

Unlocking Process Intelligence

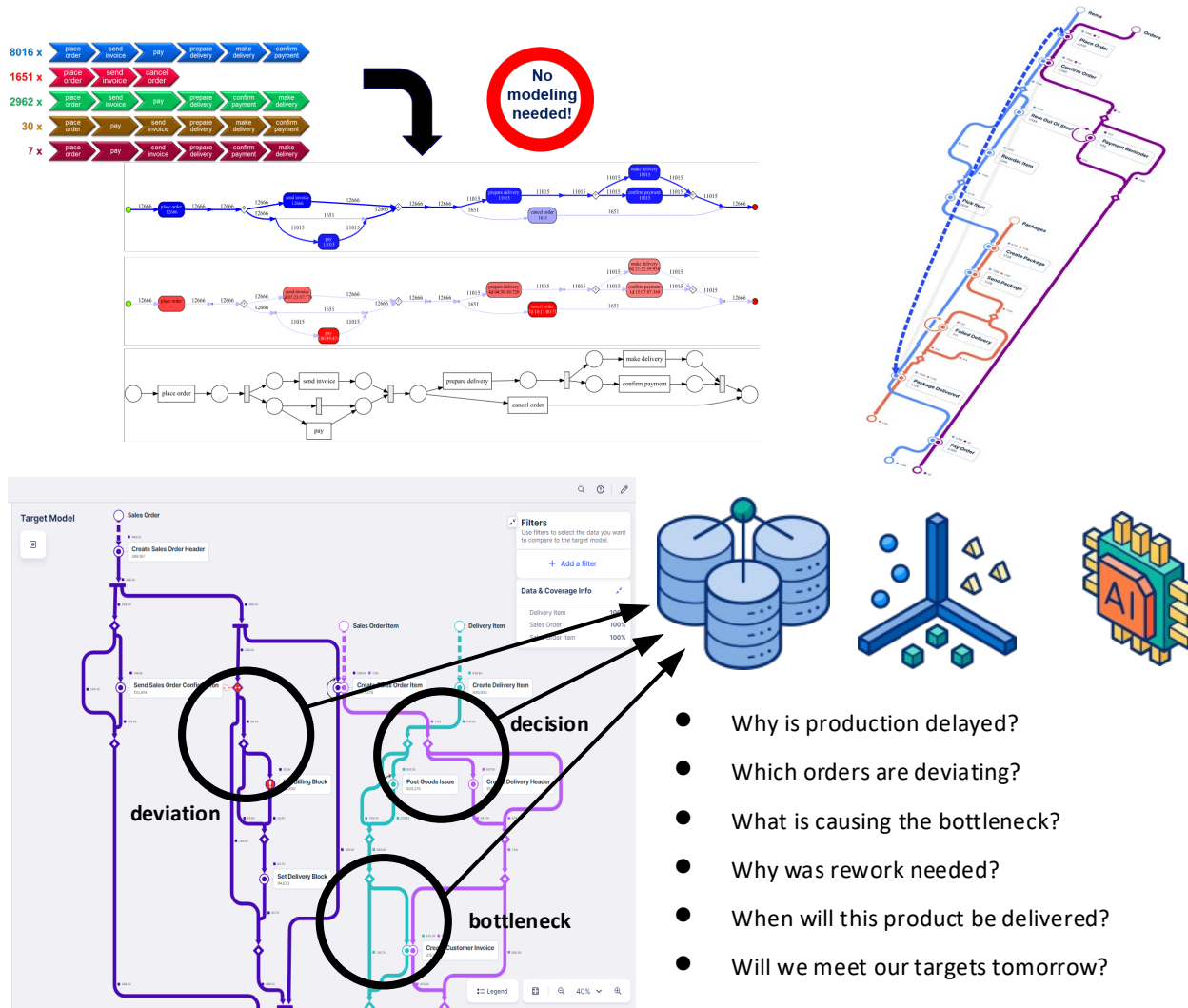
A 360 Degree Introduction to Process Mining

Wil van der Aalst

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About this introduction lecture



- ❑ What is process mining and why is it relevant?
- ❑ Development of the field
- ❑ Overview of process mining tasks and tools
- ❑ Core concepts: event data and process model
- ❑ Tools: ProM & Celonis

Motivation



Wil van der Aalst • You

Alexander-von-Humboldt professor @ RWTH Aachen, Chief Scientist @ Celon...
2w •

...

As a "process miner", traveling and visiting other countries is interesting. One gets to witness processes. Often, we do not witness a process until it goes wrong. Here is an example: We had a wedding in Sussex over the weekend, flying to London Gatwick and then traveling by rental car from there. We had booked the flights and the rental car with [easyJet](#) in one booking. This should be the convenient way, but we experienced two "process problems".

First, our [easyJet](#) car reservation was cancelled without notifying us. I found out when double-checking a few days before, although I had paid for the car. Nothing was refunded, and no message was sent. The staff member who assisted us was very friendly and helpful, and was able to recreate the reservation. It is unclear why this has happened. We were lucky to find a phone number and be able to talk to a person who could see that this was an error and who recreated our reservation (we had already paid months ago and got a confirmation that all was OK). Based on the person's response, it seemed to be a recurring problem. I'm sure that with a chatbot, we would not have resolved this.

Second, our [easyJet](#) flight to London Gatwick got delayed by one hour. This is not a problem in itself. However, this derailed our car booking again! Although we booked both the flight and the car via [easyJet](#) and never entered a time ourselves, our car reservation had expired. The staff at the rental office were very friendly and helpful in resolving this issue. They called the [easyJet](#) car rental helpdesk. However, the [easyJet](#) helpdesk insisted that it was my fault. I should have informed EasyJet that their own flight was delayed! This is an incredible rudeness. How can a company that causes a delay and sends me multiple text messages that the flight is delayed, blame me for not informing them? It was clear that this was another recurring problem. Many flights get delayed, but [easyJet](#) subcontracts car rental to another car rental agency under very strict conditions (a car should be picked up at a specific time, otherwise the booking expires). The customer who booked flights and a car with [easyJet](#) is the victim and may need to pay twice or undergo a lengthy and painful refund process.

The goal of booking both the flights and the rental car in a single transaction was to avoid precisely the above. It is very clear that both problems are process-related. I suspect that the first problem was a system-to-system error and that the second problem was an organization-to-organization error.

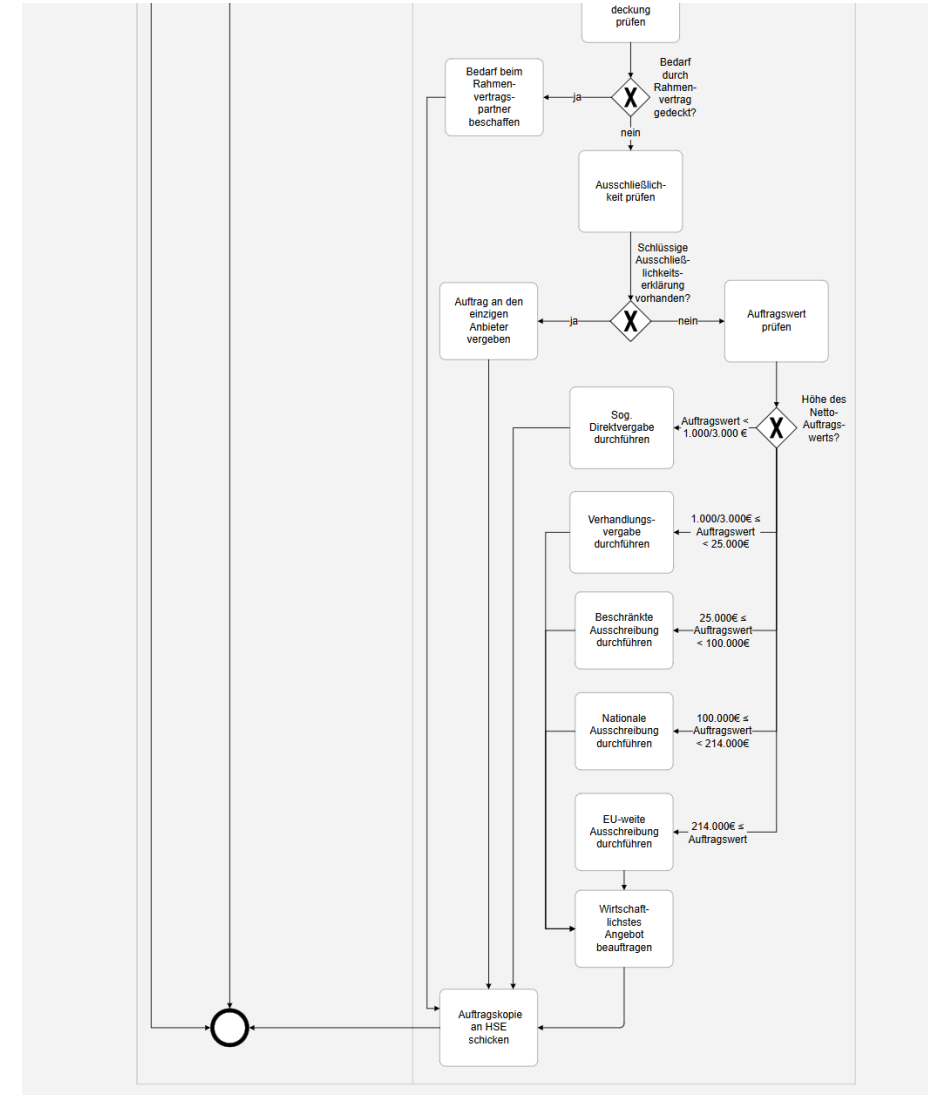
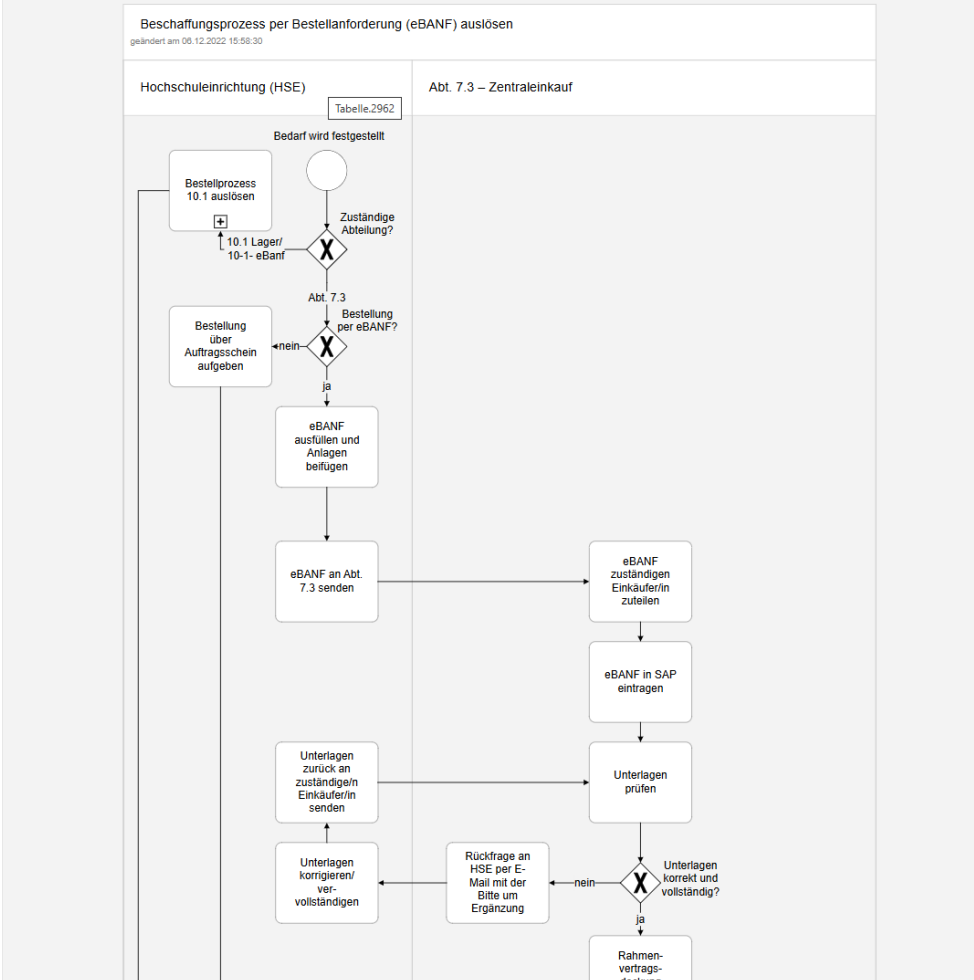
In any case, [#EasyJet](#), you can do better!! Using [#ProcessMining](#), you can identify and address these issues yourself without losing customers.



176 BPMN models (available for all via intranet.rwth-aachen.de)

Beschaffungsprozess per Bestellanforderung (eBANF) auslösen

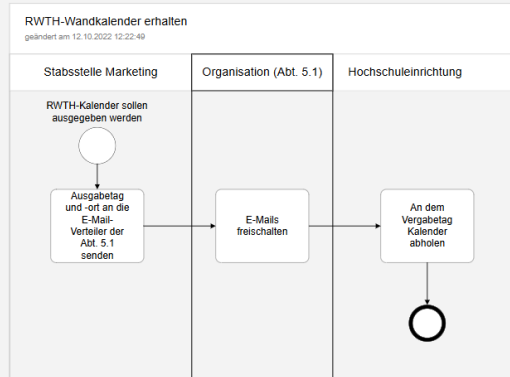
06.12.2022 | Beschaffung | Abteilung 7.3 - Zentraleinkauf



176 BPMN models (available for all via intranet.rwth-aachen.de)

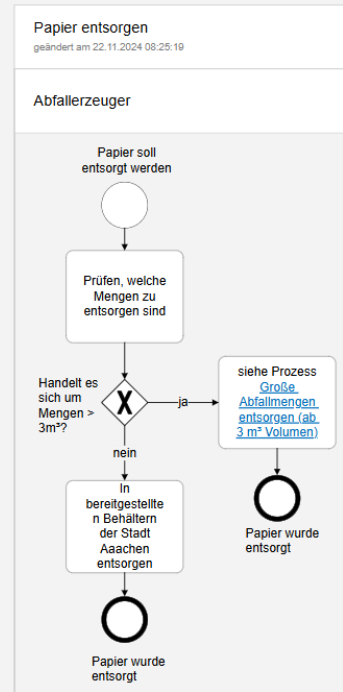
RWTH-Wandkalender erhalten

16.12.2022 | Marketing | Marketing



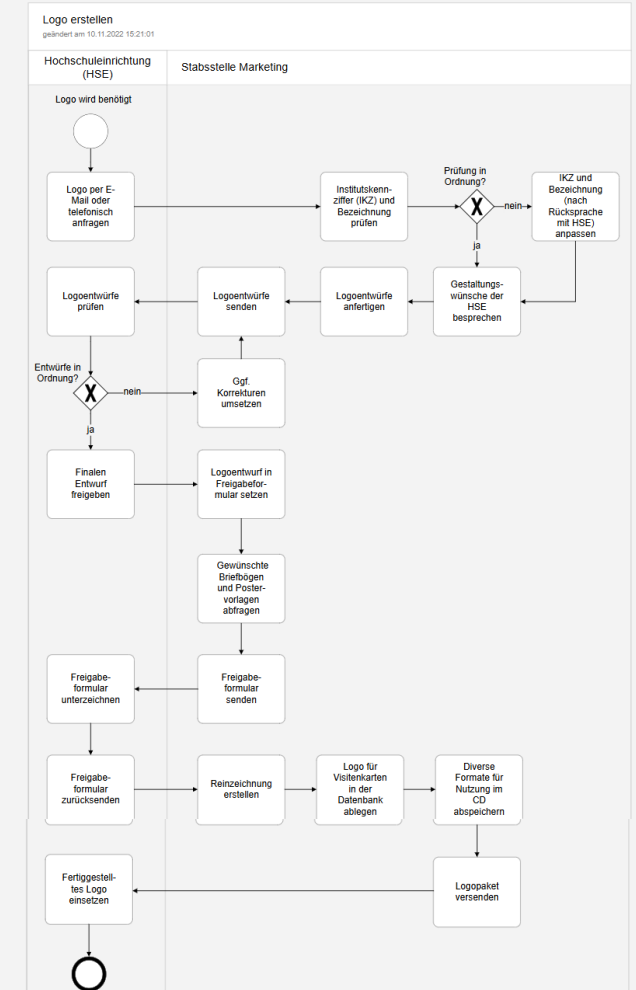
Papier entsorgen

22.11.2024 | Entsorgung | Dezernat 11.0 - Infrastruktur

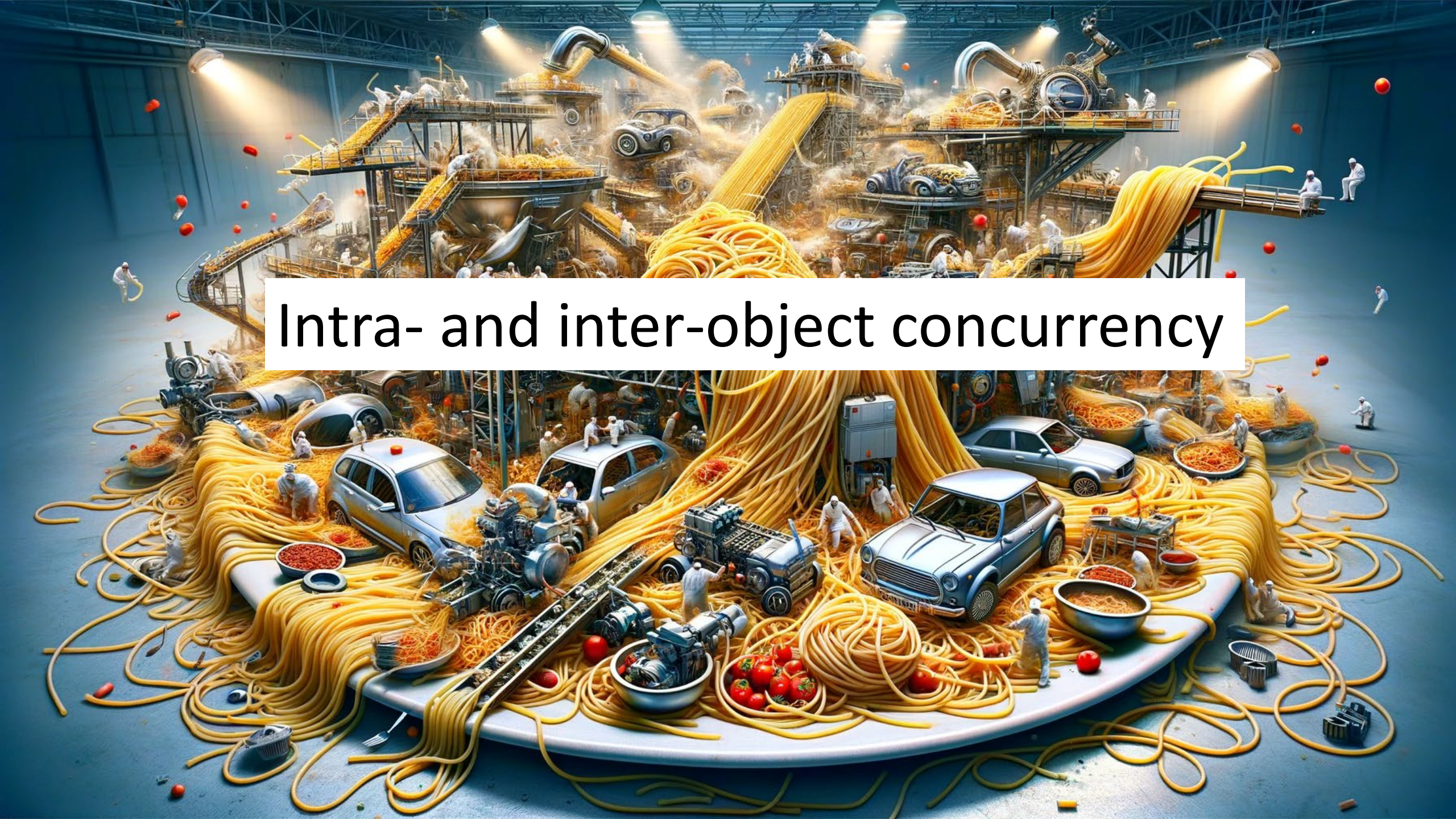


Logo erstellen

04.01.2023 | Marketing | Marketing



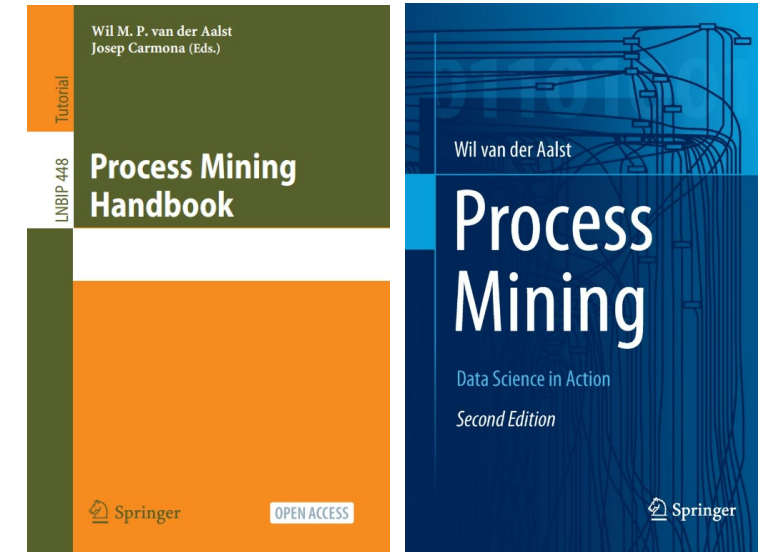




Intra- and inter-object concurrency

Key Material (see also the end of this lecture)

- First two chapters of the **Process Mining Handbook (2022)**
<https://doi.org/10.1007/978-3-031-08848-3>
 - Process Mining: A 360 Degree Overview
 - Foundations of Process Discovery
- The “Process Mining Bible” - **Process Mining: Data Science in Action**, Springer 2016
<https://doi.org/10.1007/978-3-662-49851-4>
- **Object-Centric Process Mining: Unraveling the Fabric of Real Processes**, Mathematics 2023
<https://doi.org/10.3390/math11122691>



Article Object-Centric Process Mining: Unraveling the Fabric of Real Processes

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Abstract: Traditional approaches for process modeling and process analysis tend to focus on one type of object (also referred to as cases or instances), and each event refers to precisely one such object. This simplifies modeling and analysis, e.g., a process model merely describes the lifecycle of one object (e.g., a production order or an insurance claim) in terms of its activities (i.e., event types). However, in reality, there are often multiple objects of different types involved in an event. Think about filling out an electronic form referring to one order, one customer, ten items, three shipments, and one invoice. Object-centric process mining (OCPM) takes a more holistic and more comprehensive approach to process analysis and improvement by considering multiple object types and events that involve any number of objects. This paper introduces object-centric event data (OCED) and shows how these can be used to discover, analyze, and improve the fabric of real-life, highly intertwined processes. This tutorial-style paper presents the basic concepts, object-centric process-mining techniques, examples, and formalizes OCED. Fully embracing object centrality provides organizations with a “three-dimensional” view of their processes, showing how they interact with each other, and where the root causes of performance and compliance problems lie.

