CHAPTER 1

INTRODUCTION

This chapter provides an introduction to the thesis. This chapter includes the following subtopics, namely: (1) Rationale; (2) Theoretical Framework; (3) Conceptual Framework; (4) Statement of the problem; (5) Objective and Hypotheses; (6) Assumption; (7) Scope and Delimitation; and (8) Significance of the study. Section 1.1 gives the background of this research. Section 1.2 discusses the theories that are useful in conceptualizing the research. Section 1.3 discusses the variables related to the problem. Section 1.4 describes the specific issue that the research aims to address. Section 1.5 explains the objectives and hypothesis of the research. Section 1.6 explains the assumption based on the general and specific problem. Section 1.7 identifies the scope and delimitation of this research. Section 1.8 defines the importance of the research and its contribution to knowledge.

1.1 Rationale

Cancer ranks as a prominent cause of death and a significant obstacle to raising life expectancy in every country [1]. According to the Global Cancer Observatory data in 2020, an estimated 396,914 cancer cases were diagnosed in Indonesia, with breast cancer as the highest case (16.6 percent or 65,858 cases) [2]. Breast cancer is the second mortality rate of 9.6 percent or 22,430 deaths after lung cancer (mortality rate of 13.2 percent or 30,843 deaths) among the number of cancer cases in Indonesia [2]. Most breast cancer patients are delayed diagnosis and diagnosed in the advanced stage, leading to a high mortality rate, so it has to be diagnosed and treated urgently [3]. The high prevalence and mortality rate of breast cancer in Indonesia emphasizes the importance of access to cancer treatment.

Breast cancer cases are mainly detected through clinical examination, mammography, ultrasound imaging, and biopsy [4]. Generally, The primary treatment for breast cancer is treated through surgery, either with lumpectomy or mastectomy, followed by radiotherapy, chemotherapy, hormone therapy, antibody-based therapy or a combination of these [5]. This therapy can be given before surgery, called neoadjuvant therapy, or after surgery, called adjuvant therapy [6]. These therapies reduce tumor size or kill cancer cells[6].

The Indonesian government established the Indonesian National Health Insurance or BPJS, which covers medical expenses for the citizens to provide equitable health services, including cancer treatment [7]. The health facilities are the Primary Health Facilities (FKTP) and the Advanced Referral Health Facilities (FKRTL) [8]. The FKTP is mainly based on health centres (outpatients) and primary hospitals. At the same time, FKRTL is primarily provided at second-level health facilities at the provincial level (class C or D hospitals) and third-level health facilities at the national level (class A or B hospitals) [8].

BPJS Kesehatan has several obstacles, such as unequal distribution of health services [9], lengthy treatment process [10], less transparent health service processes [11], and uncertain treatment sequence [12] as the healthcare process changes over time [13]. Thus, there is great potential to maximize the application of knowledge about the Indonesian healthcare system. One of the critical performance factors in cancer treatment is the path to diagnosis [14] or cancer waiting time [15]. Therefore, it is essential to discover clinical pathway variability, activity sequences, and delays to improve healthcare quality [9], [16].

Process mining centres on processes and aims to gain significant insights during actual execution [17]. Process mining can enhance compliance and performance in hospitals and other care organizations by extracting process models to discover, monitor, and improve real-life clinical pathways [18]. There are three categories of process mining: discovery, conformance checking, and enhancement [18]. The process discovery technique generates process models, like Petri nets [19], to represent observed behaviours [18]. The Inductive Miner (IM) algorithms accurately produce process models and offer insights for healthcare process enhancement [20]. Among its variants, The Inductive miner–infrequent (IMi) algorithm achieves the best scores, which is the most suitable for mining the BPJS Kesehatan event log, prioritizing the more frequent behaviour to enhance the healthcare process [21], quickly generating a reliable 80% accurate model [20].

This research aims to analyze treatment pathways for breast cancer in three different treatment groups and to provide recommendations for improvement of breast cancer treatment procedures in the BPJS Kesehatan dataset through process mining. The process model is visualized as a Petri net using the ProM 6.12.1 framework [22]. This research is the first attempt to explore clinical pathways in the BPJS dataset for a specific type of cancer diagnosis. Our previous study examined the same dataset for disease trajectory analysis [23]. This experiment can be followed to explore pathways of other diagnoses.

