The Impact of Object-Centric Process Mining on Business Efficiency: A Case Study Approach

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KEYWORDS

Object-centric process mining (OCPM), process mining, business process optimization, business efficiency, Celonis, business process management, data modelling

ABSTRACT

Although traditional process mining techniques have enabled substantial enhancements in process transpa-rency and optimization, they frequently prove inadequate for capturing the intricacies of actual business processes, which are characterized by multiple interacting entities. OCPM addresses this limitation by allowing a more nuanced and multi-dimensional analysis of processes. By integrating both traditional and object-centric approaches, the study provides a comparative analysis of the performance and utility of each method, highlighting the specific benefits of OCPM in improving process transparency and operational efficiency. The findings reveal that OCPM offers a more comprehensive understanding of complex business operations, which is crucial for enhancing decision-making and achieving better performance outcomes. Additionally, the study outlines the challenges and opportunities of implemen-ting OCPM in real-world settings, emphasizing its practical implications for business process optimization.

INTRODUCTION

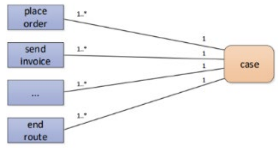
The continuously changing landscape of modern business processes requires a commitment to continuous improvement in operational efficiency and effectiveness. To remain competitive and adapt to fast changing market needs, organizations are increasingly relying on innovative methodologies and technologies. In this context, process mining has emerged as a crucial tool, enabling organizations to extract valuable insights from event logs and enhance their workflows (W. Van Der Aalst et al., 2012). The conventional approach to process mining involves analyzing the sequence of activities that comprise a particular business process, thereby providing a snapshot of how tasks are executed. Notwithstanding, the complex nature of contemporary business operations, which often encompass a multitude of interrelated entties, necessitates a more nuanced approach.

The emergence of object-centric process mining represents a big leap forward in this field as it enables detailed analysis of business processes at granular level from several aspects. By meeting interactions between different objects like orders, invoices, and deliveries it provides a wider view of process dynamics than before. (Bolt et al., 2016).

In recent years, PM has undergone a significant evolution, progressing from traditional approaches to more advanced techniques that can effectively address the complexities inherent to modern business environ-ments. One of the most promising developments in this field is object-centric process mining (OCPM). In contrast to the traditional PM approach, which is concerned with a single case, OCPM permits the examination of processes that involve multiple interacting objects and it gives an augmented view on interactions between processes.

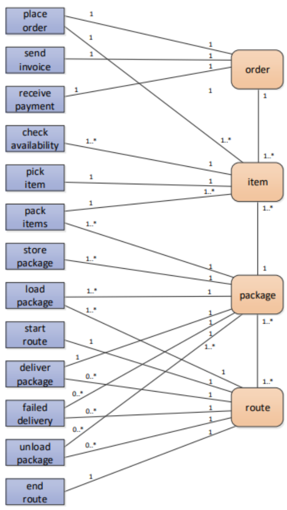
The traditional approach to process mining is based on the premise that each event log is associated with a single case notion. This reductionist approach frequently proves inadequate for capturing the complex, multifaceted nature of real world processes, where an event may be associated with multiple cases or objects. To illustrate, an order handling process may entail the participation of multiple related entities, including orders, items, packages, and route (W. M. P. Van Der Aalst, 2019).

Figure 1: Concept of a single case notion in classical process mining



Source: W. M. P. Van Der Aalst, (2019) This assumption results in the flattening of event data, which can obscure the true complexity of the process and result in the loss of crucial information. The generated models may not accurately reflect the intricacies of the actual processes, which may result in incomplete or misleading insights. (W. M. P. Van Der Aalst, 2019).

Figure 2: Overview of the interconnections between activities and object types in everyday life



Source: W. M. P. Van Der Aalst, (2019)

The objective of classical PM is to identify the sequence of events within log cases. Two principal issues may impinge upon the process of analysis. In real-world scenarios, events often pertain to multiple cases (convergence) or recur multiple times within a single case (divergence). The traditional PM approach, which assumes that each event belongs to a single, unique case, is ill-equipped to handle these complexities. Convergence results in the repetition of events across multiple cases, which increases the number of events and distorts the true nature of the process behavior. Conversely, divergence gives rise to the formation of artificial loops within the process model, whereby repeated events within the same case are erroneously interpreted as occurring in a sequential rather than simultaneous manner. Such misinterpretation can result in process models that are either overly or insufficiently fit for purpose, thereby reducing their accuracy and utility (W. M. P. Van Der Aalst, 2019).

Complex procedures are consolidated into single-case event logs, which results in the loss of crucial relational data. In cases where multiple objects are involved in a process, their interactions have the potential to exert a noteworthy influence on the eventual outcome. The application of traditional PM techniques often reduces data complexity, resulting in the intricate contextual relationships between different objects being lost. The aforementioned flattening process has the potential to result in inaccurate analyses and suboptimal decision-making, as it fails to take into account the nuances of the process dynamics (W. M. P. Van Der Aalst, 2019).

