

DAILY, WEEKLY AND SEASONAL PATTERNS IN PROCESSES: AN ANALYSIS WITH PROCESS MINING FOR THE DEVELOPMENT OF NEW TECHNOLOGIES



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ABSTRACT

This article explores the potential of Process Mining for the analysis of daily, weekly and seasonal patterns in business processes, with a focus on the development of new technologies and the optimization of management in the era of digital transformation. Increasing digitization and an abundance of data require new approaches to extract actionable insights and drive strategic decision-making. Process Mining, by analyzing the digital traces left by operations, reveals the true dynamics of processes, unveiling temporal patterns that influence performance and efficiency. Identifying these patterns with Process Mining provides companies with a deeper understanding of their operations, allowing them to optimize resource allocation, anticipate seasonal demands, prevent bottlenecks, and develop more adaptable and efficient solutions. The article analyzes the benefits, challenges, and opportunities of Process Mining as a catalyst for digital transformation, driving innovation and building more effective, flexible, and customer-centric processes.

Keywords: *Process Mining*. Temporal Patterns. Digital Transformation. Process Analysis. Process Optimization.

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THE RISE OF DATA AND THE NEED FOR UNDERSTANDING

We live in an era shaped by digitalization. Every online interaction, business transaction, or digitized record generates new data, fueling an ocean of information of unimaginable dimensions. This digital effervescence, driven by the ubiquity of connected devices, increasing automation, and pervasive digitization of business, presents an unprecedented challenge: the need to transcend the mere accumulation of data and achieve a deep understanding of its meaning and value. It's not just about storing, but about transforming data into actionable intelligence, into insights that transform decision-making, optimize performance, and reveal unexplored paths to innovation.

As highlighted by Freitas, Pelaez and Carneiro (2009), "The growing interorganizational competitiveness has not only affected the way organizations have come to see each other, but has also affected the way they have come to analyze themselves." (p.2). Many processes are carried out so automatically by the people who perform them that the step-by-step is not systematized or documented. Instead, the knowledge about how to accomplish these tasks is in the minds of those who do the process. And there is still the possibility of the transfer being done in a technical way or not so detailed because it is obvious or with a muscle memory, which leave gaps in the process. The need to adapt and evolve in an increasingly competitive scenario requires companies to look for new ways to optimize their processes and extract the most value from their data. Process mining is one of the techniques to identify and mitigate human failures, reducing the dependence on the tacit knowledge of individuals.

In the midst of this informational effervescence, Process Mining emerges as an epistemological beacon, guiding companies and organizations on their journeys of discovery and improvement. Just as a linguist deciphers the codes and structures of a language to understand human communication, Process Mining uses advanced data analysis techniques to unravel the language of business processes, revealing their patterns, their information flows, and paving the way for optimization and innovation.

Figure 01 - Basic type of process mining in terms of discovery.



By analyzing "digital footprints" – the event logs generated by information systems, also known as *event logs* – *Process Mining* reconstructs, visualizes, and analyzes the actual flow of processes, uncovering bottlenecks, inefficiencies, deviations, and opportunities for improvement. This technique transcends subjective analysis and theoretical models, relying on concrete data for a holistic and accurate view of the actual functioning of processes.

As highlighted by Baldam et al. (2019), "process mining seeks to discover, monitor, and optimize real processes, through the extraction of knowledge existing in the event records of the processes generated by information systems." (p. 456), which makes it possible to make more assertive decisions about what the process is about. Analysis of *the event logs* can reveal unexpected patterns and deviations in the process. These indications, in turn, can direct a more in-depth investigation to fully understand the dynamics of the process.

"Data mining is the process of identifying, in data, valid, new, potentially useful, and understandable patterns" (Chicon et al., 2021, p. 2). Both data mining and *process mining* share the goal of uncovering meaningful patterns and insights from data, seeking to transform raw information into actionable knowledge. However, while data mining operates on a broader scope, exploring patterns and relationships in large data sets, *Process Mining* focuses on process-specific analysis, using event logs as the primary source of information.

