A Work Project, presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

"Implementing Automated TDABC In Healthcare Settings – Deploying an End-to-End Solution using Process Mining"

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Abstract

This work project proposes a comprehensive solution to implement and automate TDABC in healthcare settings. The core of our proposal is an innovative approach that integrates RFID technology and process mining to streamline data collection and process mapping. By combining academic literature with insights from medical doctors and industry professionals, we highlight the advantages of TDABC over traditional costing methods, and outline all steps required for a practical implementation of our solution. Following this, we also present a possible business model. Finally, our work concludes with a discussion of the advantages and limitations of our solutions and provides strategic recommendations for overcoming the main challenges.

Keywords

Time-Driven Activity Based Costing, Value-Based HealthCare, RFID, Process Mining, PM4PY, FHIR, GDPR, HIPAA, VBHC, TDABC

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Table of Contents

1. Introduction

While the theoretical foundations of Time-Driven Activity-Based Costing (TDABC) in the framework of Value-Based Healthcare (VBHC) are robust, its practical implementation within healthcare organizations is often tied to challenges related to achieving accuracy in cost tracking and precise time measurement. Equally important and challenging is ensuring that introducing TDABC within a healthcare setting does not increase doctors and employees' workload, which is generally already very high (Kaplan, 2016). Such obstacles highlight the need for an innovative, automated comprehensive approach capable of addressing the discrepancies between theoretical models and the unpredictable realities of healthcare environments.

Following this direction, **this work project moves beyond traditional approaches, and presents an end-to-end solution tailored to empower healthcare organizations to implement and automate Time-Driven Activity Based Costing.**

Central to our innovative solution is the integration of RFID and process mining technologies in healthcare settings to automate and streamline activity cost tracking and process mapping.

Moreover, in order to refine and validate our solution, we have conducted interviews with medical doctors, researchers, and different professionals who operate within the realm of the healthcare industry. Their invaluable input, grounded in their first-hand experiences and academic rigor, is placed at the core of our proposed solution.

Our work begins with an overview of the current challenges and limitations of traditional approaches in the context of healthcare cost management. Then, the Value-Based Health Care Framework is introduced, highlighting the increasing need for precise cost tracking and measurement in healthcare institutions to improve the value delivered to patients. Once the context and scope of our work is defined, we introduce the TDABC method, as formulated by

Kaplan and Anderson, suggesting it as a potential solution to several of today's healthcare organizations. After laying out these core concepts, a detailed and comprehensive strategy for the implementation of TDABC in a hospital setting is presented, while also addressing the key steps to overcome the main challenges that organizations might face across all phases of the implementation. Complementarily, a careful analysis of the requisite technologies essential for ensuring a seamless process implementation is undertaken. Finally, this work projects ends with the detailed business model we intend to adopt when offering our solution to organizations, and with an overview of the current limitations, required investment and timeline for the full implementation of TDABC.

2. The Need for a Comprehensive Solution

2.1 The Importance of Cost Containment in the Healthcare Industry

Cost containment in healthcare is defined as a reduction in costs while maintaining or enhancing the quality of services, a principle articulated by Weinstein and Stason in 1977. This approach is thought to be crucial for increasing health system efficiency. It involves strategic management and control of the escalating costs associated with delivering medical services, addressing challenges posed by technological advancements, an ageing population, and the growing demand for quality care in the healthcare industry.

The importance of cost containment extends beyond the organizational level. A well-designed healthcare cost-containment strategy can provide societal benefits. Limiting excess spending that adds little value, contributes to more efficient resource allocation. This, in turn, prevents the crowding out of valuable government expenditures, upholds solidarity principles in healthcare, and enhances the overall efficiency of spending (Stadhouders, 2019). The goal is to strike a balance where cost reductions do not compromise the quality of care but rather lead to a more effective and sustainable healthcare system.

2.2 Gap in existing approaches and the need for a comprehensive solution

Historically, the methods employed in managing healthcare costs tend to fall short in effectively addressing the complex challenges faced by healthcare institutions. While diverse methodologies have been deployed to address specific facets of cost optimization, a predominant issue lies in the lack of a systematic and comprehensive approach that is indispensable for achieving optimal operational efficiency. This gap becomes particularly apparent in the context of the TDABC subject, where the complexities of healthcare operations demand a more sophisticated solution.

As previously mentioned, many existing approaches in healthcare cost management often exhibit a fragmented nature, focusing on isolated facets such as direct medical expenditures or specific operational processes. They tend to lack the granularity required to track costs comprehensively across the entire patient care continuum. This fragmented approach results in a limited perspective on the overall cost scenario, creating gaps in understanding how various activities contribute to the broader financial picture.

In fact, such methodologies mostly rely on broad estimations or generalized allocations, department-centric accounting, and simplified cost estimation techniques that fail to offer detailed insights into where costs accumulate within various care pathways. Consequently, healthcare organizations struggle to identify the specific areas where costs are incurred, hindering efforts to optimize resource utilization and operational efficiencies.

There is no doubt that healthcare operations involve a multitude of interconnected activities, each with its cost implications. The failure inserted in traditional approaches alone standing, reaches to the pressing need for an end-to-end solution capable of addressing all these challenges comprehensively. There is the need for a unified system that automatically integrates data sources, streamlines cost-tracking mechanisms, takes usage of sophisticated analytics and reporting, all aligned with value-based care principles. TDABC, specifically and automatically tailored for the healthcare industry, would be a commendable start, given that it offers a more sophisticated lens through which institutions can analyze and optimize costs, providing a holistic understanding of the interconnected nature of healthcare activities and their financial implications.

Substantial evidence indicates that the lack of a comprehensive solution contributes to overutilization and misuse of technology (Brownlee et al., 2017), leading to excessive spending that may not align with the value delivered to patients.

The gap becomes even more apparent when considering the imperative of transparency in cost allocation, resource consumption, and understanding cost drivers. The limited insights provided by current approaches hinder healthcare administrators from fostering informed discussions and making strategic decisions that are essential for efficient cost management.

A comprehensive approach is necessary to address the current gap in healthcare cost management. Getting a clear picture of expenses, assigning specific tasks to people, and being open about how resources are used are all crucial aspects. With such a solution, healthcare organizations would be able to spot inefficiencies, deal with high-cost areas, and allocate resources wisely. In order to maintain cost reduction and enhance service quality procurement, this strategy facilitates the development of realistic financial projections, successful contract negotiations, and streamlined workflows. The shortcomings of the traditional methods used emphasize the need for a more exact and sophisticated approach to maximize healthcare cost control.

Relevance of Automation

Complementary, it must be emphasized the utmost importance that automation components have in the contemporary healthcare landscape. No comprehensive solution should be considered without incorporating automatic developments. It is an imperative. An automated process fully imbibed in such solution can ensure a seamless flow of data collection, processing, and analysis, thereby granting the healthcare industry instrumental real-time insights into critical aspects such as cost drivers, resource utilization patterns, and care pathways.

Such arguments have been highlighted in a study by Blumenthal and Tavenner (2010), emphasizing the significance of Electronic Health Records (EHRs) and their role in improving healthcare quality and efficiency. Additionally, it is also argued that automation in healthcare systems not only enhances operational efficiency but also contributes to improved patient outcomes (Zayas-Cabán et al., 2022). It is further claimed that automation, in conjunction with advanced analytics, facilitates evidence-based decision-making for healthcare administrators (PricewaterhouseCoopers (PwC): "Global Top Health Industry Issues 2021"). Such advancements are also critical in meeting the increasing demand for personalized care, being technology an important vehicle to achieving patient-centered care models (Naserias et al., 2015).

2.3. Proposed Solution

2.3.1. Overview

The main objective of this work project is to present a detailed plan for the implementation of automated TDABC within the complex landscape of healthcare settings. Transitioning from the theoretical groundwork and conceptual frameworks previously discussed, we now direct our attention to the actionable strategies and critical considerations necessary for practically guiding hospitals through the adoption of TDABC.

Taking into consideration the constraints of traditional cost measurement methods outlined earlier and identifying the subsequent market need for a comprehensive solution, we propose an advanced solution to suitably address this gap. Kindly note that this solution comprehends the use of significant technical technological components that may pose challenges in comprehension. However, rest assured that each element will be meticulously explained, ensuring a clear understanding without any ambiguity.

Without further do, our proposed solution starts with a thorough facility and patient mapping through the usage of Radio-Frequency Identification (RFID) technology, namely wristbands and sensors for an effective real-time tracking. The secure storage provided by the Fast Healthcare Interoperability Resources (FHIR) database enables process mining tools to examine patient pathways and workflow effectiveness. This synergy identifies the costs incurrence from a bottom-up perspective, which maximizes resource allocation and operational efficiency by giving administrators relevant insights for well-informed decision-making. In addition to streamlining present procedures, our scalable approach that combines RFID, FHIR, and process mining also establishes the groundwork for upcoming advancements in healthcare, building a networked ecosystem that enhances patient care and boosts organizational efficiency.

Before diving deep into the technical specifics and practical implementation requirements of our solution within healthcare institutions (section 6), we provide an introduction of the two key technologies - RFID and Process Mining - that contribute to making our proposal highly innovative yet feasible. The concept and implications of FHIR will also be detailly explained in section 6.

2.3.2. Key Enabling Technologies: RFID Technology

Radio-Frequency Identification (RFID) represents a pivotal technology within the realm of wireless communication and data capturing systems. In an RFID system there are two main devices: the tag, also known as a transponder, and the reader, or interrogator. Fundamentally, RFID is a technology that utilizes electromagnetic fields to transmit information from the tags to the readers. As RFID tags are essentially small transmitters, they are capable of collecting data about the item or person to which they are attached, and then convey this information to the reader once they are within range (Want, 2006).

In the last decade, the use of RFID technology has found applications across various industries due to its accuracy in tracking and managing inventory, assets, and resources. Especially in the field of supply-chain, RFID devices have been extensively adopted for several years. For example, Walmart, currently the largest retailer across the world, effectively adopts RFID tags to accurately track its moving inventory and improve the overall efficiency of its value chain. (Angeles, 2005). For what concerns the healthcare industry, the potential of RFID technology has started to gain considerable recognition only in recent years. Initially, applications of RFID technology in the field of healthcare were limited to pharmaceutical companies and medical device providers, that leveraged the tracking capabilities of RFID mainly to minimize waste and monitor potentially fraudulent activities (Yao, Chu, & Li, 2012).

