

## Research Article

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## Process Discovery and Process Optimization of Banking Industry through Visual Mapping and Simulation of Activity Sequences

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### Abstract

Due to the fact that the banking industry is increasingly interested in process improvement to increase competitiveness and market share, the main focus of the paper is on how an anonymous bank can conduct an internal process improvement analysis in order to enhance its competitiveness and increase its market share, with the intention of identifying and eliminating existing or potential banking bottlenecks and enhancing the overall efficiency of the customer complaint support network. To do this, several Process Mining techniques were applied on anonymous private bank data through Fluxicon Disco, a popular process mining tool/platform. By using various filtering and clustering techniques, the process maps, and resources/attributes, to resolve customer incidents and inefficient points, were examined in detail. The generated process maps and simulation of the procedures provided a comprehensive understanding of the customer complaints journey from start to finish, which helped us identify areas of concern and propose solutions. Our analysis revealed several issues, including bottlenecks, departmental sluggishness, violation of rules/norms, and assignment concerns that have led to a lengthier and more time-consuming operational and management process from both customer and organizational perspectives. The analytical results and insightful findings of the study can be utilized by the decision makers in the Anonymous Bank to determine whether their procedures are efficient, effective and productive, as well as whether their new IT systems are functioning properly. Eventually, the study demonstrates the usefulness of process mining techniques in improving operational efficiency and customer satisfaction. Banks and financial institutions can use the findings of this study to optimize their processes, reduce operational costs, and enhance customer satisfaction, which will ultimately contribute to their overall competitiveness and market share in the industry.

**Keywords:** Process Analysis, Data Visualization, Process Analysis, Process Optimization, Automated Process Discovery, Process Improvement, Process Modeling, Process Mining, Business Data Mining, Open Access Data, Fluxicon Disco, Fuzzy Miner algorithm

### 1. Introduction

Market holds very intensive competition with the competitors in the existing industry. One of the major factors for the existing competition in the industry is the typical efficiency. It is critical to avoid bottlenecks, idle times, and delays in corporate operations in order to improve efficiency. A process mining exercise

can be used to identify these issues that may have an impact on the work efficiency. The Anonymous Bank focused in this study, like the other businesses is willing to know if its procedures are proficient and operative.

The Anonymous Bank used ITIL (Information Technology Infrastructure Library) in order to match its IT service with business needs.

The changed process which is used to implement changes in IT services, is one of these trials. Anonymous Bank is particularly curious as to whether modifications made as part of its change process have an impact on the workload at the facility desk and IT actions (1).

The Anonymous Bank, like other ICT organizations, is faced with the challenge of implementing an increasing number of software releases while simultaneously shortening the time to market. In accordance with the ITIL (Information Technology Infrastructure Library) processes, Anonymous Bank employs the Change-processes for the purpose of implementing these so-called planned modifications. It is the goal of Anonymous Bank to gain factual knowledge into sub questions pertaining to the impact of previous modifications so that they can estimate future workloads at the Service Desk and/or IT Operations once future changes are implemented (2).

However, several of the processes were not completed, and a number of the processes took an inordinate amount of time, which had a direct influence on the company's performance.

- What was the reason for the process not being completed?
- What caused the procedure to become stalled?
- Was it as a result of a lack of manpower?
- Was it as a result of a lack of adequate supervision?
- What caused the failure to communicate or miscommunication between the various departments was the cause of this problem?

The process mining method was utilized to analyze the Anonymous Bank's event log using the Fluxion Disco, which is a popular Process Mining and Business intelligence tool. For this report's data mining procedure, 2880 were considered. Using the business intelligence tool, the report tries to achieve the following goals.

- To find the possible bottlenecks in business processes.
- Analyzing cluster types and associated cases, as well as finding "abnormal" or "strange" clusters.
- To determine the cause of delays in business processes.

Accordingly, the main focus of this work is on applying a process-centric analysis of

financial event logs, obtained from an anonymous bank, with the purpose of conducting an internal process improvement analysis of the Anonymous Bank to enhance its competitiveness and increase its market share. Various Process Mining techniques are used to examine the process maps and resources/attributes to resolve customer incidents and inefficient points. In other words, the main goal is to identify and eliminate existing or potential banking bottlenecks and enhance the overall efficiency of the customer complaint support network. The analytical results and insightful findings of the study can be utilized by the decision makers in the Anonymous Bank to determine whether their procedures are efficient, effective, and productive, as well as whether their new IT systems are functioning properly.