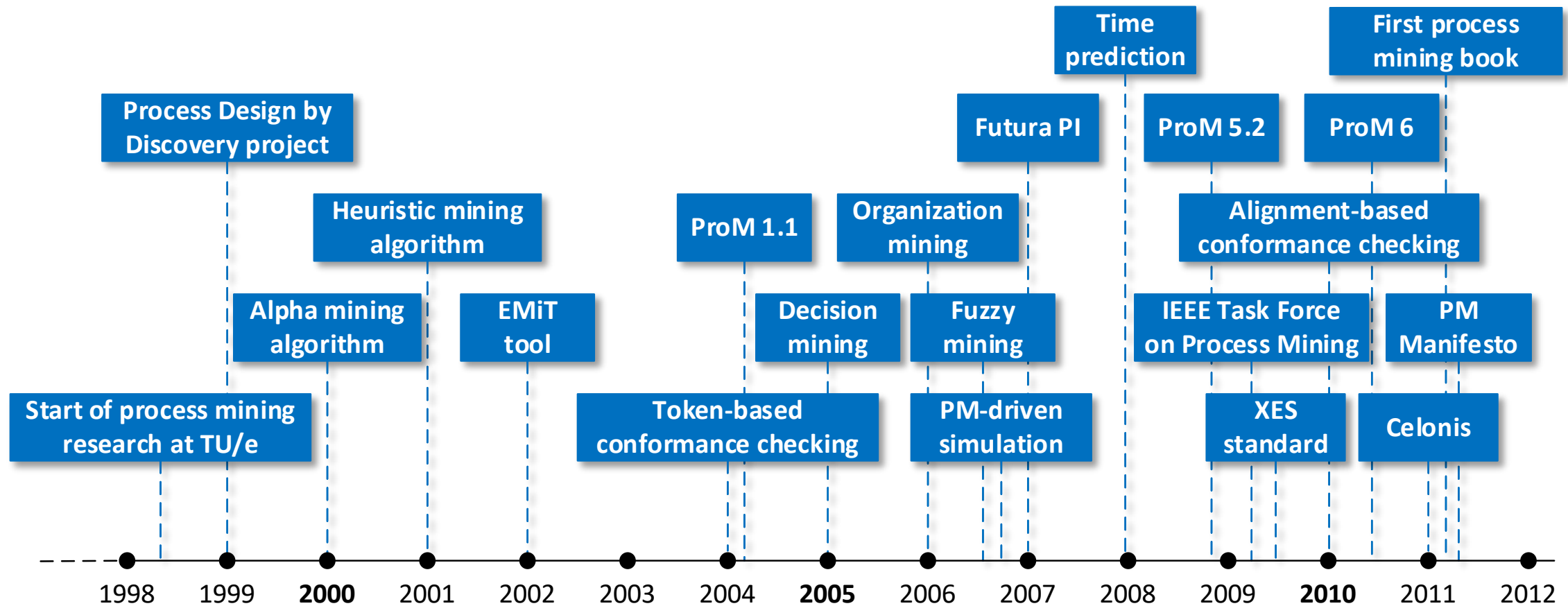
Keywords: process mining; object-centric process mining; object-centric event data; process discovery; business process management; process science

MSC: 68T99

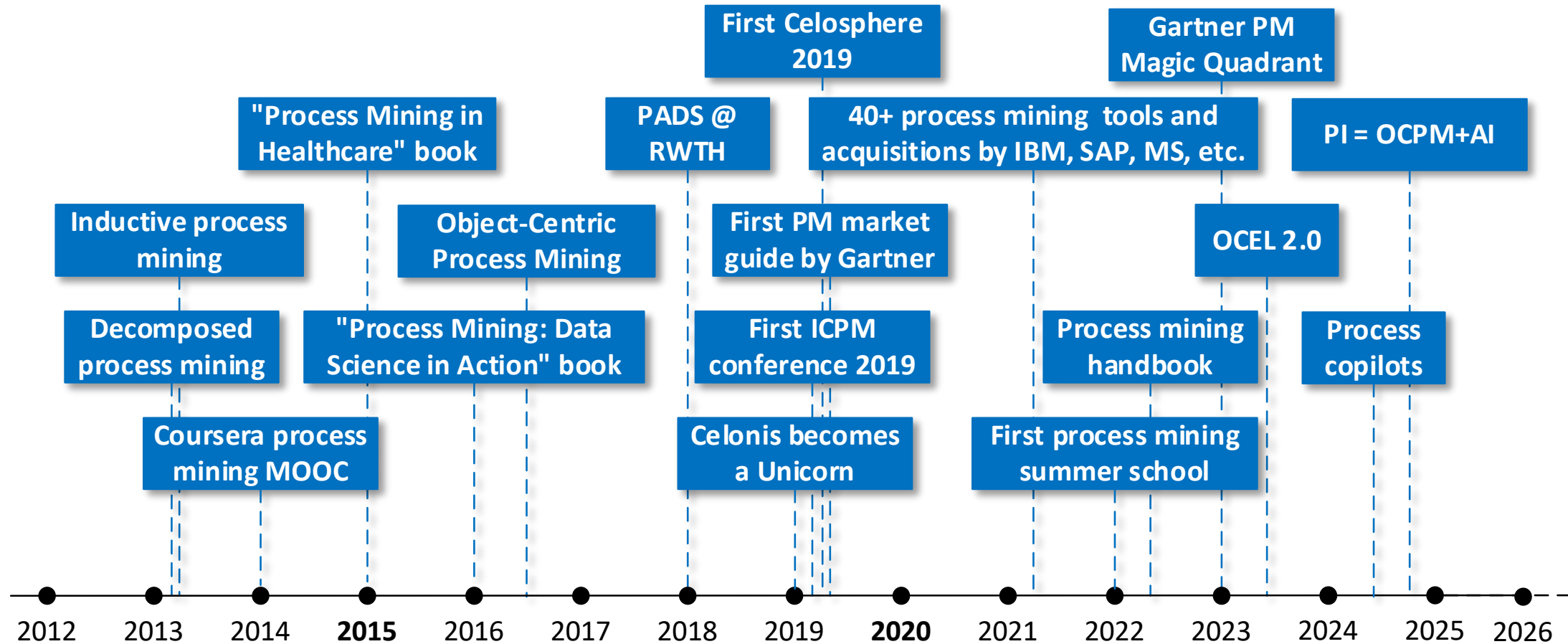


Development of the field

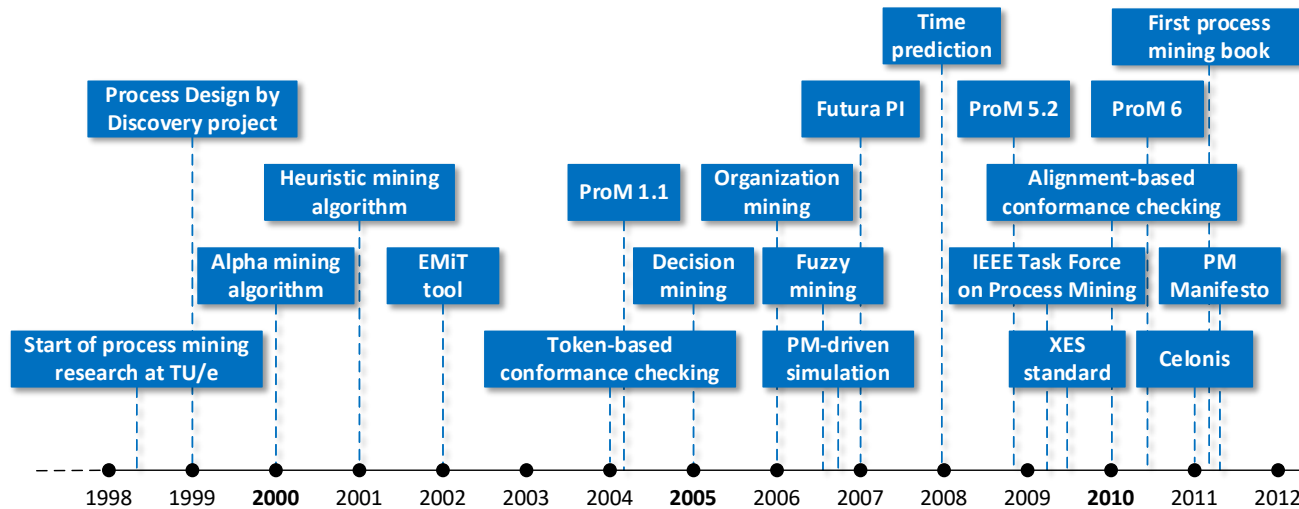
Timeline of Process Mining



Timeline of Process Mining

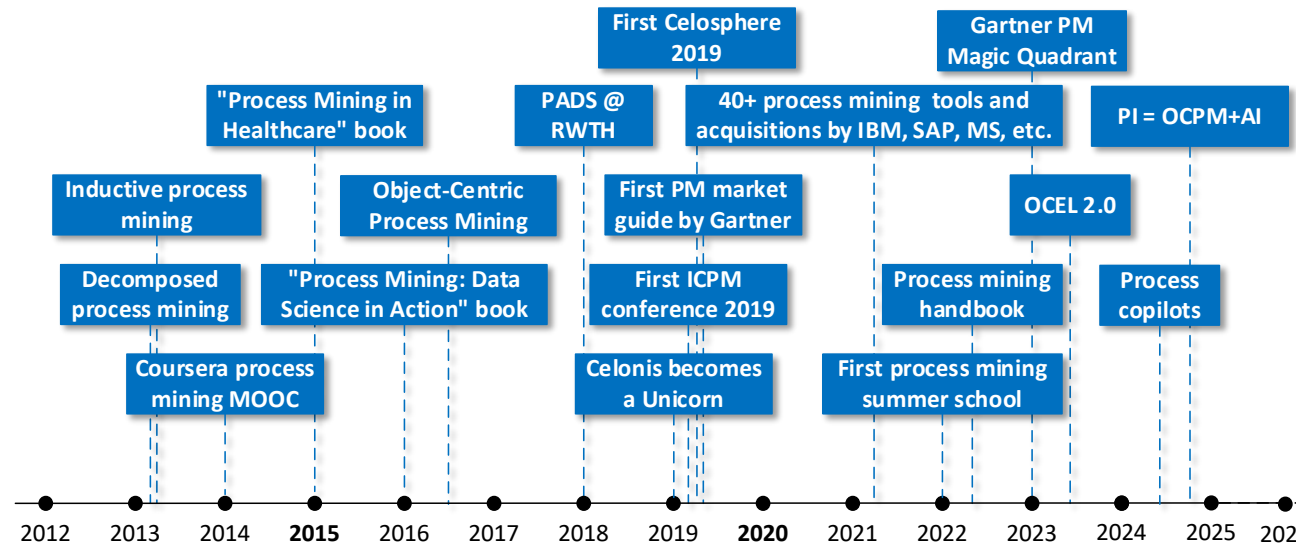


Timeline of Process Mining



Towards a PM discipline

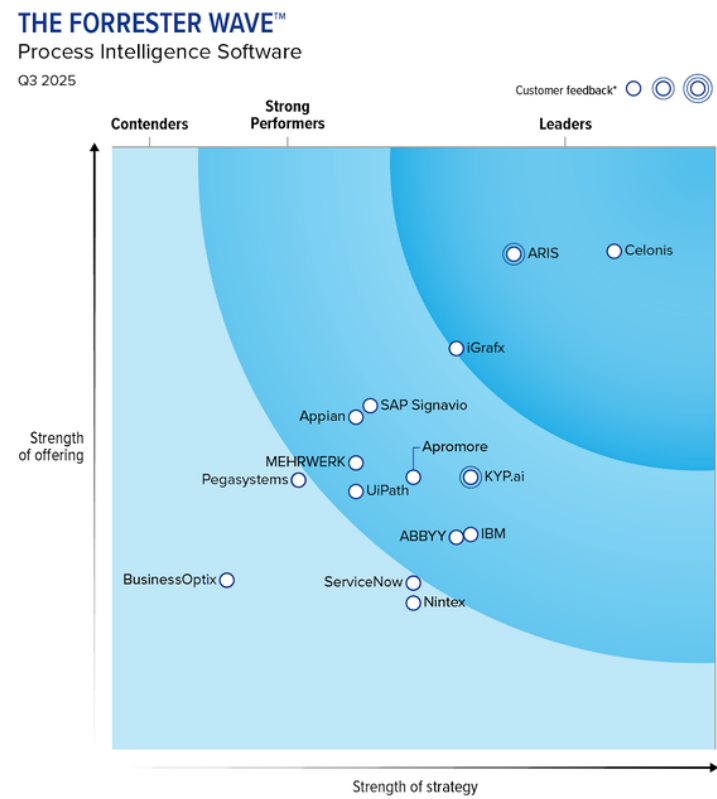
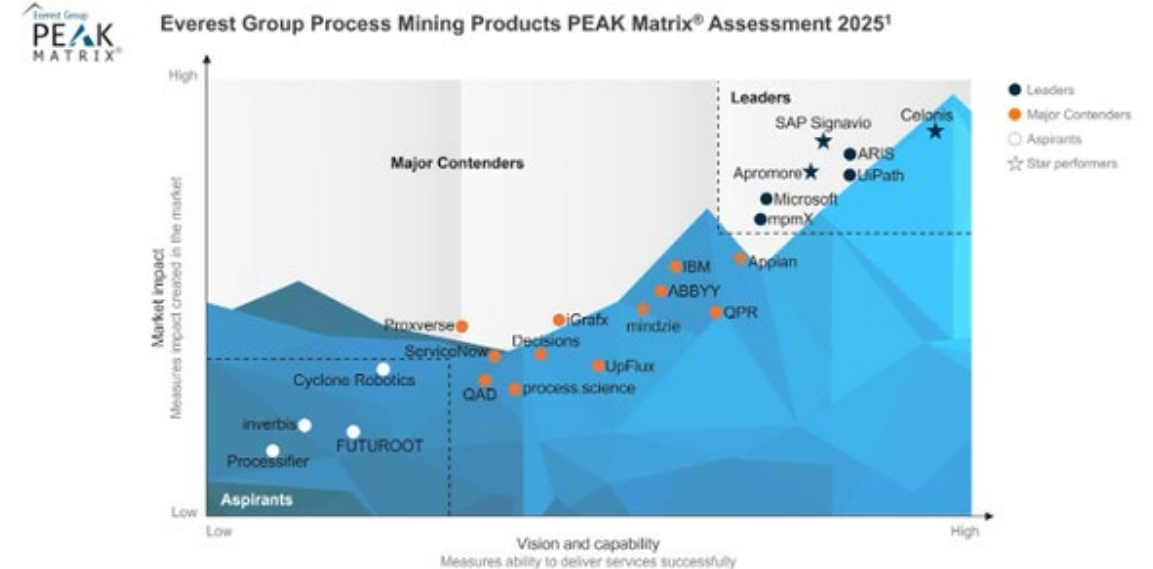
Scaling PM in industry and academia



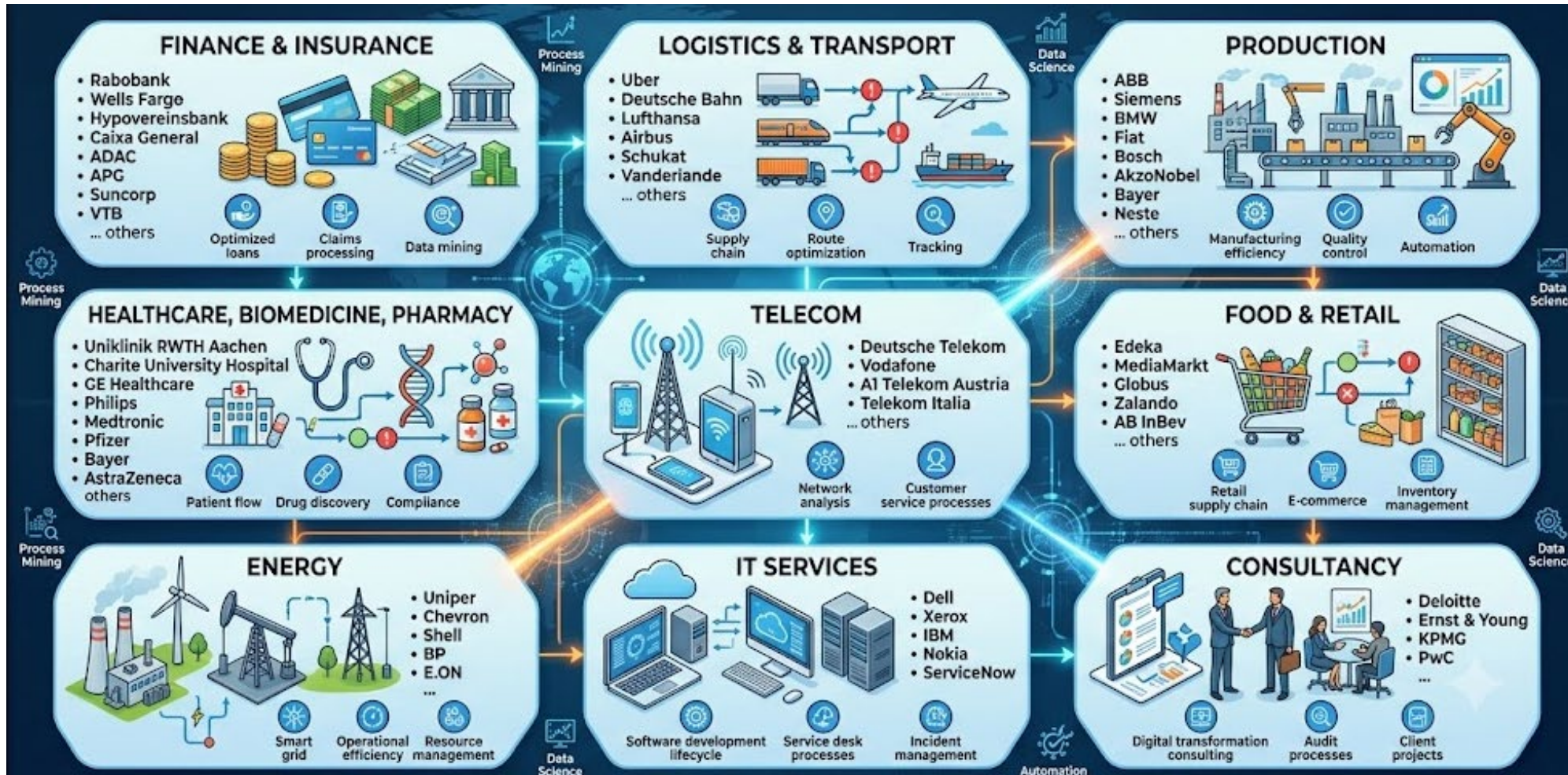
A mature market with round 50 process mining vendors



2026 Gartner Magic Quadrant for Process Intelligence Platforms
 2025 Everest PEAK Matrix for Process Mining Platforms
 2025 Forrester Wave for Process Intelligence Software



Process mining is used in all domains

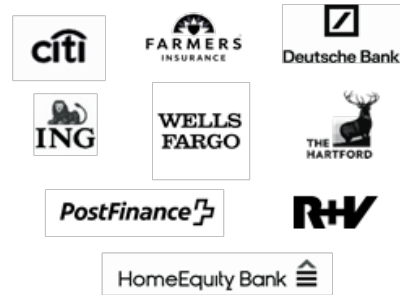


Some of the Celonis customers

Technology



Financial Services & Insurance



Life Sciences & Chemicals



Consumer & Retail



Manufacturing



Telecommunications & Media



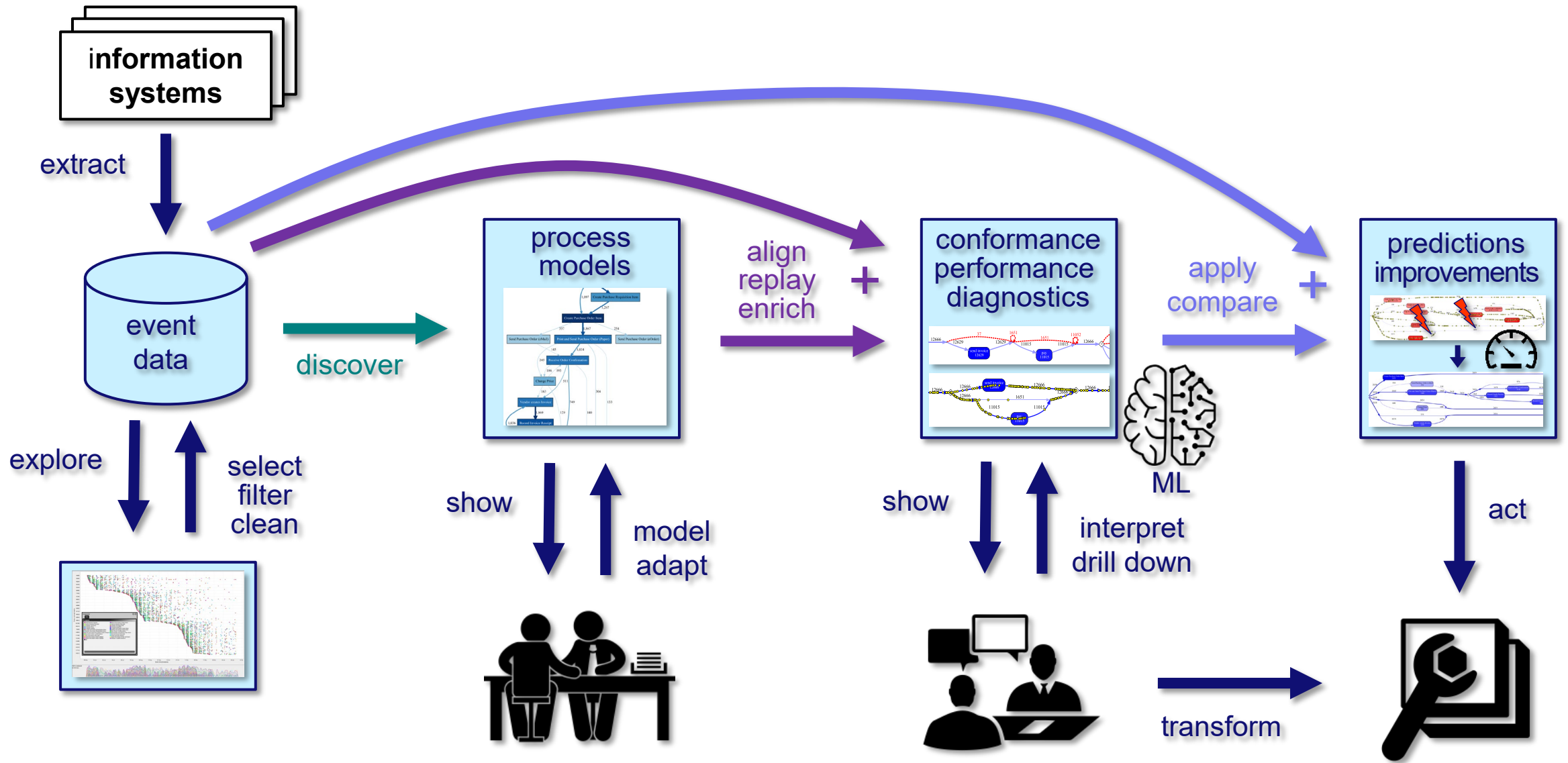
Energy & Utilities



Oil & Gas



Thousands of large organizations are using Celonis (approx. 50% of Fortune 500) and in some of these there are thousands of active users (e.g., Siemens, BMW, etc.)