A further significant drawback of traditional PM is its lack of scalability. As the quantity of event data increases, traditional PM algorithms can become computationally intensive, which may result in performance bottlenecks. This is particularly problematic in large organizations with high-frequency processes and extensive event logs, where the issue is compounded. The necessity for the adequate handling and processing of large datasets is of paramount importance, and traditional PM techniques frequently prove inadequate in this regard. The single-case notion serves to exacerbate this issue, requiring the undertaking of separate analyses for each case type, as opposed to allowing for a holistic analysis that considers all relevant entities and their interactions. This can result in the repetition of computations and an increase in processing time, which further constrains the scalability of traditional PM approaches (Adams & van der Aalst, 2021).

In addition to the aforementioned methodological limitations, traditional PM also encounters difficulties in integrating disparate data sources. In the contemporary business environment, data is often generated from many sources, including transactional systems, Internet of Things (IoT) devices, and social media. The traditional PM techniques, which are primarily designed to handle structured event logs from transactional systems, frequently prove inadequacy for the effective integration and analysis of these heterogeneous data sources. This limitation constrains the capacity of organizations to obtain extensive insights from their process data (W. M. P. Van Der Aalst, 2019).

In conclusion, although conventional PM has yielded notable benefits in enhancing process efficiency and compliance, it is constrained by a number of critical limitations. These include its reliance on single-case event logs, the loss of relational information through data flattening, inadequacy in handling concurrency and multiobject interactions, scalability challenges, and difficulties in integrating diverse data sources. The advancement of methodologies is essential to address the aforementioned limitations. One promising avenue is the development of object-centric process mining, which can provide a more inclusive and accurate view of complex business processes (Adams et al., 2022).

The main aim of this paper is to study the influence of object centric process mining on business efficiency, especially in relation to Order to Cash (O2C) and Purchase to Pay (P2P) processes. The O2C process is essential for businesses because it covers the entire sequence of events, from receiving orders to collecting payments. The optimization of this procedure enables organizations to enhance cash flow, decrease operational expenses, and enhance customer satisfaction, as stated by Van Der Aalst et al. (2012). The research seeks to address the following questions:

1. *How can object-centric process mining improve the efficiency and effectiveness of the Order to Cash process compared to traditional process mining methods?*
2. *What are the specific benefits and challenges encountered when implementing object-centric process mining in a real-world context using Celonis?*

This paper distinguishes itself by integrating key theoretical concepts related to Object-Centric Process Mining (OCPM), providing a solid foundation for developing a mockup dashboard tailored to analyze interconnected processes. It builds upon state-of-the-art methodologies, including advancements in event log standards like OCEL and tools for multi-object process visualization. By leveraging these foundations, the OCPM analysis aims to demonstrate the potential of OCPM in improving process transparency, optimizing workflows, and enabling better decision-making.

The creation of this paper was guided by the seven principles of Design Science Research (DSR), ensuring a structured and iterative approach to its development and evaluation. While adhering to the core tenets of DSR, this work embraces flexibility, as suggested by Hevner et al. (2004), to focus on practical outcomes rather than rigid procedural adherence. By balancing systematic exploration with pragmatic design, this paper under-scores the role of OCPM in addressing real-world challenges and highlights the potential for further research and implementation of such innovative IT artifacts.

OBJECT CENTRIC PROCESS MINING

Introduction to Object Centric Process Mining

OCPM is a significant step forward in the field of process mining. It overcomes constraints of traditional techniques by focusing on the interactions and relationships between multiple objects within complex business processes. The predominant methodologies employed in PM are largely based on the analysis of single-case event logs, wherein each event is associated with a specific object or case. This approach is frequently inadequate for capturing the multifaceted nature of real-world processses, particularly in contexts such as Enterprise Resource Planning (ERP) systems, where events are associated with a range of objects, including orders, items, invoices, and shipments. The multifaceted nature of these interactions necessitates a more comprehensive approach to accurately reflect the operational dynamics of these systems (Adams, et al., 2022).

The fundamental innovation of OCPM resides in its capacity to process object-centric event data, which links events with multiple objects in lieu of a singular case. This change in thinking permits a more broad and detailed examination of processes. Object-centric event logs (OCELs) represent an extension of traditional logs, incorporating references to multiple objects for each event. This approach allows for the preservation of the complex interdependencies inherent in the processes, which would otherwise be lost. To illustrate, an event in a procurement process may relate to an order, several items within that order, and corresponding invoices. This captures the true nature of the process dynamics, supporting advanced analyses and insights into complex business environments (van der Aalst, 2019).