1.2 Theoretical Framework

Breast cancer is called ductal carcinoma in situ (DCIS) when it is limited to the ducts, indicating a non-invasive medical procedure or procedure that does not require inserting an instrument through an incision in the skin [24]. However, in the majority of cases, the cancer is diagnosed as invasive cancer, which indicates the potential of malignant cells to extend beyond the boundaries of the tumor [25]. Classification of invasive cancer includes assessment of the type and histological grade of cancer cells and the size and extent of tumor spread [4].

Timely referral to a breast clinic is imperative for all individuals with suspected or potential breast cancer [26]. Clinical examination typically detects breast or axillary lumps, prompting General Practitioners (GPs) to refer symptomatic women to designated breast clinics in local hospitals [27]. The standard diagnostic process involves triple assessment,

incorporating clinical assessment, mammography and ultrasound imaging, and fine needle aspiration or core biopsy. [4].

Primary breast cancer treatment typically entails surgery, with options including breast conservation (wide local excision) or mastectomy [28]. Following surgery, the standard protocol involves administering adjuvant treatments, including radiotherapy, chemotherapy, or hormone therapy, individually or in combination [29]. Notably, these therapeutic interventions may be administered before surgery, a practice referred to as neoadjuvant treatment [30]. Applying neoadjuvant chemotherapy and adjuvant treatment effectively reduces tumour size, minimizing the necessity for extensive surgical procedures [4].

The selection of adjuvant treatment relies on factors such as age, risk of relapse, potential benefits, estrogen receptor status, and the patient's acceptability [29]. Adjuvant treatment for breast cancer is administered after primary surgical management, aiming to diminish the risk of recurrence (both locally and distantly) and enhance survival rates [31]. Radiotherapy is employed to lessen the risk of local recurrence [29]. Standard treatment includes whole breast radiotherapy following breast-conserving surgery for invasive cancer and is also considered post-mastectomy, contingent upon pathological risk factors. Systemic therapies, encompassing chemotherapy, endocrine treatment, and biological therapy, reduce the risk of distant metastases and enhance overall survival [29]. The decision to recommend adjuvant treatment is intricate, considering both prognostic and patient factors, and is arrived at through a multidisciplinary team meeting with the patient [29].

The neoadjuvant (preoperative) approach in breast cancer is well-established as a therapeutic pathway, particularly advantageous for selected high-risk breast cancers, tumours with a size greater than or equal to 2cm, and cases classified as locally advanced (including those initially ineligible for resection) [32]. The utilization of neoadjuvant therapy offers various clinical advantages. For patients with substantial tumours, its implementation is likely to result in size reduction, rendering them eligible for surgical resection or making breast-conserving surgery a viable option instead of mastectomy [33]. The preservation of the primary tumour during neoadjuvant therapy allows continuous monitoring of treatment response and facilitates the discontinuation of ineffective therapy if disease progression occurs[30]. This approach proves beneficial by sparing patients from exposure to potentially toxic treatments [30].

Metastatic breast cancer has the potential to impact various body parts, particularly the bones, lungs, soft tissue, and liver [34]. This condition manifests a spectrum of symptoms, prominently including pain and fatigue, as well as diverse issues such as persistent coughing, paralysis due to spinal cord compression, and bone fractures [34]. The treatment objective at this stage is not curative, though there may be some extension of life expectancy, but primarily to alleviate symptoms and enhance the quality of life. Patients may be presented with options like radiotherapy, hormone treatment, chemotherapy, and potentially immunotherapy [4]. Essential aspects include supportive and palliative care,

along with practical assistance in daily activities to uphold the quality of life during the later stages of the disease [4].

Stages I and II breast cancers commonly undergo treatment involving breast-conserving surgery and radiation therapy. The application of radiation therapy following breast-conserving surgery has been shown to decrease both mortality and the likelihood of recurrence. In the case of Stage III breast cancer, induction chemotherapy is typically administered to reduce tumour size, facilitating the possibility of subsequent breast-conserving surgery. However, for inflammatory breast cancer, despite its categorization as Stage III, its aggressive nature necessitates induction chemotherapy followed by mastectomy rather than opting for breast-conserving surgery [35]. In navigating the complex treatment decisions for aggressive conditions like breast cancer, process mining techniques play a crucial role in enhancing healthcare processes by offering insights into optimal clinical pathways and treatment strategies.