PM basics

Starting point: Event data

Case ID	Activity	Resource	Timestamp	product	prod-price	quantity	address
...	...	...	...	...	...	...	...
6350	place order	Aiden	2018/02/13 14:29:45.000	APPLE iPhone 6 16 GB	639,00 €	5	NL-7751DG-21
6283	pay	Lily	2018/02/13 14:39:25.000	SAMSUNG Galaxy S6 32 GB	543.99	3	NL-7828AM-11a
6253	prepare delivery	Sophia	2018/02/13 15:01:33.000	APPLE iPhone 6 16 GB	639,00 €	3	NL-7887AC-13
6257	prepare delivery	Aiden	2018/02/13 15:03:43.000	SAMSUNG Galaxy S6 32 GB	543.99	1	NL-9521KJ-34
6185	confirm payment	Emily	2018/02/13 15:05:36.000	SAMSUNG Galaxy S4	329,00 €	1	NL-9521GC-32
6218	confirm payment	Emily	2018/02/13 15:08:11.000	APPLE iPhone 6s Plus 64 GB	969,00 €	2	NL-7948BX-10
6245	make delivery	Michael	2018/02/13 15:14:04.000	APPLE iPhone 6 16 GB	639,00 €	3	NL-7905AX-38
6272	pay	Emily	2018/02/13 15:20:36.000	APPLE iPhone 6 16 GB	639,00 €	1	NL-7821AC-3
6269	pay	Charlotte	2018/02/13 15:25:21.000	SAMSUNG Galaxy S4	329,00 €	1	NL-7907EJ-42
6212	prepare delivery	Sophia	2018/02/13 15:43:39.000	HUAWEI P8 Lite	234,00 €	1	NL-7905AX-38
6323	send invoice	Alexander	2018/02/13 15:46:08.000	APPLE iPhone 6 16 GB	639,00 €	1	NL-7833HT-15
6246	confirm payment	Jack	2018/02/13 15:56:03.000	SAMSUNG Galaxy S4	329,00 €	3	NL-7833HT-15
6347	send invoice	Jack	2018/02/13 15:57:42.000	SAMSUNG Galaxy S4	329,00 €	3	NL-7905AX-38
6351	place order	Zoe	2018/02/13 16:17:37.000	APPLE iPhone 5s 16 GB	449,00 €	3	NL-9521GC-32
6204	prepare delivery	Sophia	2018/02/13 16:31:28.000	SAMSUNG Core Prime G361	135,00 €	1	NL-7828AM-11a
6204	make delivery	Kaylee	2018/02/13 16:51:54.000	SAMSUNG Core Prime G361	135,00 €	1	NL-7828AM-11a
6265	confirm payment	Lily	2018/02/13 16:55:55.000	SAMSUNG Galaxy S4	329,00 €	4	NL-9521GC-32
6250	confirm payment	Jack	2018/02/13 17:03:26.000	MOTOROLA Moto G	199,00 €	4	NL-7942GT-2
6328	send invoice	Lily	2018/02/13 17:30:16.000	APPLE iPhone 6s 64 GB	858,00 €	4	NL-9514BV-16
6352	place order	Aiden	2018/02/13 17:53:22.000	APPLE iPhone 6 16 GB	639,00 €	2	NL-9514BV-16
6317	send invoice	Jack	2018/02/13 18:45:30.000	APPLE iPhone 6s 64 GB	858,00 €	5	NL-7907EJ-42
6353	place order	Sophia	2018/02/13 20:16:20.000	APPLE iPhone 5s 16 GB	449,00 €	4	NL-7751AR-19
...	...	...	...	...	...	...	...

← event

71,043 events
12,666 cases
7 activities

Starting point: Event data

Case ID	Activity	Resource	Timestamp	product	prod-price	quantity	address
...	...	...	...	...	...	...	...
6350	place order	Aiden	2018/02/13 14:29:45.000	APPLE iPhone 6 16 GB	639,00 €	5	NL-7751DG-21
6283	pay	Lily	2018/02/13 14:39:25.000	SAMSUNG Galaxy S6 32 GB	543,99	3	NL-7828AM-11a
6253	prepare delivery	Sophia	2018/02/13 15:01:33.000	APPLE iPhone 6 16 GB	639,00 €	3	NL-7887AC-13
6257	prepare delivery	Aiden	2018/02/13 15:03:43.000	SAMSUNG Galaxy S6 32 GB	543,99	1	NL-9521KJ-34
6185	confirm payment	Emily	2018/02/13 15:05:36.000	SAMSUNG Galaxy S4	329,00 €	1	NL-9521GC-32
6218	confirm payment	Emily	2018/02/13 15:08:11.000	APPLE iPhone 6s Plus 64 GB	869,00 €	2	NL-7948BX-10
6245	make delivery	Michael	2018/02/13 15:14:04.000	APPLE iPhone 6s 16 GB	639,00 €	3	NL-7905AX-38
6272	pay	Emily	2018/02/13 15:20:36.000	APPLE iPhone 6 16 GB	639,00 €	1	NL-7821AC-3
6269	pay	Charlotte	2018/02/13 15:25:21.000	SAMSUNG Galaxy S4	329,00 €	1	NL-7907EJ-42
6212	prepare delivery	Sophia	2018/02/13 15:43:39.000	HUAWEI P8 Lite	234,00 €	1	NL-7905AX-38
6323	send invoice	Alexander	2018/02/13 15:46:08.000	APPLE iPhone 6 16 GB	639,00 €	1	NL-7833HT-15
6246	confirm payment	Jack	2018/02/13 15:56:03.000	SAMSUNG Galaxy S4	329,00 €	3	NL-7833HT-15
6347	send invoice	Jack	2018/02/13 15:57:42.000	SAMSUNG Galaxy S4	329,00 €	3	NL-7905AX-38
6351	place order	Zoe	2018/02/13 16:17:37.000	APPLE iPhone 5s 16 GB	449,00 €	3	NL-9521GC-32
6204	prepare delivery	Sophia	2018/02/13 16:31:28.000	SAMSUNG Galaxy S4	329,00 €	1	NL-7828AM-11a
6204	make delivery	Kaylee	2018/02/13 16:51:54.000	SAMSUNG Galaxy S4	329,00 €	1	NL-7828AM-11a
6265	confirm payment	Lily	2018/02/13 16:55:55.000	SAMSUNG Galaxy S4	329,00 €		NL-9521GC-32
6250	confirm payment	Jack	2018/02/13 17:03:26.000	MOTOROLA Moto G	199,00 €	4	NL-7942GT-2
6328	send invoice	Lily	2018/02/13 17:30:16.000	APPLE iPhone 6s 64 GB	858,00 €	4	NL-9514BV-16
6352	place order	Aiden	2018/02/13 17:53:22.000	APPLE iPhone 6 16 GB	639,00 €	2	NL-9514BV-16
6317	send invoice	Jack	2018/02/13 18:45:30.000	APPLE iPhone 6s 64 GB	858,00 €	5	NL-7907EJ-42
6353	place order	Sophia	2018/02/13 20:16:20.000	APPLE iPhone 5s 16 GB	449,00 €	4	NL-7751AR-19
...	...	...	...	...	...	...	...

event =
case +
activity +
timestamp +

Let's look at orders 6350, 6351, and 6352

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

Let's look at orders 6350, 6351, and 6352

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

Order 6350



Let's look at orders 6350, 6351, and 6352

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

Order 6350



Order 6351



Let's look at orders 6350, 6351, and 6352

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

Order 6350



Order 6351



Order 6352



Let's look at orders 6350, 6351, and 6352

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

Order 6350



Order 6351



Order 6352



Let's look at the whole event log again

71,043 events
12,666 cases
7 activities

Case ID	Activity	Resource	Timestamp	product	prod-price	quantity	address
6250	place order	Adrian	2018/02/13 14:29:45.000	APPLE iPhone 5s 16 GB	670.00€	5	NL-7751000-21
6283	pay	Lily	2018/02/13 14:29:15.000	SAMSUNG-Galaxy S6 32 GB	543.99	5	NL-787888M-114
6253	prepare delivery	Stephan	2018/02/13 15:01:13.000	APPLE iPhone 5s 16 GB	670.00€	5	NL-780746-15
6212	prepare delivery	Adrian	2018/02/13 15:01:43.000	SAMSUNG-Galaxy S6 32 GB	543.99	1	NL-921162-34
6189	confirm payment	Emily	2018/02/13 15:00:46.000	SAMSUNG-Galaxy S4	470.00€	1	NL-703116-21
6218	confirm payment	Emily	2018/02/13 15:08:11.000	APPLE iPhone 5s Plus 64 GB	860.00€	2	NL-794886-10
6205	make delivery	Michael	2018/02/13 14:54:54.000	APPLE iPhone 5s 16 GB	670.00€	2	NL-705018-06
6272	pay	Emily	2018/02/13 15:20:59.000	APPLE iPhone 5s 16 GB	670.00€	1	NL-781343-3
6209	pay	Constance	2018/02/13 15:22:11.000	SAMSUNG-Galaxy S6	570.00€	1	NL-782171-46
6212	prepare delivery	Stephan	2018/02/13 15:43:19.000	APPLE iPhone 5s 16 GB	670.00€	1	NL-790548-18
6313	send invoice	Marceline	2018/02/13 15:46:08.000	APPLE iPhone 5s 16 GB	670.00€	1	NL-783317-15
6286	confirm payment	Jack	2018/02/13 15:56:03.000	SAMSUNG-Galaxy S4	470.00€	1	NL-793301-15
6317	send invoice	Jack	2018/02/13 16:57:42.000	SAMSUNG-Galaxy S4	470.00€	1	NL-790548-18
6351	place order	Ilse	2018/02/13 16:17:17.000	APPLE iPhone 5s 16 GB	670.00€	1	NL-791210-21
6204	prepare delivery	Stephan	2018/02/13 16:31:28.000	SAMSUNG-Galaxy S6	570.00€	1	NL-792888M-114
6208	make delivery	Stephan	2018/02/13 16:31:34.000	SAMSUNG-Galaxy S6	570.00€	1	NL-792888M-114
6265	confirm payment	Lily	2018/02/13 18:25:53.000	SAMSUNG-Galaxy S4	470.00€	4	NL-901306-32
6262	confirm payment	Jack	2018/02/13 17:03:26.000	MOTOROLA-Moto G	199.00€	4	NL-794507-2
6378	send invoice	Jack	2018/02/13 17:29:16.000	APPLE iPhone 4s 64 GB	854.00€	4	NL-901480V-16
6352	place order	Adrian	2018/02/13 17:52:12.000	APPLE iPhone 5s 16 GB	670.00€	2	NL-901480V-16
6317	send invoice	Jack	2018/02/13 18:45:50.000	APPLE iPhone 4s 64 GB	854.00€	5	NL-790774-42
6353	place order	Stephan	2018/02/13 19:16:20.000	APPLE iPhone 5s 16 GB	670.00€	4	NL-7751000-21

8016 x

place
order

send
invoice

pay

prepare
delivery

make
delivery

confirm
payment

1651 x

place
order

send
invoice

cancel
order

2962 x

place
order

send
invoice

pay

prepare
delivery

confirm
payment

make
delivery

30 x

place
order

pay

send
invoice

prepare
delivery

make
delivery

confirm
payment

7 x

place
order

pay

send
invoice

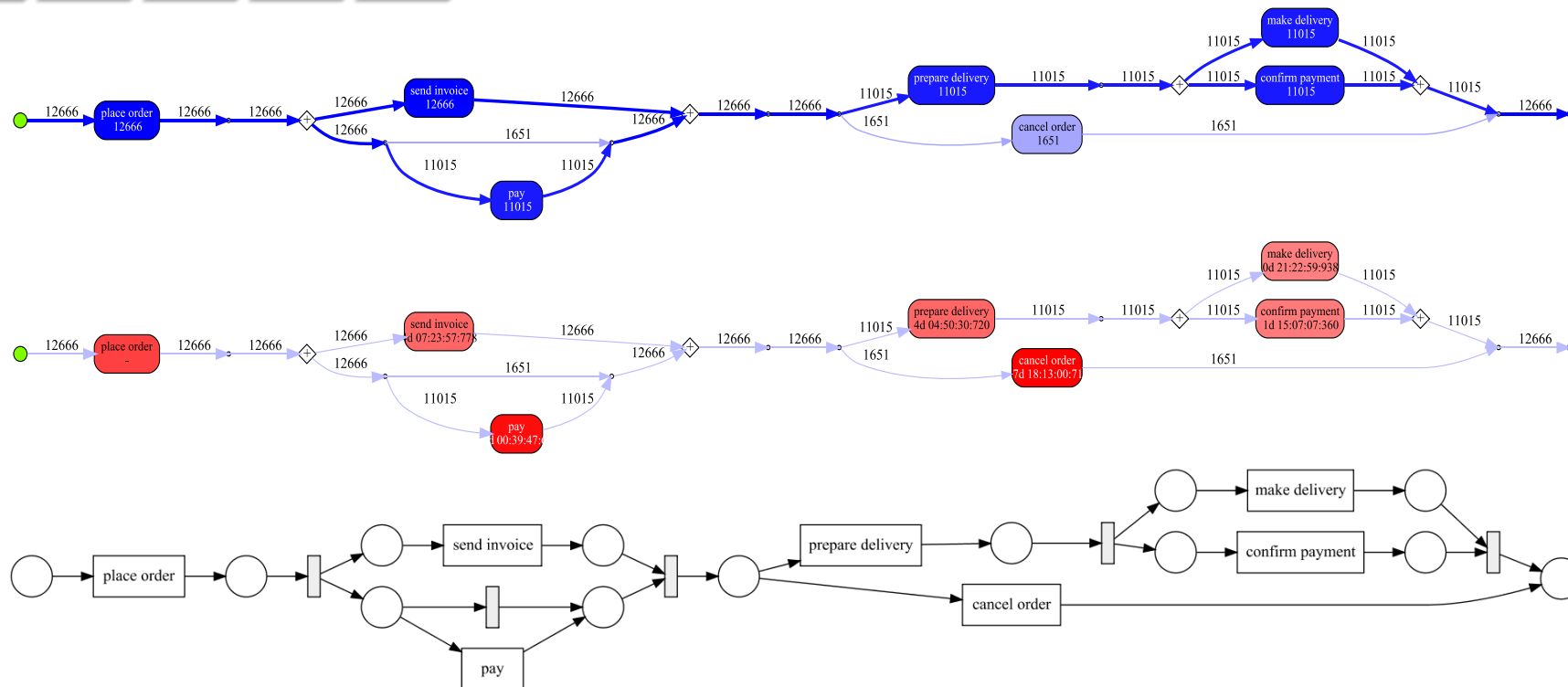
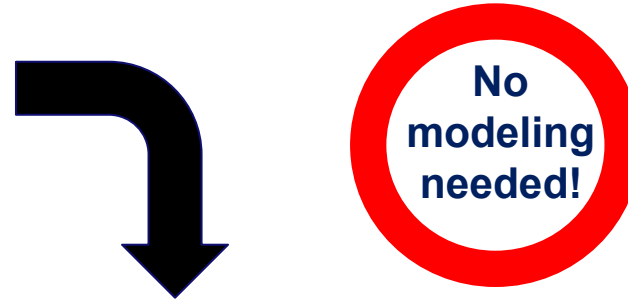
prepare
delivery

confirm
payment

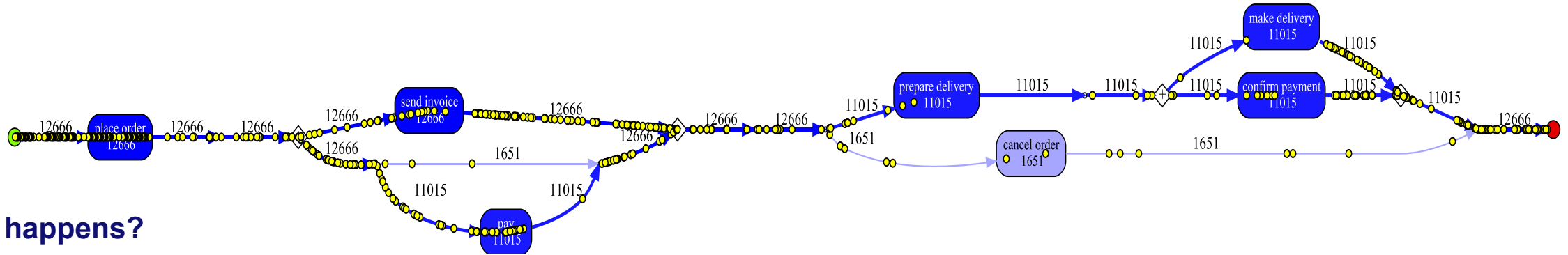
make
delivery



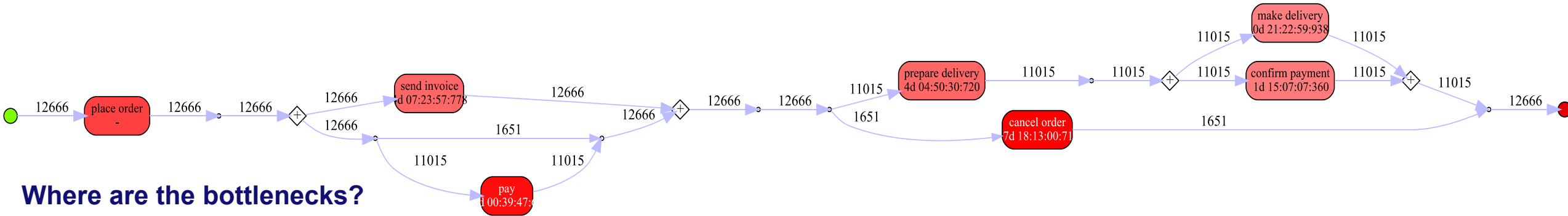
Using the whole event log



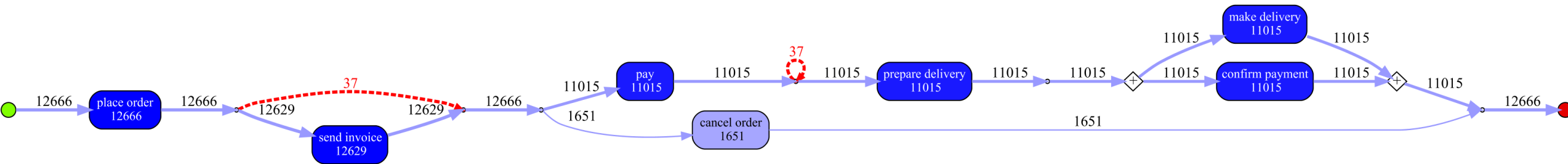
Performance and Compliance



What happens?