At the foundation of OCPM is the concept of object-centric event logs. Unlike traditional case-centric event logs that capture events at the process instance level, object-centric event logs store information about the lifecycle of individual business objects and their relationships. This data structure allows OCPM techniques to model the complex interactions between different entity types within a process. (Berti et al., 2023)
Object-centric event logs typically include the following key elements:

- Events: Object-centric process mining deals with discrete events representing actions in a system or process, like order approval or payment. Each event is unique, timestamped, and may have attributes. Events are categorized into types.
- Event Types: Events are grouped based on their nature, such as Order Created or Invoice Sent. Each event type represents a specific action in the process.
- Objects: Objects in object-centric process mining represent entities involved in events, like products or orders. Objects have attributes that can change over time.
- Object Types: Each object belongs to a type, like Product or Invoice.
- Timestamps: The timing of when each event occurred
- Qualifier: Provides additional context or qualifiers related to objects or their relationships. (Berti et al., 2023)

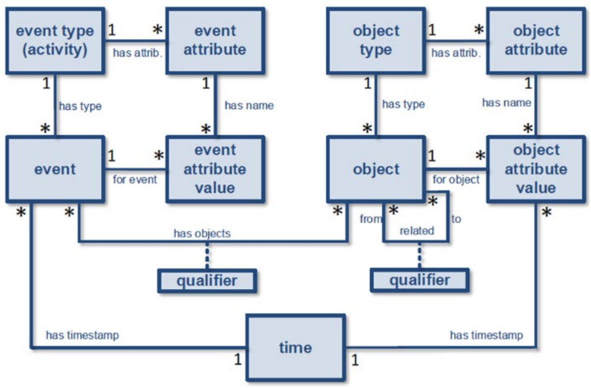
The diagram below represents an enhanced data model that supports object-centric process analysis. It extends the previous model by introducing the concept of "Object Type" and relationships between different objects.

The relationships include:

- An Event has an Event Type and can have multiple attributes stored in Event Attribute and Event Attribute Value.
- An Object has an Object Type and can have multiple attributes stored in Object Attribute and Object Attribute Value.
- An Event is associated with one or more Objects through the "has objects" relationship, allowing events to be linked to multiple objects.
- Objects can have relationships with other Objects, such as "from" and "to" relationships, representing transitions or flows between objects.

- The Qualifier entity provides additional context or qualifiers for the relationships between objects.
- Each Event and Object state change has an associated timestamp captured in the Time entity.

Figure 3: OCPM Relationships



Source: Van Der Aalst (2023)

This meta data model enables advanced object-centric process analysis capabilities, such as tracing the end-to-end lifecycle of different object types, analyzing object state changes and transitions, identifying bottlenecks or inefficiencies in object handling, performing root cause analysis based on object attributes and relationships, and conducting comparative analysis across different object variants or segments.

Advantages of object-centric process mining

Object-Centric Process Mining (OCPM) offers significant advantages over traditional process mining (PM) by addressing the complexity and interconnected nature of modern business processes. One key benefit is its single data extraction process, which captures all relevant objects and their interactions upfront. Unlike traditional PM, which often requires repeated data extraction to integrate new sources or answer additional questions, OCPM's unified approach saves time, reduces redundancy, and ensures consistent data representation for all analyses (Adams & van der Aalst, 2021).

OCPM also excels in modeling relationships between diverse entities, a limitation of traditional PM. By explicitly representing connections and dependencies—for example, between suppliers, transport vehicles, inventory, and customers in a supply chain—OCPM helps organizations understand how changes or delays in one area affect others, enabling better decision-making (Aalst, 2023).

Furthermore, OCPM offers a three-dimensional view of processes, considering interactions, attributes, and temporal aspects. This contrasts with traditional PM's linear, event-focused perspective. The multidimensional approach uncovers insights and optimization opportunities across organizational domains, providing a comprehensive understanding of complex workflows (Adams & van der Aalst, 2021).

Challenges of object-centric process mining

OCPM represents a significant advancement in process mining, offering deeper insights and capturing complex interactions among multiple entities. However, it comes with notable challenges, including data integration, scalability, computational complexity, data quality, and practical implementation (Adams & van der Aalst, 2021).

Integrating diverse datasets with varying formats and structures is a complex, error-prone process, particularly with large, heterogeneous data. Scalability remains a hurdle as processing Object-Centric Event Logs (OCELs) demands significant computational power, especially in large-scale environments like global supply chains. Additionally, the computational complexity of analyzing multiple objects and their interactions can create bottlenecks, requiring advanced techniques such as machine learning and parallel processing to ensure performance. Data quality is another critical concern, as inconsistent or incomplete data can lead to flawed models, necessitating resource-intensive preparation and validation. Practical implementation challenges include transitioning from traditional process mining to OCPM, training staff, and demonstrating tangible value to stakeholders (Adams & van der Aalst, 2021).

Overcoming these hurdles through innovation and robust methodologies is essential for OCPM's adoption and its potential to drive process optimization and operational excellence (Adams & van der Aalst, 2021).

