Process Mining applied to Emergency Room: an organizational and change management perspective

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Abstract. Struggling with the need to comply with strict budget constraints and the mission of delivering high-quality care services to their patients, healthcare organizations are increasingly interested in finding innovative solutions to tackle process pains and improve performance management. Among those, Process Mining plays an increasingly important role, as it constitutes a powerful tool to leverage the digital transformation as a driver for service and process redesign, putting the concept of patient care at the center.

This paper describes how Italian consulting firm Partners4Innovation helped a major public hospital located in northern Italy, Azienda Ospedaliero-Universitaria of Ferrara, introducing Process Mining as part of the practices to manage its strategic and day-to-day operations, leveraging what has already been done several times in this field. The distinctiveness of the approach presented lies above all in having understood that the introduction of Process Mining requires a radical evolution of the organizational culture and skillset, which if not properly addressed threatens not only the return on investment in the medium term but also the organization's ability to root the data-driven approach to process management required by the current and future competitive landscape.

Keywords: Business Process Management, Process Mining, Change Management, Healthcare Innovation, Emergency Room.

1 Introduction

1.1 The context

This paper describes how Italian consulting firm Partners4Innovation helped a major public hospital located in northern Italy, Azienda Ospedaliero-Universitaria of Ferrara (AOUFE), introducing innovative Business Process Management techniques as part of the practices to manage its strategic and day-to-day operations.

Like any other institution operating in the healthcare industry, AOUFE was dealing with the structural problems that have characterized the Italian healthcare sector over the years:

- Significant differences between regions in services supply, especially in prevention and assistance services
- Little integration between social, local, and hospital services
- Significantly high waiting times to access specific medical services

The described scenario made therefore essential, and very risky to further defer, to leverage the digital transformation as a driver for service and process redesign, putting the concept of patient experience at the center.
While one can argue that such challenge is faced by companies operating in every industry, for hospitals and other healthcare institutions, especially those operating in the public sector, this is particularly critical, as they often suffer from historical difficulty in developing process and data skills among the top and middle management and the impossibility to leverage capital markets.
Moreover, healthcare institutions typically struggle in making their organization model evolve to introduce an Operations Department. In many cases the performance management systems in place are merely formal and do not help the management to have an effective impact on the organization, its processes, and its services: the logic with which they are built is often more of fulfillment than of substance. This, in turn, is strictly related to the heavily siloed structure of these organizations, in which the various departments often act as independent organizational units, therefore making it very hard to develop a performance management system that allows these organizations to connect clearly and measurably their strategic goals with the improvement objectives of their components (processes, services, infrastructure, people, data, culture, ...).
On top of that, driven by their seamless experiences with the big brands of the digital world, patients are becoming increasingly sensitive to the overall care experience within the hospital, where factors such as quickness and simplicity play a crucial role.
Finally, hospitals face the challenge of coordinating the work of actors characterized by very different backgrounds and skills: managers, medical professionals, and administrative staff must all work together to ensure the best quality service while paying the highest possible attention to costs and efficiency.

1.2 Process mining as a possible solution

In such a scenario, processes are one of the pillars, together with people, technology, and facilities, which can allow an organization to deploy its strategy in terms of patient experience and operational efficiency.
Thus, AOUFE was looking for innovative solutions to analyze, optimize and manage its processes in a quick, cost-effective, and simple way [1].
To achieve that, the hospital resorted to Partners4Innovation. Given its proven track record of projects related to digital transformation in the healthcare sector, thanks to the experience of the professionals working both in the Healthcare Innovation practice of Partners4Innovation (and which, previously, were academic researchers on the very

same topics) and the competencies on data analysis from the Data Insights & Organization service line, AOUFE found in Partners4Innovation the ideal partner to start a transformation journey towards being a data-driven organization. The two organizations then joined forces to design an evolutionary path to enhance the organization business process management capabilities by harnessing the power of Process Mining, an innovative analysis technique based on the exploitation of log data registered by the information systems used to execute the process [2, 3, 4]. The chief executive at the time, Dr. Carradori, gave the start to the initiative, then the new chief executive, Dr. Bardasi continued it to further enhance the level of diffusion in the organization.