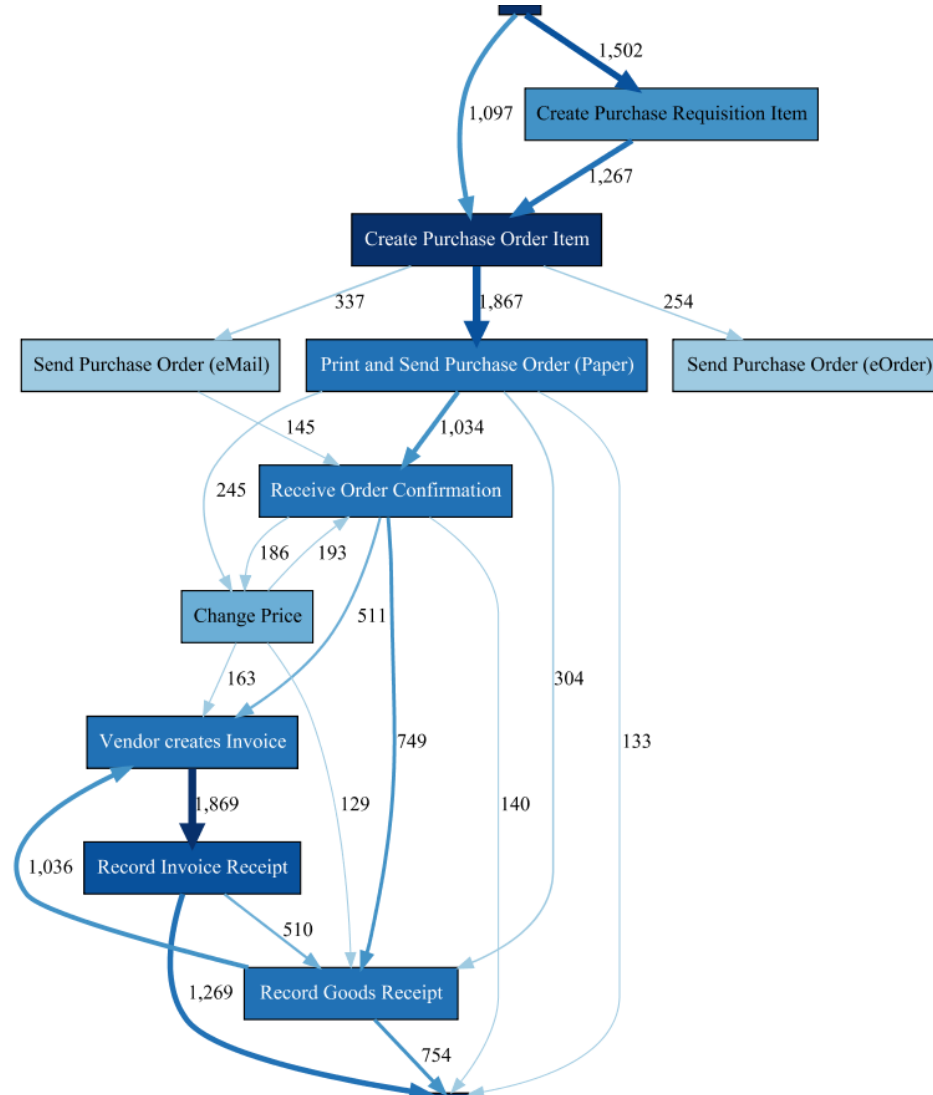
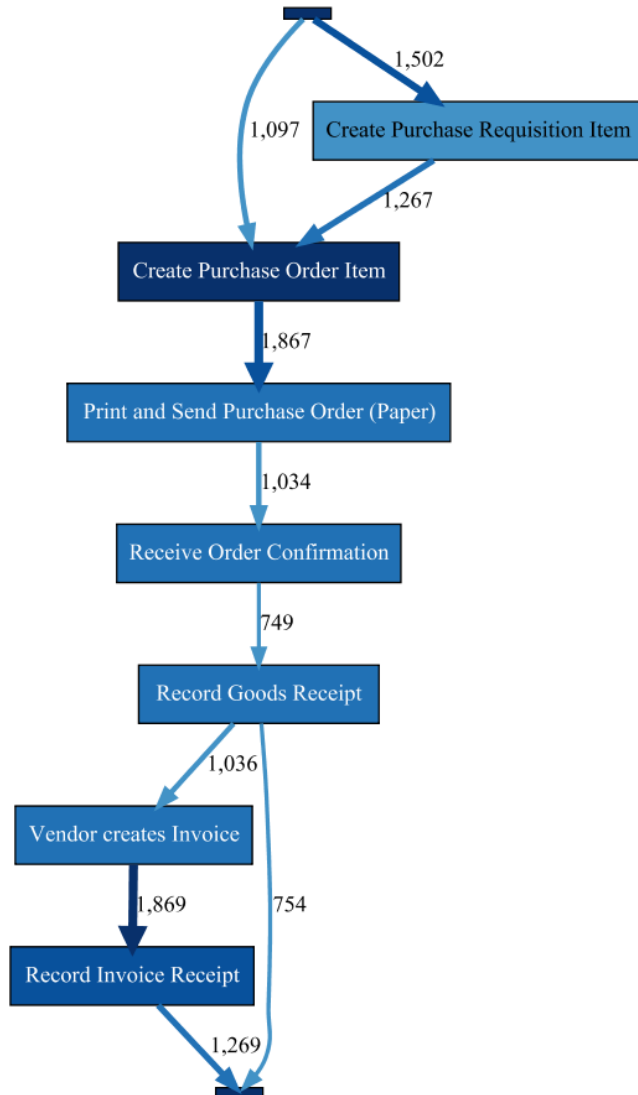


Where are the bottlenecks?

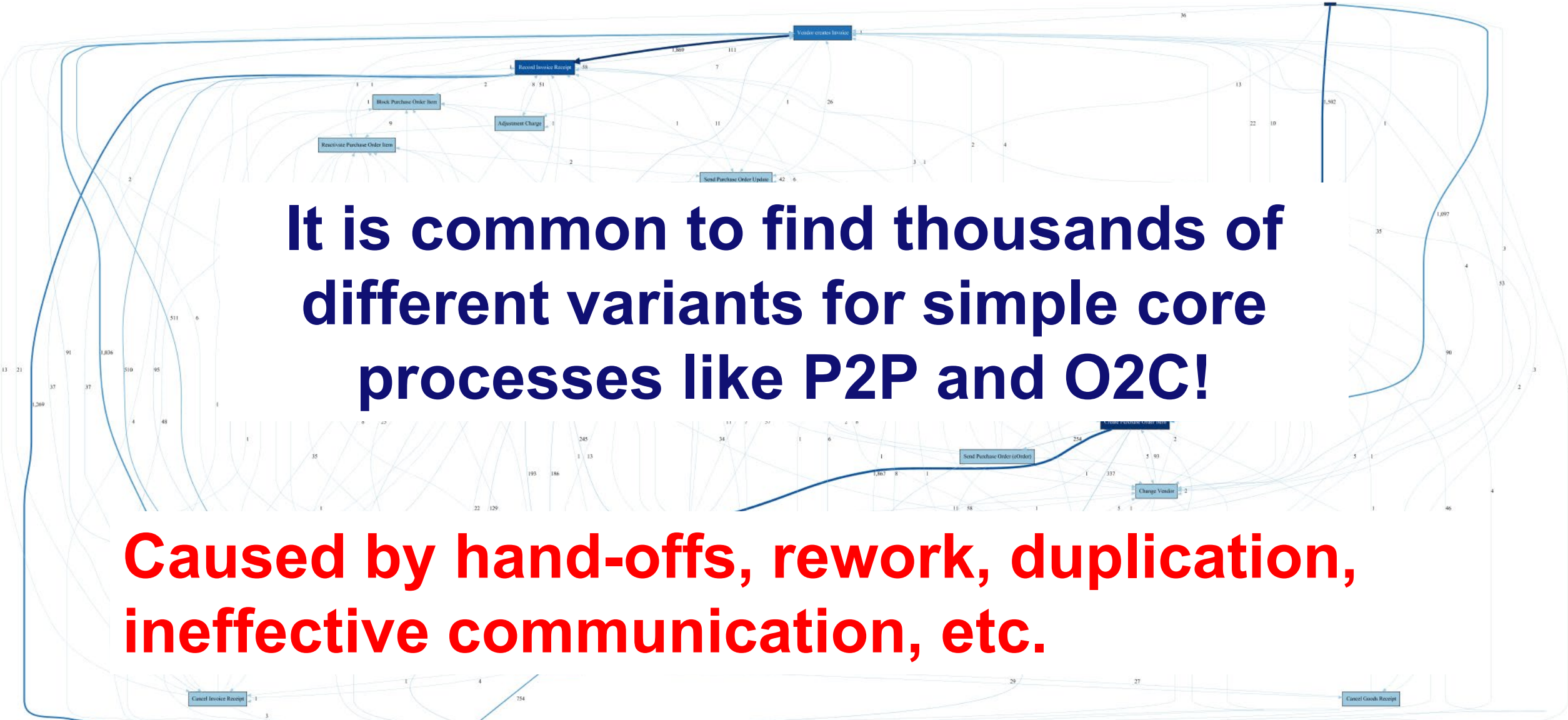


Where do we deviate from the happy path?

Reality is not so simple



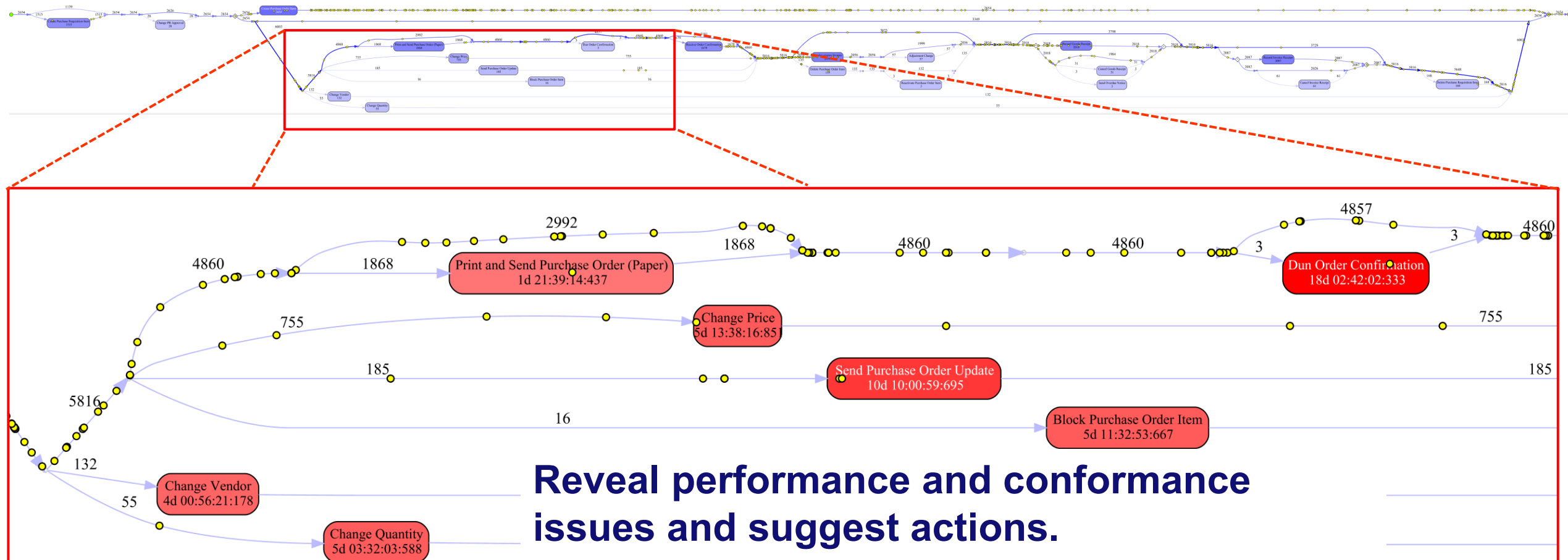
Reality is not so simple



It is common to find thousands of different variants for simple core processes like P2P and O2C!

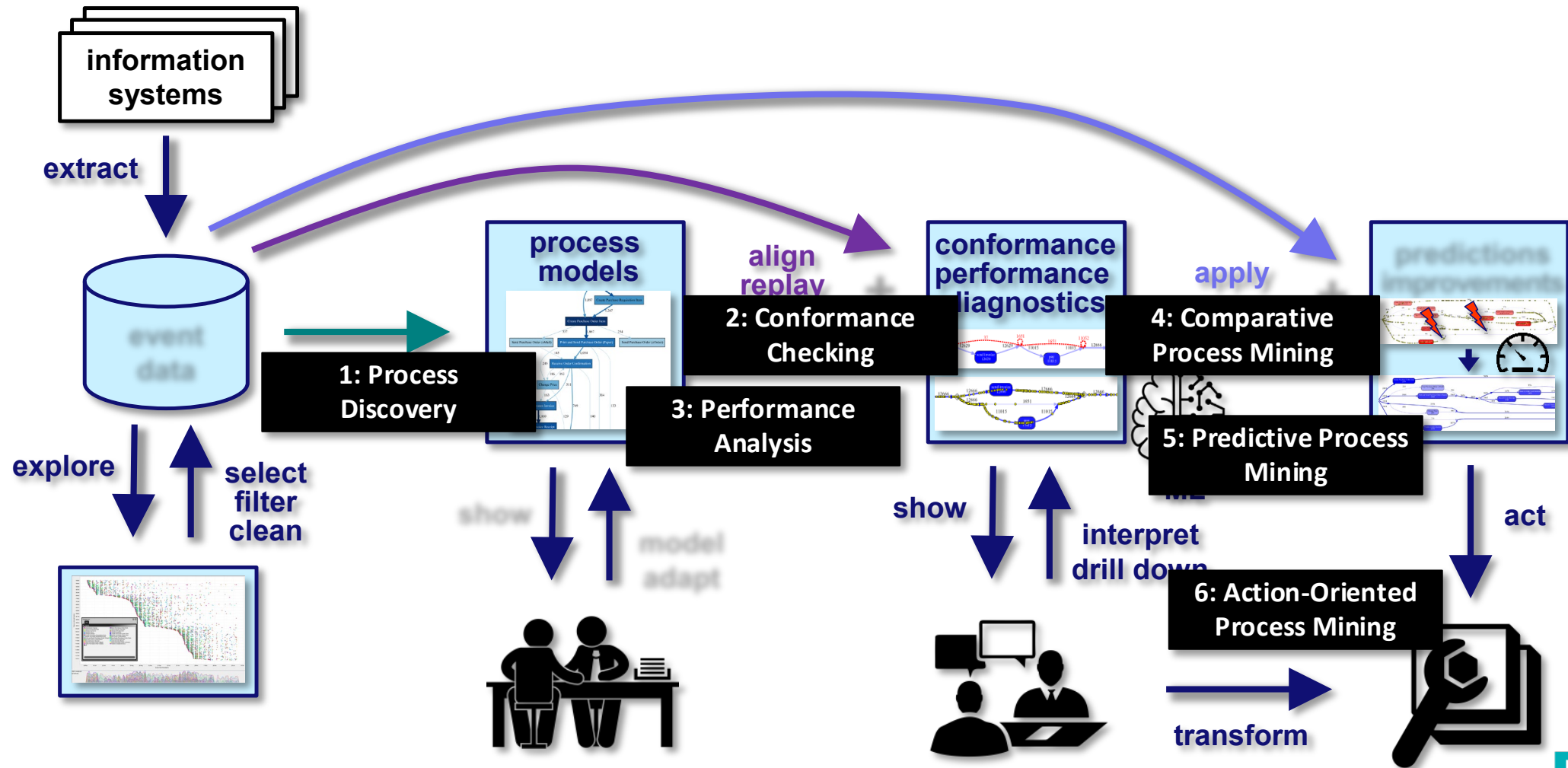
Caused by hand-offs, rework, duplication, ineffective communication, etc.

Process mining helps organizations to address compliance and performance problems



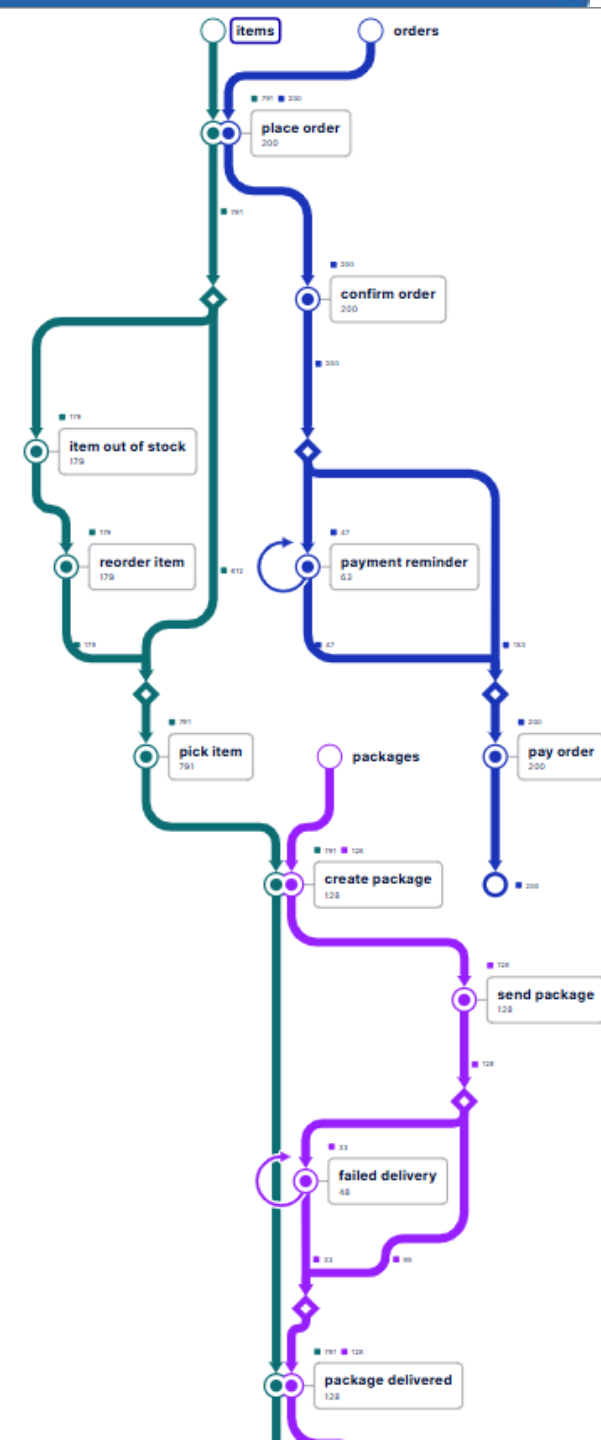
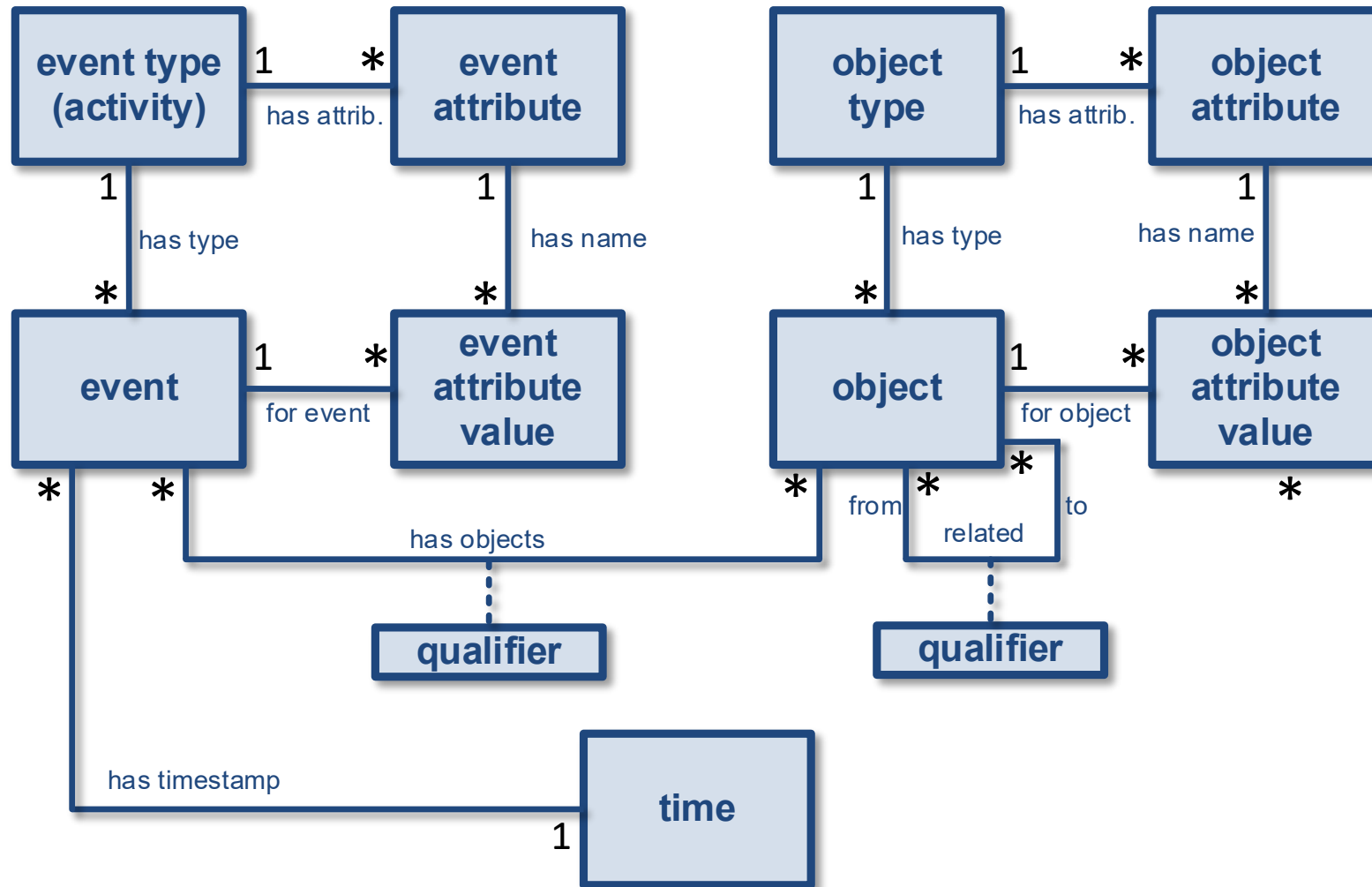
Six types of process mining