Visualization of Interconnected Processes: Celonis Process Sphere

Celonis Process Sphere marks a significant evolution in the field of process mining by fully embracing object-centric process mining. Leveraging data from multiple enterprise systems, the Process Sphere uses sophisticated algorithms and machine learning techniques to visualize and analyze end-to-end processes in a three-dimensional format. This innovative tool enables organizations to identify inefficiencies, bottlenecks, and compliance issues with unparalleled accuracy, facilitating more effective decision making and process optimization (*Celonis Moves from 2D to 3D Process Mining during Celosphere 2022 - Techzine Europe*, n.d.).

Developed in collaboration with RWTH Aachen University's PADS group, the Process Sphere builds on foundational research, including the OCEL standard and OCPM tools, ensuring robust and reliable analysis. Unlike traditional two-dimensional process mining tools, the Process Sphere's 3D perspective provides a more comprehensive view of complex workflows. Its innovative subway map-like interface simplifies complexity, allowing users to eplore interdependencies and uncover hidden patterns.

By integrating process analytics with an intuitive visualization, the Process Sphere facilitates better decision-making and operational optimization, helping organizations address root causes of challenges effectively (*Post-2022-Process-Sphere.Pdf*, n.d.)

CASE STUDIES AND OCPM-ANALYSIS

Introduction of Business Cases

WoodCorp Inc., a German manufacturer of wooden pallets and crates for shipping, faces significant operational challenges, particularly with on-time delivery and volume compliance. The company's raw materials, mainly wood, are stored in both automated and non-automated warehouses. Production starts before or after order confirmation, using both push and pull strategies. With a current delivery rate of just 64.46%, WoodCorp suffers financial losses due to delays. Despite its large network of warehouses and partners like UPS, DHL, and FedEx, the company faces ongoing delivery issues, resulting in annual losses of approximately €11.8 million.

WoodCorp is looking to gain a more in-depth understanding of its order to cash process and identify ways in which it can improve its on-time delivery performance. By outlining a clear roadmap for improving on-time delivery performance, the WoodCorp case aims to demonstrate the tangible benefits of PM and how it can be further optimiyed using OCPM.

The current system is disjointed, leading to fragmented data across procurement, finance, and operations departments. This fragmentation results in duplicate data entries, inconsistent information, and prolonged processing times. The impact on business is substantial. Woodcorp's ability to manage procurement efficiently is compromised, causing increased operational costs, supplier dissatisfaction, and missed opportunities for bulk purchasing discounts. Delays and errors in processing purchase orders and payments have strained relationships with suppliers, potentially disrupting the supply chain's reliability. Moreover, the absence of real-time data and analytics capabilities hampers decision-making and strategic planning.

OCPM Analysis

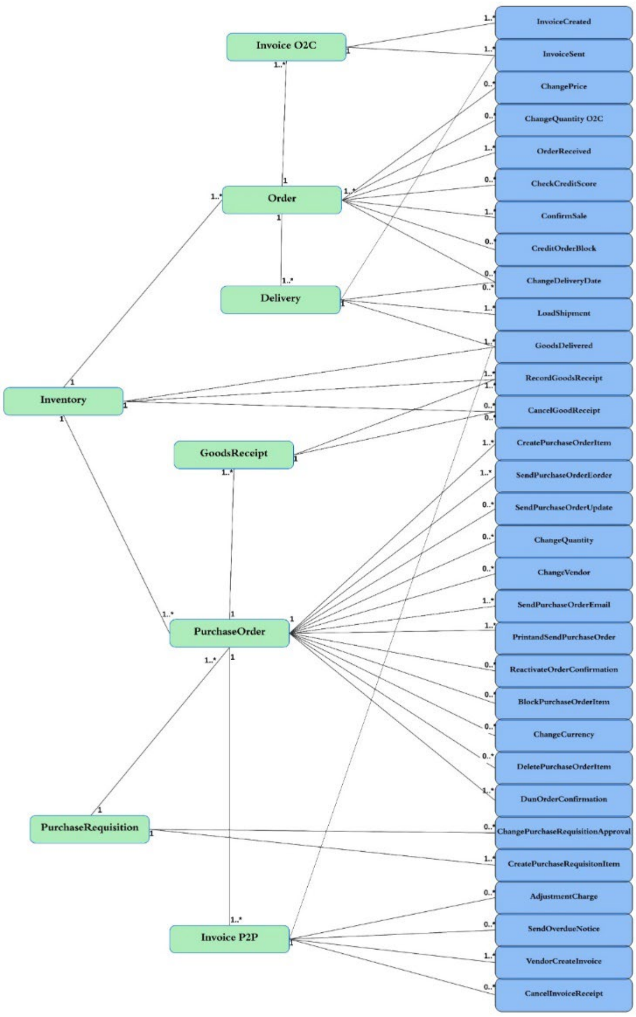
This chapter demonstrates the use of object-oriented process mining by linking two related business processes: the Order to Cash (O2C) process and the Purchase to Pay (P2P) process. We aim to demonstrate the capabilities of object-oriented process mining when dealing with multiple interacting object types in different but related business functions