However, the capabilities of this technology have advanced over the years, becoming increasingly more cost-efficient and widespread. Use cases such as error prevention, theft prevention and inventory management have emerged and have been successfully implemented. According to Abugabah et al (2023), the most common objective for tracking staff and medical equipment is to improve patient safety by ensuring correct infection control. Mostly, hospitals track their staff to ensure they comply with hygiene regulations such as hand washing. In addition, safety is another issue when implanting the device in a patient. RFID is used to ensure that the correct device is implanted in a patient and is overall an important aspect to promote safety. The patients are tracked to drive ward efficiency and cost per patient by predicting patient movement and bed utilization. Overall, safety, efficiency, and cost savings in the supply chain are reasons to implement RFID technology (Abugabah et al, 2023).

According to a report by Grand View Research, the global medical RFID market is expected to reach a global market size of USD 14.65 billion by 2030, growing at a Cumulative Annual Growth Rate (CAGR) of 17.85% from 2023 to 2030, as reported by Grand View Research (2023). This positive trajectory opened the doors to new opportunities in the adoption of RFID devices to automate the tracking of activities and resource utilizations within hospital infrastructures. In this context, RFID can be exploited as enabler technology to implement automated TDABC within a hospital.

2.3.2. Key Enabling Technologies: Process Mining

First introduced by Van der Aalst, process mining combines data mining with machine learning techniques. Through pattern recognition, process mining identifies process flows which include the sequence of events, timestamps, and allocated resources (Dallagass et al, 2022). In the healthcare landscape, the resulting output is a diagram that visualizes the care pathway of a patient with a certain condition.

Many researchers have studied the application of process mining in healthcare settings. There are studies applying process mining to emergency care, cardiovascular disease, oncology, stroke, and sepsis, creating distinctive care pathways for conditions. These care pathways provided a good foundation to test process improvement and their effect on patient outcomes (Litchfield et al, 2018). Dallagass et al (2022) further investigated the different applications of process mining in the healthcare setting. In their research, they found that 35.5 % of the applications involved identifying activities to establish or update protocols and clinical guidelines. 24.8 % were concerned with analyzing and optimizing resources as well as evaluating health technologies. The remaining use cases involved compliance analysis, evaluating discovered process models against prevailing clinical guidelines and protocols for standardization purposes; and conformity analysis, with the aim to evaluate whether a specific patient's journey adheres to the clinical guideline for a specific illness.

The use cases for process mining have increased over the years and the technology itself is continuously improving with new algorithms emerging over the years. According to a report by Markets and Markets (2023), the global market for process mining is expected to expand from USD 1.8 billion in 2023 to USD 12,1 billion in 2028, growing at a Cumulative Annual Growth Rate (CAGR) of 45.6% from 2023 to 2028.

Although there are many applications for process mining in healthcare, there is yet a study to be found that has the goal of implementing TDABC in healthcare organizations with the help of process mining techniques. Hence, we see a gap which we can fill to implement automated TDABC in hospitals.

3. Methodology: Validity and Reliability

The approach presented in this paper lays its foundation in the available academic research in TDABC, and links it with the reality of today's healthcare industry. In fact, this work project has sought validation from the "front lines": key stakeholders such as MDs, PhD candidates, Process Mining experts, and professionals with hands-on experience in similar projects were interviewed and involved in the creation of our solution. Their insights and feedback have been invaluable, helping to refine and validate our proposed approach. Our methodology is a mixed method exploratory research, using primary research methods, i.e. interviews, and including secondary research by gathering data through existing literature and online sources.

3.1 Primary Data - Interviews

We conducted semi-structured interviews to be able to adapt the questions according to the expert's expertise and professional experience within the different aspects of our project. In a first step, we identified key stakeholders who were involved in projects with the goal of implementing TDABC or process mining in a healthcare setting. We used LinkedIn and e-mail as tools to contact them and ultimately conducted five interviews. Before each interview, we prepared questions tailored to the expert's background and area of expertise to receive insights for a specific part of our solution. The interviews were conducted online via MS Teams for the duration of 30 to 60 minutes. The interviews were scheduled in the time frame between October 11, 2023 and November 10, 2023.

The interview partners are experts in different fields related to our solution from Belgium, Norway, and Brazil. The professional backgrounds range from MD, researcher, professor to specialist. Three of the interviewees had been involved in projects regarding implementing TDABC in hospitals manually. Niels Hilhorst from Belgium has worked as a MD at the University Hospital of Gent (UZ Gent) when he implemented TDABC for the condition of psoriasis. Erin Roman is a phD candidate and researcher at UZ Gent. She developed process maps and implemented TDABC in two disease domains, namely breast cancer and psoriasis. Joke Borzée, also a phD candidate and researcher at UZ Gent, implemented TDABC manually in several hospitals in the conditions of lung cancer, psoriasis, and hip surgery. Another expert that we interviewed is Anton Hasselgren from Norway. He has a profound expertise in blockchain technology in healthcare settings, being a blockchain specialist at Accenture. Eduardo Alves Portela Santos, who is a professor at the Federal University of Paraná in Brazil, has been involved in several process mining projects and is considered a thought leader in process mining (Table 1).

3.2. Secondary Data

Alongside the interviews, we used secondary data. We mainly used Google Scholar and EBSCOhost. EBSCOhost provides very tailored results as one can select specific databases. This narrows down the search to journals and papers that are in the domain of interest and gives adequate results. Hence, by combining rigorous academic exploration with professional expertise, we ensure that our methodology is not just theoretically sound and reflects the state-of-art, but also practically viable and ready to make a significant impact in the healthcare cost management landscape.

4. Implementation of Automated TDABC In Healthcare: Our End-to-End Solution

In this section, we present the technical specifics and practical implementation requirements of our automated TDABC end-to-end solution within healthcare institutions. This proposition follows the insights received through our interviews and research. First, we empathize the relevance of automation throughout the implementation process, which plays a crucial role in enhancing precision and consistency, essential for effective cost tracking. Next, we deep dive into the reasons that make RFID the most effective technology to adopt in our proposal, highlighting the role it plays as an enabler in implementing and automating TDABC. Then we explain how we deploy process mining to create care pathways automatically, which is an essential step to identify the resources and time spent for each resource as a prerequisite for TDABC. Lastly, we address data collection and privacy concerns. Adhering to EU standards, our approach ensures safety and confidentiality in the management of patients and personnel information, ensuring both compliance with the most stringent regulations, and accuracy of the collected data.

4.1 Role of Automation

As previously highlighted, the incorporation of automation components into our solution stands as a crucial imperative. This argument that sustained and concerningly emphasized during our meetings with field experts.

Throughout the conducted expert interviews, a recurring sentiment emerged among medical professionals: a reluctance to adopt TDABC or any new approaches if it implies that their administrative burden will increase. According to the estimates of an MD interviewed, administrative tasks already consume 20 % of a physician's time; thus, the willingness to spend even more time on such topics is considerably low. Moreover, both nurses and doctors expressed discontent in their manual data collection experiences within care pathway creation projects, citing that is too time consuming. Another interviewee confirmed that there is a keen interest in TDABC, but that the manual approach would be too time-consuming for it to be implemented. A third interviewee who was involved in projects of implementing TDABC in breast cancer and psoriasis described time to be one of the biggest challenges. In her projects, in which she used the observation approach, the MDs had little time. According to her, even if she was lucky, she could see a MD for no more than 20 minutes in an entire day. It was challenging for her to find a MD who was invested and committed to provide time. She highlighted that it is important to note that it does not suffice to have only one interested medical doctor but that it would require at least seven to eight committed medical doctors to enable the implementation of TDABC, which makes the success rate even less likely.

We have observed that the biggest challenge from several stakeholders who implemented TDABC with the manual approach was that MDs lose interest in committing to the project once they find out how much time investment is required from their end. Hence, automating the process of gathering data and mapping the care pathway seems to be necessary to lift this burden from the MDs to receive their commitment.

In the following sections 6.2.1 and 6.2.2, we will discuss how RFID technology enables us to gather necessary data, meticulously tracking resources - encompassing MDs and other medical staff - and precisely documenting their time spent on each activity. Subsequently, after having gathered the data, we venture into automated care pathway discovery using process mining technology. This provides a panoramic view on resource utilization and time spent per resource throughout the entire patient journey; hence, streamlining the implementation of TDABC with minimal manual intervention. This integration of automation emerges as a tool for overcoming resistance to new methodologies among healthcare professionals. By minimizing their involvement in the labor-intensive aspects of data collection and analysis, it allows medical staff to focus on their core competencies, which is delivering quality patient care.

Moreover, automation not only addresses the primary concern of time-consuming manual data entry, but also ensures consistency and accuracy in the gathered data, which are crucial for effective cost analysis and process optimization. In the context of implementing TDABC in a hospital, automation transcends mere data collection, and it represents a transformative shift towards a more efficient, accurate, and sustainable model of healthcare cost management. By leveraging technologies such as RFID and advanced data analytics, healthcare institutions can significantly reduce the administrative burden on medical staff, thereby enhancing their engagement and willingness to adopt TDABC methodologies. This not only enables organizations to streamline processes, but it also aligns with the broader objective of improving healthcare delivery efficiency and patient-centric care.

4.2 RFID Technology

RFID technology is widely used in many industries. In the healthcare environment, RFID technology is implemented to track medical staff, patients, and medical equipment (Abugabah et al, 2020). Abugaba et al (2023) show that healthcare organizations adopt RFID technology depending on factors such as perceived benefits, market uncertainty and the presence of champions. Other variables that determine the implementation of RFID include costs, security, and top management support. This is important to consider so that we can estimate the benefits of using RFID.

Alternative technologies that are used to track people and equipment include Near-Field Communication (NFC), Bluetooth Low Energy (BLE), and Real-Time Location Systems (RTLS). NFC is a wireless communication technology and connects a tag to a compatible device within a short range of 1-10 cm. Due to its short rage, the person or equipment needs to come into very close contact with the reader to be tracked, which often requires action (Singh, 2020). In comparison, RFID has a wider range of 3-5 m. Another advantage of RFID compared to NFC technology is that the RFID reader can detect multiple tags compared to a single tag at a time (Oliveira, 2022). That is crucial as we have several tags that need to be tracked at a time such as medical equipment, drugs, medical staff, and patients. BLE is a low energy wireless device that enables communication with a large number of devices. Even though BLE devices have a wider range, RFID tags are less expensive. As we will allocate a reader in every room, the range of RFID is more than sufficient (Kumar et al, 2021). RTLS systems consist of a global wireless network of location infrastructure and RFID sensors and tags. It has a better location accuracy over a greater range, whereas the accuracy of RFID decreases as the tag gets further away from the reader. However, as previously mentioned, this is not an issue as the reader is in the same room, thus, will be in proximity. Moreover, RTLS systems are more challenging to scale due to their complex infrastructure and higher costs (Bing Wang, 2013).