After a brief discussion with the organization's top management (chief executive and the structure responsible), the most suitable process to start with was identified in the Emergency Room management, which was selected based on two conditions: availability of log data and performance that could have been significantly improved. The first is the necessary condition to use Process Mining, but the latter is somehow even more important: for the process stakeholders to be truly committed to the project, this needs to target their pains and concerns.

Once the scope was defined, the goals were set. As the first step of an evolution journey, the pilot project had two clear objectives: on one hand, to contribute to improving the process performance by finding opportunities for efficiency; on the other, lay the foundation for a cultural change and the evolution of the management towards a more data-driven approach in the management of the processes.

To tackle these goals, the pilot project was structured in two complementary streams. The first one was focused on the analysis and optimization of the process, seeing Partners4Innovation data scientists mining the log data to get a clear representation of how the process was executed and to identify inefficiencies and opportunities for improvement. The second one was focused on raising awareness and developing data analysis and Process Mining capabilities, consisting of both theoretical and practical training sessions.

As a result, the hospital was able to find significant room for improvement in the Emergency Room process, with direct benefits on both operative costs and patients' satisfaction, and even more importantly, it laid solid foundations for a radical shift in the management of its processes: by directly experiencing the power of data-driven analysis [5, 6] and enhancing the skill set of process stakeholders with data and Process Mining capabilities, it became ready to expand the scope and work on embedding this new data-driven culture in both its strategical and day-to-day operations [7].

2 Situation Faced

2.1 Background: the healthcare sector

At the time of the analysis, AOUFE employed over 2500 professionals and provided healthcare services to over 360 000 people. Among those, almost 30% were represented by senior citizens (over 75 years old). It was equipped with around 700 beds for hospitalization and the Emergency Room counted an average of about 50 000 accesses per

year. In the table below, you can find some figures about AOUFE's Emergency Room process:

Yearly number of episodes	~ 50.000
Yearly number of patients treated	~ 30.000
Average throughput time of cases	~ 260 minutes
Number of variants identified	~ 4.000
Percentage of cases covered by the first 10 variants	~ 50%
Average throughput time of cases covered by first 10 variants	~ 220 minutes

Table 1. Yearly average figures of AOUFE Emergency Room process in 2018-2019

After having discussed and analyzed the issues with the stakeholders, the most suitable process for the pilot project was identified in the Emergency Room process. In addition to the availability of log data, there were many other important reasons for this choice:

- Great emphasis on performance, as it is aimed at managing emergencies, where time is a critical factor
- High focus on efficiency in the usage of facilities and resources
- Direct impact on quality perception by citizens and patients
- Presence of regulatory standards and constraints (e.g., throughput time limits, criteria for the assignment of priority codes, etc.)

Indeed, in their daily activities, hospitals need to handle different issues, and the most common concerns are as follows:

- **Compliance challenges:** in practical terms, hospitals need to respect time limits for taking charge of the patient's care and for discharge, as specifically required by regulators. One of the most effective ways to face this issue while optimizing throughput times is to precisely define each process and standardize it as much as possible.
- **Organization:** to efficiently operate, these institutions need to carefully manage and organize facilities and resources - both internal and external - and define and manage how they cooperate.
- **Technology:** it's a key factor for process optimization, as information systems and tools for operations and analysis of information are essential to complete and guarantee all the elements.