Process mining techniques help analyze business processes by using logged data created during their execution, and they find applications in various fields, including healthcare [36]. Process mining becomes a game-changer in managing healthcare when applied to the clinical pathways for breast cancer treatment. This method visually shows the entire treatment process, explaining the step-by-step activities and decision points. By understanding the differences in patient characteristics and treatment plans, healthcare providers can customize interventions to specific needs. Process mining identifies points of slowdowns and delays in the treatment journey, going beyond just visuals [37]. It helps make the process smoother, allocate resources more efficiently, and reduce waiting times for breast cancer patients. The method also supports improving quality by checking if protocols are followed and pinpointing where best practices may not be applied. With advantages like optimizing resources, keeping track of performance, and focusing on the patient's needs, process mining ensures that breast cancer treatment aligns with guidelines, produces good results, and improves over time. Eventually, process mining becomes a powerful tool for enhancing the quality and performance of breast cancer care.

1.3 Conceptual Framework/Paradigm

The research is guided by the Process Mining Methodology (PM^2) [38], which serves as the central theoretical framework. The PM^2 offers a structured approach for systematically analyzing, enhancing, and optimizing organizational workflows. The PM^2 provides insights into its stages and methodologies. The methodology comprises six stages. The initial stages start with planning, which defines the research question to improve the performance of the business process. The next stages involve extraction with the inputs from research questions and information systems. The outputs for the extraction stage are event data. The event data in the data processing stage is processed into logs used in the mining

and analysis stage. Process mining techniques are applied in the mining and analysis stage to answer the research question. It consists of four activities: process mining techniques (process discovery, conformance checking, enhancement) and process analytics. Process analytics are applied to enrich the insight of event logs and process models with additional aspects, such as visual analytics. The next stage is evaluation, which improves the idea of the research objective. It consists of diagnosing the interpreted result, verifying the findings obtained for the original data and system, and validating them compared to process stakeholders. The last stage is process improvement and support to modify the actual process by predicting future actions and suggesting recommended actions. Fig 1.1 illustrates the outline of PM^2 Methodology [38].

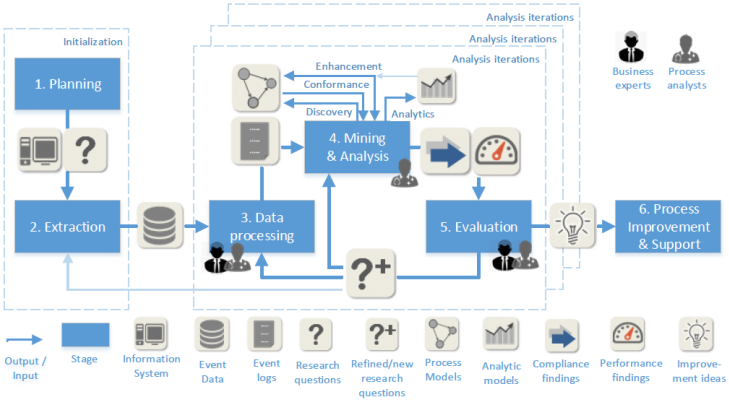

Figure 1.1: The Process Mining Methodology (PM^2)

1.4 Statement of the Problem

Many health service facilities, including hospitals and community health centers, lack in-depth knowledge of the processes. These facilities continually face process changes over time [13], with clinical pathways becoming highly flexible due to each patient's unique co-morbidity and complications [39]. Real-life process execution often deviates from expected behaviour [13], and various contributing factors influence the diversity of activities within health service processes [13].