Overall, we choose RFID due to its ease of implementation, sufficient range, and low cost of devices. Moreover, it is effective at recognizing individuals and medications and efficient due to its capability of reading multiple tags at once (Abugaba et al, 2023). Another reason for using RFID is the willingness to implement RFID technology. Healthcare organizations are likely to adopt RFID as they have seen many use cases and their positive influence on healthcare organizations. Thus, we consider the barrier to implement a solution using RFID as relatively low.

Notwithstanding, like any technology, RFID systems present certain challenges. As highlighted by Abugabah et al. (2020), these challenges include high system implementation costs, operational complexity, lack of technical expertise, knowledge in utilizing RFID data, and security issues security concerns regarding patient and staff tracing and tracking if sensitive information is compromised. Therefore, when designing and implementing the RFID system, these limitations should be proactively addressed.

In the forthcoming sections, specifics will be provided on the customization of RFID components tailored for our solution's implementation and how the previous mentioned challenges could be tackled.

4.2.1 Passive and Active RFID

RFID systems include two main categories: active and passive. Active RFID tags are equipped with a battery that provides power to the microchip's circuitry and enables the transmission of a signal to an RFID reader. These tags are typically larger, have a more extended range, and can transmit data over tens of meters. They can hold more data and are more reliable in challenging environments with high levels of interference (Engels, 2002). In contrast, passive RFID tags operate without a separate external power source and instead derive power from the reader itself. These tags, relatively smaller and cheaper, have a shorter read range, usually within a few meters, which can be considered sufficient for many applications (Landt, 2005).

In a hospital setting, passive RFID systems hold advantages over active systems because they are significantly less expensive than active tags and can be disposable, which is particularly useful for patient wristbands and tagging single-use medical instruments, reducing the risk of cross-contamination (Bosch et al., 2015). The limited range of passive tags can be advantageous in a hospital environment as it reduces the likelihood of signal interference and unauthorized reading. This provides a more secure and precise location tracking within confined areas such as patient rooms and medication storage areas (Fisher & Monahan, 2008). Passive RFID systems are more durable and require less maintenance than active systems because there are no batteries to replace (Yao et al., 2012). The infrastructure required to support passive RFID is typically less complex and can be integrated into existing hospital information systems with relative ease. This integration capability allows for the potential automation of data entry into Electronic Health Records (EHRs), minimizing administrative workload and the possibility of human error (Bosch et al., 2015). Hence, we choose to implement a passive RFID system.

A little detail worth mentioning is that our solution will focus on the use of RFID wristbands for both patients and hospital staff. These wristbands are equipped with a smart tag composed of an RFID chip and antenna, functioning identically and serving exactly the same tracking purpose of an RFID tag. The key difference lies in their suitability for human wearability and comfort.

4.2.2 Implementation & Strategic Placement of RFID tags and readers

In addition to choosing between a passive and active system, we must consider how to place the readers and tags strategically to reduce the operational complexity. In 2004, the Washington Hospital Center in Washington D.C implemented RFID readers in hallways and in Emergency Rooms. The Washington Hospital Center used ultra-wide band tags to track medical devices in the hospital. Both the hospital staff and patients wore credit card sized RFID tags (Abugabah, Smadi, Houghton, 2023). Likewise, for our solution, hospital staff and patients should wear RFID wristbands to receive concrete data on the resources.

The interviews confirmed the common perception that medical staff have limited time and capacity to commit to administrative work. An interviewee explained that the administrative workload increased during the last 10 years, which is why healthcare professionals, particularly nurses, are not likely to cooperate if the RFID system requires significant additional work for them, at least with the current incentives for them. This is crucial to consider when placing the readers.

The interviewees also addressed the question concerning granularity. Having the time stamps for the scheduled activity might be sufficient, but one must also consider that other activities might be undertaken in the same room. For instance, nurses might provide a consultation in the consultation room, but they also might conduct a part of the physical exams in the same room. This is problematic because in the case of several activities happening in a certain room at a time, the information about how much time each specific activity took would be vague in that case. In that scenario, a scanning system at the entrance of the room would not suffice if we wanted to allocate the exact time spent for each activity. To solve this issue, the medical staff would have to scan their wristband whenever they dedicate themselves to a new activity so that it is tracked that an activity has ended and a new one is being done. However, this is time-consuming and not effective as medical staff might forget to do it.

According to the interviewees, an attribute that facilitates allocating certain activities to patients is the fact that certain activities are usually located and conducted in the same one or two rooms. The place where certain examinations take place is quite standardized. The same applies to scan machines which do not get moved and are only available in predetermined rooms.

Hence, we suggest placing the readers at the door so that the resources can be tracked immediately with no additional effort from the staff. Once the patient and medical staff enter the room, the time and the activity are tracked. To avoid multi-functional use of rooms, we consider it essential to discuss with the hospital management level how to implement distinct functions for certain rooms. As a patient could sit longer in the room while the MD has already left, both medical staff and patients wear the RFID wristbands at all times. Thereby, this enables us to track the exact duration of time spent of the MD or other medical staff on a given patient, making it more traceable which resource was used at what times.

Implementing the RFID System

To launch the project successfully, two interviewees mentioned that it is important to involve not only management, but the field people, meaning medical staff who have to work with the system on a daily basis, right from the beginning. While management must approve the implementation, partially also due to patient data privacy, medical staff must be willing to be part of the transition.

Abugabah et al (2020) additionally recommend combining Machine Learning techniques with RFID technology to use the huge amount of data to “provide a personalized diagnosis and care for patients depending upon their medical history, age, gender, drug vulnerability”. This is a crucial step to identify patterns so that different care pathways can be developed for different patient groups. For that matter, we have decided to use process mining as a tool, which we will discuss in detail later (section 6.5).

4.3 Data Collection

Categorizing patients by diseases is a fundamental practice in healthcare with profound implications. This process, which involves classifying individuals based on their specific medical conditions, is crucial for various reasons. It empowers healthcare institutions to allocate resources efficiently, tailoring services to meet the unique needs of different patient categories. Therefore, ensuring accurate diagnosis and personalized treatment and allowing for tailored healthcare plans to each patient's unique needs, thus fostering a patient-centered approach that enhances overall satisfaction engagement.

As a foundational element for optimizing healthcare workflows, patient categorization identifies common patterns within each category, streamlining processes and improving operational efficiency. Moreover, it facilitates a careful cost analysis, providing accurate insights into the financial implications of each patient group. This data would allow healthcare providers to assess their performance and identify areas for improvement. In terms of cost-effectiveness, tailoring treatment to a patient's specific needs can lead to the avoidance of unnecessary tests, treatments, and hospitalizations. This not only benefits individual patients but also reduces healthcare costs for both individuals and society. The categorization seems to be indispensable for strategic financial planning and cost-containment initiatives proven to be crucial for healthcare efficiency.

Genetic factors and family medical histories are critical components, acknowledging the influence of inherited traits on disease predisposition. A patient's medical history, encompassing past illnesses, surgeries, and treatments, contributes to a complete understanding of their health profile. Lifestyle factors, including diet, exercise, and exposure to environmental elements, add depth to the categorization process. Also, the process contributes to epidemiology and public health by providing insights into disease prevalence and patterns.

An interviewee mentioned that the patient data needed is very specific to the disease. In general, gathering data on age, gender, severity of disease is important. The MD from UZ Gent confirmed this information and added that they also observed that there is a difference between being a new patient or old patient regarding the duration of an activity, e.g. new patients require significantly more time for a consultation. Hence, this would also be important data to include. They proposed that apart from the generic data, they would collect the rest of the data depending on the specific diseases. The interviewee said that as a starting point, they would aim for more generic pathways. In their project, the data related to the patient came from the patient files, whereas the financial specific information came from the financial department of the hospital.

The process of classifying patients in an automated TDABC system for healthcare is fundamental, emphasizing the need for robust data gathering. Basic patient demographics, such as age, gender, and medical history, as well as clinical data—specific information about a patient's health, diagnosis, course of treatment, and results—must be gathered before any patient categorization can take place. All this data can be collected from the hospital software, with the patient's consent.

The bracelet will automatically collect activity data, this includes the time and resources allocated to each activity. The time data is essential for TDABC accurate cost calculations. There should be a cost matrix built within each healthcare institution, including direct and indirect costs associated with patient care, comprising labor costs, equipment costs, and overhead expenses.

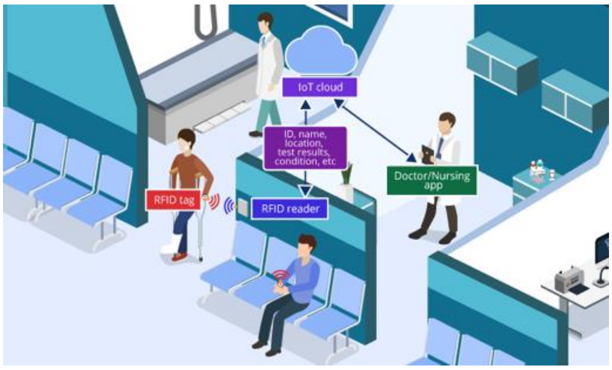

Figure 1: Smart Patient Tracking with RFID. Source by Shiklo, 2018.

As delineated in the preceding sections, the outcome of this process is the generation of an all-inclusive patient pathway. The costs can then be thoroughly examined, considering the views of individual patients as well as the different classification factors that were methodically gathered.

4.4 Process Mining

After having collected the data, we can create care pathways in an automated way through process mining. In the healthcare setting, many processes and procedures are available in theory. However, they are often not being followed in practice. We have previously mentioned that mapping pathways manually is very time-consuming and requires much commitment from medical staff that is difficult to obtain, given the high administrative workload that they are currently burdened with. In addition to collecting data in an effortless manner, analyzing the data to create meaningful care pathways in an automated way is a crucial part of our solution. By comparing all the individual pathways with each other, we can find information about the pathways and costs for a single treatment and detect outliers.