This specificity of *Process Mining* makes it a powerful tool for understanding the dynamics of business processes. By analyzing the digital traces left by the activities performed, *Process Mining* reveals not only what happened, but also how, when, and why it happened. This detailed analysis of the process flow, based on concrete data, allows you to identify bottlenecks, inefficiencies, deviations and opportunities for improvement, paving the way for process optimization and transformation.

As with data mining, data quality is a crucial factor in the success of analysis with *Process Mining*. Incomplete, inaccurate, or inconsistent event logs can compromise the reliability of results and lead to misinterpretations. Therefore, the use of data pre-processing techniques, such as cleaning, transforming, and enriching logs, is essential to ensure the quality of the analysis and the accuracy of the insights generated.

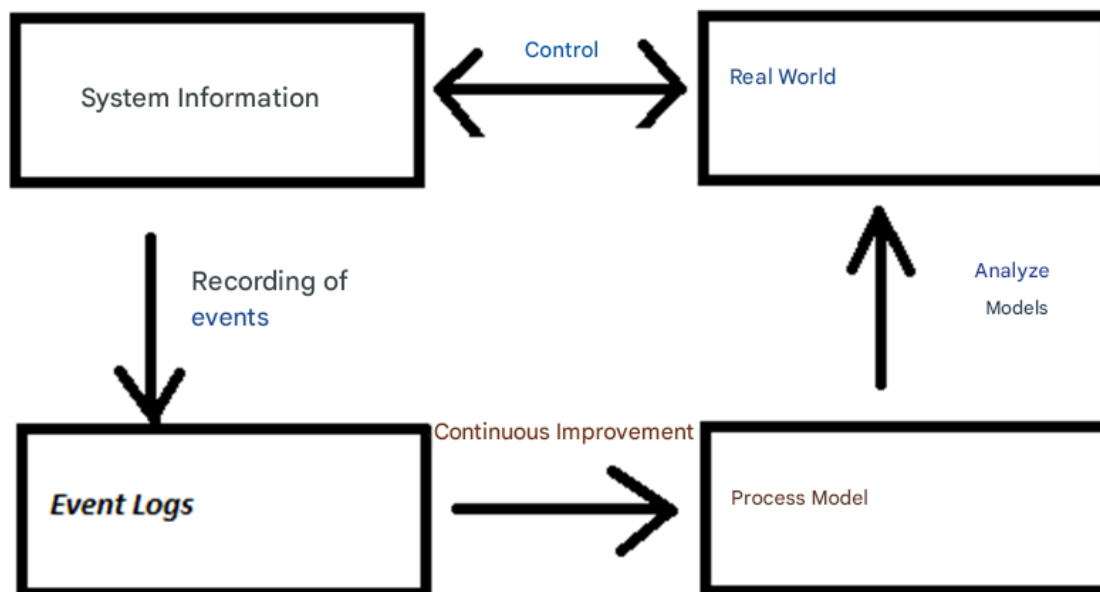
The increasing digitalization of business has brought with it the need to manage processes more efficiently and adaptably. As Freitas, Pelaez and Carneiro (2009) point out, companies began to observe their activities as business processes, which led to the prominence of concepts such as BPM (*Business Process Management*) and BPMS (*Business Process Management System*). However, process management in the digital age goes beyond simple automation or workflow mapping. It is necessary to go further, understanding in depth the dynamic reality of the processes, identifying bottlenecks, inefficiencies and opportunities for improvement.

In this scenario, *Process Mining* emerges as an essential tool for data-driven process management, allowing companies to make strategic decisions based on real data about the functioning of their processes. Lamghari (2022) corroborates this view by stating that, in the context of Business Process Improvement (BPI), "*the key idea is that a log can exist even if no process model is present*³". This characteristic makes Process Mining particularly relevant in complex environments, where traditional process modeling can be challenging or insufficient to capture the reality of process execution.

The Figure below illustrates the fundamental cycle of *Process Mining*. The starting point is the information systems that record information about the activities performed in the "Real World". This information, called "System Information", represents the set of raw data generated by the company's operations. From this data, the "Event Recording" captures the relevant information about the process activities, generating the "event logs". These logs, which capture the "digital footprints" of the processes, provide the raw material for analysis with Process Mining.