Six types of process mining

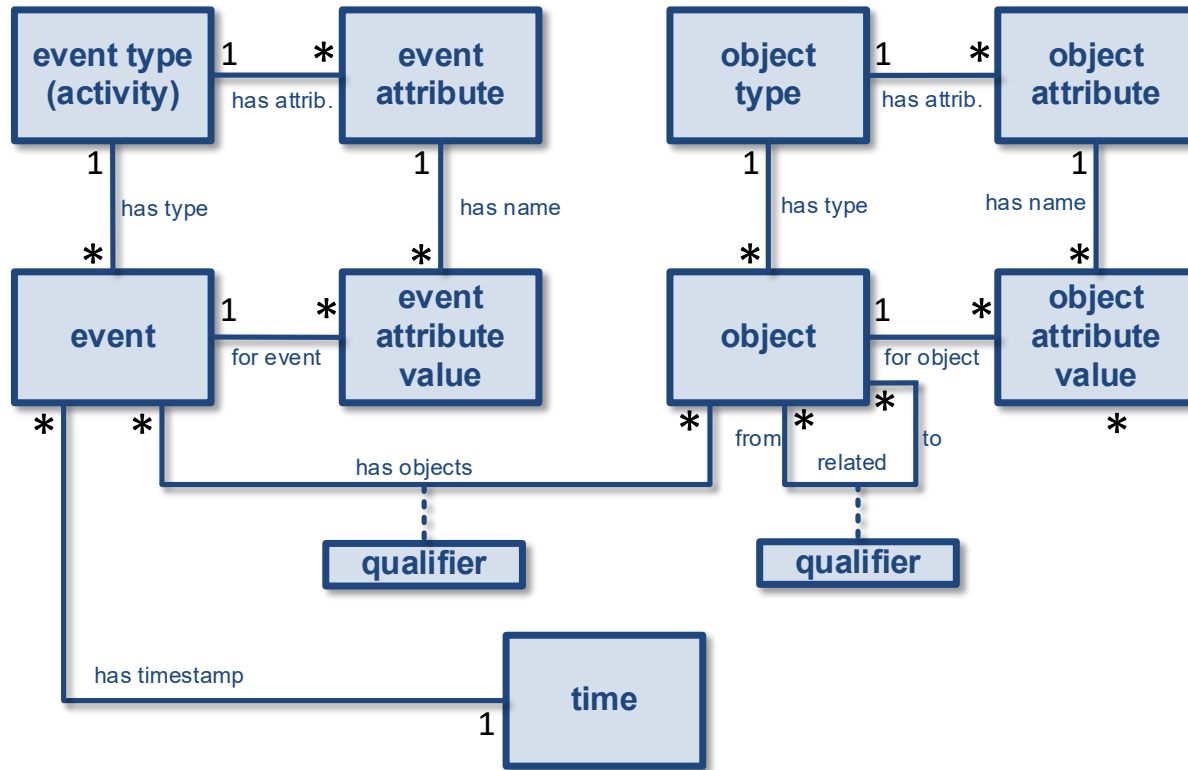


Two levels of process mining

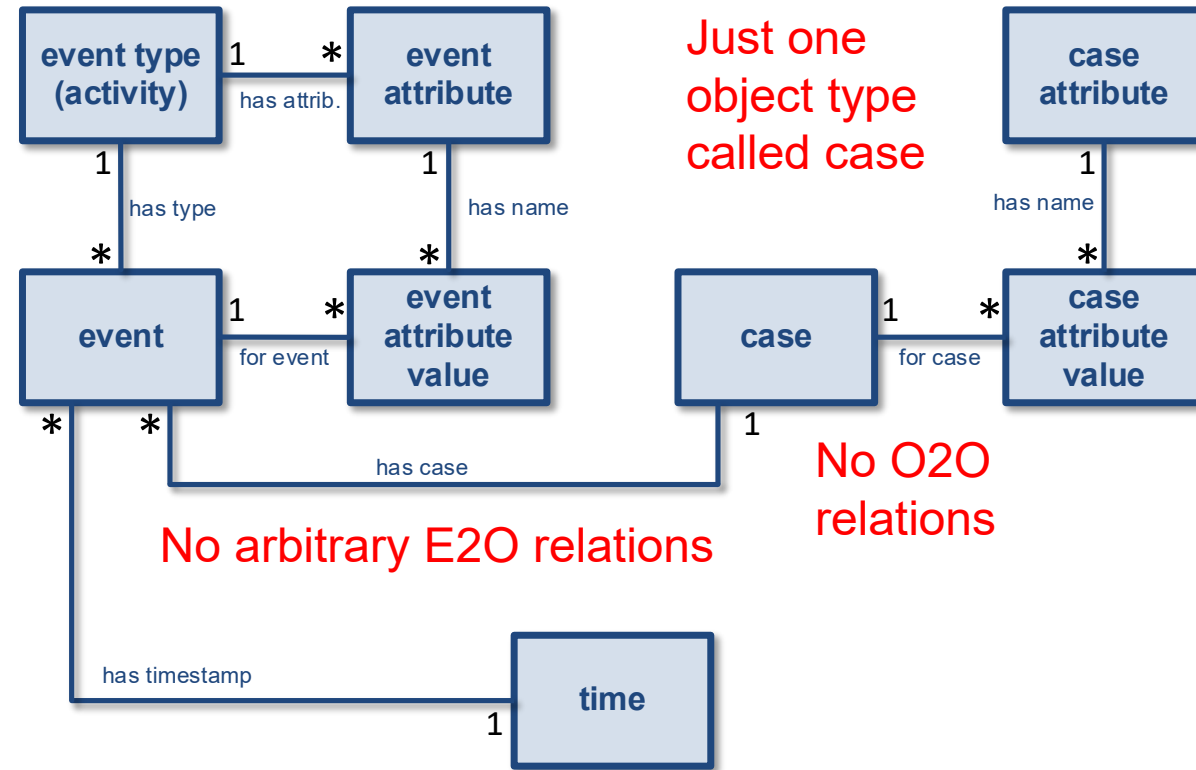
Object-Centric Event Data



Case-Centric Versus Object-Centric

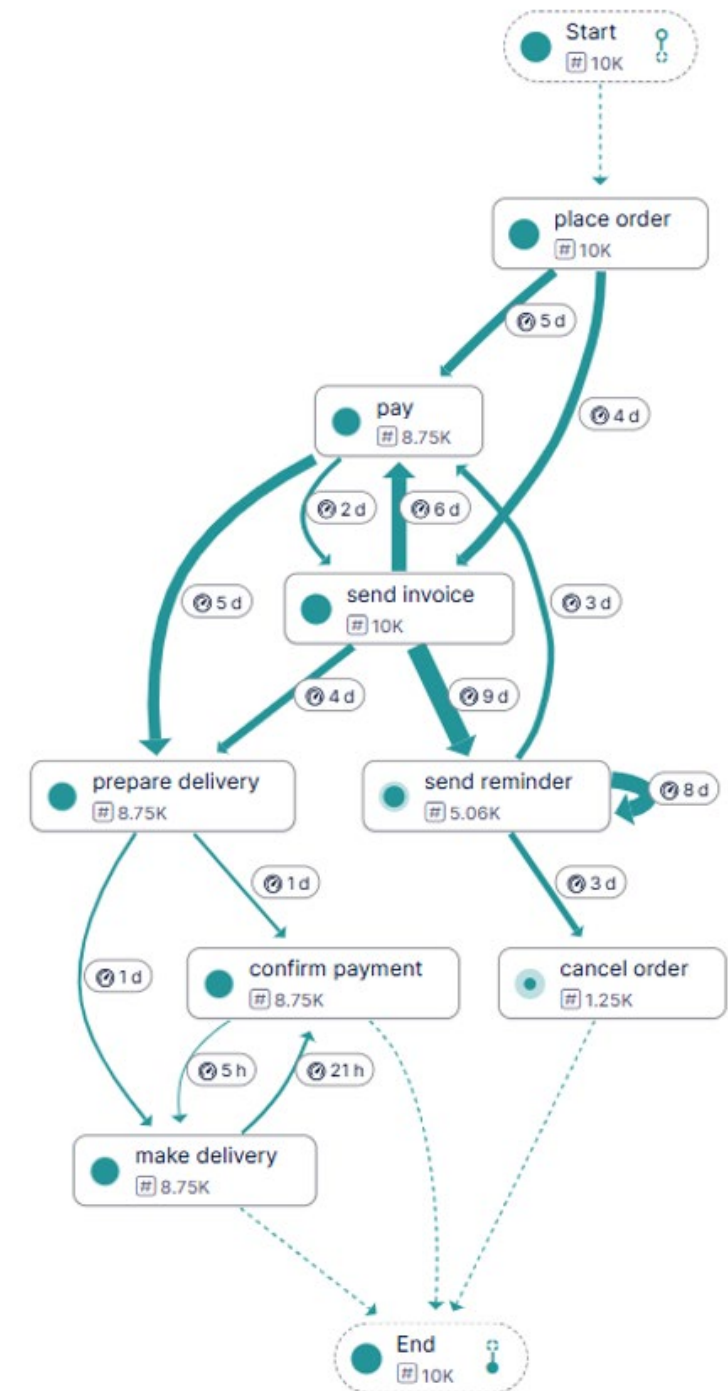
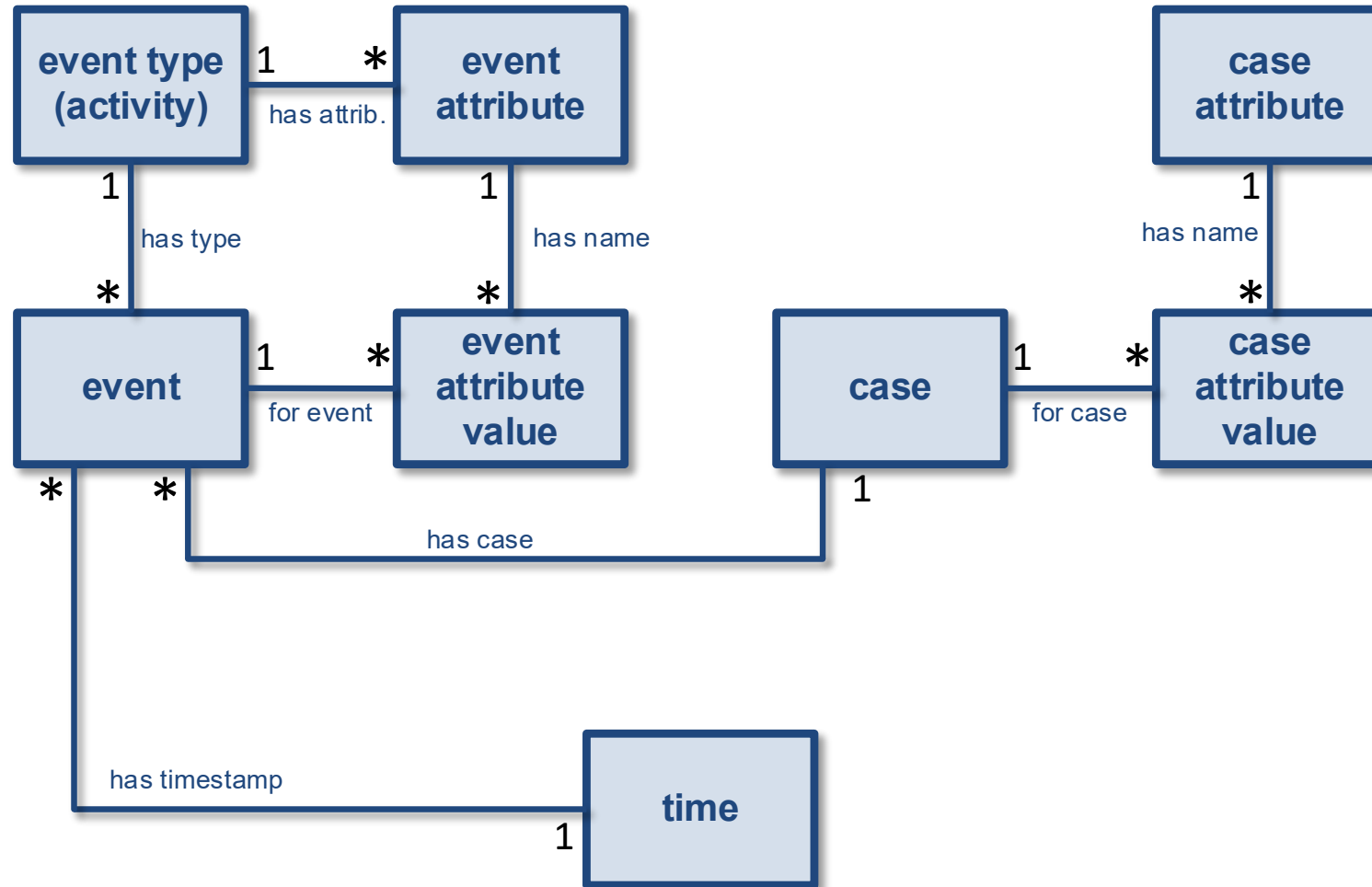


Object-Centric

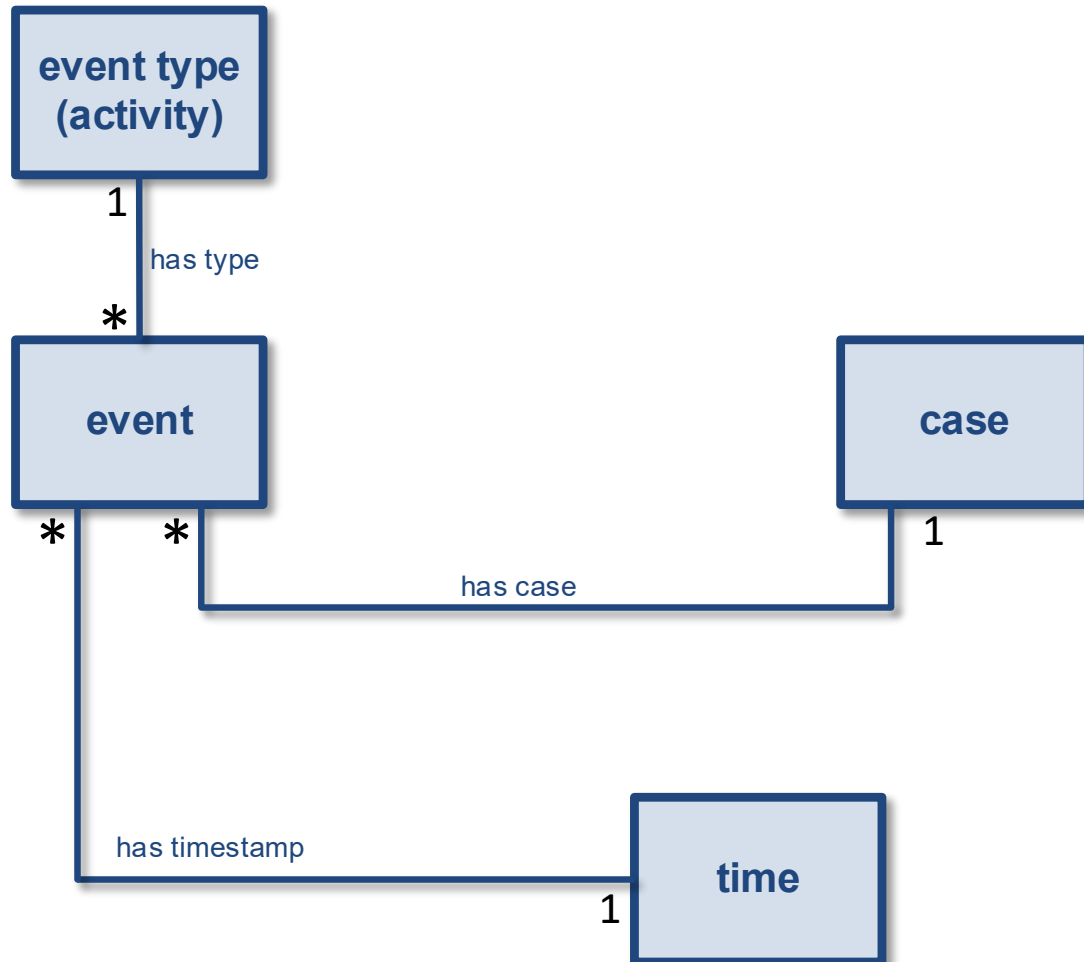


Case-Centric

Case-Centric



Removing event and case attributes



Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	send invoice	2018/02/21 09:38:16.000
6350	pay	2018/03/02 12:39:37.000
6352	pay	2018/03/05 15:46:47.000
6351	cancel order	2018/03/06 10:17:01.000
6350	prepare delivery	2018/03/07 13:50:35.000
6350	make delivery	2018/03/07 16:41:01.000
6350	confirm payment	2018/03/07 16:53:00.000
6352	prepare delivery	2018/03/07 17:05:59.000
6352	confirm payment	2018/03/07 17:59:55.000
6352	make delivery	2018/03/08 09:54:36.000

To start: Let's keep it as simple as possible!

- For now we focus on **control-flow** and **discovery** and (a bit of) **conformance checking**.
- Later other perspectives and types will follow!
- We start with introducing **process models** and **event logs**.



Process Models

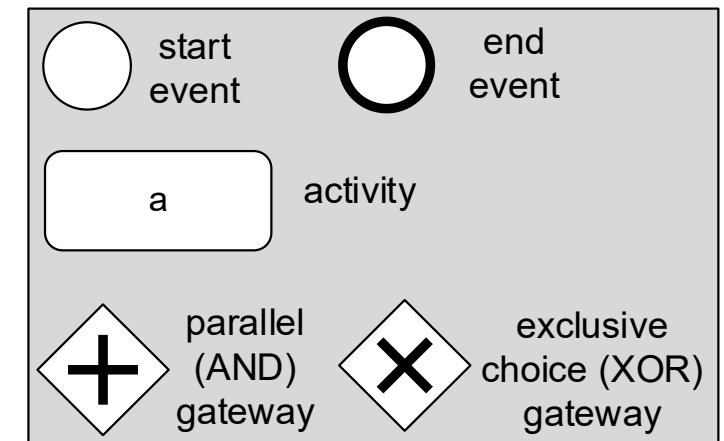
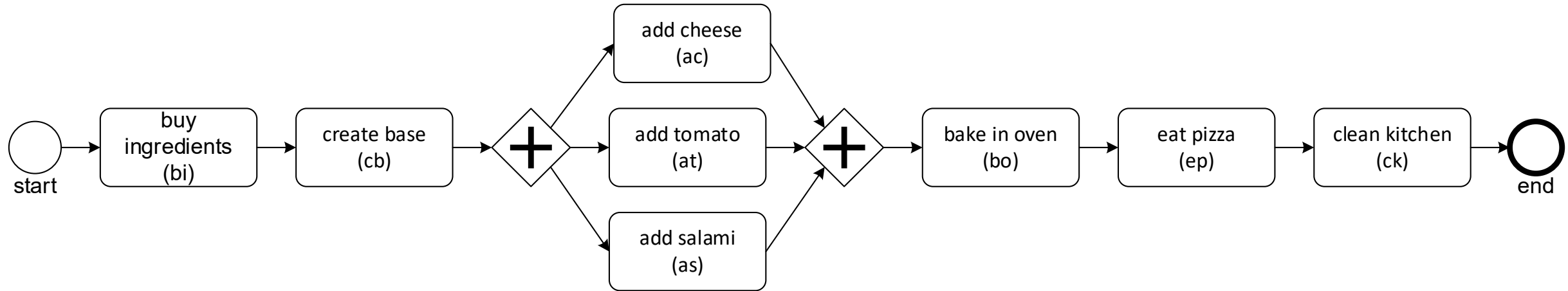
(control-flow only)

Running example

(yes, process mining is related to Italian food)



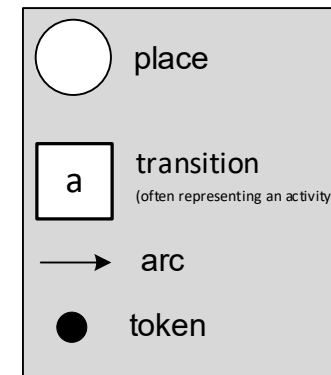
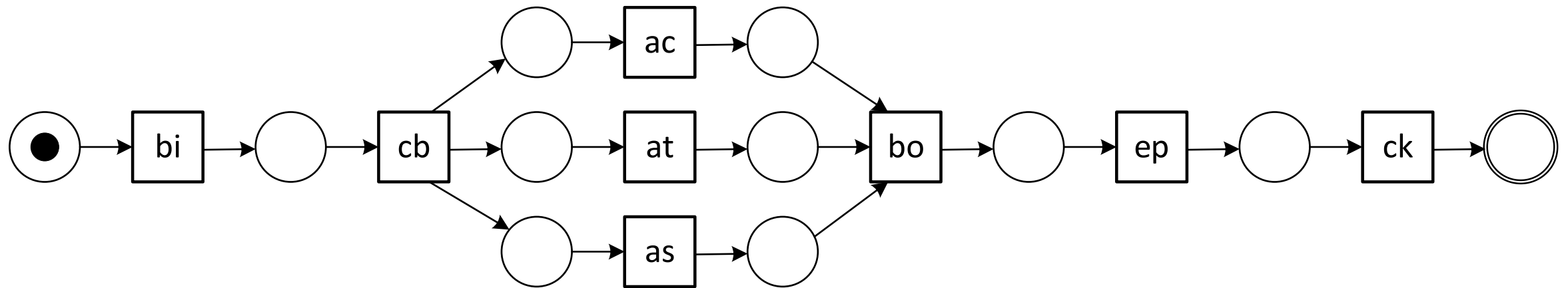
A BPMN model



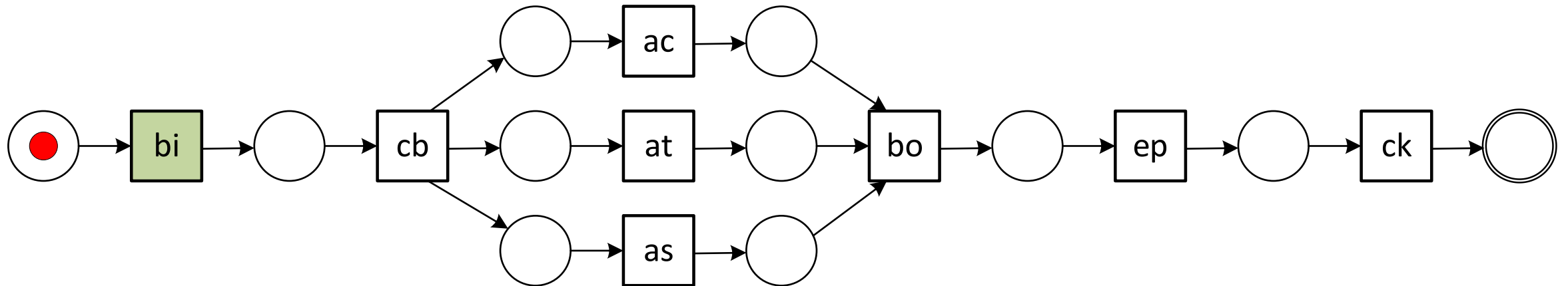
How many possible executions?