We have identified process mining to be a useful and widely used concept in the healthcare domain to discover and improve processes. In general, we differentiate between process discovery and conformance checking. The purpose of process discovery lies in obtaining insights to describe the process when there is no process model available yet. Hence, we create new leverage process discovery to create care pathways to receive information on the order of the activities throughout a treatment with the respective resources, time spent per resource, and costs. As the processes are still unknown to the hospitals, this provides insights to understand them. Conformance checking compares an existing model with a log or a new model, which is useful alongside process discovery once we have drafted a process model. We can derive knowledge from the model in what way the process of a healthcare organization deviates from the model (Leemans et al, 2014). We will leverage conformance checking at a later stage when we have derived a care pathway already and want to improve the model.

An advantage of process mining is that most healthcare organizations trace and store actions in log files as event data. As these event logs are readily available in the organization's system, process mining can be easily used to extract this knowledge (Edgar & Solanas, 2018). Agostinelli et al (2020) emphasize that the availability of system logs that can record the traces makes process mining the best solution to healthcare process discovery and diagnosis. Moreover, process mining is often used to explore variability in processes for clinical pathways, as it is easy to understand. This is particularly important considering that the target users are healthcare professionals who possess limited knowledge and time to understand what is going on in their processes.

In the following section, we discuss a framework which we will use for our approach to apply process mining. Then we deep-dive into the different steps of process mining which consist of cleaning the data and discovering processes by applying the Inductive Miner algorithm. We examine the *Inductive Miner - directly-follows framework* and the *projected conformance checking framework* and discuss the most common issues arising by implementing different algorithms. Finally, we explain how our solution enables the implementation of TDABC in hospitals.

4.4.1 Our Framework

The interviewee who is involved in several process mining projects proposed to use the open-source process mining framework PM4PY. It is developed by the Fraunhofer Institute for Applied Information Technology (FIT) and uses Python to apply process mining algorithms. Python has the advantage that it is accessible, has no license costs, has many resources available online, and is easy to develop.

After we have collected the data from the RFID readers and integrated them with the hospital’s health information system, they are recorded in the event log. We can extract information from it after importing, filtering, processing, and visualizing the data. By applying process mining techniques, we obtain a graph or diagram. To leverage our solution's potential, it should be designed in a way such that healthcare professionals can perform their analyses with little to no support.

4.4.2 Deep-Dive into Process mining

1. Data Collection

When a physician gives a patient a consultation or conducts a surgery, we capture these events with the RFID readers. As we explained before, we integrate the data collected from the RFID system with the patient data from the hospital's Electronic Health Record, which are recorded in the event log. Leemans, Fahland, and Van der Aalst (2014) define an event log as a collection of traces. Each trace is a sequence of events, whereas a sequence of events consists of the activities of a process executed in a specific order.

In the first step, we decide which kind of patients we want to create a pathway for and extract the data from the event log. We then retrieve the events related to the same process for a particular set of patients to develop a pathway (Noshad et al, 2022). As mentioned in section 6.2.2, the specific patient data which we require apart from demographic information depends on the disease for which we create the pathway. This step is important to create a clear and meaningful process model that entails only relevant data for a certain condition. Another crucial step is to pseudonymize the data to uphold data regulation standards (Litchfield et al, 2018).

2. Data Preparation

Once we have collected the event logs, we create a data table in a Comma Separated Value (CSV) format with information concerning ID, activities, and their corresponding time and further required data which we have determined to collect. Using PM4PY, we can use the built-in function to include the timestamps, "get_start_activities() and get_end_activities()" ("Getting Started — Pm4py 2.7.8.3 Documentation" n.d.).

A crucial step at this stage is to conduct data cleaning to ensure a high quality of the process model. In the following, we explain four important quality criteria for process mining algorithms and how guaranteeing high quality translates to the need for data cleaning (Leemans, Fahland, Van der Aalst, 2018).

3. Quality Criteria and Trade-offs

For both process discovery and conformance checking algorithms, soundness is an important quality criterion. A process model is sound if all process steps can be executed. Another quality criterion is fitness. A model fits a log perfectly if it can reproduce all traces in the log. The quality criterion precision expresses whether the model does not allow for too much behavior. Generalization means that the model will allow future behavior that is currently not present in the log (Leemans et al, 2013).

In healthcare settings, we deal with a large amount of data. The event log data of a highly variable process such as a patient's journey is of great magnitude and might lack structure. Furthermore, the processes are continuously exposed to changes due to new healthcare procedures, guidelines, or drug innovations, which increases the complexity when conducting processes (Edgar & Solanas, 2018). In addition, a patient's interaction with the organization might last for years, involving many different activities. These characteristics often lead to an unstructured model referred to as "spaghetti model."

This involves several challenges. These models are complex and consist of many nodes and interconnections. This makes it difficult to obtain any useful structure and information (Litchfield et al, 2018). Also, algorithms often fail if the event log is too large. Event logs can be large as they entail many events or many different activities, leading to complex processes (Leemans et al, 2018).

In practice, there is often a trade-off between strong quality guarantees such as soundness of the model and fitness when it comes to handling large logs. For process discovery, the problem occurs with larger and more complex logs, whereas conformance checking struggles handling medium and complex logs. The challenges concern having either too much information, meaning infrequency and noise, or having insufficient information, referred to as incompleteness. A model with too much noise includes too much additional behavior, making it imprecise and not generalizable as it “allows for too much additional behavior that is not described in the scribes (of) the behavior in the log and therefore might disallow future behavior absent in the log” (Leemans et al, 2014). The problem is that these process models are difficult to interpret, which is exactly what we want to prevent because we want to make it easy as possible for healthcare professionals to understand the processes.

4. Data Cleaning

Having identified the challenges to guarantee the different quality criteria, it is evident that data cleaning is an essential step. The interviewee who is an expert in process mining emphasized the need to filter the data to avoid a spaghetti model. For that purpose, we can use aggregation and clustering techniques. Thereby, we group repeated events by time interval and related activities into a more abstract event type.

To further reduce complexity, we filter the events whose activities are too precise (Edgar & Solanas, 2018). The classical approach is to filter the log before discovering a model to obtain an 80 % model. By applying the Pareto principle, also referred to as the 80-20 rule, to event logs, models explain 80 % of the observed behavior with a model that is only 20 % of the model required to describe all behavior. However, it is important to note that by implementing this approach, we exclude infrequent behavior (Leemans et al, 2014).

We have explained that applying a technique that entails all quality criteria is crucial to create insightful care pathways. In the next step, we introduce a suitable framework that ensures a robust and sound model.

4.4.3 Process Mining Algorithms and Frameworks

An important step in process mining involves choosing a suitable framework to mine the data. Leemans et al (2018) introduce the Inductive Miner—directly-follows framework (IMd framework) for process discovery and the Projected Conformance Checking framework (pcc framework) for conformance checking to overcome these challenges.

There are several process mining algorithms, but they are rarely applied to healthcare settings. Using these algorithms to develop processes in healthcare would change the result, which is why their ability to perform well in the mentioned quality criteria is difficult to predict. The Heuristics Miner is an algorithm that is frequently used as it can handle noisy and incomplete data. Likewise, Fuzzy Miner is a common algorithm as it can handle unstructured processes (Dallagass et al, 2022).

Leemans et al (2018) introduced the Inductive Miner as an algorithm which is capable of delivering a model with both perfect fitness and log precision. We focus on this algorithm as it performs better than the other algorithms and has been previously used in many healthcare settings.

The IMd Framework

The Inductive Miner – directly-follows framework can handle over 70 billion events while only needing 2 GiB of RAM, which makes it superior to other algorithms which require more memory.

The Inductive Miner algorithm works the following: First, it divides the activities in the log into disjoint sets. In a second step, the Inductive Miner splits the sets into sub logs. The sub logs are then mined recursively until they only contain a single activity, referred to as base case. By cutting the event logs into smaller sub logs, we create various cuts on the directly follows graph. A directly-follows graph "describes what activities follow one another directly, and with which activities a trace starts or ends. In a directly-follows graph, there is an edge from an activity a to an activity b if a is followed directly by b. The weight of an edge denotes how often that happened" (Leemans et al, 2018).

By combining the Inductive Miner with a directly follows graph, we receive a highly scalable algorithm which performs well compared to other algorithms in terms of completeness, noise, speed, and infrequent behavior (Leemans et al, 2018).

The Pcc Framework

The projected conformance checking framework (pcc framework) is a divide-and-conquer technique that compares logs to models and models to models. It is a commonly used approach, "in which the event log is split, and a model is constructed recursively" (Leemans et al, 2014).

Instead of comparing the complete behavior over all activities, the framework divides the model into subsets of activities. For each such subset, a recall, fitness, or precision measure is computed. The averages over these subsets provide the final measures, while the subsets with low values give information about the location in the model/log/system-model where deviations occur. This results into the generalization over many of these abstractions, so that many relations between the projected activities are captured. By projecting both system and system model-log onto subsets of activities, the framework measures the fitness of the model and its precision. When comparing an existing model with a log, the PCC framework "allows to measure fitness and precision of a model with respect to an event log, even in cases where classical techniques fail, and can give detailed insights into the location of deviations in both log and model."

When comparing an existing model with a new model, the PCC framework evaluates discovery techniques that scale well and provide new insights on the robustness of various algorithms. The framework can handle logs that previous measures could not handle, which is why it is most suitable to use it to improve process discovery processes and ultimately, our care pathways (Leemans et al, 2018).

4.4.4 Discover Process: Visualization

To increase the crucial aspect of understandability, different visualization techniques can help to provide medical staff with the needed insights. Common visualization tools that are easy to understand include Directly-Follows Graphs (DFGs), and Business Process modelling and Notation (BPMN) diagrams (Figure 3). To read the diagram, it is important to understand that events "are represented by nodes, paired events are identified by an edge, and edge labels show the probability of those two events occurring in that order. The nodes of the graph are time-ordered from earliest to latest (top to bottom) to create pathways from the beginning of a process to its end" (Leemans, Fahland & Van der Aalst, 2014).