³ The key idea is that a log can exist even if no process template is present.

Figure 02 – General example of Process Mining



Through the analysis of the "Event Logs", *Process Mining* allows the construction of a "Process Model", which visually represents the flow of activities, the decisions made and the relationships between the different stages. This model provides a clear and objective representation of the actual process, in contrast to theoretical or subjective models. "Continuous Improvement" is a core objective of *Process Mining*.

By analyzing the "Process Model" in relation to the "Real World", identifying bottlenecks, inefficiencies and deviations, it is possible to implement measures to optimize the process, as shown in Figure 02. This constant analysis and the search for improvements drive the evolution of the process over time. "Control" is also prominent in the *Process Mining* cycle, allowing the identification of critical points and the implementation of measures to ensure compliance, quality, and efficiency of operations. "Organizations are not inert entities: they need to recognize and react to changes in the environment" (Fernandes et al., 2020, p. 41). Companies operate in a dynamic scenario, where internal and external factors require adaptation and flexibility. Business processes, as a reflection of this ever-changing reality, also need to evolve to remain relevant and efficient.

In the context of process analysis, as observed by De Amo (2004), "Data Mining consists of the analysis of data after extraction, seeking, for example, to raise the real and hypothetical needs of each client to carry out marketing campaigns". This same logic

applies to Process Mining, where the analysis of event logs after their extraction allows you to identify the "needs" of the process, such as bottlenecks, inefficiencies, and deviations.

Just as a marketing campaign seeks to achieve a specific objective, Process Mining allows you to define optimization "campaigns", based on concrete data, to improve the efficiency, quality, and compliance of the process. The analysis of temporal patterns, in turn, provides valuable insights for the definition of these "campaigns", revealing the moments in which the interventions will be most effective. For example, by identifying peak demand times, the company can focus its optimization efforts on these critical periods, maximizing the impact of the actions.

Data analysis with Process Mining provides companies with the ability to monitor these changes, identify their impacts on processes, and take proactive steps to ensure optimization and adaptability.

Em um mundo empresarial marcado por constantes transformações, a compreensão da dinâmica temporal dos processos de negócio se torna essencial para a sobrevivência e o sucesso das organizações. Como destaca Hayes et al. (2020), "Organizations are not inert entities: they need to recognize and respond to changes in the environment. These changes can affect both what the organization uses as input and its expectations about the outcomes generated in its internal production or transformation processes" (Hayes, 2018, p. 41)⁴.

The analysis of temporal patterns - daily, weekly, monthly and seasonal - emerges as a crucial element to understand the fluctuations, rhythms and nuances that influence the performance of processes. This understanding allows companies to adapt to changes in the environment, optimize their resources, and remain competitive in an ever-evolving market.

The identification of temporal patterns, driven by Process Mining, is not limited to retrospective analysis. Its insights transcend diagnosis, serving as a foundation for developing new technologies that drive innovation, automation, and strategic decision-making.

In this context, the combination of Process Mining with other techniques, such as simulation, emerges as a promising field for process redesign and optimization. Aguirre,

⁴ In the book (The Theory and Practice of Change Management): Organizations are not inert entities: they need to recognize and react to changes in the environment. These changes can affect both what the organization uses as input and its expectations about the results generated in its internal production or transformation processes.

Parra and Alvarado (2013) point out that "the combination of process mining and simulation techniques for business process redesign offers a robust methodological approach" (p. 24), allowing companies to assess the impact of different improvement alternatives before their implementation, which contributes to the creation of more effective and sustainable solutions.

This article delves into the analysis of daily, weekly, and seasonal patterns in processes, exploring the potential of Process Mining for the development of new technologies. Analyzing use cases, discussing techniques, tools, challenges, and opportunities, we seek to elucidate how understanding the hidden rhythms of processes can drive the creation of innovative, efficient, adaptable, and intelligent solutions.

In the next chapters, we will dive into the details of Process Mining, explore methods for identifying temporal patterns, analyze use cases in different sectors, and discuss the challenges and future prospects for the application of this tool in the development of new technologies.