## 2. Literature Review

Similar case studies were discovered when evaluating the data presented above, which featured a complete incident and actions that were uploaded to the internet in order for researchers to evaluate the Anonymous Bank's customer service concerns. Many research articles employ data patterns that are similar to ours; the main difference between our paper and other papers is that the size of our data was limited and concentrated on incidents that occurred within 30 days only (i.e., did it by applying the time filtering on the data). In our study, a period of 30 days of data was selected because it was deemed a reasonable period to capture a sufficient amount of process-related events that could be analyzed using the process mining techniques employed in our study. Moreover, this time period allowed us to obtain a representative sample of the process and minimize any potential biases that may arise from analyzing data from a longer or shorter period.

The focus of other research investigations appeared to be on bottlenecks, idle hours, and less efficient resources, on the other hand. Many bottlenecks in the process were identified by researchers in the reviewed articles, many of which are connected to the performance of specific activities by certain teams (2). In order to discover the cause of the problem and design the most effective solutions, it was decided to concentrate on evaluating the data.

The other reviewed papers mainly asked questions such as Identification of Impact patterns and the correlation between the

implementation of a change and the workload in the service desk or IT Operation (1-5).

Parameters for every impact pattern: In order to be able to use the results of prior changes to predict the workload for the service desk directly.

- What is the average period to return to a steady state?

- What is the average increase/decrease of closed interactions once a new steady state is reached?

Change in average steps in resolution: to check the consistency of the Anonymous Bank's managers service level provided to the customer they need to be consistent and acceptable under the company's guidelines Anonymous Bank is looking for confirmation that this challenge is indeed being met for all or many service components.

Creative challenge: To see the problems from different perspective and provide the Anonymous Bank's managers with quality insight on how to deal with them for better results and help change the teams accordingly to continuously improve their standard operation procedures.

### 3. Methodology

The research project report using process data mining was produced by utilizing Fluxicon Disco, a Business Intelligence Tool, and reviewing the Activity log for incidents. The data was downloaded and sorted using Microsoft Excel, which is the most widely used and best software available for spreadsheets and sorting. The data was saved to disc in a comma separated values format, which is one of the most widely used and best formats out there for spreadsheets and sorting (csv) Disco is a process mining tool with an easy-to-use graphical user interface (GUI). Disco makes it simple and straightforward to work with large amounts of data and logs. The technique for the report includes the use of the Business Intelligence tool, Disco, to import the data from the Business Process Intelligence website and to define the settings of each data set suitably, including the customer ID, time stamp, activities, attributes, and resources. It was discovered that the first activity in the event log occurred on 3rd March 2014 at 12:31:15 and ended on 2nd April 2014 at 15:48:46, resulting in 2,395 instances, 24,273 events, and 33 activities during the course of the two-week period. The maximum number of events

executed per case is 79 per 10 minutes, and the smallest number of events executed per case is 0 per 10 minutes, according to the data. The largest number of active instances has grown to 514 throughout time, while the shortest number of active cases has shrunk to 1. Among the possible outcomes in a given length of time, 514 is the most possible number of events to be executed, and 1 is the lowest possible number of events to be executed in a given amount of time (6-12).

The most popular activity was "Activity," which was done 4926 times, while the least popular activity was "Incident reproduction," which was done 1 time.

The following procedures were employed in order to analyze the data (13-17).

a) Case ID: The Case Id is the incident id from Business Process Intelligent dataset, which is a unique identifier.

b) Time Stamp: The time stamp keeps track of the date and time of the various activities that are being carried out.

c) Activity: The activity is denoted by the case id and the resources as the task that was completed.

d) Resource: assignment groups are referred to as the Resources in the organization.

e) Attribute 1: The incident activity number is assigned to the first activity.

f) Attribute 2: The activity two is denoted by the number KM Number.

g) Attribute 3: The activity three is denoted by the following information ID for the interaction.