The nodes, edges, and weights contribute to identifying the most common pathway (MCP) and allows us to examine an individual pathway's level of conformity compared to another (Noshad, Rose, Chen, 2022). Through the IMd framework, we obtain a DFG, which we can transform into a BPMN diagram. Our interviewee highlighted that both visualization tools are fit to draft care pathways which medical staff could understand. By obtaining the diagram or graph, we can extract the information on costs, resources, and detect flaws such as redundant steps, bottlenecks, and inefficiencies.

4.4.5 Challenges and Limitations of the Frameworks

We have applied the Inductive Miner—directly-follows framework and the conformance checking framework under the requirement that we remove noise before applying the algorithms. However, this approach generates process models that only cover a small part of the problem at hand. Such approaches might not be sufficient for many real-world healthcare applications because they only provide a partial view of the process and may hide valuable infrequent behavior. Hence, we should be aware of the variability issue when providing solutions, tools and frameworks to understand and deal with this variability. So-called workarounds provide insights into common inefficiencies and obstacles that healthcare professionals face in their daily work. These insights provide a basis for a thorough analysis, enabling healthcare organizations to improve their processes (Batista & Agusti, 2018). Finding a solution that goes beyond filtering out infrequent behavior from the event log to understanding why infrequent behavior is observed and what this could mean would provide us with valuable knowledge. Hence, we should be aware that our models can result in blind spots, causing us to miss important opportunities for process improvement.

Moreover, while the IMd framework generates sound models while providing high quality compared to other algorithms, as of right now, there is no algorithm that guarantees soundness while handling large and complex logs and contains infrequent behavior at the same time (Leemans et al, 2018).

4.4.6 Automated TDABC Implementation

We have explained how we gather data regarding the activities that hospital staff and patients undergo by implementing a passive RFID system in the hospital organization. By integrating these with the Health Information System of the hospital and merging it with the financial information, we obtain the essential information regarding costs, resources, and activities involved in a certain pathway. In a second step, we use process mining to order the activities from top to bottom. This will result into pathways which illustrate a process from the beginning to its end. For that, we introduced the pm4py framework which uses the Inductive Miner—directly-follows framework and the conformance checking framework.

We have considered at first both process mining and blockchain technology such as Ethereum or Hyperledger as there are many applications in the healthcare environment for both technologies. After extensive research and expert interviews, we concluded that there is no need for a decentralized system because the implementation of the solution will be centralized in a specific healthcare organization. Although we would solve security issues by having a Blockchain architecture, the efforts and required expertise for double-checking are not feasible. Most importantly, depending on the amount of data, the additional costs would be significantly high. Hence, we decided to solely rely on process mining to develop our solution.

By applying process mining, we obtain a comprehensive diagram that enable hospital professionals to understand their processes. At the same time, we receive an understanding of the entire care pathway and the costs to treat a patient over the entire care pathway.

Our expert interviewees have also emphasized that the involvement of physicians, nurses and other healthcare professionals from all relevant departments is essential, which is closely involved in all stages of the process mining effort: data collection, data analysis, data interpretation, the communication of its results and its translation to practical actions.

Moreover, it is recommended to validate the results at each stage with medical staff to validate our results and identify problems that might occur from wrongly interpreting the data, errors in recording the data which would indicate a need for further data cleaning or missing important behavior due to mining too little data (Litchfield et al, 2018).

As we have previously mentioned, our solution gives us the opportunity to detect inefficiencies and to eliminate steps in the pathway that are redundant and inefficient. Hence, we can optimize the care pathway, thus, improving not only costs but also outcomes.

5. Business Model

In the dynamic world of healthcare innovation, our solution emerges as an automated comprehensive end-to-end approach to more efficiently track patient costs within healthcare institutions. Having incorporated the VBHC and TDABC methodologies with the technologies of RFID and Process Mining, we have it named "WristFlow Navigator". This cohesive synergy of technologies aligns with our key activities and forms our competitive advantage. To position our solution in the market, a business model has been outlined, covering each of its constituents and setting their strategic relevance. It is set to reshape the operational work of healthcare institutions.

In its core, our proposition represents a comprehensive solution designed to optimize resource allocation and improve operational efficiency, being then specifically targeted at healthcare institutions and insurance companies. Positioned as pioneers in comprehensive innovation, our brand strategy focuses on data integration, cost-effectiveness, and tangible benefits for institutions. Through targeted marketing strategies, scoped on digital platforms and industry engagement, we aim to position ourselves as trusted partners in advancing healthcare technology. Emphasis is further given to the legal topics. Data security and patient privacy are extremely important. Following with the geographical regulatory environment is a topic that cannot be overlooked. To sustain our operations, diverse revenue streams were mapped, including setup fees, subscription models, volume-based pricing, customization charges, and data analytics consulting services. The diversified approach was thought to ensure sustainable growth while addressing the diverse needs of our market segments. On the costs side, the structure includes the technology infrastructure, software development, personnel salaries, marketing, administrative, regulatory compliance, risk mitigation, and flexibility needs. We aim to guarantee financial sustainability.

5.1 Value Proposition

In today's healthcare and innovation landscapes, our proposition is bold yet practical, a testament to transformative innovation set to redefine the landscape of patient cost tracking. At the heart of our mission lies a comprehensive solution designed to advance healthcare operations with a higher precision and efficiency.

Our mission revolves around redefining cost management in healthcare institutions by integrating TDABC principles, harmonized with the core values of VBHC. The solution revolves around the disposition of wristbands powered by RFID technology that meticulously track and record each patient's entire care trajectory. By capturing real-time data on the duration spent in each care activity, a level of precision and granularity is provided to cost analysis, a crucial aspect in optimizing resource allocation and operational efficiency.

The journey does not end with data collection; it begins there. Leveraging process mining techniques, we uncover reflective insights from that repository of patient-centric data. Through the incorporation of using RFID technologies and process mining, our approach was aimed to surpass the limits of traditional patient tracking systems and provide a more comprehensive evaluation of costs, resource utilization pattern. This data analysis forms the foundation for informed decision-making aimed at optimizing costs while enhancing the quality and effectiveness of care delivery.

We empower healthcare institutions with a dynamic toolkit to ultimately analyze, strategize, and execute. By delivering comprehensive, actionable insights, they are further equipped with transparency into financial plans, allowing for a more-informed pricing, negotiating of contracts, and allocating of budgets. We target health professionals, administrators, and decision-makers, offering them a sophisticated approach to cost management that enhances both agility to adapt, operational effectiveness and financial sustainability.

5.2 Target Segments

Our offering emerges as a pivotal solution aimed at systematically optimising the operational activities and associated costs within healthcare institutions, using the TDABC and VBHC frameworks. Specifically tailored to the complexities of the healthcare industry, our primary target segment are healthcare institutions seeking a sophisticated approach to cost management. These institutions stand to achieve unprecedented levels of efficiency and precision in their resource allocation, enhancing both operational effectiveness and financial sustainability.

Our solution facilitates a clear understanding and management of costs, allowing for more precise cost allocation to activities and processes as well as a better comprehension of resource consumption and cost drivers. This transparency proves to be crucial for healthcare institutions, as it fosters more informed discussions and strategic decision-making. Additionally, our product enables institutions to elaborate more realistic financial projections, facilitating appropriate pricing, negotiating contracts, and allocating budgets effectively.

The insights provided by our solution are essential for process improvement initiatives, empowering healthcare institutions to standardize and streamline workflows, ultimately reducing costs and elevating overall service quality. Regular analysis of costs encourages ongoing evaluation and adjustment of processes, ensuring that the institution remains adaptable and responsive to the evolving dynamics of the healthcare industry.

Furthermore, our solution extends its value proposition to include insurance companies operating within the healthcare ecosystem. Given that our product covers a comprehensive spectrum of costs associated with patient care, insurance companies stand to advantage with significant benefits from the transparency and granularity embedded in our automated TDABC-based solution. This includes not only direct medical expenditures but also indirect operational expenses, offering insurers a more accurate and thorough understanding of their exposure.

The approach on insurance companies is to provide access to the useful data that the product extracts, rather than selling the product itself. We offer a service that enables businesses to use and examine the insightful data produced by our automated TDABC-based solution in place of a typical product sale. This distinction demonstrates our commitment to providing strategic value and actionable intelligence through the application of our technology, in line with a data-centric model as opposed to a product-centric one.

In healthcare sector, insurance companies continue to place a high priority on cost control. This strategic focus results from a confluence of interrelated factors that together shape financial stability, competitiveness, and sustainability. The financial viability of insurance companies is closely related to efficient cost management. In a sector where healthcare costs are constantly rising, efficient management is critical to reducing financial stress and maintaining insurers' long-term viability. Strong cost control strategies give insurers a distinct advantage in a competitive market where they must navigate complexities to achieve cost-effectiveness.

Strategic cost management serves as a form of risk management, protecting insurers from financial vulnerabilities and improving overall resilience. Moreover, regulatory frameworks frequently require insurance providers to actively demonstrate efforts to reduce healthcare costs. As our product maps every process within healthcare institutions and associates it with a cost then insurers can provide comprehensive coverage at a justifiable price, emphasizing the perceived value of insurance plans in relation to incurred expenses.

Our product's distinct strength lies in its ability to handle the complexity of healthcare cost systems, providing an overarching view that extends beyond traditional cost management methodologies. This positions us as a strategic partner for both healthcare institutions and insurance companies, allowing for more informed decision-making, improved resource allocation, and more financial accountability. Through ongoing support, customization, and a keen understanding of the dynamic healthcare landscape, we aim to empower our clients with the tools they need to navigate the evolving challenges of the healthcare industry effectively.

5.3 Channels and Customer Relationships

Our business model is strategically aligned to deliver sustainable value, positioning healthcare institutions and insurance companies at the vanguard of a cost-conscious and patient-centric paradigm. The journey starts with the realization that the healthcare sector demands not only a thorough awareness of its specific challenges but also a tailored approach that speaks directly to the needs of healthcare institutions and insurance companies.

A comprehensive engagement plan must be established to reach and interact with our target customers. This plan should include a dedicated and skilled team with a profound understanding of the healthcare sector which would directly establish one-on-one relationships with decision-makers within healthcare institutions and insurance companies. Attendance and actively participate in prominent healthcare conferences and industry events should also be included in this plan. These venues provide invaluable opportunities to showcase your product, engage with industry leaders, and gain first-hand insights into the challenges faced by healthcare institutions and insurance companies. Additionally, we could demonstrate our expertise by publishing articles and case studies that address pertinent issues within the healthcare and insurance sectors, emphasizing how our product aligns with industry trends and provides innovative and effective healthcare cost management.