DEVELOPMENT: EXPLORING THE POTENTIAL OF PROCESS MINING IN THE AGE OF DIGITAL TRANSFORMATION

Digital transformation, more than a mere incorporation of technologies, represents a profound change in the way companies operate, relate to their customers, and create value. This revolution, driven by the convergence of technologies such as cloud computing, artificial intelligence, the internet of things, and data analytics, is redefining business models, creating new markets, and requiring companies to reinvent themselves to remain competitive.

In an increasingly digital world, the ability to collect, analyze, and extract insights from data becomes a crucial competitive differentiator. Companies that can master these skills will be better positioned to understand their customers' needs, optimize their processes, innovate in products and services, and adapt quickly to market changes.

In this context of accelerated digital transformation, Process Mining emerges as a powerful tool for process analysis and optimization, allowing companies to make strategic decisions based on real data about the functioning of their operations. Through the analysis of event logs, Process Mining offers a holistic and accurate view of processes, revealing bottlenecks, inefficiencies, deviations, and opportunities for improvement that might otherwise go unnoticed.

As Baldam, Valle and Silva (2019) point out, "Process mining is a technique that has been relevant in recent years, due to the constant need to improve business processes in competitive environments" (p. 454). In a digital transformation scenario, this relevance intensifies, as the ability to analyze and optimize processes in an agile and efficient way becomes even more crucial for the success of companies.

Process Mining offers a number of benefits that make it a valuable tool for companies looking to excel in the era of digital transformation Mendling, Jan, et al., in their article "Challenges of Business Process Management in Digital Business Transformation" (2018), argue that "Business process analysis goes beyond the mere creation of flowcharts. It involves a detailed understanding of the actual processes, allowing for the identification of inefficiencies and the implementation of data-driven improvements. This is essential for the digital transformation of organizations, as it provides a precise and actionable view of business processes" (Mendling et al., 2018, p. 5).⁵ This clear and objective view of processes, based on real data, is essential for strategic decision-making and the optimization of operations.

- **Clear and Objective View of Processes:** In contrast to traditional process documentation, which may be outdated or incomplete, Process Mining provides an accurate, data-driven view of how processes actually happen.
- **Identification of Bottlenecks and Inefficiencies:** Through the analysis of process data, Process Mining allows you to identify bottlenecks, redundant steps, delays, and other inefficiencies that negatively impact performance.
- **Process Optimization and Cost Reduction:** By identifying problem areas, Process Mining allows companies to optimize their processes, eliminating unnecessary steps, reducing rework, and optimizing resource usage, which translates into cost savings and increased efficiency.
- **Improved Decision-Making:** The insights provided by Process Mining allow companies to make strategic decisions based on real data about the functioning of their processes, which increases the assertiveness and effectiveness of the actions taken.

⁵The analysis of business processes goes beyond the mere creation of flowcharts. It involves a detailed understanding of actual processes, allowing for the identification of inefficiencies and the implementation of data-driven improvements. This is essential for the digital transformation of organizations, as it provides an accurate and actionable view of business processes.

In addition to optimizing existing processes, Process Mining also acts as a catalyst for innovation and adaptability, which are essential elements for success in the era of digital transformation. Gustavo Tito Martins and Luís Silva Rodrigues, in their article "Process mining and digital transformation of organizations: A literature review" (2020), argue that "Process mining allows organizations to gain competitive advantages and optimize their results by identifying hidden patterns and gaining valuable insights into process performance. The growing availability and volume of data on events suggest that process mining will take on an increasingly important role in the development of organizations" (Martins and Rodrigues, 2020, p. 3).

- **Identify opportunities for automation:** Analyzing process data can reveal repetitive tasks that can be automated, paving the way for the implementation of solutions that increase efficiency and reduce the occurrence of errors.
- **Develop more flexible and adaptable solutions:** By understanding how processes behave in different scenarios and conditions, companies can develop more flexible and adaptable solutions that are able to quickly adjust to market changes and customer demands.
- **Innovate in products and services:** The analysis of process data can generate valuable insights into customer behavior, their needs, and expectations, which can be used to develop more innovative products and services that are aligned with market demands.