2.2 The presented case studied

The case presented in this paper was no exception. Focusing on the Emergency Room process, the process owner was suffering from the inability to have a clear and objective picture of the process, despite well-known performance problems were present, especially for the time boundaries imposed by the regulation and in the management of

those patients needing hospitalization after first aid. Moreover, there was a widespread feeling that the process was heavily unstandardized, with significant coordination problems with the units responsible for laboratory exams and image diagnostics departments.
On top of that, the hospital lacked a structured, effective, and most importantly data-driven performance management system: process assessments were conducted sporadically and with a mainly qualitative approach based on experience and gut feelings, despite some structured reports produced from the statistics department being present, which was related to a general lack of data culture, especially in the medical professionals.
Therefore, as mentioned in the introduction, the goal was twofold: on one hand, dig into the Emergency Room process, clarify its real execution, expose its improvement areas, and identify bottlenecks and inefficiencies to develop an evidence-based plan of improvements that could boost both the performance of the process and the satisfaction of patients; on the other, introduce a new approach to the management of operative processes and establish a data-driven culture.

3 Action taken

3.1 The different streams of the project

To deliver the desired output, the project was structured in two parallel but complementary and integrated streams:

- **Process analysis:** it represented the analytical part of the project, in which log data were mined to expose the dark areas of the process and identify inefficiencies and opportunities for optimization
- **Change management:** it represented the qualitative part of the project, aimed at raising awareness and developing data analysis and Process Mining capabilities across both process stakeholders and management

3.2 Process Mining Analysis

As regards the first stream, since AOUFE had no previous experience in Process Mining analysis and given the need to contain the initial investment, it was designed and carried out with a methodology-centered approach, rather than a technology-centered one. Indeed, Process Mining initiatives are often technology-driven, rather than focused on the empowerment of process stakeholders. In other words, in many cases companies rush in buying expensive software tools, thinking that a good software represents the solution to their problems, and overshadow the importance of empowerment and upskilling, ending up in the failure of the initiative because the organization is not able to correctly use the software and evaluate the value it brings. Especially in organizations with a cultural deficit in data-driven decision-making, such an approach is doomed to fail, as these initiatives are likely to be just a one-time experience, with no real change in the attitudes and mindset of people in general and process owners. Of course, this

does not mean that Process Mining software is not relevant, but simply that it cannot be more important than competencies.
Following this approach, AOUFE, therefore, chose to start working with a free licensing technology stack, focusing its effort on embracing the methodology and developing a data culture across the organization. In particular, the following tools were used:

- **Data preparation:** R programming language
- **Process Mining analysis:** Celonis Snap (free web-based version of Celonis) & R programming language
- **Data visualization:** Microsoft Power BI Desktop

Before digging into the analysis of log data, two important preliminary steps were taken. First, Partners4Innovation ensured the full sponsorship of the hospital's top management, which is crucial to guarantee deep commitment to change from all the actors involved, especially in contexts in which existing behaviors and attitudes are strongly rooted. The nature of the project was twofold: as the general management (chief executive and structure responsible) encouraged the initiative, it is primarily top-down. However, to make the desired cultural change and process mining a viable and effective tool for the organization, process owner and process stakeholder needed to be fully empowered and involved, turning the top-down commitment into a bottom-up approach to change. Therefore, the intuition of the chief executive was a great starting point, but each actor needed to understand the potentiality of process mining techniques and, in this case, to be aware of the competitive advantages that a data-driven approach can generate. Constant dialogue, cooperative design at each step, and focus on pains and concerns are the key ingredients for this to happen.
Then, a small but heterogeneous working team was put together: the process owner, recovery department and diagnostics managers, IT professionals, and analysts (in this case represented by Partners4Innovation data scientists and healthcare innovation consultants) were brought at the same table to deliver their contribution to the project success.
Once roles and responsibilities were defined, the actual analysis work began.
First, the IT department was appointed with the extraction of log data, with the time horizon set to the entire year 2018. During this first step, one of the main obstacles arose, namely the long duration of the data extraction process. Since the management of several systems was being outsourced to third-party suppliers, the gathering of data was (at least partially) delegated to such external companies, which took a very long time, and in some cases even ended up in the wrong implementation of the specified functional requirements. This of course raised awareness on a very important element: Data Governance, which is essential for companies aiming at adopting a data-driven approach to business management.
Then, once the data was retrieved, the data preparation phase started. This was carried out by Partners4Innovation data scientists, who put together data sets extracted from different information systems and produced an overall log ready to be processed. Here, another major obstacle arose: data quality. Indeed, the raw data extracted was affected by a variety of quality issues: missing data, duplicated records, odd values, ambiguous process instances. Only through a constant dialogue between Partners4Innovation and