Offering tailored educational workshops and training programs for healthcare professionals and insurance company staff about how the product works by providing detailed insights into the functionalities and how our partners can benefit from using it, could also be an interesting measure to engage and attract our target customers. These sessions should be interactive, addressing specific concerns and showcasing the practical application of your solution in real-world scenarios. Collaborate on initiatives that contribute to industry advancement, solidifying your position as a key player committed to the betterment of the sector.

Establish a routine communication channel and implement mechanisms, allowing for continuous feedback, through newsletters and regular updates. Share industry insights, product enhancements, and success stories with personalized customer reports and insights. Maintaining an open line of communication to keep healthcare institutions and insurance companies informed about the ongoing benefits and developments related to our solution and to understand their experiences with our solution and help us to identify areas for improvement.

The success of WristFlow Navigator depends on cultivating a close relationship with our target customers. This calls for extensive interaction with both the administrative group and the employees who work directly with healthcare facilities on a daily basis. We make sure that frontline employees' needs, challenges, and perspectives are fully understood by involving them, as they will be directly interacting with our solution.

Our strategy places a strong emphasis on open communication about the observable advantages that our solution offers to their day-to-day operations. It's critical to explain how our product offers insightful data that enables employees to be more productive in their jobs. These insights have the potential to improve decision-making procedures, expedite workflows, and increase overall operational effectiveness. Our goal is to instil a sense of ownership and enthusiasm in the staff by showcasing the positive effects of our solution on their daily tasks. This will facilitate the solution's successful adoption and integration into their workflows.

The secret to successfully managing the healthcare and insurance professional environment is to take an exhaustive and flexible approach that combines industry knowledge, individualised engagement, and a dedication to meeting the specific needs of our target customers.

5.4 Key Activities

At the heart of our proposed solution lies a crated framework mentioning the key activities. These activities form the pillar of our approach towards improving patient cost tracking accuracy and operational efficiency within healthcare institutions and will be followingly presented. Details on how they will strategically and operationally deliver value to our identified costumers will additionally be outlined. The framework will not only entail technological implementation, but also staff readiness. We present the crucial activities involved in hardware installation, software application, and preparing all crucial staff through specialized workshops.

1. Patient Journey Mapping: Our initiative begins with an in-depth examination of patient journey. Through detailed mapping, we aim to chart every point within the healthcare system—initiating from admission, progressing through treatment, to eventual discharge. The ultimate purpose is to identify the incurred costs, possible inefficiencies and streamlining patient flows. Such process will be possible through the use of the mentioned RFID bracelets/ wristbands.

2. Staff Preparation Workshops and Training Sessions: Recognizing the dangerous potential resistance that healthcare staff may have towards the requirements of our proposed solution, it is fundamental to proactively prepare, educate, and empower these professionals. Without them on board, no insights will be collected. To achieve this, our strategy is to have specialized workshops and training sessions designed to equip the healthcare force with a comprehensive understanding and proficient utilization of the implemented systems. The primary goal of such initiatives is to cultivate a skilled workforce capable of leveraging these technological advancements while fostering a culture of continuous improvement.

3. RFID Integration and Infrastructure Setup: Deploying RFID technology is central to our strategy. For that, a designated team will orchestrate the deployment of RFID hardware components, taking care of the installation and configuration of RFID wristbands, readers, gateways and supporting infrastructure across designated areas within the healthcare facility. (Its strategic disposition was previously mentioned in *chapter 6.2.2*). Each installation process will undergo quality checks to ensure a complete coverage, connectivity, and functionality.

4. Software Application and Integration (data harmonization through process mining): Following the hardware setup, a team of the corresponded experts will then focus on application and integration of software systems. Such process involves coordinating disparate data streams, transforming them into coherent, structured insights, conducted in accordance with industry´s legal guidelines. Ensuring robustness and compatibility across existing systems is crucial to then extract actionable conclusions, facilitating informed decision-making and process optimization.

5. Workflow Optimization and Operational Refinement: Considering the data insights, a team of professionals will elaborate workflow optimizations. This phase will be more concentrated on identified costs tracking, fine-tuning operational processes, optimizing resource allocation, and synchronizing workflows. The intended outcome is to provide an operational blueprint that enhances efficiency and reduces obstructions.

6. Ongoing Support and Consultation: Our services will be extended beyond the initial implementation, with the provision of continuous support and consultation. Regular performance assessments will be conducted to ensure system effectiveness and operational efficiency on the business as usual activities. Simultaneously, ongoing assistance will be provided to guarantee that staff has access to support resources and guidance to navigate any operational challenges that may arise. These ongoing evaluations and consultative approach steer our strategy towards a smooth transition and effective utilization of the implemented systems.

5.5 Revenue Stream

In the ever-evolving landscape and ultra-competitive of healthcare technology, sustainable revenue streams are vital components that reinforce the success and viability of innovative solutions. Focused on the integration of RFID-based patient tracking and process mining, this section delineates a strategic roadmap for revenue generation tuned to the TDABC and VBHC frameworks. Our analysis navigates through a range of models, namely tiered subscriptions, volume-based pricing structures, customization fees, training packages, data analytics services, and strategic partnerships. Each stream serves a different purpose and is strategically considered to address distinct customer segments. Thus, it is our opinion that taking usage of a combination of these streams might be more effective to ensure a diverse income flow and cater to different market segments, while ensuring scalability, value delivery, and sustainable growth in an era driven by digital transformation.

The considered revenue streams are: Start by charging for a one-time sale of the initial setup, hardware installations, and software licensing. The pricing will be defined by the scope of the hardware installation (how many wristbands, readers, gateways, and other components) all of these will depend on the institutions quantity plan and of course the size it entails), and on the software modules purchased. By doing so, there will be an immediate revenue influx from the implementation phase, covering initial costs.

Simultaneously, we would follow the tiered subscription-based models' strategy. We intend to sell subscription plans for ongoing support, maintenance, and updates of the implemented systems, based on the scale and needs of healthcare institutions, and offering service levels or functionalities offered. The payments would be on a monthly, quarterly or annual basis. This strategy is predicted to bring recurring revenues, ensuring continuous customer support and system enhancements. It would also be a way to guaranty scalable pricing that accommodates institutions of different sizes, while ensuring value alignment with their requirements. That is, a way of ensuring scalability without compromising value.

Additionally, we believe in a differential pricing approach, charging prices based on project sizes to leverage cost reduction advantages for larger-scale implementations. This principle guides our adoption of a volume-based pricing strategy, meaning that scaled pricing or discounts will be proposed to larger healthcare facilities based on their usage or facility size. Ideally, such strategic thinking will encourage a broader adoption among larger institutions, while fostering widespread implementation of our solutions through enticing and scalable pricing models.

Our intention is also to offer customers the opportunity for tailored solutions beyond the offered standard proposal. For that they will be charged customization fees. Such approach will allow us to provide specialized customization or integration services that go beyond standard offerings and that cater to diverse institutional requirements. By embracing this flexible approach to address specific customer needs, we ensure a more precise alignment of our solutions to meet the unique requirements of each institution. This initiative not only enhances customer satisfaction and fosters stronger partnerships but also brings in additional revenue, creating a mutually beneficial arrangement for both parties. Complementally, advanced data analytics services that transcend standard the system functionalities will be provided. These encompass in-depth data analysis reports or tailored analytics solutions, charged for a fee.

It goes without saying that integrating our proposal technological solution is inherently complex. In the post-implementation phase, during the “business as usual” routine operations, it is expected that various inquiries and complexities will emerge, requiring our deemed attention and support. For that, specific consultation and training/ support packages will also be part of our services’ portfolio. These premium packages include specialized on-site consultation, workshops, and staff instruction sessions, offered for a fee. Following the same line as before, such strategy aims to not only boost our revenue, but also to guarantee continual support, elevating customer satisfaction through sustained assistance. Implementing a licensing model serves as an additional revenue stream, offering licensing options for specific features, advanced modules, or supplementary functionalities at a cost. Although coming up with some challenges such as imitation concerns and heightened exposure of Intellectual Property, such strategy presents a significant opportunity for generating passive income and exploiting new market chances.

5.6 Cost Structure

Knowing how revenues will be generated comes as crucial to any business, and so does the cost structure. This section details a breakdown of the anticipated expenses across various categories, examining both direct and indirect costs. From hardware and software investments to personnel salaries, training, and compliance considerations, this section details the financial aspects for the successful implementation and sustenance of our innovative solution.

5.6.1 Direct Costs

Comprising our business proposal, one would notably think of the hardware and software expenses in order to make in properly running. And so, for the technology infrastructure, costs involving the procurement and maintenance of RFID components – such the wristband bracelets, readers, gateways, and requisite software systems – must to be accounted for.

The use of RFID wristbands has become widespread, serving a range of purposes such events accessories, payment methods, tracking devices). As a result, their costs are typically not exorbitant, ranging approximately between cents to €10 per unit. This pricing fluctuates based on several factors such as functionality, quality, and specific vendor offering. Also varying based on bulk purchase discounts, customization options, and additional features like durability, waterproofing, or specific integrations required for given applications. Specifically tailored for the healthcare sector, *Zebra Technologies* stands out as a strong supplier of RFID wristbands. Alongside, companies like *Impinj*, *Alien Technology*, *Smartrac*, *Avery Dennison* and *GlobeRanger* have also gathered recognition for providing similar products designed for a multitude of industries. Concerning, RFID readers costs' surround the zone of $200 to $2000, depending on the features in the device. Server infrastructure costs may vary widely based on scalability needs but estimated between $5,000 to $20,000 or more for initial setup. It is crucial to invest in scalable, cloud-based infrastructure to handle increased data loads and user demands.

Needless to say, that all costs related to software development should not go unnoticed. Such costs vary significantly based on the complexity of the system, the level of customization required, the number of features, the technology stack used, the development team's expertise, and ongoing maintenance needs. Initially, the costs involve the creation of the core system, emphasizing database architecture, user interface, and basic functionalities that facilitate RFID data management and patient movement tracking. Furthermore, customizing the software to integrate with existing hospital systems and creating analytics reports as per client demands constitutes another significant expense. Ongoing costs include continuous software improvements, updates, bug fixes, and provision of technical support, ensuring optimal system performance and user assistance. While the actual figures vary based on project intricacies, industry estimates suggest software development costs can range from tens of thousands to hundreds of thousands of dollars.