Process Mining, by providing a complete and reliable view of processes, transcends the role of a mere descriptive analysis tool. Its insights, extracted from the minutiae of the data, open a portal to a new level of management, where proactive action and anticipation become key pieces for success.

Process Mining, as van der Aalst (2011) argues, democratizes process management by making information accessible and understandable to different audiences, including managers, analysts, and users. Visualizing complex data through charts and dashboards allows for clear and efficient communication, driving collaboration and informed decision-making at all levels of the organization.

Os benefícios da aplicação do Process Mining se estendem por toda a organização, impactando desde a otimização de custos e a melhoria da eficiência operacional até a criação de novos produtos e serviços. Lars Reinkemeyer, em seu livro "Process Mining in

Action: Principles, Use Cases and Outlook" (2020), argumenta que "Process mining allows organizations to gain a detailed and accurate view of their business processes, going beyond traditional flowcharts. By analyzing event logs, it is possible to identify bottlenecks, optimize resource usage, and reduce rework. This data-driven approach provides valuable insights that can be used to improve operational efficiency and customer satisfaction" (Reinkemeyer, 2020, p. 15)⁶.

Process Mining, by providing an accurate and data-driven view of processes, becomes a crucial tool for effective management, allowing companies to identify and eliminate inefficiencies, optimize the use of resources, and improve communication between areas. Let's look at some practical examples of how it can be applied to optimize processes and achieve better results:

- **Reduced Operating Costs:** By identifying and eliminating redundant activities and inefficient processes, businesses can significantly reduce their operating costs, freeing up resources to invest in strategic areas.
- **Improved Customer Experience:** Optimized processes translate into faster deliveries, higher quality of products and services, and more efficient interactions with customers, which contributes to loyalty and the strengthening of the brand's image.
- **More Assertive and Agile Decision-Making:** With accurate insights into the actual functioning of processes, managers can make more strategic and effective decisions, based on data rather than assumptions.
- **Increased Compliance and Risk Reduction:** Process Mining allows you to monitor compliance with standards and regulations, identify deviations, and implement preventive measures to minimize risks and ensure compliance.

Em um mundo inundado por dados, a capacidade de transformar informações em conhecimento acionável se torna um diferencial competitivo inegável. Como destacam Fernandes e Chiavegatto Filho (2019) em sua pesquisa sobre Data Mining e Machine Learning, "Data mining has become an increasingly common alternative to deal with public health databases, making it possible to analyze large volumes of morbidity and mortality

⁶ Process mining allows organizations to gain a detailed and accurate view of their business processes, going beyond traditional flowcharts. By analyzing event logs, you can identify bottlenecks, optimize resource usage, and reduce rework. that can be used to improve operational efficiency and customer satisfaction

data. Such techniques are not intended to replace the human factor, but to assist in decision-making processes, serve as a tool for statistical analysis and generate knowledge to support actions that can improve the worker's quality of life." (p. e13)⁷.

In the context of process management, Process Mining assumes this role of connecting data and decisions, providing managers with the tools to fully understand the reality of their operations and make more strategic and effective decisions.

No cerne da análise de processos com Process Mining, a identificação de padrões temporais - diários, semanais e sazonais - emerge como um elemento crucial para a otimização e o desenvolvimento de novas tecnologias. "Process mining techniques allow for the extraction of process models from event logs, providing insights into the actual processes as they are executed. This enables organizations to identify bottlenecks, optimize resource allocation, and predict future process behaviors, ultimately leading to more efficient and effective business operations" (van der Aalst, 2011, p. 3)⁸.

Temporal analysis, therefore, goes beyond the mere description of the process, allowing the understanding of how it behaves over time and the identification of patterns that influence its performance. By analyzing event logs with a temporal lens, companies can uncover a range of insights, such as:

- **Peak and Low Demand Times:** Identify the times of the day, week, or year when demand for certain processes is higher or lower, allowing for dynamic adjustment of resource allocation and optimization of responsiveness.
- **Seasonal Variations:** Detect patterns of behavior that are repeated at certain times of the year, such as increased retail sales during the holiday season or increased demand for healthcare services during the winter, which allows for anticipation and strategic planning to address these fluctuations.
- **Impact of External Factors:** Understanding how external events, such as holidays, climate change, or economic crises, affect process performance, allowing companies to prepare to deal with impacts and minimize risks.