AOUFE it has been possible to identify how to manage all the different issues and exceptions, finally arriving to the creation of the dataset for the analysis.
Coherently with the overall approach, then the actual analysis was carried out with an iterative working method, characterized by a series of quick and auto consistent analyses performed at regular intervals, which allowed to obtain tangible value in a very short amount of time and, more importantly, keep all stakeholders committed to the initiative.
As mentioned before, the primary focus of the Emergency Room process analysis was its performance. Therefore, the following analyses were conducted:

- **Process overview:** descriptive analysis aimed at providing a quantitative measurement of the overall phenomenon.
  Among other important findings, this analysis showed a relevant difference between the mean throughput time (258 minutes) and the median throughput time (226 minutes): indeed, the distribution was characterized by positive skewness, and a staggering 21,5% of instances showed a duration over 6 hours, the limit imposed by the regulation. See also *Table 1* for a small sample of metrics used in this phase
- **Automated discovery of the process and variants analysis:** the focus here was to display the various ways in which the process was executed, evaluating its degree of standardization, and analyzing the differences in performance between the different process variants. This analysis showed a huge number of process variants (4087), among which the first 10 by frequency accounted for just over 52% of total instances, meaning that there were a lot of variants executed very sporadically. Focusing on performance, this analysis also showed that laboratory and image diagnostics exams were on average associated with longer throughput times

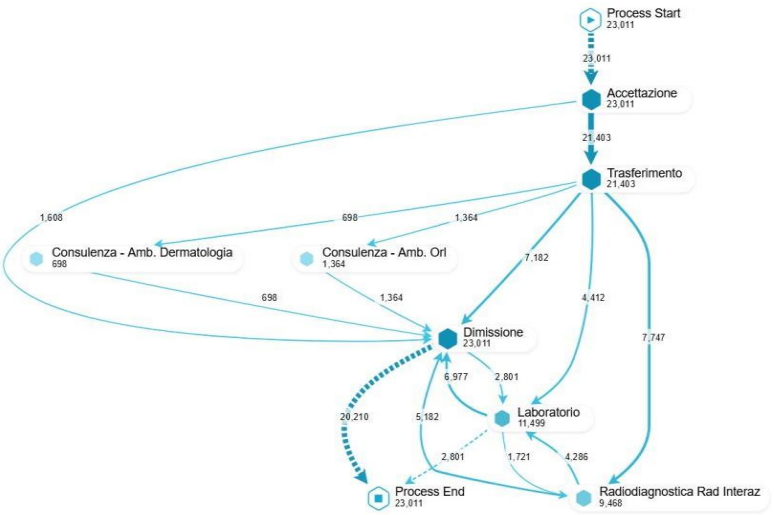

Fig. 1. Process map for the first 10 variants at full activities and connections detail

