Status and Future of Process Mining: From Process Discovery to Process Execution

Abstract

During the last two decades Process Mining has seen a rapid global adoption: first in academics and then in corporate business. It has evolved into a foundational technology, allowing users to discover actual process flows with unprecedented transparency, speed, and detail. In a business environment Process Mining has no purpose of its own, but companies leverage it to identify process inefficiencies, improve process execution and ultimately drive value. Process discovery and transparency does not provide immediate business value, but requires specific use cases combined with human intelligence to identify and deploy levers for process improvement. In this article we argue that the future focus and evolution of Process Mining shall not focus on lateral expansion - i.e. with further processes and discoveries - but vertically by enhancing the depth of added value for business users with artificial intelligence, proactive and predictive enablement and other levers which boost process execution. In essence, focus should be on deploying smarter technologies for driving business value in process areas where Process Mining has shown impact.

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1 Setting the Stage

1.1 The Evolution of Process Mining in Operational Business

Process Mining was invented at the end of last millennium by Wil van der Aalst and has seen a strong adoption by academics in the first decade of this millennium. In the second decade of this millennium companies started to use Process Mining for transparency, to discover, understand and improve actual processes. To this respect, numerous use cases i.e. in horizontal support functions such as Procurement and Order Management have been defined and deployed by companies like BMW, Siemens, Uber and many more around the world, across all industries, in organizations of any sizes and for processes along the whole value chain, as the following selected examples show:

* Procurement Experts use Process Mining for order processing e.g., to discover duplicate payments, payment term deviations and maverick buying.
* Logistic Experts use Process Mining to discover reasons for late deliveries, improve supply chain resilience and assure on-time deliveries.
* Order Manager use Process Mining to discover customer order processing, identify inefficiencies resulting from rework and improve customer satisfaction.
* Plant Managers use Process Mining to find bottlenecks in manufacturing processes, conduct value stream analysis and improve efficiencies.
* Sustainability Manager use Process Mining to discover operational root causes for waste and CO2 impact of single process decisions.

All these sample have in common that Process Mining is used to discover actual process flows. Then human intelligence is applied to interpret the achieved transparency, identify root causes for process inefficiencies, and turn these into business value. However, the evolution on Process Mining should progress, similar to the evolution of the imaging method in healthcare.

For an analogy, the evolutions in Healthcare and Process Mining show many similarities: prior to inventing xRay at the end of the 19th century, a Medicus needed to guess what is happening in the human body and what are the root causes for a particular disease. Similarly – before using Process Mining – process experts had to use process models and subjective assumptions to guess actual process flows and define process improvement. The invention of xRay allowed to discover the root causes for diseases and thus decide on appropriate remediation. Similarly, Process Mining enables users to discover process gaps and decide on improvements. Imaging methods have become smarter and capable to interpret the images, identify diseases and propose curative measures. Furthermore, medical devices are trained not only to “read” the images, but also to propose and conduct treatments. In a similar form, we expect Process Mining to develop more “intelligence”: in a first step by automatically identifying process gaps and proposing measures for remediation to the users who will then execute the action. And in the future even “learn” to execute process activities autonomously based on defined criteria, with only exception based human interference.

1.2 Achievements in the Decade Starting 2010

Process Mining has seen some impressive developments in the last decade and enabled many companies towards a data- and fact-based culture, using single sources of truth for process assessment and optimization. The evolution from Business Process Modeling (BPM, the design how processes should happen) to Process Mining (full transparency how processes actually happen) allows organizations to understand and improve processes.

Many organizations started using Process Mining in single functional silos (e.g. audit, procurement) and then expanded the usage across different functions. While there is an amazing variety of use cases, experience shows that the biggest impact is achieved in the core processes Accounts Payable (A/P), Accounts Receivable (A/R), Purchase-to-Pay (P2P) and Order-to-Cash (O2C). These horizontal support processes are critical to any company and are typically executed in transactional systems, providing sufficient digital event logs with a high degree of standardization, and requiring a high degree of automation. Many companies, which started their Process Mining journey with a focus on these core processes, achieved short term transparency and operational impact e.g., by eliminating duplicate payments, identifying payment term deviations, and reducing rework [[1](https://link.springer.com/chapter/10.1007/978-3-031-08848-3_13#ref-CR1)].