The first step in conducting an object-centric process mining analysis entails the creation and utilization of an object-centric event log. These logs differ from traditional event logs because they allow for the tracking of multiple object types within a single process. Every event in an object-centric event log is associated with one or more objects, which capture their interactions over time. This structure facilitates the analysis of complex dependencies between different entities. For the purpose of this analysis, the object types identified in the integrated O2C and P2P processes are:

- Order - refers to the customer's request for goods. As such, it includes the following attributes: Order ID, Product Type, Ordered Quantity, Customer Market, Customer ID, Order Date, Order Value and Unit Price.
- Delivery - the logistical process of transporting the goods ordered by the customer from the warehouse to the customer's location. The delivery object contains valuable information: Delivery ID, Delivery Company, Delivered Quantity, Delivered Date, Promised Date, Delivery Status (e.g., tolerance met), Delivery Unit (e.g., kg) and Warehouse Type.
- Invoice O2C - a financial transaction that occurs after the successful delivery of goods. Details related to the invoice process are included in this object: Invoice ID, Invoice Value (derived from the order value), Invoice Date and Customer Country.
- Purchase Requisition - is a company-created document that requests the purchase of goods. The following attributes are required for this object: Purchase Requisition ID, Plant, Unit, Quantity, Document Type, Material Number, Vendor, and Item Number.
- Purchase Order - a formal document issued by a buyer to a seller, indicating the types, quantities, and agreed prices for products. It includes the following details: Purchase Order ID, Purchase Requisition ID, Document Type, Order Type, Created Date, Vendor, Currency, Item Number, Material Number, Order Quantity, Order Unit, Net Price, Plant and Storage Location.
- Invoice P2P - issued after the delivery of the goods or services and their receipt by the buyer. Therefore, the below information is required: Invoice ID, Purchase Order ID, PO Line, Amount, Currency, Company Code and Vendor.
- Goods Receipt - document used to record the receipt of goods or services by the buyer. The following attributes are pertinent for this object: Goods Receipt ID, Purchase Order ID, Item Number, Vendor, Plant and Storage Location.
- Inventory - represents the physical stock of goods held by the organization. It is a critical object type that connects both the Purchase-to-Pay and Order-to-Cash processes, as changes in inventory levels directly impact the organization's ability to fulfil orders and meet customer demand. Inventory ID, Purchase Order ID, Order ID, Material Number.

Object to object relationships are defined as part of object types. They show the expected relationships of objects to each other in business processes. The diagram below shows the relationships between our objects. Each of these objects represents a crucial stage in the procurement lifecycle, from initial purchase requisitions to final payment processing.

Figure 4: Identified objects, events, and relationships



Source: Own Work

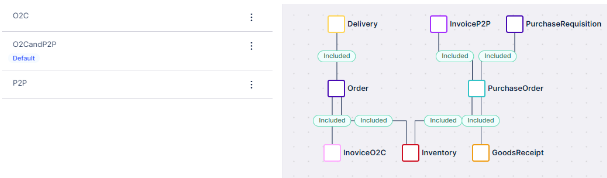
OCPM focuses on discrete events that represent distinct actions that occur at specific times. Unlike traditional PM, where events are linked to a single instance, OCPM links events to multiple types of objects, enabling multi-dimensional analysis of complex processes. These event-to-object (E2O) links convey how events affect or are affected by different objects, revealing rich interdependencies within the system. The diagram below displays all the events that have been detected and their correlation with our objects. All of our events involve their unique id and timestamp, and additional attributes related to each event.

After identifying Object Types, Events and Relationships the next step is to build an object-oriented data model. The process for building an object-oriented data model is focusing on the key steps of data extraction, transformation, and population. We will utilize the Celonis tool to implement this process. The initial step involves connecting to the source system and extracting raw data. Celonis offers pre-built extraction methods for popular systems such as SAP ECC and Oracle EBS that can pull data directly into the OCPM database. However, for this paper's purposes, we have manually uploaded the files. Although this approach works for demonstration purposes, it is much more efficient to connect to the database if possible, so that data can be dynamically refreshed and updated.

When the data is retrieved, we start modelling the business scenario by defining our object and event types, which we introduced in the previous section. The subsequent step entails implementing SQL transformations to utilize the raw extracted data and populate the appropriate object and event tables within the OCPM schema. This involves carefully defining the relevant tables and mapping them to appropriate objects. For example, for the O2C process, we used case and activity tables that were mapped to the relevant objects associated with the process. The P2P process, on the other hand, relied on several tables, such as the EBAN table containing information for purchase orders, which was mapped to the Purchase Order object.

