Process Mining For Evaluating Hospital Billing System Based On DSS01 Domain COBIT 2019 Framework

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***Abstract*— An information system streamlines operations and provides valuable data, but insufficient control can lead to inefficiencies in the process. The audit using the COBIT 2019 framework has provided optimal results in managing and controlling information technology. However, the assessment process, which is still conducted manually, has the potential to introduce bias in the evaluation results. This study proposed process mining method for evaluating processes based on DSS01 COBIT 2019. The proposed method will be evaluated to a hospital billing system to demonstrate how process mining can identify bottlenecks in processes in the system for providing insight for process improvement. Our findings highlight significant bottlenecks within five key connection processes and identify specific activities that impede the optimal flow of operations. These discoveries are aligned with the DSS01 objective of COBIT 2019, which aims to enhance the management of IT delivery and support services.**

Keywords—Bottlenecks, COBIT 2019, DSS01, Hospital Billing, Process Mining

I. INTRODUCTION

An information system is a crucial component of a company that implements advanced technology to streamline operational activities across various divisions[1]. This system also provides valuable information to the staff of a company. However, certain activities are not fully controlled in accordance with required policies, leading to discrepancies such as fraud[2], malpractice, negative risks, and inefficiencies[3]. One of the remedial measures is the implementation of quality control through an information system audit. According to a systematic process, an audit involves acquiring and objectively evaluating evidence related to allegations of economic activities and other operations. The aim is to assess the level of conformity between the reports and predefined criteria, and to communicate the results to relevant users, in this case, the organization responsible for establishing information system governance.

One of the proven frameworks for information system auditing is the Control Objectives for Information and Related Technology (COBIT) 2019, which is utilized as the reference framework in this research [4]. COBIT 2019 offers an effective methodology for evaluating the capability of information technology processes, specifically focusing on Deliver, Service and Support (DSS01) - Operation Management. This framework guarantees that the data processed is received, managed fully, accurately, and promptly, but also supports the generation of outputs that meet the organizational needs.

Safwandi et al.[5] evaluates academic management at a university by using sampling techniques within the campus area and applying the Deliver, Service, and Support (DSS) domain to assess the performance of the system and the standards implemented. Bahari et al. [1] valuate the governance capabilities at the Customer Care unit using the COBIT framework, specifically within the Deliver, Service, and Support (DSS) domain. The primary focus is on assessing process controls related to Information Technology (IT) services and technical support. Data collection is conducted through surveys to support this evaluation.

This study adopts a novel approach in identifying COBIT processes, specifically DSS01, through process mining techniques rather than traditional surveys. Process mining utilizes event logs recorded from daily operations. This technique enables real-time process analysis by applying various analytical methods to process these logs. This approach provides deeper and more accurate insights into the effectiveness of existing processes and facilitates the identification of potential improvements in information system governance that are more evidence-based and data-driven.

Process mining has demonstrated its worth as an effective technique for analyzing event logs, allowing for the tracking of workflow progress and delivering important insights [6]. A major benefit of this method is its ability to use existing database logs, which can decrease the time and cost needed for data collection. Furthermore, using recorded data can reduce the likelihood of information distortion. Given its capability to analyze log data across different systems, process mining has become popular among companies aiming to examine their processe Thus, process mining not only plays a role in improving operational efficiency but also in enhancing the overall quality of healthcare services.

This study discusses how process mining can be implemented to support information system audits based on COBIT 2019 for DSS01 Objective, particularly as a method of collecting and validating data within the process assessment program. Experiments are conducted by analyzing performance and identifying bottlenecks in event logs related

to hospital billing cases. Through this approach, auditors can update their methods for obtaining, analyzing, and validating data based on event logs stored in the information system, thereby generating more effective processes overall.

II. Literature Review

A. DSS01

Deliver, Service, and Support (DSS) domain of the COBIT framework, with a specific emphasis on managing IT operations [5]. Its main goal is to guarantee that IT operations are executed effectively, securely, and in accordance with business requirements. Essential activities under this process include the monitoring and management of IT service performance, handling incidents and problems, and ensuring the security of the system[7]. TABLE I provides a detailed overview of the activities and performance indicators associated with the DSS01.01 domain of managed operations.