1.3 Hurdles and Challenges

While the concept of Process Mining has seen a rapid expansion, operational adoption has faced key challenges:

* Focus on the right *Purpose*: some initial use cases – built with passion for this exciting new technology – did lack appropriate purpose. Providing process transparency is great, but it is only valuable if it serves a clearly defined business purpose, e.g., improving throughput times or on-time delivery. This purpose must be defined prior to starting any Process Mining project and the deployment should be continuously measured regarding impact and value.
* Engaging the right *People*: as part of human nature, most people are reluctant to leave their comfort zone. Discovering process inefficiencies does not always resonate well with people, who have designed or operated a particular process for many years. Reactance is a typical reaction which needs to be managed proactively with appropriate change management and initially engaging people who are open to change.
* Process Mining can enable an *operational transformation*, which requires the right organizational setup. Experience shows, that the majority of companies, which have successfully deployed Process Mining, established a Center of Excellence as central accelerator to drive change, process transformation and value.
* *Technical performance*: since my very first days with Process Mining, I have personally seen a continuous race between business requirements and technical performance. Once the concept of Process Mining was understood and data access had been arranged, the demand for transparency grew exponentially in the organization. This obviously goes in hand with an exponentially growing demand for data, which must be extracted, analyzed and presented to the operational users. Technology is required to assure performance for high customer experience, and has seen a similar exponential evolution to match demand, with cloud technology and standard connectors being only two sample for innovation.

1.4 The Power of Processes

Processes represent the lifeblood of any organization and efficient process execution is a critical success factor to stay competitive. Amazon is probably one of the most efficient companies, when it comes to process execution and the following quote from Jeff Bezos shows his reluctance to adopt rigid process frameworks, but rather continuously adjust and improve processes to maintain Day 1 efficiency and agility:

“You stop looking at outcomes and just make sure you’re doing the process right. Gulp. It’s not that rare to hear a junior leader defend a bad outcome with something like, “Well, we followed the process.” A more experienced leader will use it as an opportunity to investigate and improve the process. The process is not the thing. It’s always worth asking, do we own the process or does the process own us? In a Day 2 company, you might find it’s the second.” [[2](https://link.springer.com/chapter/10.1007/978-3-031-08848-3_13#ref-CR2)].

2 The Future of Process Execution

Process Mining has enabled thousands of organizations around the world to better understand their actual processes, to fuel data- and fact-based discussions and thus derive process improvements. However, the ultimate goal for any organization must be to minimize transactional cost, i.e. the cost induced by executing business processes. The digital age has seen the raise of an increasing number of digital native companies, which are built on highly efficient, automated processes e.g. for sales order or purchase order processing. Think of Amazon’s Marketplace, with a maximum degree of automation in order processing leading to a minimum degree of transactional costs. Traditional companies, with a grown legacy of IT infrastructure, are challenged to compete against these digital native companies. While Process Mining is focused on process discovery, process execution focuses on enabling the companies to execute processes more efficiently and thus reduce transactional cost by leveraging smart technologies.

2.1 Process- and Organizational Transformation

Leveraging Process Mining and process execution implies a significant transformation in the way a company operates. Transformation as a popular buzzword comes in multiple flavors, such as e.g. digital transformation or transformation of the business model – which shall not be discussed in further detail. Our focus shall rather be on process transformation and transformation of the operating model, thus focusing on the way a company executes its processes and how it is setting up operations to drive change. Processes are essential for the value generation of any company, and typically show a high degree of inertia as employees got used to a certain way of doing things and typically show reluctance to change. While Process Mining can discover process inefficiencies and process execution can provide solutions for increasing efficiency, operational transformation is a crucial factor for success, which needs to be managed proactively. Experience shows that many Process Mining projects fail due to organizational / human reluctance in respect to change. Tools and technology represent only one side of the equation for an organizational transformation, as the following statement shows: “While cutting edge technology and talent are certainly needed, its equally important to align a company’s culture, structure, and ways of working to support broad AI adoption. In most firms that aren’t born digital, mindsets run counter to those needed for AI” [[3](https://link.springer.com/chapter/10.1007/978-3-031-08848-3_13#ref-CR3)].

Driving process- and organizational transformation implies a range of different success factors:

* Value focus: the target value needs to be defined, e.g. strategically (transforming towards a data driven organization) or operational in measurable value such as e.g. reduction in working capital or rework, improvement of payment term deviations or degree of automation. A very tangible definition of measurable value, which is turned into operational targets, is crucial for a successful transformation.
* Executive sponsorship with a clear focus on targets: all transformational efforts must be sponsored by a senior executive for priority and guidance. Operationalization via defined strategic targets, which are ideally aligned with individual incentives, have yielded maximum success.
* Change Management as a conscious approach to prepare, support and enable individuals and teams to adopt process transformations.
* Organizational setup with a defined accelerator to drive transformation, e.g. a Center of Excellence (CoE), which is enabled and empowered by an executive sponsor to drive process transformation across the organization.