The following Fluxion Disco techniques were applied on the dataset to achieve the research's main goal.

a) Fuzzy mining (18-22). The process mapping provides a visual representation of the activities that were carried out and how consistently they transpired. This is performed through the usage of the Fuzzy miner, a type of mining algorithm. The log data could be explored and analyzed by filtering information that it was genuinely examined in depth, such as order fulfillment timeframes or the time it takes for one operation to occur before another.

b) Clustering (18-22). The clustering technique was utilized to identify "abnormal" or "strange" behavior in the data. This aided in determining if the order processing process for each case followed a similar pattern or whether each order was unique.

c) Filtering (18-22). A better understanding of a certain process subset was

obtained by using this technique. The following three types of filters were utilized.

d) Performance Filter (18-22). Using a collection of performance measures, it was possible to extract information about the case using the performance filtering technique. Performance indicators such as total duration, mean duration, median duration, and so on are available.

- Endpoint filter (18-22). This filter was used to locate the beginning and ending events in the operation of fine management, respectively.

- Follower filter (18-22). This filter was used to detect specific process tendencies based on the relationship between the followers. It was used to determine whether the event had successfully reached the desired end point or not. It aids in determining which activity is following which path and identifying bottlenecks in the process.

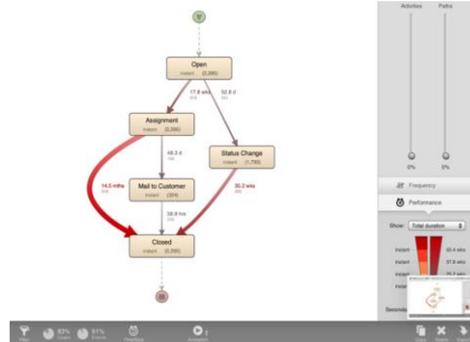
e) Animation/Simulation (18-22). When an issue with follower relationships has been detected in the system, Disco provides recommendations on where the bottlenecks are most likely to be located and shows the problem in a live view style. This function, in particular, is quite beneficial for observing data being watched in real time and pinpointing trouble spots where data is being bottlenecked, as well as identifying idle teams.

#### 4. Findings and Results

A total of 2880 cases were analyzed, with 26395 events and 33 activities recorded. The Anonymous Bank event log started on 03/03/2014 at 12:41:15 and ended on 02/04/2014 at 15:48:46. This makes it possible to conduct an analysis over a 29-day period that shown in Figure 1.



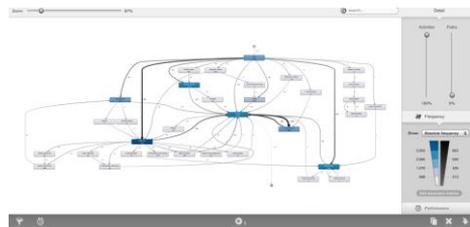
**Figure 1** An illustration of the total number of cases and events analyzed in the study.



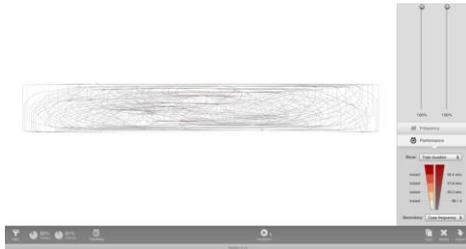
**Figure 2** Process Map Showing Activity and Path Thresholds at 0% for Event Log.

It was seen in this diagram that after opening, there are two paths: one is the assignment path and the other is the status change path. When the request is open, it either uses the first path, which is open, assignment, mail to the customer to close, or it uses the second path, which is open, status change, mail to the customer to close. There is also the option of opening, assigning, and closing a task that shown in Figure 2.

The most typically followed path in this customer complaint chain is shown in Figure 3. When a complaint is received, a ticket is created, which is then sent to assignment, where it is assigned to the appropriate channel to resolve the issue. The ticket is then sent for closure once the issue has been resolved. The most followed path was from open to assignment with 976 requests.



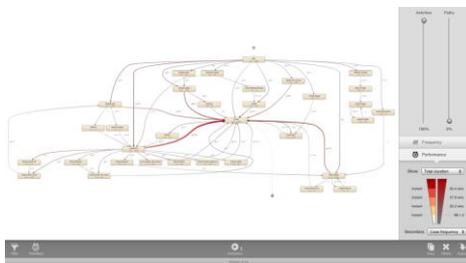
**Figure 3** Visualization of Process Map for Event Log with 100% Activity and 0% Path Thresholds.