- **In-depth analysis of specific areas of the process:** focus on some specific process pains. In particular, the following areas, identified as the most critical by the process stakeholders, were subject to a dedicated deep dive:
  - **Triage and first visit:** these activities are the very first steps of the process, often playing a key role in the overall process performance. Then, the patient is visited by a doctor, who determines the required set of exams and/or medical procedures to be executed. This initial step is very important for two reasons: first, it has a direct impact on the rest of the process, as it sets priorities and pre-determines the patient journey; second, it is subject to specific time limits specified by the regulator. Therefore, conformance checking analysis was very relevant.
    This analysis showed that while on average the priority defined by triage codes was respected, there was a significant number of instances for which the time limits imposed by the regulation were exceeded, especially in the afternoon and night shifts, where the average time for patient's charge was respectively 73.5% and 63.7% higher than the one registered in the morning shift. The root-cause analysis showed that this was due to issues related to the shift changes procedure
  - **Diagnostics exams and consultancies:** as these activities involved actors external to the Emergency Room (namely laboratories, diagnostic departments, and specialized doctors), the process owner was very interested in evaluating their impact on the duration of the entire process, as well as identifying potential frictions in their interactions. Therefore, the analysis focused on the evaluation of request volumes and response times, together with the identification of those exams and consultancies associated with the highest process duration.
    This analysis showed that laboratory and image diagnostics exams were the ones associated with the longest throughput times, which was particularly relevant considering that 43% of all patients did both at least one time in the process.
  - **Hospitalization after first aid treatment:** this represents the final step of the process and was the main concern for all the process stakeholders, as it was very clear that the ways and supporting tools used to manage the hospitalization in dedicated departments after first aid was inadequate, often causing very long waiting times. Therefore, the analysis focused on the interaction between the Emergency Room and the bed management unit, to determine the root causes behind the high waiting times.
    The first striking result of this analysis was that in only 32.8% of the cases the request for hospitalization was done using the dedicated information system, meaning that in over 2/3 of the times the bed management activities were carried with the only help of phone and emails, with obvious effects in terms of efficiency. Moreover, the analysis showed a great variation in the bed waiting time according to the shift, with morning requests taking twice as much as those made in the afternoon, and department of destination, with five departments identified as the most problematic.

As said before, all these analyses were conducted in iterative cycles, and their results were presented to the working group with the help of data visualization tools, which

proved very effective in helping everybody understand the phenomena driving the process performance.

Fig. 2. Example of data visualization artifact used to discuss pieces of evidence and findings

Following a co-design approach, such sessions were designed to spark evidence-driven discussions between all the stakeholders on how to tackle the issues that had emerged, and so they were used to define the improvement plan. Moreover, a set of specific KPIs was designed to support the continuous monitoring of the process and the evaluation of the corrective measures to be implemented.

3.3 Change management

Concerning the change management stream of the project, it is important to underline again that the working group needed to improve its data analysis competencies, and in general, the whole organization needed to work on its data culture. To tackle these aspects, Partners4Innovation designed a dedicated training program, which was tailored for the two main categories of stakeholders: those who work with the data and those who consume the data, making decisions based on that data. For the first group, the training focused on the logic that drove the data preparation activities; while for the second, it was centered around Process Mining analysis and data understanding. In both cases, the training was carried out with a mix of live practical sessions and sharing of documentation.

4 Results

Focusing just on the Emergency Room, the pilot project allowed to identify several potential areas for improvement, which spanned across four different but strictly

connected dimensions: processes, people and skills, roles and organization, and systems and technology. Among the main areas for improvement identified we can find:

- **Spreading of best practices:** the analysis revealed some practices associated with better-than-average performance, such as:
  - Make simultaneous requests for specific couples of activities: for example, data showed that when blood tests and x-ray diagnostics were requested concurrently the associated throughput time was 14.3% lower than when they were requested in sequence, due to queue efficiency savings.
  - Anticipate the request for bed in recovery departments: data showed a 10.5% reduction in bed waiting time when the request was made before the actual ending of Emergency Room care treatments, a practice that was done only for 6.35% of all patients needing a bed.
- **Re-allocation of medical and administrative staff** according to patient affluence patterns, both intra-day and year-wise.
- **Set up of new standardized treatment paths** dedicated to specific categories of patients (the so-called "Fast Tracks").
- **Data Governance and Data Quality:** being able to retrieve high-quality data quickly and simply is critical to adopt a data-driven approach to decision-making, so the hospital needed to review their outsourcing contracts and work on the quality of data, both from a technological standpoint (implementing data quality controls) and from a people perspective (educating human resources on the impacts of poor application usage on data quality)
- **Activities association:** from the analysis, an insight showed that in a particular case, in more than 50% of the occurrences, laboratory analysis, as well as x-rays, were required. This led to a new procedure in the treatment of the specific illness, reducing significantly the throughput time in the management of those cases