Once the core model is populated with objects, events, and their relationships, we can define perspectives and generate event logs. These perspectives help to narrow down the focus to specific parts of the process, making it easier to analyze. For example, we could create a perspective for the O2C process that includes objects such as orders, invoices, and deliveries, along with events such as order creation and goods delivery. The event logs are then created within these perspectives, providing a sequence of events linked to specific objects. This is key to process analysis in Celonis.

Figure 5: Building a perspective that combines the two processes

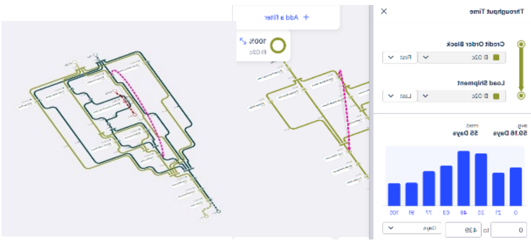


Source: Own Work

The final phase involves the publication and execution of the model within the OCPM data pool. Once the model has been fully configured and populated with data, it can be published and made accessible for analysis. When dealing with dynamic data and therefore databases, to keep everything up to date, data jobs are scheduled to update the model regularly with added information from the source systems. This ensures that the data reflects the most recent business operations, enabling organizations to monitor their processes in real-time, identify inefficiencies, and make necessary enhancements. There were several limitations to the process discovery and analysis of process variation and object behavior using OCPM in this study, which are described later in this article. These limitations constrained our ability to fully leverage the potential benefits of OCPM. Although OCPM offers considerable flexibility in visualizing and analyzing the relationships between diverse objects, the immediate advantages of this transformation may not be evident in all scenarios, particularly in cases of limited scale or data availability, such as the present instance.

Nevertheless, the study has indicated that OCPM offers a more adaptable and comprehensive understanding of interrelated processes than conventional PM techniques. By allowing multiple objects to be analyzed simultaneously, OCPM can link two or more processes in a way that traditional PM would struggle to accomplish effectively. This flexibility's value depends mainly on the specific needs of the business and the data's complexity. Before implementing OCPM, organizations should carefully assess their business case, as the benefits of this approach are context dependent.

Figure 4:Connecting events from different objects to calculate throughput time

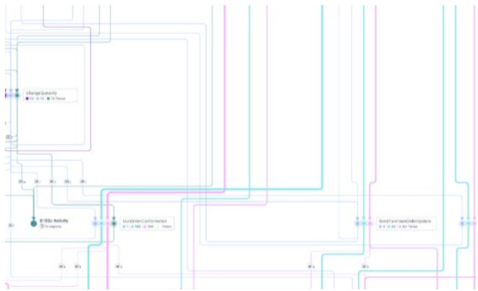


Source: Own Work

Unlike traditional process mining's step-by-step approach, OCPM focuses on individual cases or objects, enabling organizations to uncover concealed bottle-necks and inefficiencies that may otherwise go unnoticed. It provides a holistic view of multiple objects and their relationships, which allows analysts to gain insight into the interdependencies that drive process performance.

In our case study, we used the Process Explorer in Celonis to examine different objects and their associated activities. For each object, we were able to select the number of activities to include in the analysis and the connections between those activities. This resulted in a 'metro map' visualization, where each station repre-sented a different activity. As discussed earlier, each activity may involve sever-al different object types, allowing us to observe various aspects that could influ-ence the performance of processes, such as the fulfilment of an order.

Figure 5: A piece of our "metro map"



Source: Own Work

Regardless, while OCPM provides a more detailed view of processes and interactions, whether it delivers immediate and tangible benefits depends heavily on the specific context of the business and the quality of the available data. Organizations with complex, multi-object processes may find OCPM invaluable in identifying and resolving inefficiencies, but smaller or simpler cases may not derive as much benefit from this approach. Therefore, it is advisable to conduct a comprehensive assessment of the organization's process complexity, data quali-ty, and specific objectives prior to selecting OCPM. The WoodCorp case demonstrated the method's ability to uncover more profound insights into process rela-tionships, but its utility in smaller-scale cases remains limited by data availabil-ity and process complexity.

EVALUATION AND DISCUSSION

Based on the foundations established previously this chapter shifts the focus to the primary objective of this study: investigating the impact of implementing object-centric process mining on business. The directions of our study have been shaped by the research questions outlined in introdcution.

This first question focuses on the comparative analysis of traditional process mining methods versus object-centric process mining, specifically in terms of their impact on the efficiency and effectiveness of the O2C process. *How can object-centric process mining improve the efficiency and effectiveness of the Order-to-Cash process compared to traditional process mining methods?* Due to certain limitations encountered during the study, this question is addressed primarily from a theoretical perspective. As previously discussed, traditional process mining is constrained by its reliance on single-case identifiers. This approach may result in a fragmented view of processes, as it typically analyses each object—such as orders, deliveries, or invoices—in isolation. In contrast, object-centric process mining, which incorporates multiple objects, provides a more comprehensive overview. The integration of diverse objects within a unified analysis enables the capture of intricate relationships and interactions between disparate events.