**Figure 4** Process Map of the Event Log with 100% Activity and 100% Path Thresholds.

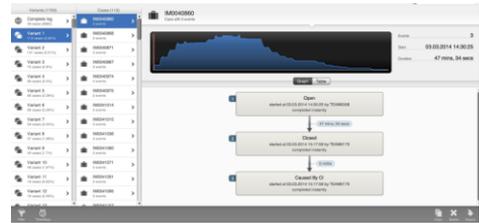
One of the most important processes displayed on this map that shown in figure 4 is the opening of an incident, which is then assigned, which assigns it to various branches depending on the event, and then the branches fix the issue and send it for closure.

There were 2,880 issues recorded, but only 1797 of them were resolved, as can be seen in the table below. Despite the fact that the remaining 1,083 incidents were reported, the inquiry was never completed. The input and output do not have the same values that shown in Figure 5.



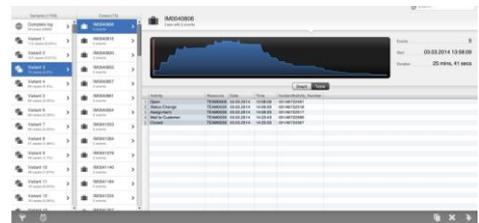
**Figure 5** Time Duration/Interval Map generated using the Fuzzy Miner algorithm.

The above-mentioned cluster and pattern contained multiple anomalies in Cluster 1, including a large number of complaints that were opened and closed without being assigned and then transferred to the cause by the CI department. This shows that either consumer intelligence is to blame for the vast majority of complaints, or that the customer service department is deliberately disregarding customer issues and complaints (shown in Figure 6).



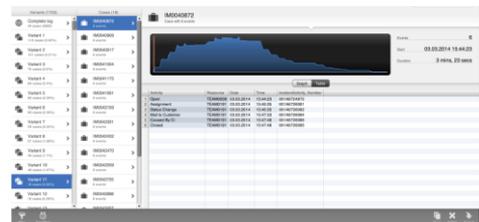
**Figure 6** Identification of abnormal clusters/groups in Variant #1.

Additionally, a few anomalies were discovered and seen in Cluster 3 since the statuses had been modified before the assignment was sent out. Several complaints were opened, their statuses were changed, they were forwarded to the assignment, they were mailed to the customer, and eventually they were closed in the aforementioned cluster that shown in Figure 7.



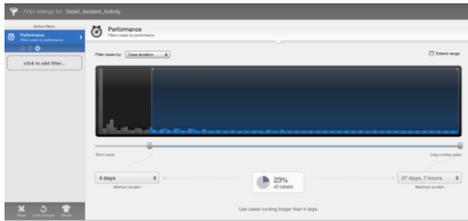
**Figure 7** Another identification of abnormal clusters/groups in Variant #3.

In cluster 11, the clusters were normal complaints were opened, it was sent to the assignment, after that the status was changed after that it was mailed to the client who was caused by CI and it was finally closed in the aforesaid cluster (shown in Figure 8).

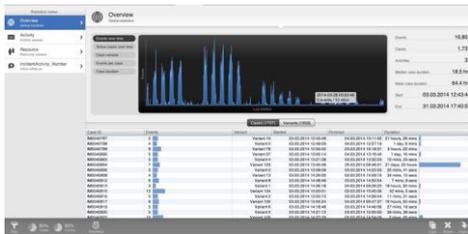


**Figure 8** Identification of a normal cluster/group in Variant #11.

A total of 27 days have elapsed between the time a ticket was opened and when it was finally closed, with around 23 percent of cases lasting more than 4 days, as indicated in the graph above (shown in Figure 9).



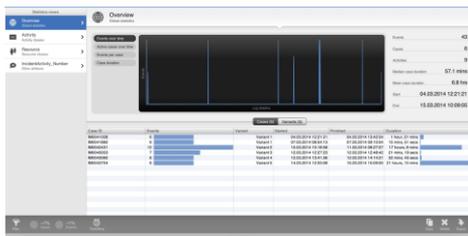
**Figure 9** Identifying the percentage of cases exceeding a duration of 4 days using time performance filter.