Hand-in-hand with the core expenses just mentioned, lie the vital personnel costs. This encompasses all salaries and wages allocated to the diverse range of professionals engaged in the development, implementation, consultation, training, and ongoing support for our solution.

These include experts in TDABC and VVBHC, specialists proficient in RFID technology and process mining, project managers, software developers, data analysts, cloud architects, marketers, and more. Notably, the scarcity of professionals specializing in TDABC, VHC, RFID, or process mining means considerable investments in salaries to attract and retain talent possessing such expertise. It goes without saying that salaries will vary according to the role of player and the contributive part the person has to the final solution.

In terms of capital expenditure (CAPEX) planning, one could predispose the allocation of funds for technology upgrades in order to ensure perpetual enhancements, thereby aiming at making our solution's competitive and in alignment with industry benchmarks. Concurrently, budgetary resources should be dedicated to ongoing research and development (R&D) initiatives to proactively tackle emerging challenges while seizing novel opportunities in the healthcare technology landscape. In the dynamic world of technology, rapid change is a constant. Failing to invest in continuous innovation risks could mean missing out on crucial breaks.

5.6.2 Indirect Costs

Complementary, expected spending in Marketing and Sales comes as fundamental. The aim is not solely focused on attracting new clientele but also solidify our position as a frontrunner in delivering innovative comprehensive solutions in the healthcare landscape. A way of ensuring successful market penetration and a sustainable growth. (More details on our marketing and brand strategy are explained in *chapter 7.10*).

Administrative costs are also anticipated. These encompass various essential aspects, including administrative staffing, office infrastructure, insurance, utilities and general operational expenses necessary to sustain day-to-day functions.

Regulatory compliance matters are also anticipated on our costs' structure framework. Given the sensitive and highly regulated nature of healthcare data and patient information, adherence to stringent regulatory standards such as HIPAA and GDPR is fundamental (extensive details provided on *chapter 7.11*). Investing towards comprehensive regulatory compliance, not only mitigates legal risks but also upholds the trust and confidence of healthcare institutions in our solution's capability to handle patient data ethically and securely.

Irrevocably, envisaging costs regarding risk mitigation and flexibility is indispensable to fortify our operational resilience. Having incorporated contingency plans strategies serve as a shield against unforeseen challenges or financial risks that may arise during our solution deployment. It is of clear importance to be prepared to navigate any operational disruptions and ensuring uninterrupted service delivery and maintaining the trust of healthcare stakeholders. Furthermore, retaining flexibility in budgeting stands as a cornerstone, allowing agile adaptation to fluctuating market dynamics and unexpected expenses.

As an additional costs overview, one can consider the difference between fixed and variable costs. In our solution's business framework, Fixed expenses encompass administrative costs, software development, and infrastructure maintenance. Conversely, variable costs entail consultation/training fees, project-specific personnel expenses, and marketing expenditures.

5.7 Key Resources

The success of any innovative solution is intricately tied to the robustness and effectiveness of its foundational resources. Being our proposed solution comprehensively focused on using RFID technologies and process mining to do a better cost allocation according to the TDABC principles in a VBHC landscape, there is an array of resources required that smoothly work together. The following section delves into a comprehensive exploration of those key resources that underpin our proposed solution.

Firstly, one would have to highlight the expertise on the methodologies of TDABC and VBHC. The first stand as a foundation to our cost optimization strategy, enabling meticulous cost allocation and monitoring across various healthcare activities. This approach will enable to assess resource utilization, identify inefficiencies, and streamline processes more precisely. At the same time, the focus on VBHC principles guides the strategic alignment of our solution with value-driven care models, prioritizing patient outcomes and care quality.

Followingly, at the core of our solution lies RFID technology, comprising RFID wristbands, readers, and associated infrastructure. Beyond its primary function in patient identification and tracking within healthcare facilities, our expertise extends to leveraging this technology to integrate TDABC methodologies. This innovative approach allows for a more precise cost allocation and monitoring of activities, contributing to optimized resource utilization and cost efficiency. Complementary, we will take upon the utilization of process mining software to comprehensively analyze and optimize healthcare workflows. By applying TDABC principles into process mining, data insights will be holistically extracted from operational data. Overall, this integration empowers healthcare institutions to streamline processes, identify cost drivers, and prioritize value-adding activities within patient care pathways.

To develop this comprehensive approach, we rely on skilled professionals that excel in different areas, such RFID technology, process mining software, data analytics, software development, cloud architecture, healthcare operations, and the dominate the nuances of TDABC and VBHC methodologies. Ultimately, the synergy among these resources amplifies value delivery within the healthcare ecosystem. Their collective roles and complementary activities align with our key activities (outlined in *chapter 7.4*). While these resources represent innovative developments, their standalone contributions do not singularly drive healthcare advancement. It is the comprehensive nature of our solution that truly sets us apart, working as the pillar serving as of our competitive advantage.

6. Discussion

How our solution creates value to Organizations

Our proposed solution, designed to streamline Time-Driven Activity-Based Costing (TDABC) in healthcare settings, represents a significant step forward in enabling healthcare organizations to implement TDABC effectively. The core components of our proposal synergize to create a semi-automated TDABC process that can be implemented in a hospital setting and have a positive impact on the overall value delivered to patients. In fact, each technology or feature that we propose in our solution contributes to creating value to healthcare organizations.

Central to our idea is the strategic use of RFID technology. This technology plays a critical role in automating the tracking of activities and resource utilization, significantly reducing the likelihood of manual data entry errors and the associated administrative workload. The precision of RFID technology in tracking patient movements and activities within healthcare facilities is extremely valuable and it provides accurate data essential for the allocation of costs in TDABC, ensuring that every aspect of patient care is accounted for. Additionally, RFID allows for the above advantages without increasing the workload of Medical Doctors and staff, thus facilitating the overall process of acceptance and implementation.

Complementing RFID technology in our solution is the adoption of process mining techniques. Combining TDABC with process mining considerably reduces the time and resources required to map the activities that patients undergo in a hospital. We utilize the open-source process mining framework PM4PY that uses Python to apply process mining algorithms. For our solution, we apply the currently best performing algorithm for discovering processes which is the Inductive Miner algorithm. We use the Inductive Miner - directly-follows framework to enhance the understandability and generalization of the pathway. By developing an in-house solution, we mitigate costs and trust issues that healthcare organizations might otherwise have.

Furthermore, we have the flexibility to constantly review and adapt our techniques to the state-of-art.

Process mining techniques are instrumental in converting complex patient data into clear, actionable insights. Therefore, they enable not only a fast and detailed mapping of clinical processes, but also allow doctors to identify and flag inefficiencies, pinpointing areas that necessitate improvements, and redesigning processes that are non-functional to the specific medical condition treated. By visualizing the entire patient care pathway, healthcare organizations can also gain a deeper understanding of resource allocation and patient flows. This is crucial for the effective implementation of TDABC, as it allows for a more nuanced approach to healthcare cost management, aligning closely with patient needs and care patterns.

Furthermore, the integration of our solution with Hospital Information Systems (HIS) is another cornerstone of our approach. This integration ensures a smooth and seamless transition of data, maintaining the integrity and accuracy of information crucial for effective cost tracking and resource allocation within the TDABC framework. Additionally, aligning our solution with the Fast Healthcare Interoperability Resources (FHIR) emerges as a paradigm-shifting framework that overcomes the drawbacks of conventional interoperability standards in healthcare data exchange. It guarantees integration with modern technologies with ease and simplicity. Because of its extensibility, FHIR can be tailored to changing healthcare needs, resulting in a more intuitive understanding of data. FHIR is an essential part of TDABC solution because it makes real-time information flow standardized and interoperable, which is necessary for precise cost calculations and well-informed decision-making in the ever-changing healthcare environment. Moreover, its standards set forth by the European Union adds another layer of feasibility, scalability, and sensitivity to privacy concerns. This compliance ensures that our solution is not only technically sound, but also adheres to the strict regulatory requirements of healthcare data management.

Challenges and Limitations of our solution

While we believe that our solution has enormous potential, we are also faced with several challenges and limitations in implementing it in a real-world context. Being a highly innovative and transformative solution, its successful implementation in healthcare organizations requires a mindset shift and committed professionals who are invested in ensuring the success of the solution. Ultimately, we need to target management level and field staff who will directly work with our solution on a daily basis. To ensure a smooth transition, our solution needs to be supported by a strong onboarding and training process that facilitates buy-in across all stakeholders.

We identified the optimal technology solutions to automate TDABC, which are RFID and process mining. However, there are several trade-offs between simplicity and precision for RFID, where we needed to make a decision to fulfill our priorities. Likewise, for process mining, the algorithms are not optimal and include risks such as creating blind spots through too much filtering. Furthermore, in order to capture the value created by our solution, the creation of entry barriers is key to ensure that other parties may not easily replicate our solution and business model. Finally, as several initial investments are required to initiate the transition to semi-automated TDABC, it is important to ensure that these investments are feasible for the hospitals interested in our solution, and that our business model is properly structured to make the initial set-up costs as low as possible for organizations. In the below sections, we address in depth the major challenges and limitations of our solution from multiple perspectives.

Stakeholders' Buy-In

In the specific case of our proposal, the success of our solution strongly depends on the willingness of medical professionals and management team to embrace change. A shift in mindset towards patient care and administrative processes is crucial for the effective implementation of our solution. Without broad-based acceptance and commitment, the feasibility of real-world implementation is significantly diminished, as well as the potential benefits of our solution. Moreover, to obtain financial data from a particular healthcare organization, we need the trust and commitment from the medical staff to provide us with the necessary information. They need to be invested in implementing our solution so that they share their sensitive data with us and their time and resources. For these reasons, our proposal poses a great emphasis on the need to support the transition to TDABC with intense personnel training and formation, involving MDs, nurses, managers and IT and HR personnel.