Process mining techniques are crucial in providing a deep understanding of diverse processes, offering a rapid overview of actual occurrences and revealing process flows [40]. In healthcare institutions, process mining can uncover the representation of the actual execution of processes through human-understandable models. The primary motivation behind this research stems from a lack of transparency in the patient's journey. As patients navigate through clinical pathways, each encountering different services or departments, there is a lack of awareness of the entirety of the patient's pathway. This results in patients experiencing obstacles and delays within the healthcare system, with the lack of visibility

hindering accurate identification of specific locations where these delays occur. Therefore, the main goal of the research is to highlight the actual pathways, enabling more accurate and improved decision-making to enhance healthcare quality.

1.5 Objective and Hypotheses

The first objective is to evaluate the performance of the Inductive Miner-infrequent algorithm in modelling process pathways for each treatment group. The second objective is to identify the differences between each treatment group, conducting a comparative analysis of the general treatment pathway and three specific treatment groups. The third aim is to analyze breast cancer treatment to highlight the waiting time, sojourn time, elapsed time, and remaining time to provide recommendations for activity that may be a concern during the breast cancer treatment procedure based on the Indonesian Health Insurance Dataset.

The utilization of process mining techniques of the Inductive Miner-infrequent method can better analyze detailed pathways throughout the treatment process. This approach assists clinicians in making informed decisions by enabling them to identify recurring patterns within clusters of patients and acquire knowledge about areas where patients experience delays. As a result, the study aspires to provide valuable insight into breast cancer care in healthcare.

1.6 Assumption

The assumptions of this research are:

1. The data recorded in the BPJS data is valid.
2. Patient treatment timestamps and activities are correctly integrated into the database.
3. The tools of process mining are well-performed and give trustworthy results.

1.7 Scope and Delimitation

The scope and delimitation of this research are:

1. This study's scope focused on treating breast cancers (C50).
2. The study will rely on limited access to data sources from Indonesia National Health Insurance's data records for 2015 to 2018.
3. The study does not include severity level.
4. The data does not include the characteristics of the patient's health, the other factors influencing the clinical pathway, and the other congenital diseases and complications.

5. The study only used BPJS Kesehatan data. In time measurements such as calculating elapsed time, remaining time, sojourn time, and waiting time, patients who underwent examinations outside hospitals affiliated with BPJS Kesehatan were not included in this study

1.8 Significance of the Study

Understanding a specific healthcare system becomes crucial for enhancing the quality of care. Due to its convoluted pathway, clinicians, patients, and clinical administrators lack a detailed picture of patient movement, making tracking the patient's path challenging. Gaining valuable insight involves viewing the detailed pathway throughout the treatment process. This approach assists clinicians in making informed decisions by enabling them to identify recurring patterns within clusters of patients and acquire knowledge about areas where patients experience delays.

In this research, the importance of process mining is growing due to its potential to enhance healthcare processes and organizational performance. Analyzing data from event logs through process mining helps organizations identify inefficiencies and improve clinical pathways, leading to significant cost savings, enhanced productivity, and increased customer satisfaction.

This research provides techniques that facilitate a clearer understanding of the patient path within a healthcare system. The study describes information captured at each step of the patient's pathway, utilizing Indonesian health insurance data to depict patient journeys using breast cancer as a model. It establishes connections among various systems necessary for analysis, conducts a systematic review of process mining techniques and perspectives in healthcare, and demonstrates how visualization tools from process mining enhance understanding of patient pathways in a complex healthcare system. Furthermore, the research identifies and visualizes bottlenecks, deviations, and delays in the current pathway.

Beyond practical applications, process mining holds theoretical implications for fields like computer science, artificial intelligence, and data science. Consequently, research in process mining has the potential to contribute to the development of more effective cancer treatments by identifying potential treatments and predicting the effectiveness of different treatment strategies. It can lead to the discovery of new therapeutic options and more personalized treatments for cancer patients.

Considering the rationale, problems, and significance of this study, this research was conducted from March 2023 to February 2024 within a year. The remainder of this chapter is structured as follows. Chapter 2 gives a related work to the predictive techniques that have been applied in process mining. Chapter 3 outlines the proposed method of the process mining experiment in healthcare from a research point of view. Chapter 4 discusses a case study on the potential of process mining in the context of breast cancer, analyzing the

results to demonstrate its effectiveness. The chapter ends with elaborated conclusions and suggestions remarks in Chapter 5.