**Figure 10** Identifying the number of cases that were ended with Close using Endpoint filter.

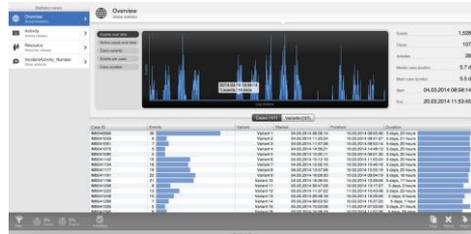
When it came to determining how many customer complaints were received and how many were resolved, an end point filtering was applied. It was discovered that just 1737 of the 2880 cases had been closed (shown in Figure 10).

As can be seen from the figure above, just 6 of the 2880 customer complaint cases that were opened were assigned and did not make it to the closed status (shown in Figure 11).

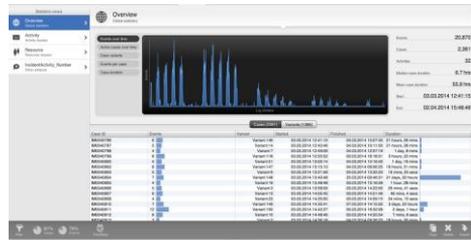


**Figure 11** Identifying the number of cases that were ended with Assignment using Endpoint Filter.

According to the results it was realized that there were 107 cases in which assignment was followed by closed (shown in Figure 12).



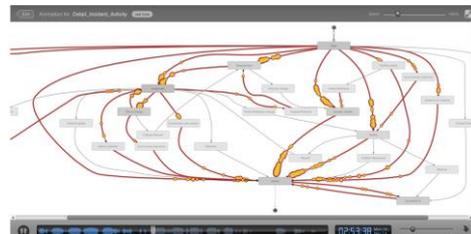
**Figure 12** Identifying the times the Assignment activity was followed by Closed using Follower Technique.



**Figure 13** Identifying the times the Assignment was never directly followed by Closed.

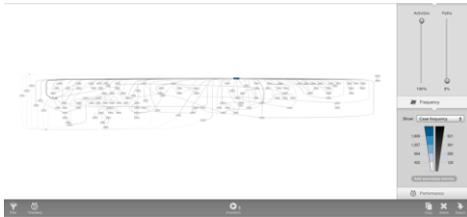
According to the result it was realized that there were 2,361 cases in which assignment was never directly followed by closed (shown in Figure 13).

This depicts the process map's animation, or stimulation, which aids in the identification of bottleneck areas (shown in Figure 14).

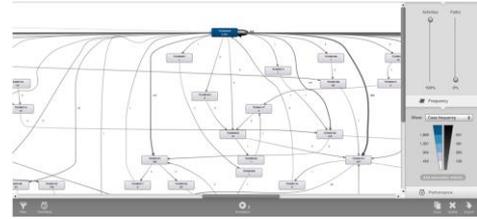


**Figure 14** Simulation/animation of the process map of the event log with activity threshold is set to 100% and path threshold is set to 0%.

In order to get the process map, the activity variable was changed into a resource variable. Assignment Group is now considered to be a separate activity. From what it is seen and observed, team 8 is very active and receives a large number of inquiries. Because this team deals with a significant number of problems on a daily basis, it can be identified as a possible bottleneck in the whole system (shown in Figures 15 and 16).



**Figure 15** The resulting process map where the Resource attribute is set and predefined as the Activity, when activity threshold is set to 100% and path threshold is set to 0%.



**Figure 16** A close-up screenshot of the resulting process map where the Resource attribute is set and assigned as the Activity with 100% and path 0%.

### 5. Discussions and Conclusions

It is concluded from the process map model that the primary processes throughout the entire customer complaint are illustrated below while observing the results (13-17) as shown in Figure 17.



**Figure 17** Primary/Standard Processes in Customer Complaint Journey.

But while this was supposed to be the path followed for the customer tickets which were opened, it was noticed that many of the complaints received were following an unusual path depicted in Figure 18.