RFID

There are different levels of granularity that we can pursue regarding how detailed we want to record the data. In our solution, we capture the data of the overall activity and ignore the single actions of the medical staff that are involved. For instance, when a patient has a consultation with a medical doctor for 50 minutes, our RFID system will track the activity "consultation" and the resource medical doctor for 50 minutes. However, if the medical doctor has given the patient a vaccine during the consultation in the same room, we will not record this to make our solution simpler. This has the disadvantage that there might be important information that we will forego which could help optimize the pathway. Ultimately, we are trading-off precision with simplicity. We mitigate the issue by implementing a planning schedule with the management team and medical staff that ensures that a certain kind of activity is conducted in a certain room. Thus, by allocating activities to a set of rooms and limiting the amount of activity that can happen in each room, we have more accurate information on the activities in a certain room. In general, it is noteworthy to mention that our focus is to implement TDABC by creating pathways. By being too detailed, we might lose focus on the ultimate goal – to record the resources and times spent per resource; hence, having an overall picture of the activity would also suffice for our solution.

Process mining

Algorithms are constantly evolving. In the current state-of-art, there is no process mining algorithm that performs well on all four quality criteria, namely soundness, generality, precision, and fitness. In our solution, we apply the Inductive Miner—directly-follows framework and the conformance checking framework to discover and improve pathways. We evaluated them to be the best performing algorithms compared to other common algorithms measured on all four criteria overall. Nonetheless, by filtering to ensure sound and simple process mining models, we might not reflect the entire real-world pathway. We remove outliers in the process and do not reveal infrequent behavior. An issue could arise when these infrequent behaviors contain valuable information, for instance information on inefficiencies and obstacles that medical staff face in their day-to-day work. By filtering out infrequent behavior from the event log, we could forego valuable knowledge and the opportunity to obtain a holistic view of the process.

We are limited by the technological advancement as there is no process mining algorithm which captures the variability while having the ability to develop meaningful pathways that healthcare professionals can understand and utilize. Thus, we will constantly improve our solution as there are new and better option for process mining algorithms available with time.

Patent and Replicability Protection

Our innovative use of RFID technology in healthcare cost management is not easily patentable, making it vulnerable to replication by second-mover parties with more resources. To mitigate this risk, transforming RFID wristbands into certified medical devices could be a strategy, albeit increasing costs and legal complexities. However, our know-how and specialized expertise is not easy to imitate. Hence, other parties might be able to replicate certain parts of our solution, but offering a holistic end-to-end solution that enables the implementation of TDABC such as ours would be difficult.

Initial Investment Required

The implementation of our solution requires significant upfront investment from healthcare organizations. This includes the procurement of RFID tags in large quantities, mining large data logs, comprehensive staff training, and potential expansions or enhancements in IT infrastructure and personnel. These initial costs may pose a barrier for some institutions, particularly small institutions with limited financial resources. Accounting to the fact that healthcare organizations would not have the knowledge of how much their cost structure would decrease by implementing TDABC, we can expect a certain hesitation from the healthcare organizations to make such a huge financial investment.

We can provide some exemplary calculations how much they could potentially save from other organizations who have introduced TDABC in their organization to decrease doubts. Furthermore, discussing on the government level to fund projects that aim to implement TDABC to improve value for patients could solve this challenge.

7. Conclusion

In this work project, we addressed the flaws in the current costing systems and discussed the need for a new costing system. Current costing systems fail to capture the true cost of patient care as they lack cost tracking mechanisms as well as accurate and granular cost data.

As an integral part of the transformative Value-Based Health Care concept, we introduced Time-Driven Activity-Based-Costing which enables organizations to track resources and costs for a specific treatment. TDABC observes all activities in the entire healthcare process or care pathway and measures all the resources and the time spent of each resource that was devoted to each activity. This allows a precise assessment of resource utilization. Moreover, by examining every step of the care pathway, we can observe bottlenecks and obtain relevant information to improve the processes.

Having outlined the significant contribution of TDABC to enhance patient care quality, we proposed an end-to-end solution for implementing semi-automated TDABC in healthcare settings which represents a ground-breaking approach to healthcare cost management. Our interviewees emphasized the need for an automated solution as medical staff would otherwise be reluctant to commit to implement the solution. As they are burdened with a high administrative workload, finding a solution that demands as little time from medical staff as possible generates a higher commitment and success rate. Another benefit that automation delivers is the consistency and accuracy of the data that we gather which is possible through RFID technology.

We explained that RFID technology is superior to other common technologies to track assets such as equipment, medications, and people in terms of ease of adaption and high integration capability, low cost of devices, and efficiency. To increase accuracy, we suggested both hospital staff and patients to wear RFID wristbands. We also described that we would place the readers at the door of each room and allocate a certain function for each room. This enables us to know which activity was done based on the room. We highlighted the importance of determining which patient data to collect as it varies depending on the disease. Basic patient demographics as well as clinical data are essential, which can be collected from the hospital software. We also discussed interoperability standards when exchanging data between the different eHealth systems and introduced the FHIR framework. Together with the activity data that we collect automatically with the RFID wristbands and the financial data, we gathered the necessary data to visualize the care pathway with the respective activities and costs.

We discussed the benefits of process mining to discover processes and to visualize care pathways in a way which medical staff can comprehend easily. We use the process mining framework PM4PY which uses Python to apply process mining algorithms. We discussed the four crucial quality criteria soundness, fitness, precision, and generalization for process mining algorithms and the challenges of generating an unstructured model known as the spaghetti model due to the variability and magnitude of healthcare data. To counteract this issue, an interviewee emphasized the importance of filtering, aggregation, and clustering techniques to minimize the complexity. We explained why the Inductive-Miner – directly-follows framework is best to discover a process, evaluated based on its performance on the four quality criteria. To compare processes, we introduced conformance checking, for which the Projected conformance checking framework is the best alternative as it can handle large logs while performing well on the quality criteria.

By leveraging RFID technology, process mining, and seamless HIS integration, we offer a comprehensive, efficient, and precise method for tracking and analyzing healthcare service delivery and resource utilization. Our approach not only simplifies the complexities associated with TDABC but also aligns with the evolving needs of Value-Based Health Care models. We proposed a business model while identifying a competitive advantage due to the uniqueness and complexity of our solution that requires a distinct set of expertise and know-how. By targeting hospitals and insurance companies, we enable them to obtain more transparency and informed decision-making regarding costs, pricing, negotiating contracts, and budget allocation. We introduced an engagement plan to reach our target customers which includes educational workshops and training programs for medical staff and insurance company employees. Furthermore, we ensured that our solution is compliant with GDPR and HIPAA.

Given the complex setting and multiple layers of our solution, we acknowledge the challenges, including the need for stakeholder buy-in, replicability protection, and significant initial investments. Nonetheless, the value and significance of our solution in enabling healthcare organizations to optimize their cost management and improve patient outcomes cannot be overstated. We will ensure that we update our technology and leverage the technology advancements of RFID and process mining to always incorporate the state-of-art. For RFID, we aim to further reduce the currently required involvement of medical staff to collect data. Concerning process mining technology, we will continuously update the algorithms based on the emergence of new and better performing process mining algorithms. By addressing the current limitations and continuously refining our approach, we are confident that our solution will play a pivotal role in shaping the future of healthcare cost management and patient care delivery.

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9. Appendix

Glossary

VBHC – Value-Based Healthcare

TDABC – Time-Driven Activity-Based-Costing

IPU – Integrated Practice Unit

RFID – Radio-Frequency Identification

NFC - Near-Field Communication

BLE - Bluetooth Low Energy

RTLS - Real-Time Location Systems

MD – Medical Doctor

UZ Gent – University Hospital of Gent

EHRs - Electronic Health Records

PM4PY – Process mining Framework by the Fraunhofer Institut

ImD framework – Inductive Miner direct-follows framework

PCC framework - Projected Conformance Checking framework

Table 1: Interviews

	Full Name	Working Country	Organization	Profession	Expertise
1	Niels Hilhorst	Belgium	University Hospital of Gent	MD	Implemented TDABC for the condition of psoriasis
2	Erin Roman	Belgium	University Hospital of Gent	PhD/ researcher	Developed process maps and implemented TDABC in two disease domains, breast cancer and psoriasis
3	Joke Borzée	Belgium	University Hospital of Gent	phD/ researcher	Implemented TDABC manually in several hospitals in the conditions of lung cancer, psoriasis, and hip surgery
4	Anton Hasselgren	Norway	Accenture	Blockchain Specialist	Expertise in blockchain technology in healthcare
5	Eduardo Alves Portela Santos	Brazil	Federal University of Paraná	Professor	Process mining

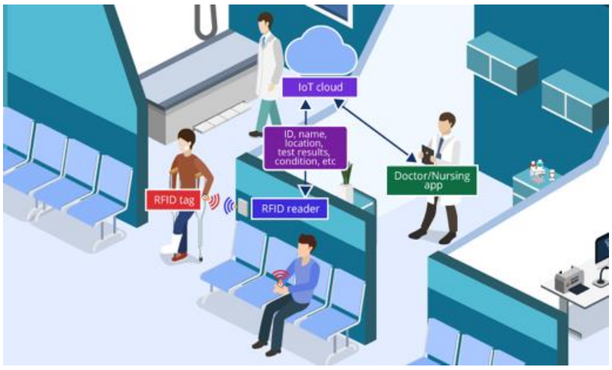

Figure 1: Smart Patient Tracking with RFID. Source by Shiklo, 2018.

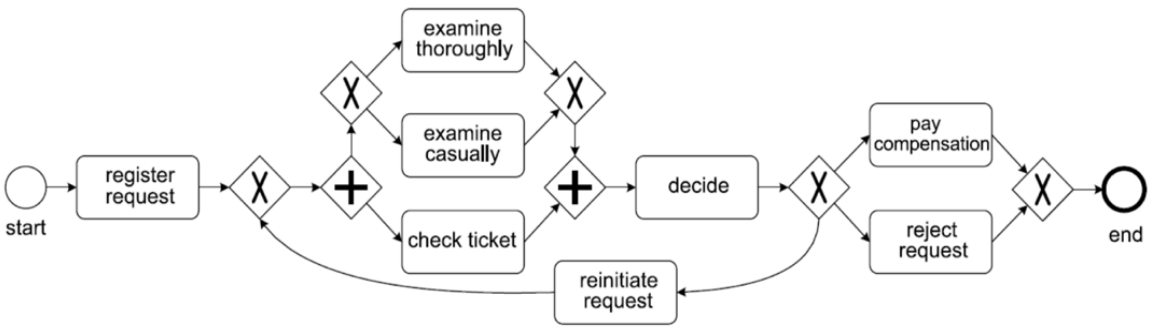

Figure 2: BPMN diagram. Source by Fraunhofer Institute for Applied Information Technology, 2023.