To illustrate, in the context of the Order-to-Cash (O2C) process, object-centric process mining permits the combination of objects, including orders, deliveries, and invoices, within a unified framework. This holistic approach allows for a more accurate identification of inefficiencies and provides clearer insights into the specific locations within the process where such issues occur. Traditional process mining, on the other hand, conducts separate analyses for each object, limiting its ability to identify such bottlenecks or violations. As a result, object-centric process mining presents a significant advantage in offering a more de-tailed and interconnected view of the O2C process.

Another key benefit of using object-centric data model is its ability to create more accurate and detailed process maps that reflect the intricate realities of business operations. Unlike traditional models that may oversimplify processes, object-centric models capture the full complexity of interactions between various entities, offering a more faithful representation of the actual process landscape. This detailed mapping is crucial for organizations looking to optimize their processes, as it provides a clearer picture of where improvements can be made.

A further significant advantage of object-centric process mining is its ability to reduce system dependencies. By unifying processes and data into a standardized format, organizations can create a consistent and reliable process model that is less reliant on specific systems or technologies. This standardization not only facilitates integration and scalability across different platforms but also ensures that business insights are derived from a holistic view of the process, rather than being constrained by the limitations of individual systems. This approach ultimately leads to more robust and flexible process management, enabling organizations to adapt more readily to changing business environments and technological advancements.

Focusing on the relationships between objects within a process allows for a more nuanced and comprehensive understanding of process dynamics. This approach enhances the visibility of these relationships and significantly improves decision-making capabilities. For example, by analyzing the time it takes to deliver goods to customers using different postal providers, organizations can identify patterns where certain providers consistently result in delayed deliveries. Armed with this insight, companies can proactively choose alternative providers for cases where timely delivery is critical, thereby addressing the root cause of customer dissatisfaction due to late deliveries. This capability to quickly pinpoint and address inefficiencies highlights the value of object-centric process mining in improving customer satisfaction and operational efficiency.

OCPM provides a comprehensive view of process dynamics through the analysis of object relationships, enhancing decision-making. This approach improves efficiency by identifying and addressing insufficiencies and bottlenecks more effectively. Additionally, it simplifies system integration and provides a unified, accurate representation of complex processes.

The second research question examines the benefits and challenges of imple-menting OCPM in a real-world context, using the Celonis tool. *What are the specific benefits and challenges encountered when implementing object-centric process mining in a real-world context using Celonis?* As the adoption of OCPM represents a significant shift from traditional process mining methodologies, understanding these benefits and challenges is critical for organizations considering this approach.
One of the primary challenges involves obtaining access to relevant data and ensuring its quality. In this study, limitations were encountered in acquiring sufficient and appropriate data to construct a robust object-centric data model, which constrained the ability to derive granular insights into the detailed interac-tions between different events and objects within the process. Data quality issues such as inconsistencies, missing values and incomplete records further complicated the modelling process, highlighting the need for rigorous data governance practices in OCPM implementations.

Further, implementing OCPM demands a considerable investment of time and resources. Unlike traditional process mining, which often focuses on a single case identifier, OCPM requires a profound understanding of the various objects that make up a business process and the complex interactions between them. This complexity requires a thorough re-evaluation of existing business processes, data structures and system configurations. Organizations accustomed to single-case process mining may find this transition challenging, as it frequently involves reconfiguring existing systems to accommodate the multi-object framework of OCPM. In addition, the need for specialized knowledge of both business processes and advanced data modelling techniques adds another layer of complexity to the implementation process.

The relative newness of OCPM presents further challenges. As an evolving field, OCPM lacks established best practices and standardized methodologies. This lack of a standardized approach can lead to significant variability in implementation outcomes, making it difficult to predict the success of OCPM initiatives. Organizations that opt to implement OCPM are essentially pioneers in the field and may encounter unforeseen obstacles during the implementation phase. The absence of standardization also raises concerns regarding the reproducibility and scalability of OCPM solutions, particularly in diverse organizational settings. As a result, it is essential for organizations to conduct a thorough analysis to determine whether their processes would benefit from the complex implementation of OCPM, and to assess the potential risks associated with adopting such emerging technologies.

Regardless of these challenges, once OCPM is successfully implemented, it offers numerous benefits. One of the key benefits is the ability to perform data extraction only once, reducing the manual effort typically required in traditional process mining. By integrating multiple objects into a single analytical frame-work, OCPM provides a more holistic view of the process, allowing the identification of inefficiencies and bottlenecks that might be missed with a single-case approach. This integrated view not only increases productivity, but also supports more informed decision-making by providing a comprehensive understanding of process dynamics.