**Figure 18** Process map showing the unusual path followed by customer complaints.

It demonstrates that a ticket that was opened by the customer and was immediately closed without any assignment was later identified as having been caused by customer intelligence. Many instances have this unique cluster, which could be a sign of customer service team negligence, or it could be legitimate

data confirming the proof of numerous cases being caused by CI, as has been demonstrated in many situations. Furthermore, when examining the performance mapping of the data using the maximum duration filter, it is observed that the process from assignment to closure takes more time than any other processes involved in resolving complaints. This can be attributed to the task assignees being overburdened with work or having low motivation to complete the task within the expected timeframe.

The bottleneck areas were identified in Assignment during our evaluation of the animation, which shows that there is a backlog of customer complaints and that the assignment system is having difficulty allocating the issues to their appropriate departments in a timely manner. I that more than 1000 cases are still active and in the pipeline to be addressed, out of approximately 2900 total cases, which means

that 35% of the cases are still pending. This indicates that there may be issues with the problem solving rates, which may point to the efficiency of the team or that not all of the resources available are being readily utilized and only some teams are working extremely hard to complete their tasks. This information can be supported by the observations made while investigating the teams that were being employed and the environments in which they were being deployed. It was noticed that just a few of the teams were functioning smoothly and efficiently, and that many of them were only dealing with a small number of cases.

As a result of the above-mentioned analysis, which was conducted using approved data and the necessary software, it was discovered that, despite the fact that the Anonymous Bank has implemented a new software for handling its customers' complaints and queries, there are numerous points of bottleneck in a significant portion of the structure, as well as numerous redundant resources, which is causing an imbalance in the flow of work, resulting in cases being stuck in the pipeline or being resolved extremely late. In order to enhance these figures, the Anonymous Bank must update its customer care ticket structuring system as well as its ticket assignment system to make it more robust and efficient, according to the bank. The Anonymous Bank has a section that monitors how client complaints are handled through internal audits; by enhancing these, the bank will be able to make better use of the new tools and reduce costs. Not to mention the multiple process bottlenecks that is related with the execution of certain activities and/or the participation of specific teams, which they have been identified in this research.

Consequently, to conclude, the findings of the analysis conducted on the customer complaint logs from the Anonymous Bank have revealed some crucial insights that can help improve the overall efficiency of the bank's complaint handling system. The study has identified several bottlenecks, departmental sluggishness, violation of rules/norms, and assignment concerns that have led to a lengthier and more time-consuming operational and management process from both customer and organizational perspectives. These insights can be used by the decision-makers to determine whether their procedures are efficient, effective,

and productive and whether their new software for handling complaints is functioning properly.

However, the study has also revealed that there are still many pending cases that have not been resolved, and the assignment system is having difficulty allocating the issues to their appropriate departments in a timely manner. This indicates that there may be issues with the problem-solving rates, which may point to the efficiency of the team or that not all of the resources available are being readily utilized. Therefore, it is necessary for the Anonymous Bank to update its customer care ticket structuring system and ticket assignment system to make it more robust and efficient.

Moreover, the study has also highlighted the need to monitor how client complaints are handled through internal audits to make better use of the new tools and reduce costs. The analysis has also identified multiple process bottlenecks that are related to the execution of certain activities and/or the participation of specific teams, which can be resolved by enhancing the structure and resources.

Overall, the process-centric analysis of customer complaint logs from the Anonymous Bank has proven to be an effective approach for identifying process inefficiencies and bottlenecks, and proposing solutions to enhance the overall efficiency of the bank's complaint handling system.

## 6. Limitations and Future Work

The limitations of a study are an important aspect to consider as they provide a critical evaluation of the scope and reliability of the findings. In the case of the analysis conducted on the customer complaint support network of the Anonymous Bank, it is necessary to identify and discuss the limitations that may have influenced the results. By acknowledging the potential limitations of the study, researchers and decision-makers can gain a better understanding of the reliability and generalizability of the findings. Below, the limitations of the analysis and their implications, for the interpretation of the results, will be discussed as the following.

- The study only analyzed data from a single organization (only an anonymous bank), which limits the generalizability of the findings to other organizations.

