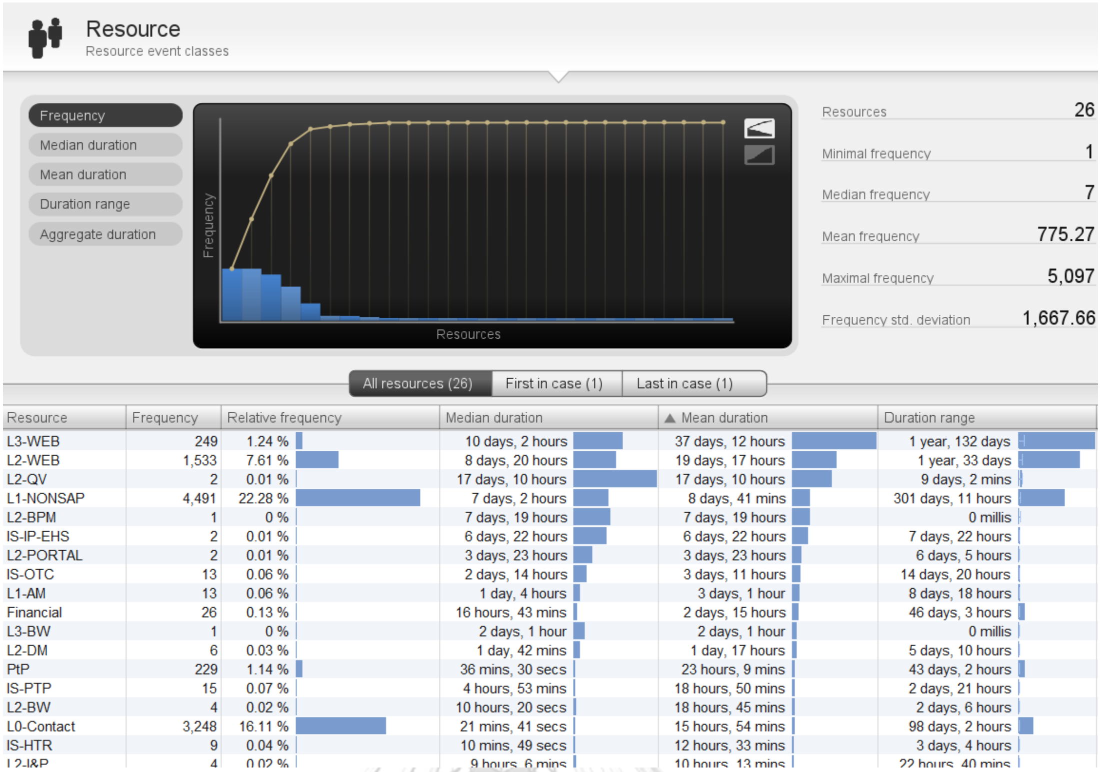


Figure 31 Focus on the performance highlight from Figure 29



Resource	Frequency	Relative frequency	Median duration	Mean duration	Duration range
L3-WEB	249	1.24 %	10 days, 2 hours	37 days, 12 hours	1 year, 132 days
L2-WEB	1,533	7.61 %	8 days, 20 hours	19 days, 17 hours	1 year, 33 days
L2-QV	2	0.01 %	17 days, 10 hours	17 days, 10 hours	9 days, 2 mins
L1-NONSAP	4,491	22.28 %	7 days, 2 hours	8 days, 41 mins	301 days, 11 hours
L2-BPM	1	0 %	7 days, 19 hours	7 days, 19 hours	0 millis
IS-IP-EHS	2	0.01 %	6 days, 22 hours	6 days, 22 hours	7 days, 22 hours
L2-PORTAL	2	0.01 %	3 days, 23 hours	3 days, 23 hours	6 days, 5 hours
IS-OTC	13	0.06 %	2 days, 14 hours	3 days, 11 hours	14 days, 20 hours
L1-AM	13	0.06 %	1 day, 4 hours	3 days, 1 hour	8 days, 18 hours
Financial	26	0.13 %	16 hours, 43 mins	2 days, 15 hours	46 days, 3 hours
L3-BW	1	0 %	2 days, 1 hour	2 days, 1 hour	0 millis
L2-DM	6	0.03 %	1 day, 42 mins	1 day, 17 hours	5 days, 10 hours
PtP	229	1.14 %	36 mins, 30 secs	23 hours, 9 mins	43 days, 2 hours
IS-PTP	15	0.07 %	4 hours, 53 mins	18 hours, 50 mins	2 days, 21 hours
L2-BW	4	0.02 %	10 hours, 20 secs	18 hours, 45 mins	2 days, 6 hours
L0-Contact	3,248	16.11 %	21 mins, 41 secs	15 hours, 54 mins	98 days, 2 hours
IS-HTR	9	0.04 %	10 mins, 49 secs	12 hours, 33 mins	3 days, 4 hours
L2-I&P	4	0.02 %	9 hours, 6 mins	10 hours, 13 mins	22 hours, 40 mins