B. Process Mining

Process mining involves deriving business processes from the log files associated with a company's business operations, aimed at better understanding and optimizing each activity more effectively[8] . From the data obtained, specific patterns will be identified to provide deeper insights into process behavior. These business processes can be analyzed from various perspectives[9]. Every event that occurs, including what is done, when, and by whom, will be documented and can be applied across various systems that produce event logs (capturing a range of real activities). The main objective of process mining is to gather information from business processes [10] by leveraging the information recorded in the event logs.

C. Event Logs

An event log is historical documentation within an information system, serving as proof of ongoing transactions [11]. It sequentially and concurrently records activities, capturing tasks that are performed simultaneously by different individuals. Each event log is recorded at varying levels of detail, and each level of abstraction captures occurrences within a process that may be influenced by noise[12]. Event logs offer insights into the processes they record, describing the events of specific cases. Utilizing these logs in an information system facilitates the creation of an accurate business model [13].

TABLE I. DSS01.01 Managed Operations Overview

Domain DSS01	Managed Operations
DSS01.01	a. Number of incidents caused by operational problems
	b. Number of nonstandard operational procedures executed
Activities	
1	Develop and maintain operational procedures and related activities to support all delivered services
2	Maintain a schedule of operational activities and perform the activities
3	**Verify that all data expected for processing are received and processed completely, accurately and in a timely manner. Deliver output in accordance with enterprise requirements Support restart and reprocessing needs. Ensure that users are receiving the right outputs in a secure and timely manner.**
4	Manage the performance and throughput of the scheduled activities
5	Monitor incidents and problems dealing with operational procedures and take appropriate action to improve reliability of operational tasks performed.

D. Heuristic Miner

Heuristic Miner, a process mining algorithm, is reliable and has been effectively used in numerous scenarios [14]. It specifically mines data from the control flow perspective of a process. A key advantage of Heuristic Miner over the Alpha++ algorithm is its ability to calculate the frequency of activity relations [15]. Additionally, it can handle noisy data effectively, providing a more robust analysis where other algorithms might fail. This capability makes Heuristic Miner particularly useful in complex environments where data may not always be clean or well-structured [9]. Moreover, it offers insightful diagnostics about the process flow, helping to identify bottlenecks and inefficiencies that other algorithms might overlook[16].

III. Proposed Method

This section discussed the research workflow illustrated in Fig. 1. The research stages encompass four critical steps involved in managing and analyzing the event log dataset within the hospital billing system. These steps are designed to optimize data collection, processing, and evaluation of the billing processes. The process begins with the collection of raw data from the event logs gathered by the hospital's Enterprise Resource Planning (ERP) system. Following this, the preprocessing stage involves cleaning and preparing the data for further analysis. During the process discovery phase, actual billing process patterns are explored and modeled based on the available data. The final stage is performance analysis, where the effectiveness and efficiency of the billing processes are reviewed to identify potential areas for improvement. Overall, these stages are crucial to ensure that the billing practices at the hospital are conducted efficiently and transparently.

A. Dataset

The "Hospital Billing" event log was obtained from the financial module of the ERP system used by a regional hospital [17], This log records various incidents related to the billing of medical services provided by the hospital. Over a three-year period, from 2013 to 2016, a random sample of 100,000 traces was collected, each representing a recorded example of the process in the system. Within this event log, there are 18 different activities, each depicting distinct stages in the medical billing process. TABLE II provides a detailed overview of the billing attributes and their descriptions, crucial for understanding the flow and related activities within the hospital's operational context.

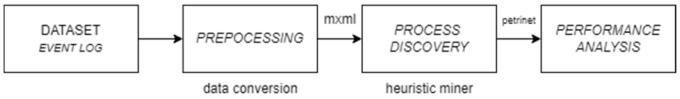

Fig. 1. Research Method

TABLE II. HOSPITAL BILLING ATTRIBUTES DESCRIPTION

Atributes	*Description*
ActOrange	A flag that is used in connected with services that may not be covered by the standard health insurance.
ActRed	A flag that is used in connected with services that may not be covered by the standard health insurance, if it is blocked by the standard health insurance (i.e., for the type of the billing package, which may be blocked).
BlockedType	A code that is used when the billing may not proceed due to the service's handling.
CloseCode	There may be several reasons to close a billing package, this attribute stores the code used.
DiagnosisCode	A code for the diagnosis used in the billing package.
LagB	An anonymized flag.
LagC	An anonymized flag.
LagD	An anonymized flag.
IsCanceled	A flag that indicates whether the billing package was eventually canceled.
SsCode	A flag that indicates whether the billing package was eventually closed.
SsType	The type of messages returned.
SsCount	The number of messages returned.
Speciality	A code for the medical specialty involved.
Version	A code for the version of the rules governing the process.