Same process now as a Petri net

Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

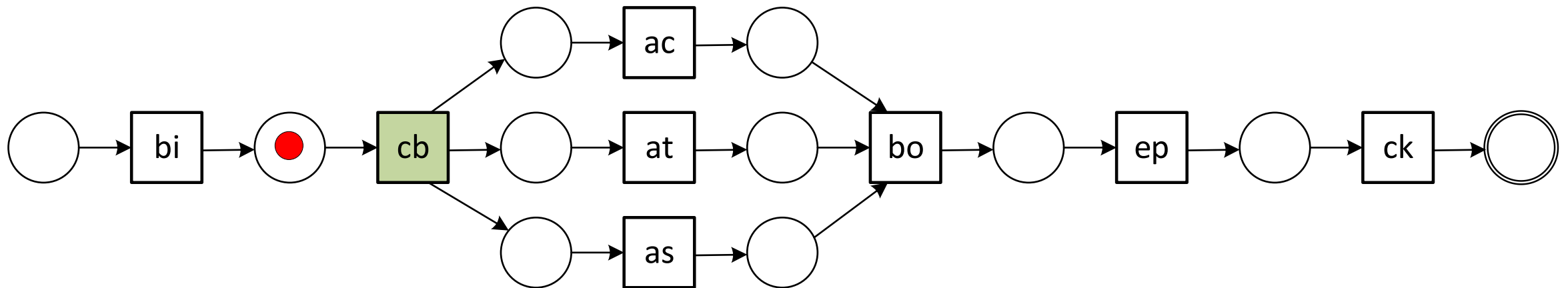


One execution of the Petri net (1/9)



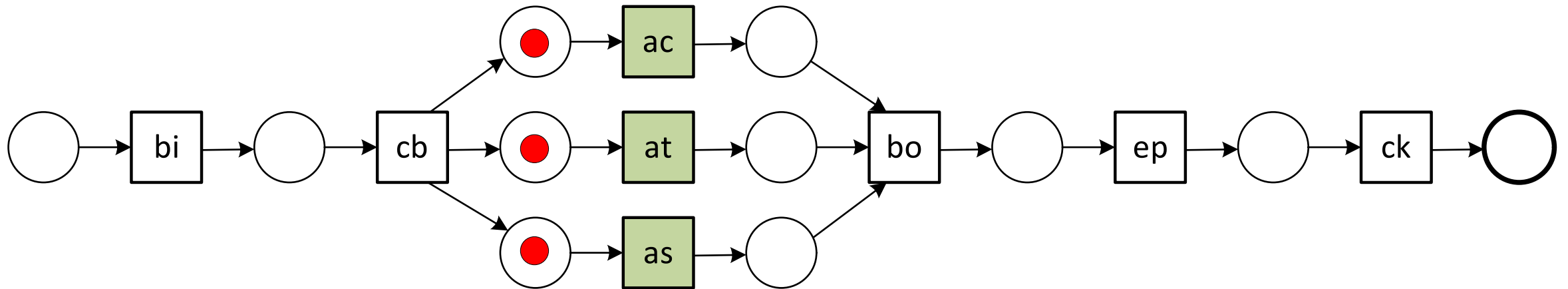
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (2/9)



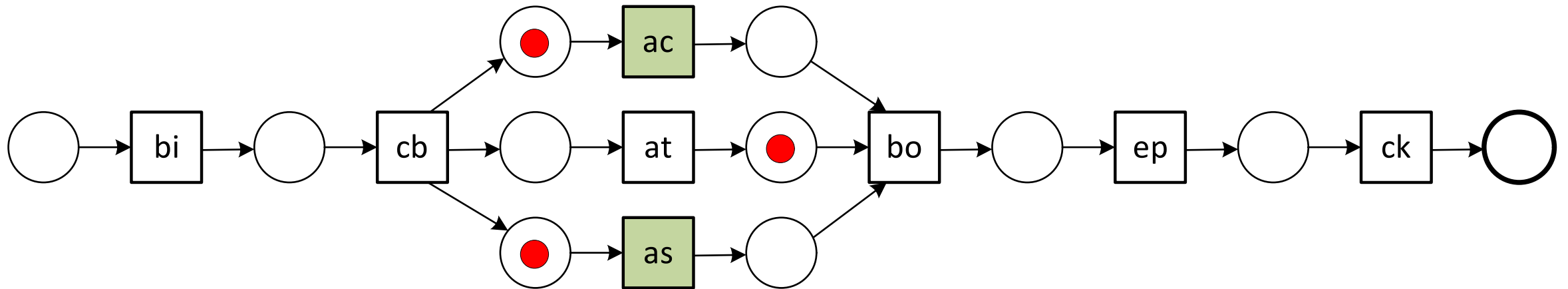
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (3/9)



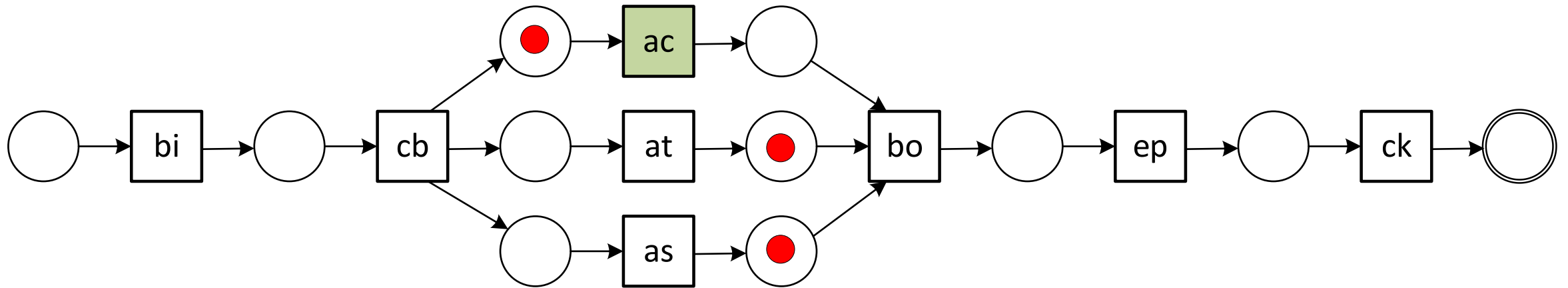
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (4/9)



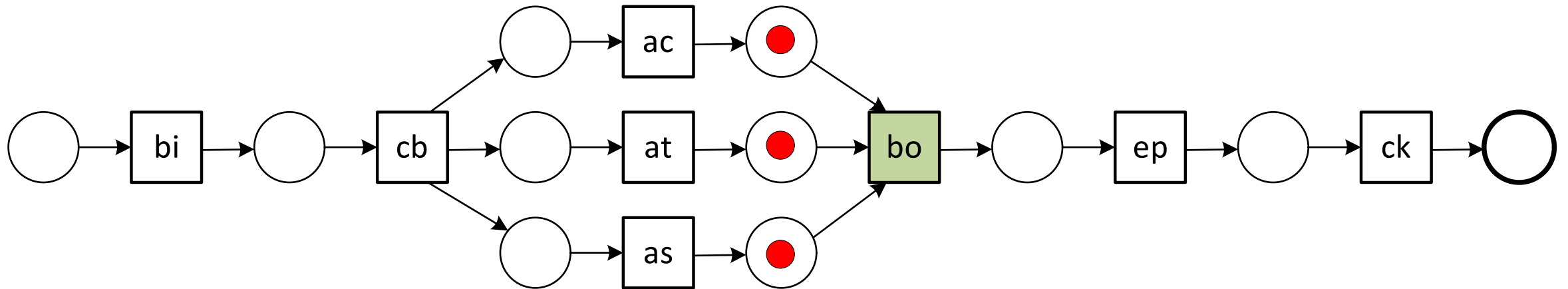
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (5/9)



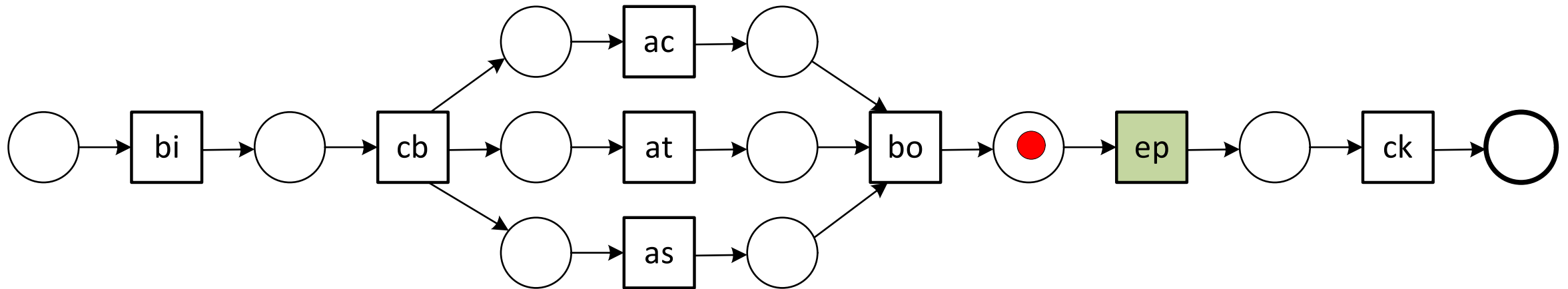
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (6/9)



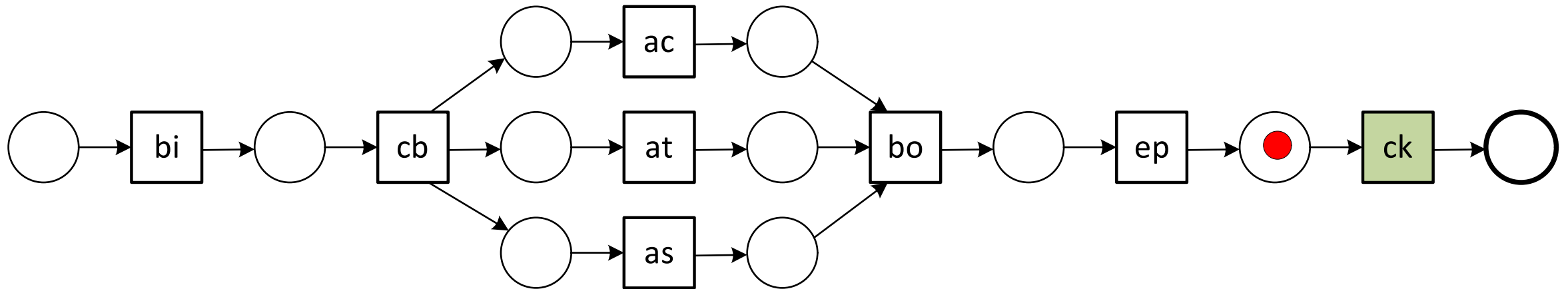
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (7/9)



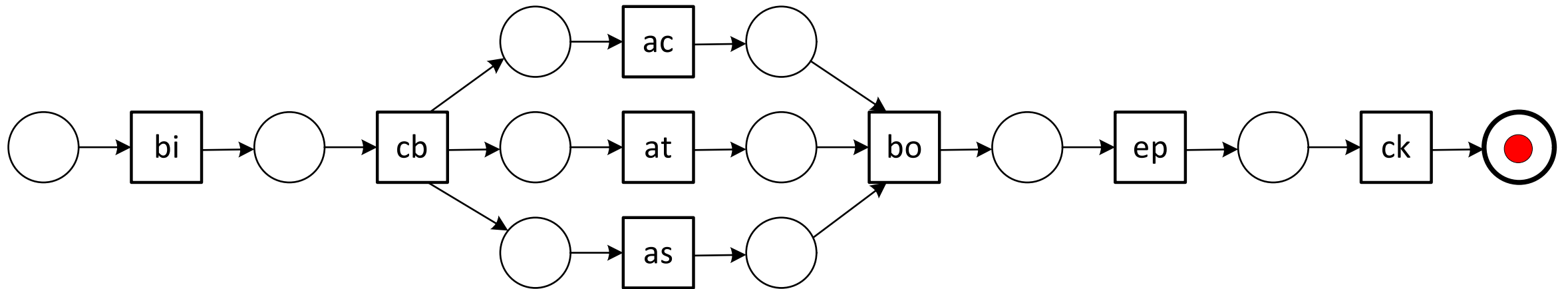
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (8/9)



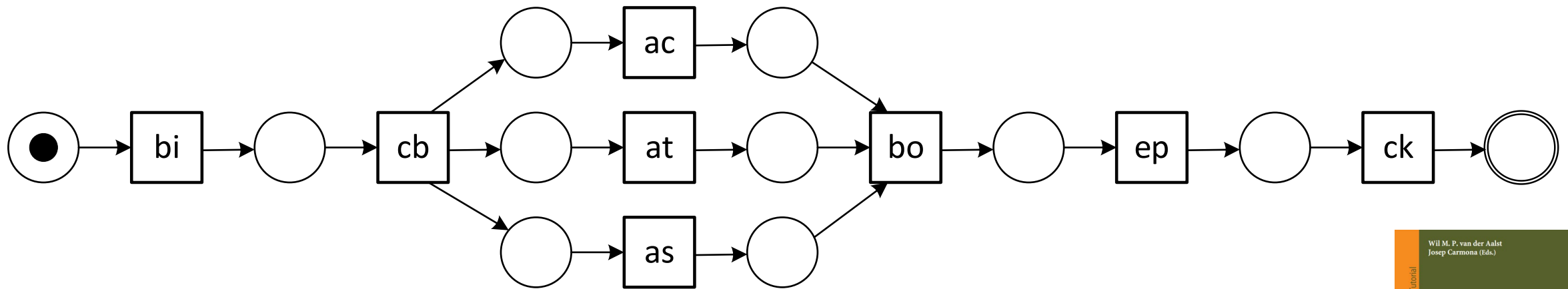
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the Petri net (9/9)

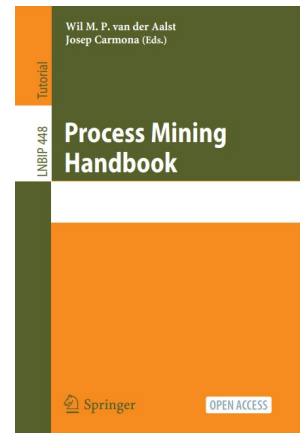


Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

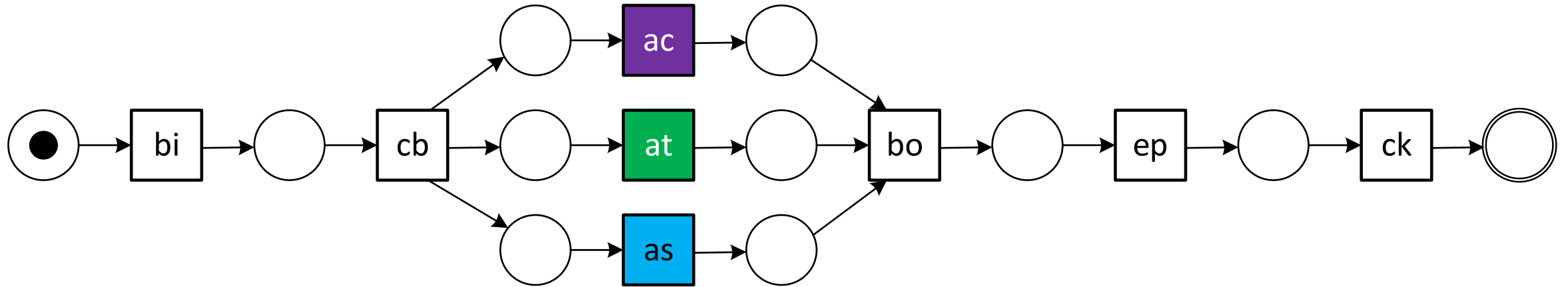
An accepting Petri net has an initial and final marking



Definition 14 (Accepting Petri Net). An accepting Petri net is a triplet $AN = (N, M_{init}, M_{final})$ where $N = (P, T, F, l)$ is a labeled Petri net, $M_{init} \in \mathcal{B}(P)$ is the initial marking, and $M_{final} \in \mathcal{B}(P)$ is the final marking. $\mathcal{U}_{AN} \subseteq \mathcal{U}_M$ is the set of accepting Petri nets.

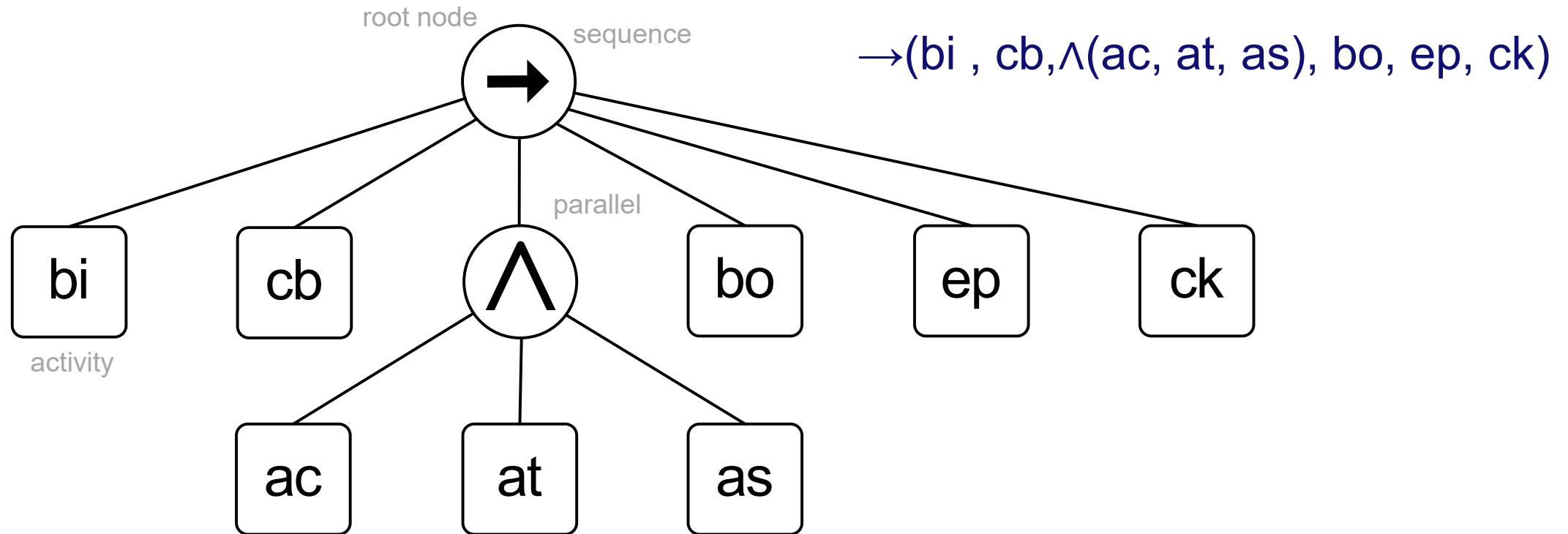


An accepting Petri net defines a set of traces



$3! = 3 \times 2 \times 1 = 6$ possible traces

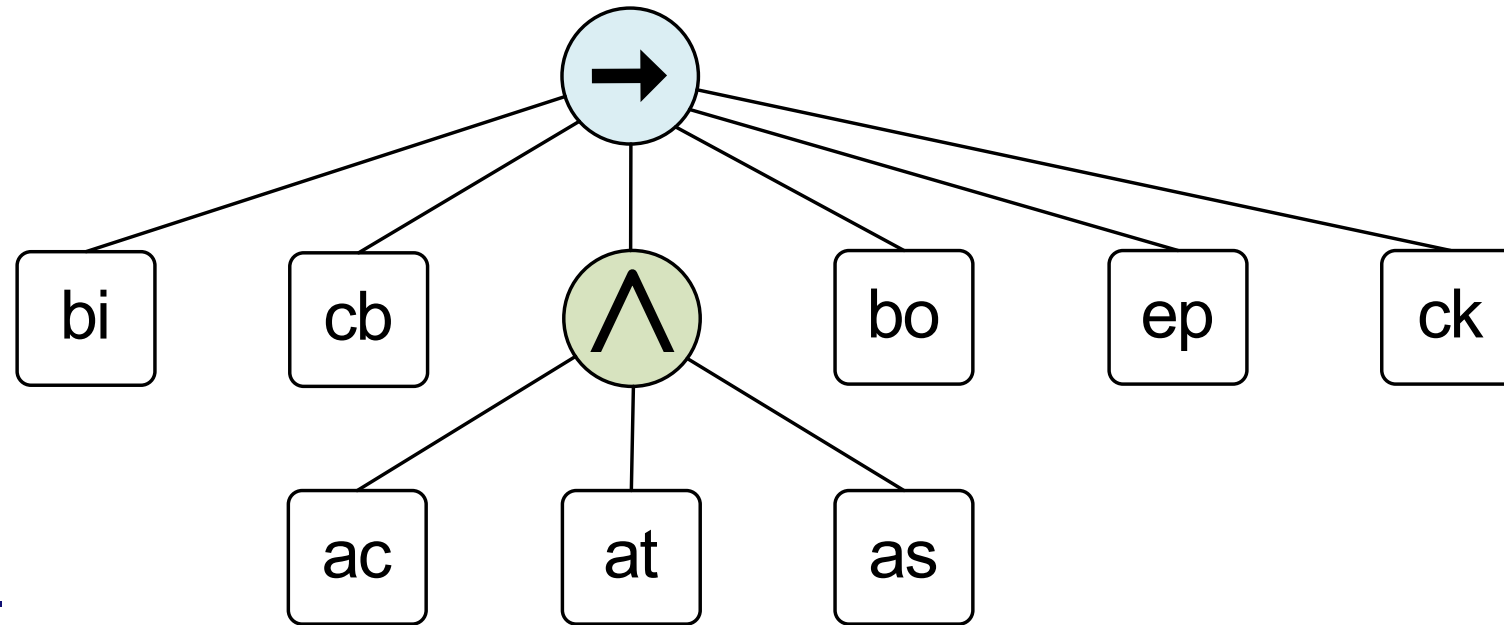
A process tree



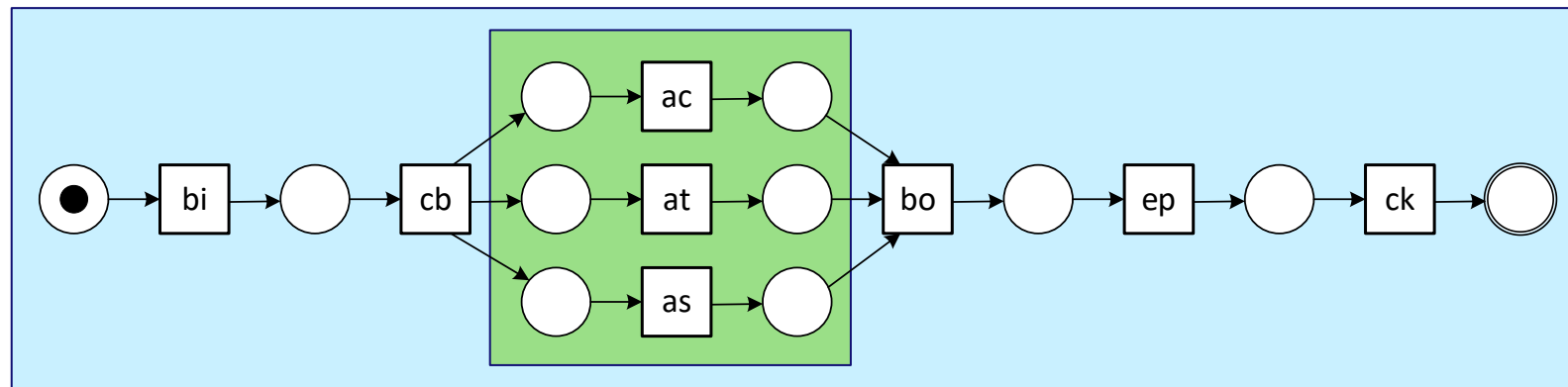
Four types of operators: $\rightarrow$ (sequential composition), $\times$ (exclusive choice), $\wedge$ (parallel composition), and $\odot$ (redo loop).

Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

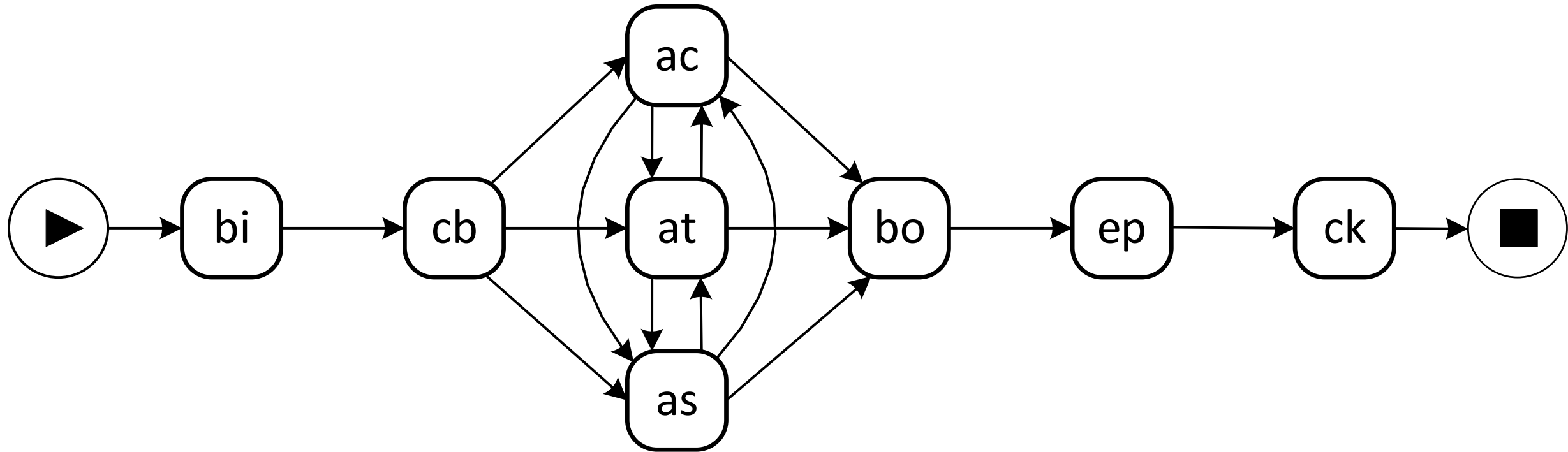
The semantics of a process tree



Direct or in terms of
accepting Petri nets.

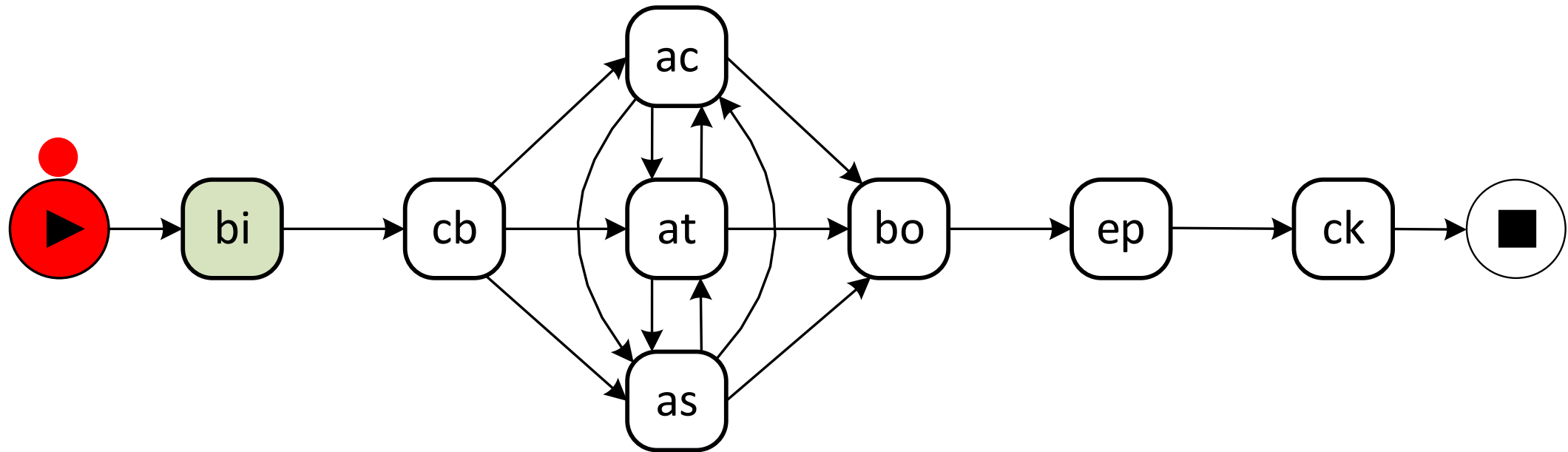


Directly-Follows Graph (DFG)



- A one-to-one correspondence between activities and nodes (except for start and end).
- One can think of the “state” as the last activity executed, i.e., just one token.

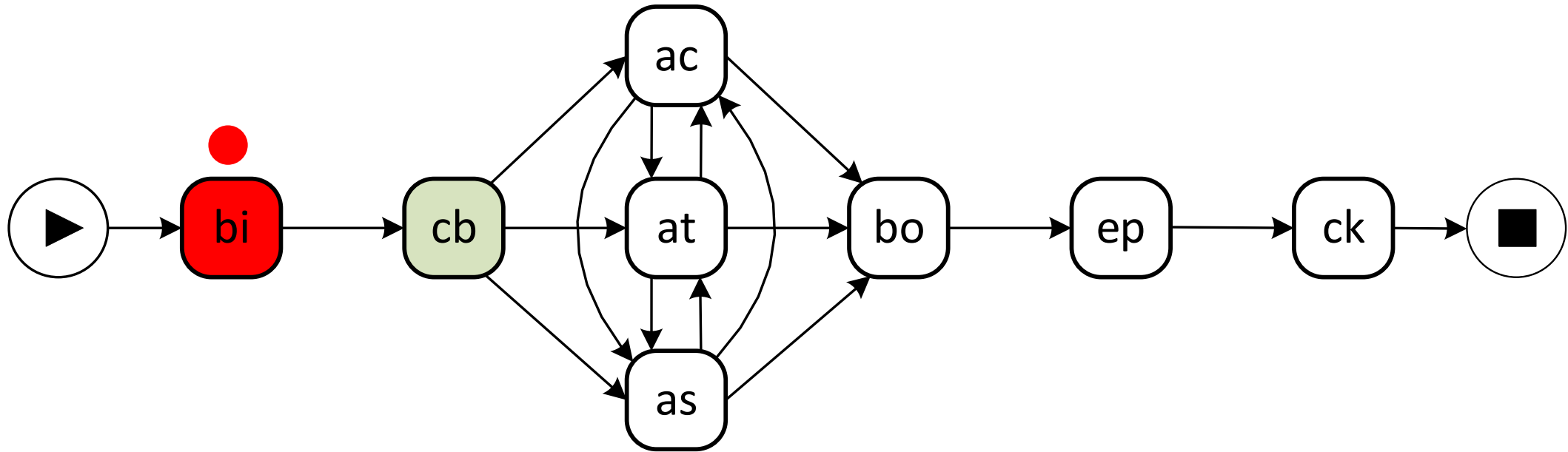
One execution of the DFG (1/9)



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

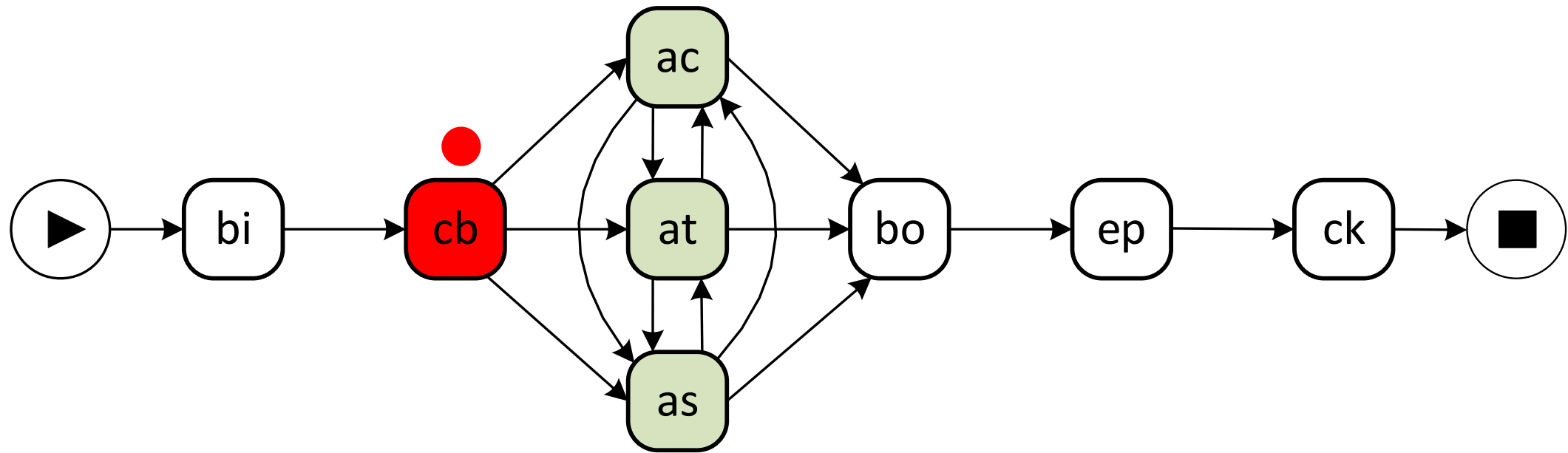


One execution of the DFG (2/9)



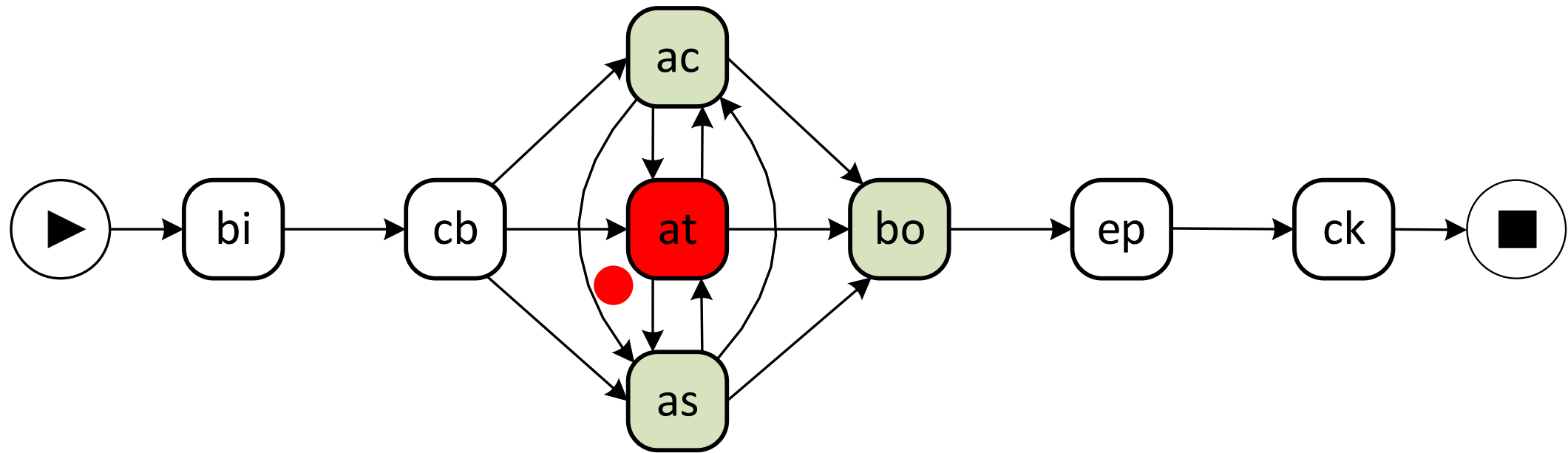
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the DFG (3/9)



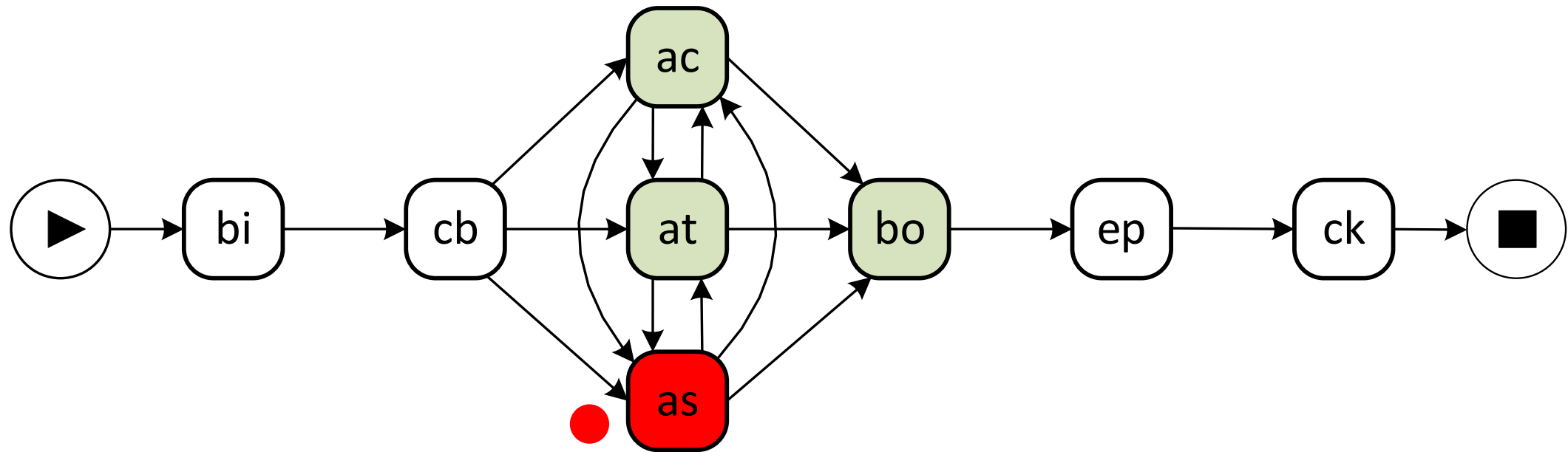
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the DFG (4/9)



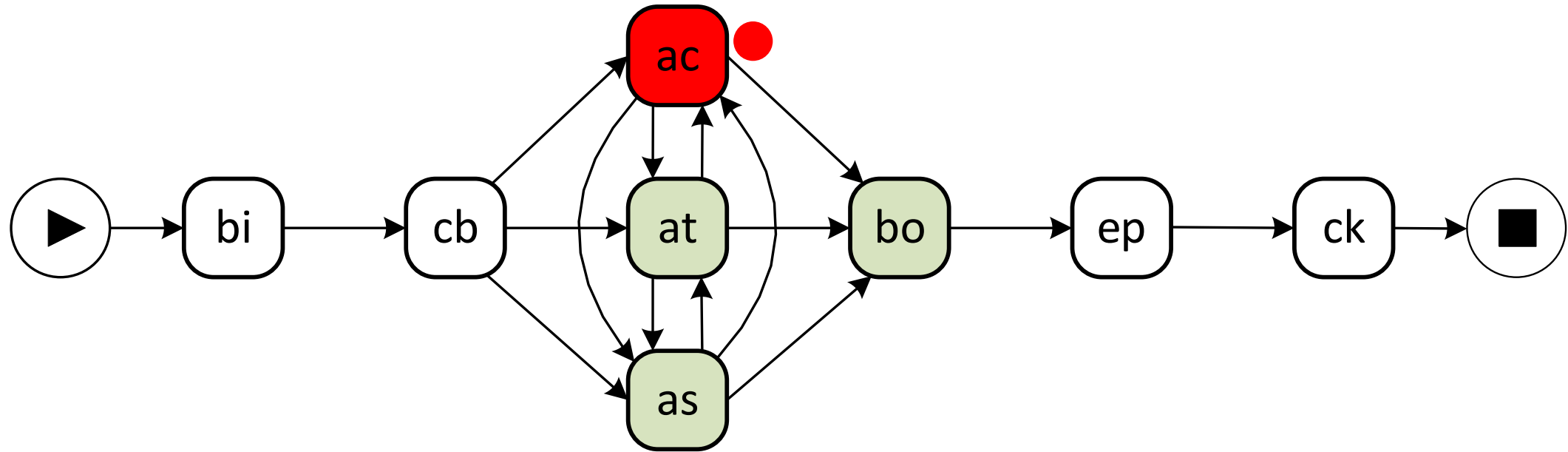
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the DFG(5/9)



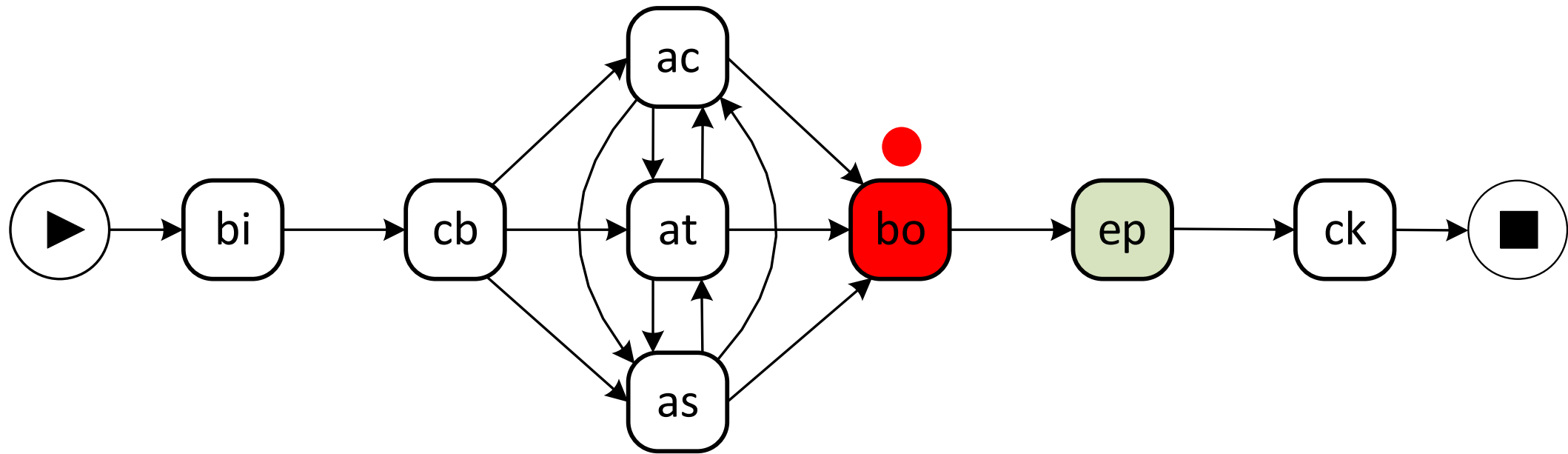
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the DFG (6/9)



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

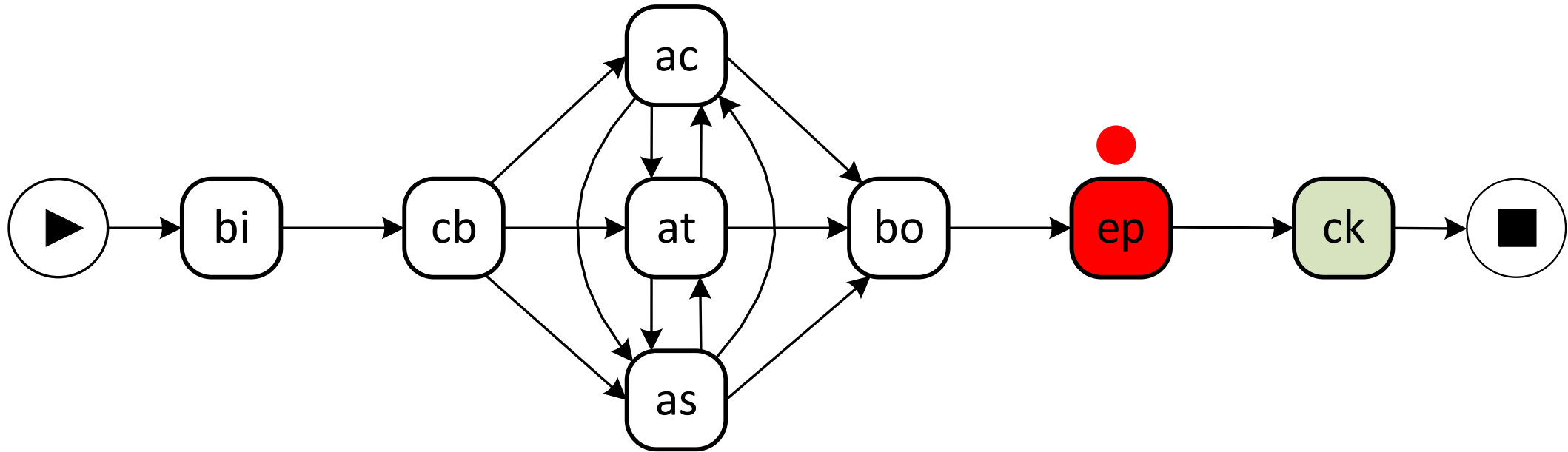
One execution of the DFG (7/9)