Figure 32 The statistics of the team working on the ISR

With the availability of the support team attribute in the event logs from Table 12, Disco visualized the process flow and workload (frequency) of activities on each team assigned to work on the requests. Team L1-NONSAP, L0-Contract as shown in Figure 30 are the teams most often assigned to work on the requests. The resource performance as shown in Figure 29 with the flow of the activities from “Open” to “Closed”, indicating the average of time spent from each team on each request, and Figure 31 focus on the performance highlight contains L3-WEB, L2-WEB and L2-QV with 37, 19 and 17 days holding the requests as an average and in addition the statistics with detail of event logs provided in Figure 32.

The next exploration, the XES of event logs from Table 12, which the support team considered as a resource fed into ProM “Mine for a working-together Social Network” then started mining. The result shown in Figure 33 is the social analysis of teams working together on the same requests with a centrality degree metric. The circle's size represents each team's popularity, or we can say a bigger circle when more teams collaborate and connect with the edges.

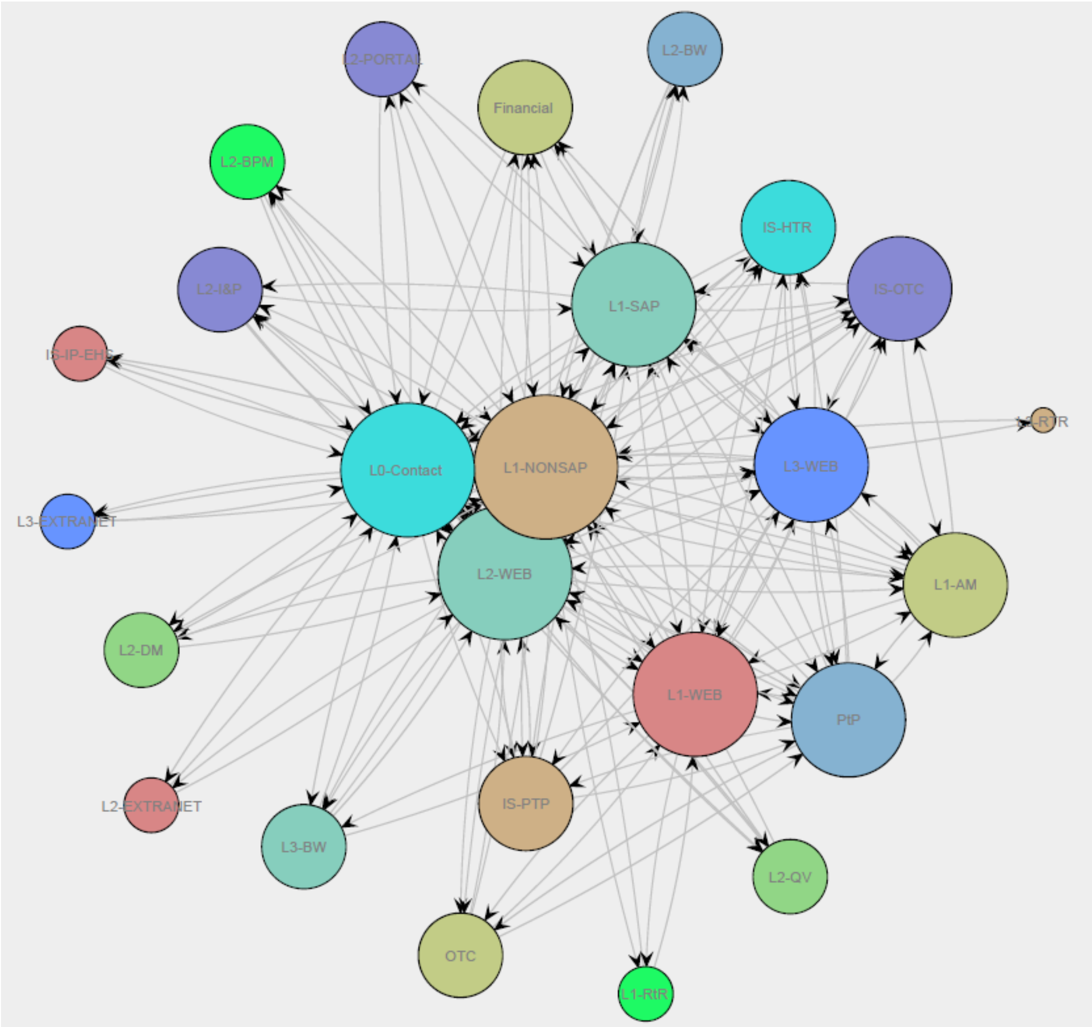


Figure 33 Network of the team working together

The resource has been represented in control-flow and social network analysis layout, and metrics workload, duration and working together. Workload fall in L1-NONSAP, L0-Contract and L2-WEB while the long holding request are L3-WEB, L2-WEB, L2-QV and L1-NONSAP, and with degree centrality of social network analysis can be seen that L0-Contract, L1-NONSAP and L2-WEB are likely to hold most information, collaborated and worked with almost on the team in IRS.

The support team, L1-NONSAP and L2-WEB caught attention from the above information, and changes or improvements of this team could reflect on the overall process since they connected with all teams, major performers of the system and spent a long time on the requests.

4.6 Result and Analysis

The experiment has been with 5,097 traces (requests) and 35,173 events. As a result, we discovered the actual process, checked process conformance with two main attributes status and support team.

Status movement, the actual process different from the defined process model, we observed the following points needing attention.

1) Wrong events– The activities or paths in the event logs but not aligned with the defined process model.

2) Missing events or states skipping– The reference model expected activities to be performed on the request but unobservable. This does not comply with the defined process model. There are a significant number of cases that were skipped “Resolved”, and this might cause the missing move at “Reopen”, the state next to “Resolved”. If the organization would like to improve the alignment of missing events, could be done by enforcing the rule for the performers to follow or prevent at the system itself from allowing of bypass step.

3) States repeating consists of a) repeating on the same state, and b) looping on one another. Repeating transfer from one another is not a violation but not a good practice from a business point of view since it might cause waiting time and the requestor might be frustrated about it.