B. Pre-processing

The raw data from the event logs undergoes cleansing and preparation for detailed analysis. The preprocessing step includes eliminating any incomplete or irrelevant records, rectifying errors, and normalizing the data formats. This phase is essential for securing the integrity and dependability of the data prior to conducting deeper analytical procedures. The stage is also carried out by converting the dataset format from XES format to MXML format using Disco tools[14]. This is done for further analysis in ProM tools which require data in MXML format.

C. Process Discovery

After preprocessing, process discovery techniques are applied to the cleaned data to identify the underlying processes reflected in the event log. This step aims to construct a model that accurately represents the real-world processes of hospital billing, based on the sequences and patterns observed in the data. The process discovery algorithm used in this study is Heuristic Miner.

1) Heuristic Miner

This approach assesses the efficiency, speed, and reliability of various billing activities and is particularly adept at identifying bottlenecks, a primary objective of this analysis. By pinpointing bottlenecks through heuristic mining, the team can specifically target and address areas that significantly impact workflow, thereby facilitating substantial operational improvements. Additionally, this method allows for a comprehensive evaluation of the overall effectiveness of the hospital's billing practices. Insights gained from this heuristic-based analysis can be instrumental in optimizing processes to boost overall operational performance.

D. Performance Analysis

The final step involves performance analysis of the billing process. This includes assessing the efficiency, speed, and reliability of various billing activities, as well as identifying bottlenecks, which is one of the primary objectives of this analysis. By pinpointing bottlenecks, the team can target and address the area's most affecting workflow, thereby enabling significant operational improvements. The analysis also aims to evaluate the overall effectiveness of the hospital's billing practices. Insights gained from this analysis can help optimize processes to enhance overall operational performance.

IV. RESULTS

A. Process Discovery Results

1) Overall Case

The process discovery results for all overall cases in this study shown in Fig. 2. The process begins at an initial point and follows a sequence of evaluations and decision-making stages, including the handling of code errors and status