- The study only analyzed customer complaint processes, and did not explore other processes within the organization, which may have different challenges and bottlenecks.
- The study only used Fluxicon Disco as one of the process mining tools which runs based on the Fuzzy Miner algorithm. Yet, there are many other process mining tools and techniques to investigate and apply on the dataset.
- The study did not take into account the perspectives and experiences of the employees who are involved in the customer complaint processes, which may have provided valuable insights into the challenges and limitations of the processes.
- The study did not explore the impact of external factors, such as changes in regulations or industry trends, on the customer complaint processes.
- The study was limited to the data that was available at the time of the analysis, and did not take into account any changes or improvements that may have been made to the processes since then.
- The study did not explore the cost-effectiveness of the proposed solutions to enhance the efficiency of the customer complaint processes, which may impact the feasibility of implementing these solutions.
- The study did not take into account the potential impact of the proposed solutions on customer satisfaction and loyalty.
- While Fluxicon Disco is a powerful process mining tool, it has limitations in terms of the complexity of analysis it can perform. For instance, it may not be able to analyze processes with a large number of process variations or complex decision-making scenarios.
- Fluxicon Disco may require significant data preprocessing before analysis, such as cleaning and transforming data to ensure it is in the correct format for analysis. This can be time-consuming and requires expertise in data preprocessing techniques.
- Fluxicon Disco may not offer enough customization options for users who need to tailor their analysis to specific business needs or industry standards.
- Fluxicon Disco may be difficult to use for users who are not familiar with process mining techniques, as it requires a certain level of technical expertise and training to operate.
- Fluxicon Disco is primarily designed for analyzing event log data, which may limit its usefulness for organizations that rely heavily on other types of data sources for process analysis.

The application of process mining techniques supported by Fluxicon Disco on the event log collected from the Anonymous Bank has provided valuable insights into the efficiency of their customer complaint support network. However, there are still areas that need to be explored to further improve the process. One potential future work is to conduct a more in-depth analysis of the identified bottlenecks and inefficiencies. This can be done by applying more advanced process mining techniques, such as social network analysis, decision mining, and predictive process monitoring. These techniques can provide a deeper understanding of the underlying causes of the identified bottlenecks and inefficiencies, and can help to develop more effective solutions. Another future work is to implement the proposed solutions and evaluate their effectiveness. This can be done by comparing the performance of the updated systems with the performance of the old systems before the proposed changes were made. This can provide valuable insights into the effectiveness of the proposed solutions and can help to further optimize the process. Additionally, the analysis can be extended to include other types of data sources, such as customer feedback and social media data. This can provide a more complete view of the customer experience and can help to identify additional areas for improvement.

Furthermore, it would be interesting to investigate the impact of the proposed solutions on the overall customer satisfaction and loyalty. This can be done by conducting customer surveys and analyzing the feedback. This can provide valuable insights into the effectiveness of the proposed solutions from the customer's perspective.

In summary, the application of process mining techniques on the event log collected from the Anonymous Bank has provided valuable insights into the efficiency of their customer complaint support network. Further

research can be conducted to deepen the understanding of the identified bottlenecks and inefficiencies, implement the proposed solutions, explore additional data sources, and evaluate the impact on customer satisfaction and loyalty.

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### Declaration of conflicting interests

The authors declared that they have no conflicts of interest in the research, authorship, and this article's publication.