Team working-together, the statistics shown in Figure 32, most activities performed by three support teams; L0-Contact, L1-NONSAP and L2-WEB, they performed 45% of activities and worked with all teams as we can see in working together. The performance analysis by the support team in Figure 29 indicates teams who spent a long time on the requests, including L1-NONSAP and L2-WEB. The worst one is L2-QV, and requests were finally transferred back to L1-NONSAP. We suspect the requests were transferred to the wrong team, and the team lacked the monitoring process. In addition, non-information service teams such as Financial, OTC and PtP appeared on the process and later routed them back to the correct teams.

The proposed model provided was generated from the event logs with rules defined and evaluated with The Multi-perspective Process Explorer with 82.2% of average fitness and 19.7% of violations. The implementation might be that we revise the process if the deviation is because the defined process does not reflect the reality, outdated or not flexible enough. The deviation cloud leads to a positive result, new better process. On the other hand, the non-conform process execution might cause issues in regulation or legal requirements. The result and analysis will need further investigation and discussion with the business will clarify the direction of process improvement.

CHAPTER 5
Conclusion

In this work, we applied the process mining tools to discover the actual process performed in the organization and identified the discrepancies compared with the reference process model. The current reference process model was recreated in BPMN, a standard for business process modeling, together with the proposed process model. The proposed process model was generated from the event logs with criteria of the required and violation traces. The discovered process was visualized in several layouts and parameters to help the business realize the actual process and have all necessary information for analysis and support any decision-making in the future. The statistics, performance, and bottleneck analysis presented at process discovery and conformance checking showed that the most time-consuming states are "Waiting on Third Party", "Activities before closure" and "Need for more information". Moreover,"Need for more information" and "Activities before closure" are the second and fourth most frequent activities. This information will be on the table of discussion with the business, on resource point of view, L1-NONSAP worked on 22% of requests and took eight days as an average and a big gap compared to L0-Contact and L2-WEB in terms of workload and duration. Therefore, L1-NONSAP played a significant role in the performance of the service and needed to investigate more on resource, workload, and complexity of work. Further investigation and discussion with the business will clarify the direction of process improvement.

Further direction would be monitoring the results of decision-making based on the findings and suggestion. Periodical evaluation is required for continuous improvement. If possible, the proposed approach could be expanded to other types of service requests such as Purchasing requests and Finance requests. More exploration on social network analysis with other centrality measures: betweenness centrality and closeness centrality would provide useful relations information for further investigation. Also, the researcher would like to convince the organization to study logging standards for establishing useful sources of event data to support the efficient process mining.

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