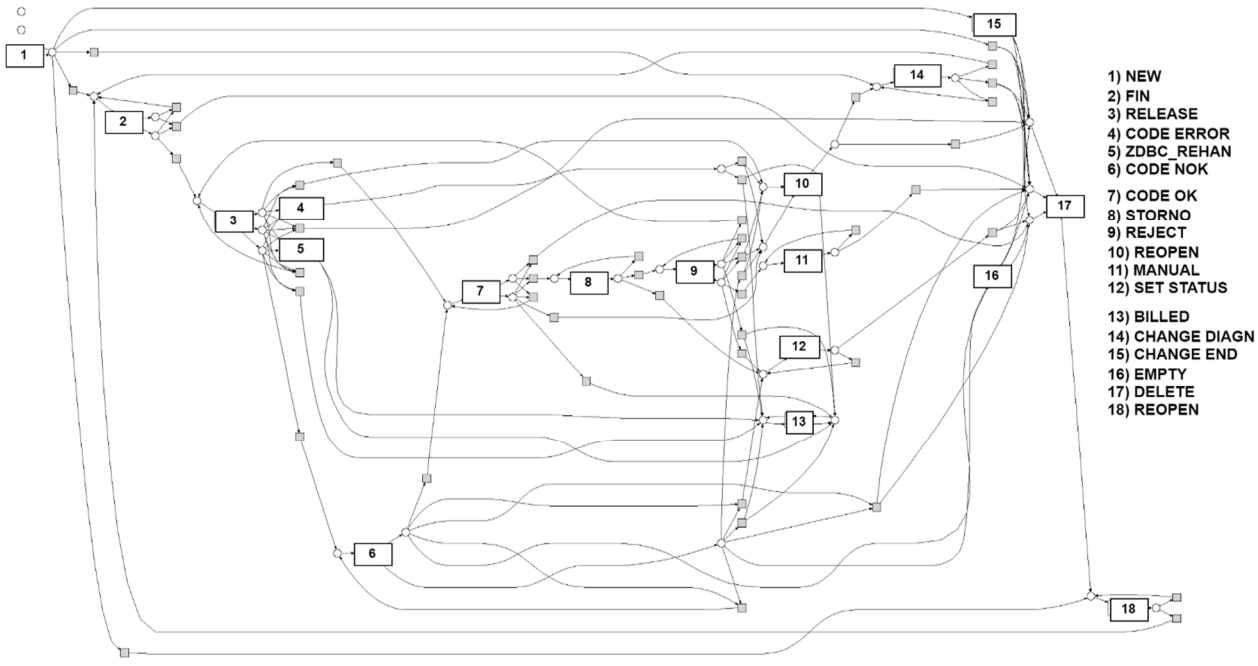

Fig. 2. Process Discovery Results

adjustments. There are also paths indicating manual interventions and options to modify, bill, or delete data entries. This process model is strategically designed to ensure that each case is handled effectively and accurately, considering specific conditions that arise during the recovery process. The process model serves as a crucial tool for understanding and ensuring the efficiency and accuracy of case processing.

To learn more about various case variations that often occur in the system process, we do further analysis on the top ten variants and most common variants of the cases in the dataset. Further explanation will be discussed in the next section.

2) Top 10 Variants

The process model diagram for the top 10 variants of cases in the process shown in Fig. 3. The top 10 variants account for 91% of system cases recorded in the event log, indicating that the system's process flow is primarily executed through this process activity sequences. The process begins with a 'NEW' state, which leads through a sequence of potential steps including a diagnosis change ('CHANGE DIAGN'), completion ('FIN'), and release ('RELEASE'). Following these stages, specific conditions such as 'CODE NOK' and 'BILLED' dictate subsequent actions, ultimately leading to either a 'CODE OK' outcome or a 'REOPEN' step to revisit the case. This process model diagram highlights the critical steps and decisions involved in the case processing, focusing on the efficiency and accuracy in managing various potential scenarios. TABLE III presents the top 10 most frequent process patterns observed in the hospital billing system, detailing their activity traces, frequencies, and case ratios, which highlight the prevalent pathways and potential inefficiencies within the process.

3) The Most Common Variants

The process model for the most occurring variant of the cases in the dataset shown in Fig. 4. It starts with a 'NEW' state, progresses through a 'CHANGE DIAGN' stage where the diagnosis or case details are adjusted, continues to 'FIN' indicating the completion of initial processing, then moves to 'RELEASE'. After release, the case may encounter 'CODE NOK' which suggests an issue or negative outcome that leads to billing ('BILLED'). Once resolved, the process ends with 'CODE OK', which indicates that the case has been successfully resolved according to the required standards.

TABLE III. TOP 10 MOST FREQUENT PROCESS PATTERNS

Activity Traces (Variants)	Frequency	Case Ratio
NEW > CHANGE DIAGN > FIN > RELEASE > CODE OKE > BILLED	33,673	33.67 %
NEW	22,373	22.37 %
NEW > FIN > RELEASE > CODE OK > BILLED	20,902	20.9 %
NEW > DELETE	4,813	4.81 %
NEW > FIN	3,508	3.51 %
NEW > CHANGE DIAGN > CHANGE DIAGN > FIN > RELEASE > CODE OK > BILLED	2.121	2.21 %
NEW > CHANGE DIAGN > DELETE	1,555	1.55 %
NEW > FIN > RELEASE > CODE NOK > BILLED	977	0.98 %
NEW > CHANGE DIAGN > FIN > RELEASE > CODE OK > REOPEN > FIN > RELEASE > CODE OKE > BILLED	869	0.87 %
NEW > FIN > RELEASE > CODE OKE > BILLED > CODE OKE	512	0.51 %
TOTAL	91,303	91.3 %

B. *Performance Analysis*

1) Identifying Bottleneck

TABLE IV highlights the bottleneck process activities, showcasing throughput times and distribution for various billing stages, emphasizing the critical points where efficiency can be improved. This study discovered significant variations in the time required to complete specific activities, indicating potential areas for process optimization. Specifically, the FIN → RELEASE activity demonstrates very high efficiency, with 99% of cases resolved within two days, indicating that the transition from completion to release is highly efficient. Despite the high efficiency shown by the FIN → RELEASE stage, factors such as a high volume of cases can cause even minor changes in handling times to have a significant impact on the overall process efficiency. Small delays in this stage can lead to backups or delays in subsequent stages, making it a potential bottleneck due to the impact it has on the overall