⁷ Data mining has become an increasingly common alternative for dealing with public health databases, enabling the analysis of large volumes of morbidity and mortality data. Such techniques are not intended to replace the human factor, but rather to assist in decision-making processes, serve as a tool for statistical analysis and generate knowledge to support actions that can improve the quality of life of workers.

⁸ Process mining techniques allow for the extraction of process models from event logs, providing insights into actual processes as they run. This allows organizations to identify bottlenecks, optimize resource allocation, and predict future process behaviors, ultimately leading to more efficient and effective business operations.

Identifying temporal patterns with Process Mining is not limited to a retrospective analysis. Its insights transcend diagnosis, serving as a basis for the development of new technologies and innovative solutions. As Baldam et al. (2019) point out, "Process mining allows the transformation of data into useful information for the generation of organizational knowledge. The use of the technique would reduce the complexity in gathering information about the workflow of the processes and would allow greater time and agility for decision-making in relation to the continuous improvement of the implemented processes" (p. 461).

The ability to transform data into knowledge and speed up decision-making, combined with the understanding of temporal patterns, allows companies to develop smarter and more adaptable solutions, such as:

- **Adaptive Systems:** By identifying seasonal variations and process behavior patterns, companies can develop adaptive systems, capable of adjusting their workflows, priorities, and resource allocation according to real-time demands.
- **Predictive Models:** The combination of Process Mining with Machine Learning techniques makes it possible to create predictive models that anticipate future process behaviors, such as predicting seasonal demands, identifying potential bottlenecks, and detecting anomalies, which allows for proactive decision-making and problem prevention.

Process Mining is consolidating itself as an essential tool for process management in the digital age, empowering companies with actionable insights and driving innovation in their processes. Araujo et al. (2023) highlight that Process Mining is a pillar of digital transformation, enabling visual and analytical analysis of data, which allows for strategic decision-making, process optimization, and compliance with regulations. By unraveling the temporal patterns hidden in data, Process Mining paves the way for the creation of smarter, more efficient, and adaptable solutions, preparing companies for the challenges and opportunities of an ever-changing world.

CONCLUSION

In an era marked by the abundance of data and the need for agility and innovation, Process Mining stands out as a crucial tool for process management. Its ability to extract valuable insights from the digital footprints left by operations, revealing the true dynamics

of processes and uncovering hidden patterns, empowers companies to make more strategic decisions, optimize their resources, and adapt quickly to market changes.

The analysis of time patterns with Process Mining, in particular, stands out as a fundamental element for the development of new technologies and the construction of more efficient, flexible and intelligent processes. By understanding the rhythms, fluctuations, and nuances that govern processes over time, companies can optimize resource allocation, anticipate seasonal demands, prevent bottlenecks, and develop adaptive solutions that adjust to market dynamics.

Despite the undeniable benefits, the adoption of Process Mining still faces challenges, such as the need to ensure data quality, deal with the complexity of processes, and overcome cultural and technological barriers in some organizations. However, the opportunities that open up with the advancement of this technology are vast and promising.

The integration of Process Mining with other technologies, such as Artificial Intelligence, Machine Learning, and Robotic Process Automation (RPA), creates a powerful ecosystem for intelligent automation, predictive analytics, and real-time process optimization. The application of Process Mining in new sectors and business areas also expands the frontiers of innovation, revealing opportunities for the creation of more efficient, personalized and customer-centric solutions.

Process Mining is not limited to optimizing existing processes, but acts as a catalyst for the digital transformation of companies, driving innovation, agility, and competitiveness. By providing a clear and objective view of processes, based on real data, Process Mining empowers companies to make more strategic decisions, adapt their processes to market demands, and build a more efficient, innovative, and customer-centric future.

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