The implementation of object-centric process mining may encounter difficulties due to data accessibility, complexity, and the absence of standardized approaches. However, its potential advantages in terms of effectiveness, adaptability, and comprehensive process insight make it a promising approach for organizations looking to enhance their process mining capabilities. As OCPM continues to evolve, more research and practical experience must be used to develop more robust methodologies and overcome obstacles identified in this study.

Despite the valuable insights gained from this study, it is imperative to acknowledge several limitations that have significantly impacted the depth and scope of the research findings. The limitations stem from both the evolving nature of OCPM as a field, as well as the practical challenges encountered during the research.

One of the primary limitations of this research is that OCPM is still a relatively new discipline within the broader realm of process mining. Given its novelty, there is a lack of academic literature and empirical studies that examine the practical implementation of OCPM in different industries. Although theoretical frameworks and initial studies have established the foundations, the field remains underexplored, especially in terms of real-world applications. The absence of comprehensive research presents a challenge in validating the study's findings against a broader body of knowledge. Moreover, the absence of well-documented case studies and practical examples hinders the possibility of benchmarking and generalizing the outcomes across diverse business contexts.

The absence of practical examples also complicates the analysis workflow, as it is difficult to draw on already existing examples of how to address specific challenges inside the OCPM implementation.

Another important limitation relates to the practical application of OCPM in industry. OCPM has only been adopted by some companies, which means that access to reliable databases specifically dedicated to OCPM analysis is limited. In this study, we encountered the challenge of utilizing a dataset that was not specifically designed for OCPM. The data we received was originally intended for conventional process mining analysis, which typically focuses on logs of individual events rather than the multiple, interrelated objects that are central to OCPM. Moreover, the data set’s limitations extended to the level of detail available for individual events. For example, critical information regarding event connections and object interactions was often insufficient, preventing a deeper exploration of process variants and behaviors. In order to maximize the benefits of OCPM, it is essential to have data that captures the full complexity of an organization’s processes. This includes having rich event logs with multiple object types and detailed relationships between events, which were not available in this study. The absence of such data limited the scope of our analysis, making it dif-ficult to draw definitive conclusions about the full range of interactions within the O2C process.

Furthermore, the limitations of the Celonis software platform used during the study posed a significant challenge, given the limitations of our account option. Our access was restricted to a training account, which regrettably did not provide all the advanced functionality required for a comprehensive implementation of OCPM. This prevented us from fully exploring and utilizing the sophisticated process visualization, data modelling, and analysis tools that Celonis offers. As a result, we were unable to fully utilize OCPM's potential to visualize and analyze process flows at a granular level. The extent of our findings was limited due to the inability to explore certain process enhancements or optimizations that could have been revealed through a more sophisticated utilization of the software.

Although OCPM has significant potential for improving process transparency and uncovering inefficiencies in intricate, multi-object processes, there is still room for improvement. This study demonstrates the importance of robust data collection, advanced software functionality, and further research to fully realize its potential. Future research should prioritize addressing these limitations by utilizing more comprehensive data sets, exploring advanced software tools, and conducting comprehensive empirical analyses across diverse industries.

CONCLUSION

This article examines the potential of object-centric process mining (OCPM) to enhance the Order-to-Cash (O2C) and Purchase to Pay (P2P) process, using the Celonis process mining platform. The primary objectives of this study were to assess the efficiency of OCPM in comparison to conventional process mining methodologies, to identify the obstacles associated with its implementation, and to evaluate its potential to enhance business performance. Combining a thorough literature review with an in-depth case study, the investigation offered insights into both the advantages of OCPM and the substantial obstacles it presents.

OCPM offers a more nuanced and comprehensive analysis of complex business processes, considering multiple interconnected entities, such as orders, invoices, and deliveries. However, the process of implementing it poses numerous significant obstacles. The development and management of object-centric data models are notably complex and require advanced technical expertise that may not be readily available in many organizations. Furthermore, OCPM requires extensive data collection and significant computational resources, which can impose significant financial and logistical burdens, particularly on smaller enterprises. The steep learning curve associated with OCPM tools, such as Celonis, further complicates adoption, requiring specialized training. Furthermore, the integration of data from disparate sources presents obstacles, particularly in organizations with siloed or fragmented systems, which may result in inconsistencies in data analysis. Additionally, the detailed and complex insights generated by OCPM can result in information overload, underscoring the need for clear analytical objectives and strategic focus.

OCPM has considerable potential for improving the analysis and optimization of business processes, but the challenges identified in this study must be carefully addressed. Future research should prioritize the development of solutions to mitigate these obstacles, including more intuitive tools, enhanced training resources, and strategies for managing data complexity. Addressing these issues will be critical to making OCPM more accessible and effective across a broader range of organizations, thereby allowing its full potential to be realized.

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