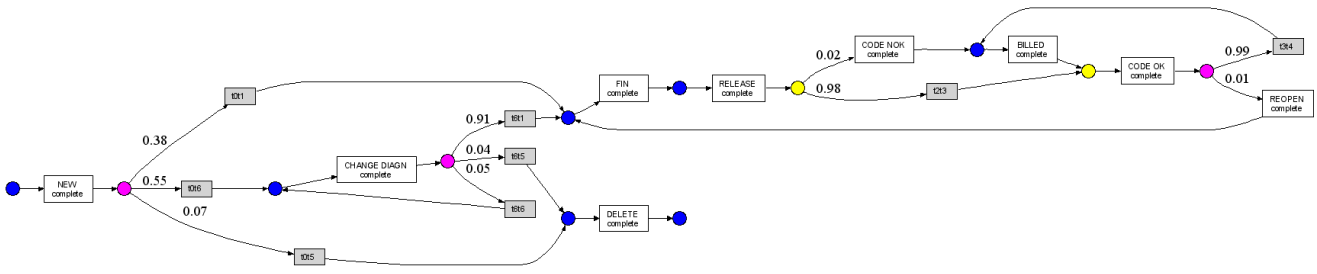

Fig. 3. Process Model Top 10 Case Variants

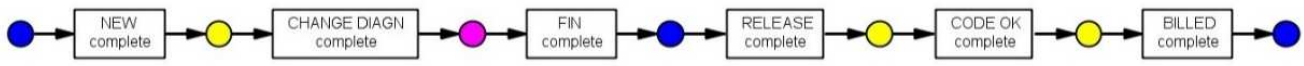

Fig. 4. Process Model of the Most Occurring Variants

TABLE IV. BOTTLENECK PROCESS ACTIVITY

Process Activity	Case Count	Throughput Time Average	Throughput Time Median	Distribution of Throughput Time
FIN → RELEASE	67,079	2 days	0 days	Wide, mostly within 3 days
CODE OK → BILLED	63,106	33 days	8 days	Wide, from 0 to 100 days
CHANGE DIAGN → FIN	40,459	74 days	89 days	Wide, from 0 to 160 days
NEW → CHANGE DIAGN	40,443	7 days	0 days	Mostly within 1 day
NEW → FIN	26,635	184 days	120 days	Wide, from 0 to 500 days

workflow. This underscores the importance of continuous monitoring even in stages that appear efficient.

Moreover, activities such as CODE OK → BILLED show significant variability in processing times, with an average of 33 days and a wide distribution of times, indicating potential issues that require further investigation. Stages like CHANGE DIAGN → FIN and NEW → FIN also experience substantial delays, with the latter taking an average of 184 days to complete, highlighting a critical bottleneck in the process from the receipt of new cases to their resolution. Activities with lower incidence rates, such as REOPEN, STORNO, REJECT, SET STATUS, and EMPTY, record very high throughput times, often due to the need for complex and non-routine evaluations required in handling these specific cases.

Based on this analysis, several areas from the Process models in Fig. 3 and Fig. 4 have been identified as potential bottlenecks, aligning with previous findings regarding long throughput times at specific stages. Some bottlenecks consistent with previous findings in this process model include CODE OK → BILLED, CHANGE DIAGN → FIN, NEW → CHANGE DIAGN and NEW → FIN. In the process model these bottlenecks are indicated with red or yellow color. This process model diagram is highly effective in visualizing the flow of the process and the time involved, providing direct insights into which stages are functioning efficiently and which may be impeding the overall process efficiency.

V. CONCLUSION

In this study, we have introduced our novel application of process mining techniques to automatically evaluate the DSS01 objective of the COBIT 2019 framework within a hospital billing system. This approach leverages event log data to analyze and optimize operational processes in real-time, focusing specifically on the effectiveness of IT delivery and support services. Our method successfully identified significant inefficiencies within the hospital's billing system, pinpointing several critical bottlenecks that can be targeted for process improvements.

From the hospital billing system case study, several bottlenecks have been identified that can be improved to optimize the ongoing processes. These findings indicate that bottlenecks occur among five connection processes out of the overall process activities. Additionally, five activities have been identified as bottlenecks. These results are in line with the reference process implementation based on the DSS01 objective in COBIT 2019. With this process, we can identify key points to improve processes that are running sub optimally, based on the processing time of an activity observable from the event log.

Future research can be conducted by further identifying bottlenecks within the existing process domains of COBIT, especially focusing on the "Deliver and Support" aspect. Additionally, the outcomes of the bottleneck analysis can be assessed based on two key aspects: resources and costs within the operational system, as observed through the event log.

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