Broadening the perspective over the analysis of the Emergency Room process, the project allowed AOUFE to achieve other important results.
First, it allowed both the top management and the process stakeholders to directly experience the great potential of Process Mining, which is critical to ensure commitment to the continuation of the evolution towards a quantitative approach to business process management. This result was particularly significant, as it secured this methodology as an integral part of the best practices of the hospital. The same experience has spread across different areas of the institution, so that process owners have an effective tool to address process performance. It has, for example, proven to be very effective in the reorganizations of beds and operatory rooms between the waves of the COVID-19 pandemic, to regain efficiency and recover procedures that were skipped due to the pandemic.
Then, it laid the foundation for a radical shift in the approach to process management, as it showed everybody the benefits of a data-driven approach to all its aspects, from analysis to improve definition and monitoring. During the pilot project, process owners and stakeholders all experienced the importance of the process. Understanding the

process became an invaluable asset: while before one was only interested in measuring, now the focus moves to analysis, knowledge, and governance.
Finally, it contributed to the upskilling of the employees, who have become autonomous in the set-up and execution of the analysis, therefore making the hospital ready to progressively expand the scope and spread a new data-driven culture to all its strategical and day-to-day operations.

5 Lesson learned

As said, hospitals and, more in general, the healthcare sector can highly benefit from advanced data analysis techniques, such as Process Mining. Being able to uncover each stage of the process clearly and objectively is particularly useful in every company but becomes essential when the understanding of it can save lives, as in these organizations. With the growing need to cut costs and enhance the quality of care, the AS-IS situation is the natural starting point to plan improvements. Changing the process from a simple operational element to a real asset requires, however, a paradigm shift. Again, since in the healthcare sector the final goal is to maximize efficiency and effectiveness, the scientific analysis of objective data can provide valuable insights. This is particularly true when the traditional analysis cannot cover the entire scope of variants of the process and is therefore limited to unveil just a small portion of reality. Process Mining does not suffer this limitation and can empower the decision process. However, to succeed and effectively employ this data mining technique two more ingredients are essential: the involvement of every line of business - or actors - and data sensibilization.
This project clearly shown to the entire organization as Process Mining can be a real, effective lever to real change, as it gave the process stakeholder tangible, objective evidence to make actors from different areas of the organization as a basis for their discussions. This point completely changes the usual dynamics between the different areas of the organization, which were relying more on personal relationships and sensations based on experience and personal feelings rather than on objective, clear and understandable measures of performance.
When the goal is to radically change the organization's culture rather than complete a stand-alone project, the general commitment of every level is crucial. To ensure that the innovation will last and successfully integrate into people’s behaviors and mindsets, it needs to overcome the purely technical dimension, becoming a driver for organizational change. The contribution of all stakeholders to the analysis and their direct empowerment is therefore fundamental. Moreover, to fully harness the power of data-driven insights, a strong data culture must be established: without it, the initiative is doomed to be just a one-time experience, with no real change in the attitudes and mindset of people.
An agile approach, aimed at delivering tangible value in the short period, can be a key factor in ensuring the success of this kind of initiative. As big initial investments are a huge disincentive for organizations willing to leverage the power of data when the number of resources is limited, one might be more prone to choose short-term advantages

over a long-term, radical innovation. However, an agile approach can successfully overcome this barrier, thanks to its great advantages in terms of flexibility and adaptability, allowing to reach long term advantages one fast, auto consistent, step at a time. This case was no exception: with the spread of Covid-19 in 2020 priorities quickly changed, and the efforts of the whole healthcare sector were entirely devoted to fighting the pandemic. However, at that time the pilot project was already completed, and the organization was able to 'pause' its evolutionary journey to tackle the emergency without risking being forced to restart from scratch when the pandemic will finally be over. Furthermore, the experience made during the project proved to be useful for AOUFE to tackle also the challenges brought by the COVID-19 pandemic, proving that Process Mining and, more in general, a data-driven mindset, are nowadays essential to achieve operational excellence and improve the performances of the organization.

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