### References

- Cacciola G, Conforti R, Nguyen H. Rabobank: A Process Mining Case Study. BPI Challenge 2014 Report. Available from: [https://www.win.tue.nl/bpi/2014/bpic2014\\_submission\\_5.pdf](https://www.win.tue.nl/bpi/2014/bpic2014_submission_5.pdf)
- Van Dongen B. BPI Challenge 2014: Activity log for incidents (Version 1) [Data set]. Rabobank Nederland; 2014. doi: 10.4121/uuid:86977bac-f874-49cf-8337-80f26bf5d2ef.
- Van Dongen BF. BPI Challenge 2014. Version 1. 4TU.ResearchData. collection. doi: 10.4121/uuid:c3e5d162-0cfd-4bb0-bd82-af5268819c35.
- Cacciola G, Conforti R, Nguyen H. Rabobank: a process mining case study BPI challenge 2014 report. BPI Challenge. 2014;1-3. doi: 10.13140/RG.2.1.3427.5681.
- Lopes IF, Ferreira DR. A survey of process mining competitions: the BPI challenges 2011–2018. Business Process Management Workshops: BPM 2019 International Workshops, 2019;362 doi: 10.1007/978-3-030-37453-2\_22.
- Cortellessa V, Iazeolla G. Performance analysis of optimistic parallel simulations with limited rolled back events. Simulation Practice and Theory . 1999;7(4):325-347.
- Rozinat A. Installation Instructions for Academic Partners [Internet]. Last updated: 26 July 2013. Fluxicon; 2013. Available from: <https://fluxicon.com/academic/material/files/Installation.pdf>
- Bleisinger O, Cobra JPC. Machine Learning Based Simulation for Wear Estimation in Commercial Vehicle Applications. Commercial Vehicle Technology 2022: Proceedings of the 7th International Commercial Vehicle Technology Symposium; 2023: Springer.
- Dongen BFV. BPI Challenge 2014. 2014. 4th International Business Process Intelligence Challenge (BPIC'14), Haifa, Israel. doi: 10.4121/uuid:c3e5d162-0cfd-4bb0-bd82-af5268819c35.
- Gunther CW, Van Der Aalst WM. Fuzzy mining - adaptive process simplification based on multi-perspective metrics. Fuzzy mining-adaptive process simplification based on multi-perspective metrics. Lecture Notes in Computer Science. 2007;4714:328-343.
- Van Der Aalst W. Process mining: discovery, conformance and enhancement of business processes: Springer; 2011.
- Porouhan P, Premchaiswadi W. Process Mining and Learners' Behavior Analytics in a Collaborative and Web-Based Multi-Tabletop Environment. Int J Online Pedagogy Course Des. 2017;7(3):29-53. doi: 10.4018/IJOPCD.2017070103.
- Porouhan P, Premchaiswadi W. Behavioral Performance Evaluation and Emotion Analytics of a MOOC Course via Fuzzy Modeling. 16<sup>th</sup> International Conference on ICT and Knowledge Engineering (ICT&KE); 2018. Bangkok, Thailand; 2018;1-8. doi: 10.1109/ICTKE.2018.8612402.
- Porouhan P, Premchaiswadi W. Big Data Analytics of Supply Chains with Process Mining. 19<sup>th</sup> International Conference on ICT and Knowledge Engineering (ICT&KE); 2021. Bangkok, Thailand; 2021;1-5. doi: 10.1109/ICTKE52386.2021.9665705.

15. Premchaiswadi W, Porouhan P, Premchaiswadi N. Process modeling, behavior analytics and group performance assessment of e-learning logs via fuzzy miner algorithm. 2018 IEEE 42<sup>nd</sup> Annual Computer Software and Applications Conference (COMPSAC); 2018;304-309 doi: 10.1109/COMPSAC.2018.10247.
16. Porouhan P, Premchaiswadi W, editors. Development of a process-aware instructor-aware multi-tabletop collaborative learning environment. 2016 14<sup>th</sup> International Conference on ICT and Knowledge Engineering (ICT&KE); 2016;62-70 doi: 10.1109/ICTKE.2016.7804100.
17. Arpasat P, Premchaiswadi N, Porouhan P, Premchaiswadi W. Applying process mining to analyze the behavior of learners in online courses. *Int. J. Inf. Educ. Technol.* 2021;11(10):436-443.
18. Rozinat A. ProM Tips—Which Mining Algorithm Should You Use [Internet]. Fluxicon BV; [cited 2023 May 13]. Available from: <https://fluxicon.com/blog/2010/10/prom-tips-mining-algorithm/>
19. Günther CW. Disco 3.3 [Internet]. Fluxicon BV; 2022 Oct 21 [cited 2023 May 13]. Available from: <https://fluxicon.com/blog/2022/10/disco-3-3/>.
20. Weijters A, van der Aalst W, van Dongen B, Günther C, Mans R, De Medeiros AA, et al. Process mining with ProM. 19<sup>th</sup> Belgian-Dutch Conference on Artificial Intelligence (BNAIC 2007); 2007.
21. Nammakhunt A, Romsaiyud W, Porouhan P, Premchaiswadi W. Process mining: Converting data from MS-Access Database to MXML format. 2012 Tenth International Conference on ICT and Knowledge Engineering; 2012;205-212. doi: 10.1109/ICTKE.2012.6408557.
22. Data Requirements [Internet]. Fluxicon BV; [cited 2023 May 13]. Available from: <https://fluxicon.com/book/read/dataext/>