2.2 Trends

The following discussion on Trends results from numerous discussions with process owners and experts, other Process Mining evangelists and market players.

**2.2.1 Intelligent Process Execution**

While Process Mining has enabled users to discover process inefficiencies with human intelligence, the concept of intelligent process execution builds on this discovery and supports users by providing just that kind of information which is relevant. While Process Mining can screen millions of purchase orders, intelligent process execution provides the individual users with only those purchase orders which require attention or call for immediate action. While Process Mining can discover millions of manual activities, intelligent process execution enables the user to execute multiple activities in one step in a suitable user interface. In essence, intelligent process execution takes Process Mining to the next level by leveraging AI, proactive and predictive solutions for the benefit of providing users only with the relevant information and smart forms of process execution.

**2.2.2 Proactive Solutions**

While big data and new tools allow unprecedented transparency, most software provides insights for users to search for relevant issues. Process Mining allows insights where users can identify e.g. late deliveries, rework effort, process delays and much more. But should users apply human intelligence to search for relevant issues, spending high effort and wasting precious time while searching for relevant issues? We don’t think so. Virtual assistants should provide proactive, customized and individual support. Intelligent process execution is capable to “learn” current operations and develop skills to propose relevant exceptions proactively to the users. The software is evolving into a smart companion, which is capable to discover the operational process, understand exceptional issues and propose these proactively to the user. E.g. overdue payments can be presented to the user per push-mail or pop-up message, delayed customer deliveries will be flagged out and potentials for automation proposed. Dedicated execution Apps condense execution gaps or exceptions for the user to decide how to proceed in these cases.

**2.2.3 Predictive Solutions**

Upcoming events can be predicted to enable users to take preventative measures. It might – to take an example from procurement - be helpful to get a prediction, which purchase order will not be delivered on time. Equally, in logistics it is helpful to get predictions, which shipment will not be delivered on time. Based on historical data, predictions are calculated and presented with probability thresholds: as one example, predictions can identify all supplies, which will not be received on an expended date with a defined probability threshold. Those kinds of solutions have been developed for several years, e.g. based on algorithms programmed with Python on R-server, analyzing open and closed orders including times for process execution, leading to a vast number of operational execution support cases.

**2.2.4 Usability**

Application development shows a strong focus on the consumer, with a requirement to provide intuitive user interfaces (UIs) which are fun to use and quick in interaction. Usability is equally relevant for standard Apps as well as for individual data analytics:

* Standard Execution Apps: Horizontal core processes such as A/P or A/R should be standardized to a maximum and can be executed with standard Apps, which provide the users with a convenient way of interaction. Execution Apps can provide one single layer across multiple traditional transactional systems and thus allow users to focus on relevant process exceptions and executions in one user interface.
* A second trend supports dynamic sets of data analytics cubes, which can be consumed individually and intuitively, thus moving away from predefined, static Dashboards which had been designed centrally in the past to provide standard transparency frameworks.

**2.2.5 Impact on Digital Workforce and Data Democratization**

With the trends for process transformation and organizational change, methodologies such as Process Execution and AI gain increasing relevance. New digital tools and data democratization have a major influence on the digital workforce, with changing requirements and roles. Process Execution enables and supports data analysts to drive execution efficiency, but at the same time requires new skills, roles and responsibilities. A new generation of experts has been educated, with a thorough understanding of computer science, data and IT.

The mindset of a digital workforce differs significantly to the traditional mindset e.g. regarding access to data: while the traditional approach was extremely restricted in respect to data access – typically with “eyes only” principles - the democratization of data is a trend which drives major change towards open data access. Access to data as well as the preparation and analytics of data was traditionally rather a task conducted by specialized experts in organizational silos. As the general perception changes towards an understanding, that data is essential for today’s business, data ubiquity, accessibility, and usability for everybody becomes a standard requirement.

**2.2.6 Data Collection and Preparation**

While projects in the past required high effort to identify, collect and prepare event logs, there is a trend towards usage of standard connectors. In particular structured data from homogeneous systems (e.g. SAP ERP) can easily be identified and read by standard extractors. Discovering e.g. P2P processes across multiple systems has become possible with much less effort due to standard connectors, which require little customization. Automated discovery of event logs is expected to become possible, building on the growing experience gained from data preparation and technical innovations. Machine learning algorithms will understand the format and structure of data in similar source systems, facilitating an automation of data collection and preparation. In addition, transactional ERP systems as well as workflow platforms such as Pegasystems and ServiceNow play an increasing role for process automation and execution. Data collection and preparation across different types of platforms allows seamless execution for e.g. financial and customer data.

**2.2.7 Task Mining**

While Process Mining is based on event logs from backend systems, Task Mining allows for process insights based on recorded activities from individual users, typically from front office systems. Samples for captured activities are mouse clicks, keystrokes, application inputs and field entries, thus providing a much deeper understanding of an individual working behavior. Task mining allows to discover actual human activities with the purpose to identify potentials for improvement. Any activity can be recorded, including phone calls, eMail or excel documentation, where no log files are available, and data is stored in unstructured format. While task mining provides a micro-picture of individual behavior and thus allows optimization of individual tasks, it does not allow insights into overarching operational processes, which can only be visualized with Process Mining. Task mining typically complements Process Execution as a “magnified” analysis of actual user behavior e.g. in Call Centers. Solutions have matured quickly and become a valuable support for operational experts.

**2.2.8 Cloud Technology**

Storing digital traces in a public cloud has become commonly accepted and will support the possibilities to use proven algorithm for extraction and customization of data, deploy standard use cases and benefit from analytics available in the Cloud. Hosted AI is expected to become attractive and available in form of Software as a Service (SaaS) and accessible with standardized Application Programming Interfaces (APIs) to provide applications, technology, and best practices to a wide number of users.

**2.2.9 IIoT Platforms**

The Industrial Internet of Things (IIoT) has set the technical foundation for an extensive access to event logs, as devices become connected to an internet hosted platform, thus allowing easier access to digital footprints, which are generated from these devices. IIoT platforms such as MindSphere already today receive data from millions of single devices, including relevant event logs. Value can be generated for example by understanding manufacturing processes based on the event logs from multiple machines – even across machines at different sites. The collection of event logs from different machines, sites, and companies on one common IIoT platform will allow new use cases such as the visualization of cross-company supply chain processes or inter-company benchmarking. As a crucial benefit, the IIoT platforms provide a standardized and secured environment and protocol, which has been adopted to industrial requirements.

2.3 Midterm Future

**2.3.1 Self-learning and -Optimizing Systems**

With AI becoming more mature and suitable to assist even in environments where profound high domain knowledge is required, technology will evolve towards self-learning and -optimization. Imagine a process execution system, which is autonomously capable to learn, i.e. to detect and resolve process inefficiencies. Like self-driving cars, there will be “self-driving” Process Execution tools which are capable to learn factors which determine efficient process flows and autonomously suggest or even initiate measures to optimize process efficiency including optimization of variants and reduction of process exceptions.

**2.3.2 Artificial Intelligence**

While the impact of AI, which has been experienced in operational use cases to date, has been limited, it will grow up to its promises. Some innovative providers show exciting use cases with virtual process analysts discovering and documenting actual processes by imitation learning. A virtual digital companion learns from actual and optimum process handling and is thus trained to become an accepted artificial co-worker, understanding also complex domain know-how, which is the big challenge in the B2B environment. Virtual companions are trained to identify and remediate process flaws, which can start with simple, repeatable process tasks such as the removal of delivery blocks. Besides all excitement about AI, it must remain explainable in order to ensure ethical data usage with clear transparency about what and how AI is applied. AI governance will play an increasing role and will have a significant impact on the acceptance of these new technologies in particular in a corporate environment.

**2.3.3 Benchmarking**

Process Mining makes process efficiency measurable and transparent. As it is based on big data and facts, it is predetermined for benchmarking purposes. Standard processes such as P2P and O2C will be benchmarked on operational performances such as automation rate, throughput time or rework across different organizations. With digital traces available on standard platforms and in the cloud this will also become available as a self-service, where companies can access benchmark data – based on appropriate data anonymization – to assess their own performance versus other market players. And consulting companies will be able to lift cross-company benchmarking analysis to a new level of data foundation, as benchmarking can be conducted based on the full set of all relevant events from different players.

2.4 Longterm Future

**2.4.1 Inter-Company**

The long term perspective provides significant economic and ecologic benefits through optimization of cross-company supply chains, based on data from different companies and sources. Process optimization will become possible for inter-company value chains, including supplier, manufacturer, freight forwarder and customer. Companies like Slync already today offer multi-party supply chain interaction with a high degree of automation, across different organizations and multiple data sources. The value proposition offers logistics orchestration across manufacturers, suppliers, freight forwarder and customers. With Process Execution, this could be taken to a new level by understanding the extended end-to-end process chains. On-time delivery, integrated manufacturing and optimization of stock/working capital are just a few benefits of a transparent supply chain processes, which can be monitored and managed with the support of Process Execution. Empowering the business partner with access to own process data will allow all parties to benefit. Besides economic benefits this will lead to a sustainable ecological optimization due to the wholistic approach, which will allow to reduce e.g. the number of empty deliveries, reduce waste and allow for a better resource management and more sustainable business.

**2.4.2 Sustainability**

The sustainability revolution should be supported by technological innovations such as Process Execution. Think about process inefficiencies in your immediate environment and how better process efficiency could support sustainability: from traffic congestions to waiting times in hospitals, from wasted time in call center queues to waiting times for bureaucratic decisions, from delayed goods deliveries to delayed flight arrival. Process inefficiencies are omnipresent, producing friction, waste and avoidable emission. Understanding the end to end processes allows to track down inefficiencies and reduce waste in time and resources. While Supply Chain Management is probably the primary field, where Process Mining can support a sustainability revolution, CRM and other functions can equally support as ecological driver. The management of resources in ERP systems (financials, materials, assets and HR) will become more efficient with Process Mining, thus allowing to optimize scarce resources. In a world with more than 7.9 billion people and increasing issues due to limited resources this will become a strong purpose.

**2.4.3 B2C**

While the primary focus on Process Execution to date has been on business-to-business (B2B) processes, there is a huge potential for process optimization in the business-to-consumer (B2C) field. Understanding consumer interactions with the additional dimensions of time and activity sequences allows to better interpret and predict e.g. consumer behavior. B2C use cases could include for example activity tracking for the timing and sequence of user clicks on shopping pages or in social media platforms. Understanding of strategies, how users approach challenges such as search for restaurants or music, appear valuable and might allow for trail prediction. As another example, the insight into the search sequence for web offerings could – based on large amounts of activities – not only be interesting for psychometric analysis, but also for product management and sales.

2.5 Vision of a Digital Enabled Organization

Imagine an organization which has been automated for most standard processes, such as procurement of indirect material, financial transactions, order deliveries and customer order processing. Standard tasks are conducted automatically, supported by an AI, which is capable to learn not only how to execute standard cases, but also minor exceptions, conducting immediate actions and corrections. This “intelligent system” processes most of all activities with zero human touch, and humans only interfere exception based, thus providing a high process reliability at minimum transactional cost.

Data ingestion from diverse source systems is supported by AI, which allows to identify and customize structured and unstructured data from various sources such as ERP or workflow systems. Cloud technology is commonly established as basis for data hosting, collaboration, and data mining, with the application providers applying continuous monitoring and optimization. Streamed event data allows real time process analytics for immediate reaction e.g. for customer interaction. Platforms offer standard Apps for process execution in a secure environment and share best practices for process handling and monitoring.

As most operational processes have been fully automated, the focus of Process Execution changes. Based on this vision, there will be less demand for transparency and discovery in respect to today’s focus areas. Standard support processes such as P2P and O2C provide decreasing marginal benefits, as they are mostly optimized and the focus shifts towards more challenging processes such as e.g. customer interaction, manufacturing, HR and legal proceedings. Besides inter-company automation, process optimization is happening cross-organization in integrated supply chain process flows. Exception based activities remain in focus, as they require optimization with appropriate digital tools. Similar to tele-medicine, remote diagnosis and optimization of processes based on smart automation will be available through dedicate Process Mining Analysts, who are alerted by intelligent virtual assistants, which conduct a continuous real-time monitoring and provide predictive and proactive alerting.

The role of humans has changed significantly: mundane tasks have been completely automated and new tasks and roles emerged instead. The focus of human responsibility has changed towards data analytics and steering, using tools which are provided by the digital enabled organization. Process analysts use digital tools such as virtual assistants, which collect data from Process- and Task Mining, thus empowering the digital enabled organization. Value generation shifts towards service innovation. In their book “Dreams and Details” Snabe and Trolle describe how to reinvent business from a position of strength and with a compelling vision. An innovative “’Digital Enabled Organization” could provide the dream to set the mindset and framework to unleash the human and digital potential.

As a positive ecological contribution, the process optimization has yielded significant reduction in carbon footprint e.g. due to reduction of empty trips and optimization of routings. Transactional costs have been reduced to a minimum.

3 Conclusion

While the first two decades of Process Mining have been focused on transparency and discovery, the real impact in a corporate environment is driven through intelligent execution management. Process Mining provides an excellent foundation, which will be enhanced with standard process execution Apps, common extractors, process transformation capabilities and artificial intelligence in order to execute business processes in an easier, smarter and more efficient manner. Thus Process Mining is the base for a much wider field which is still to be developed.

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