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

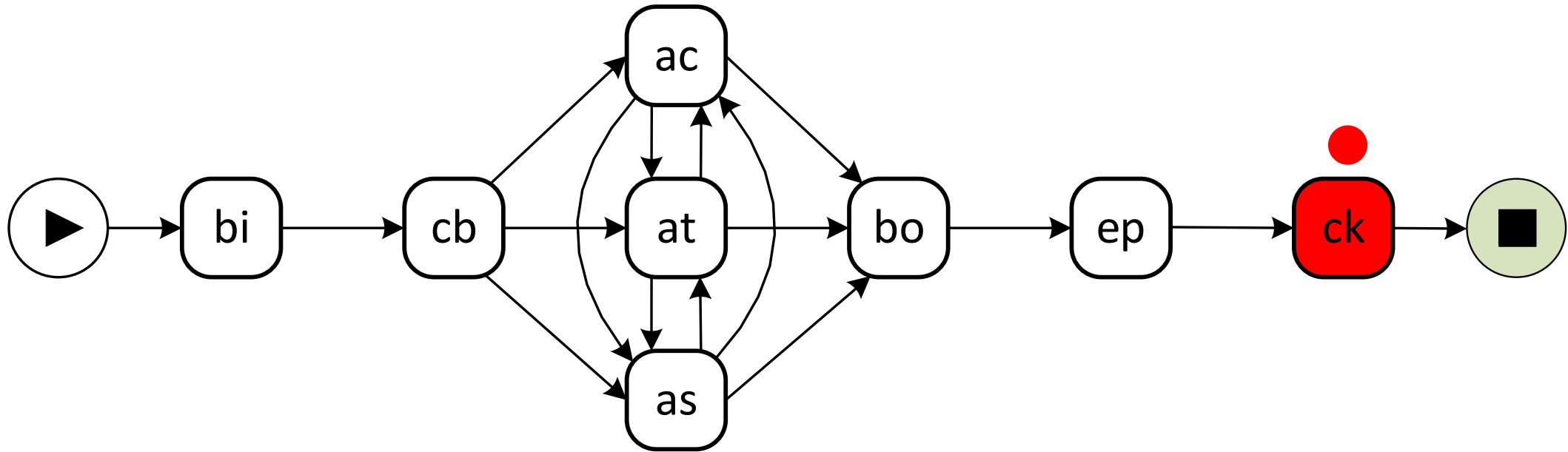


One execution of the DFG (8/9)



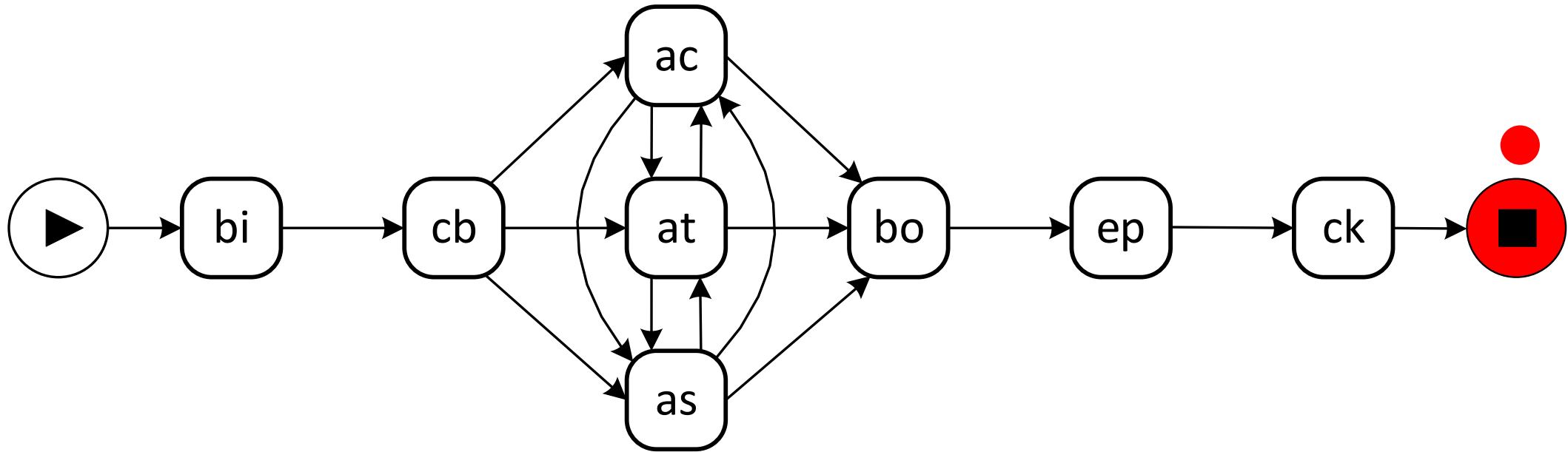
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

One execution of the DFG (9/9)



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

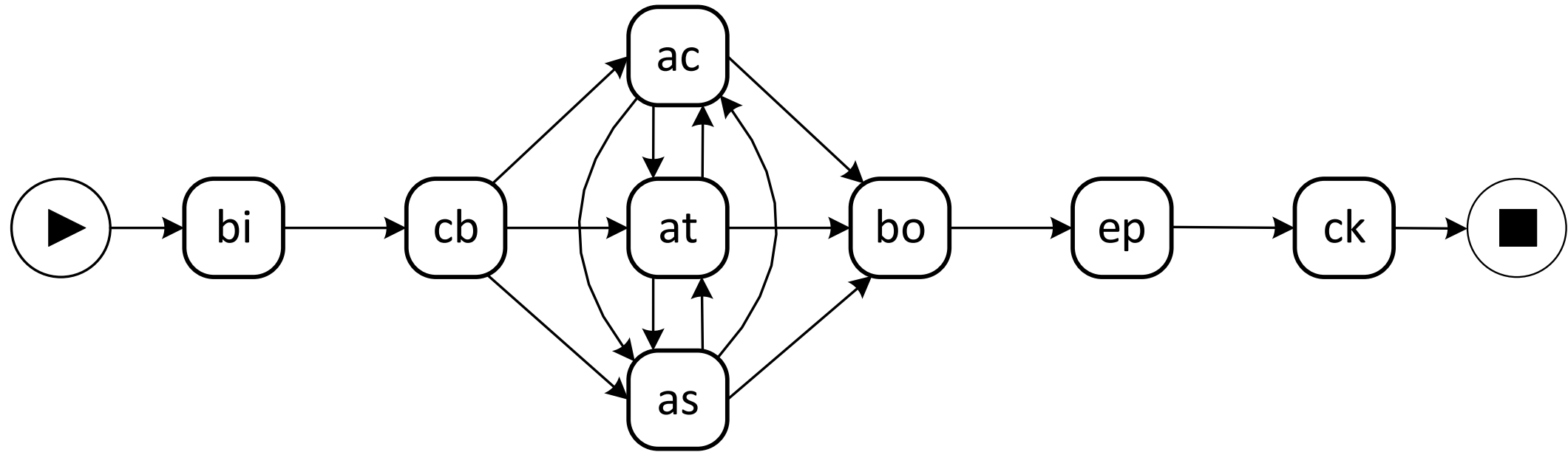
One complete execution of the DFG



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).



The DFG allows for many more traces



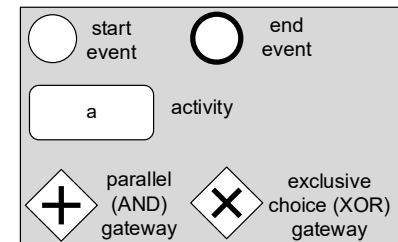
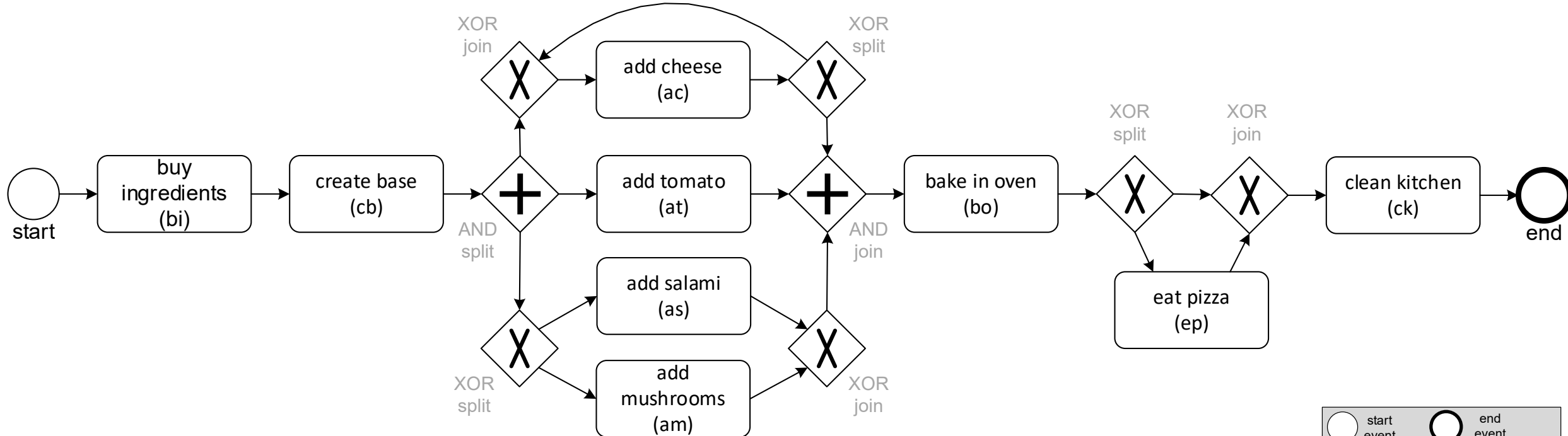
Infinitely many possible traces!

Extended process

Differences: (1) choice between salami and mushrooms, (2) cheese can be added multiple times, and (3) one can skip eating the pizza.

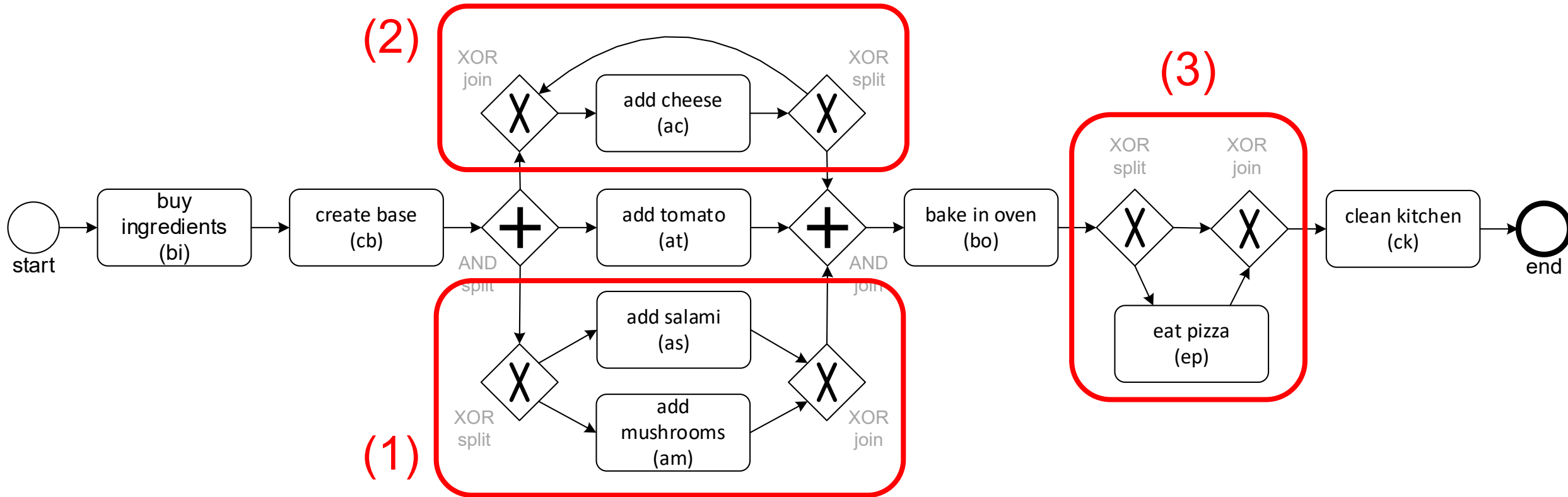


Alternative BPMN model



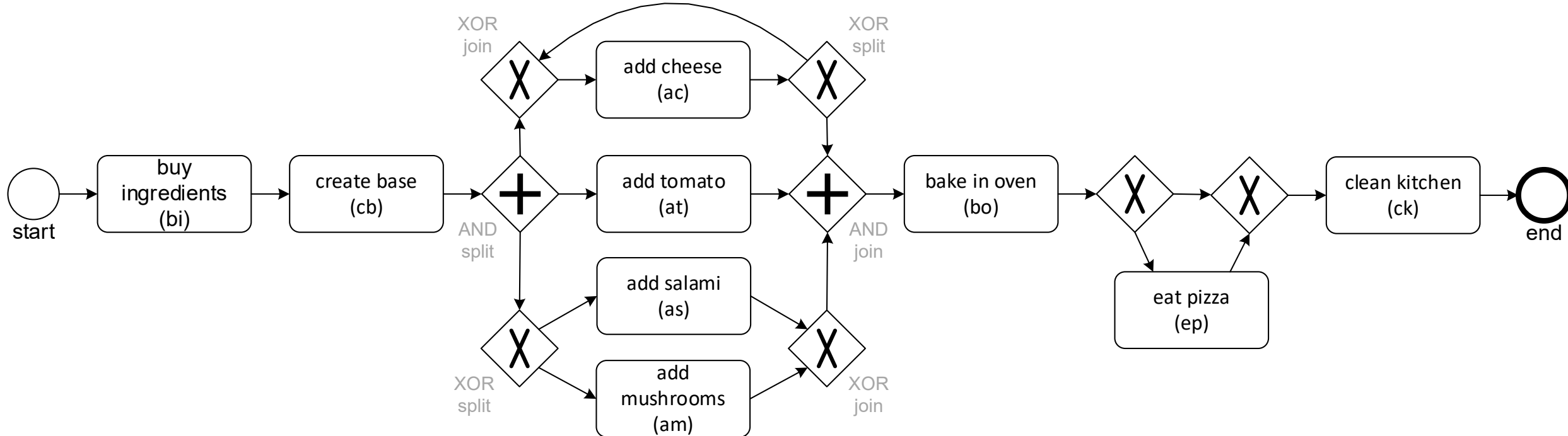
Differences: (1) choice between salami and mushrooms, (2) cheese can be added multiple times, and (3) one can skip eating the pizza.

Alternative BPMN model

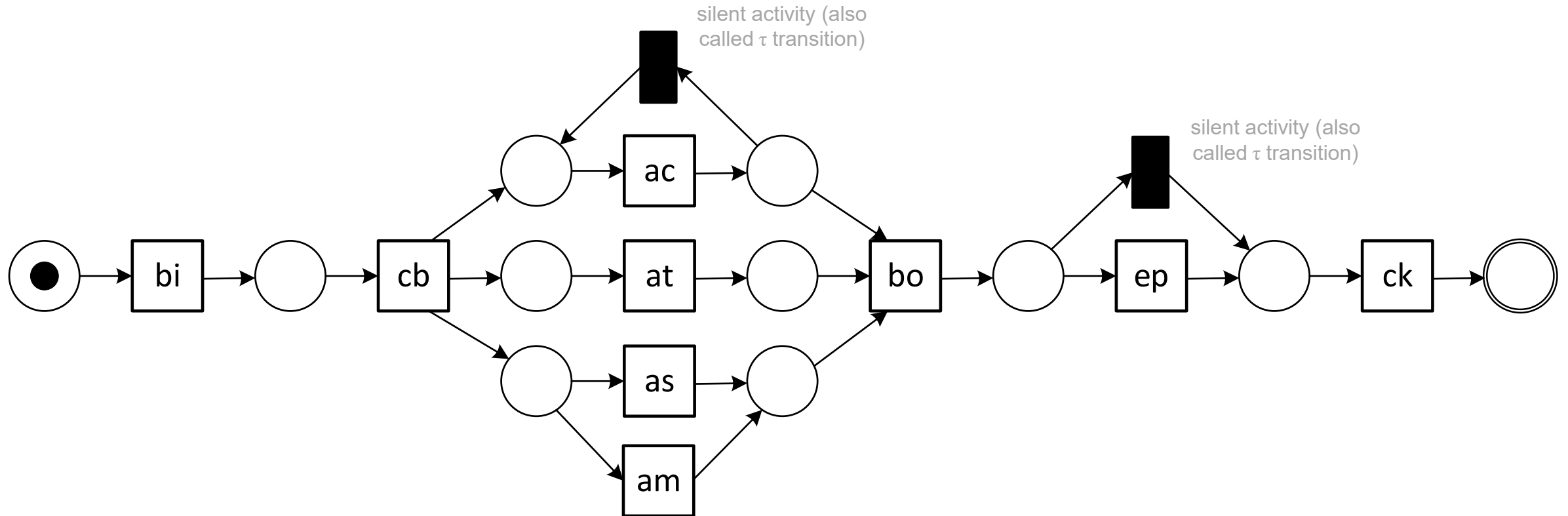


Differences: (1) choice between salami and mushrooms, (2) cheese can be added multiple times, and (3) one can skip eating the pizza.

How many traces?

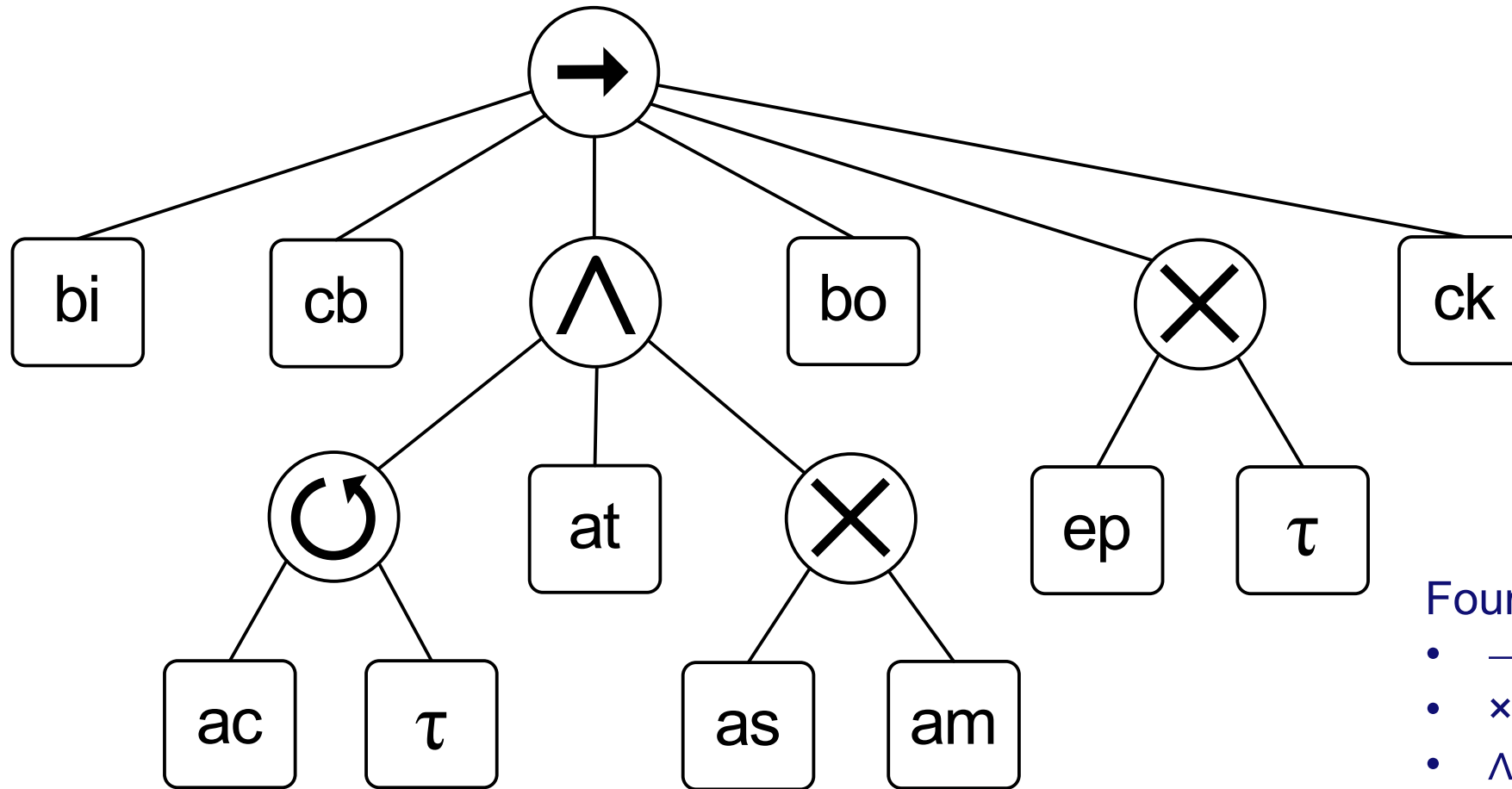


Corresponding Petri net



Same differences: (1) choice between salami and mushrooms, (2) cheese can be added multiple times, and (3) one can skip eating the pizza.

Corresponding process tree

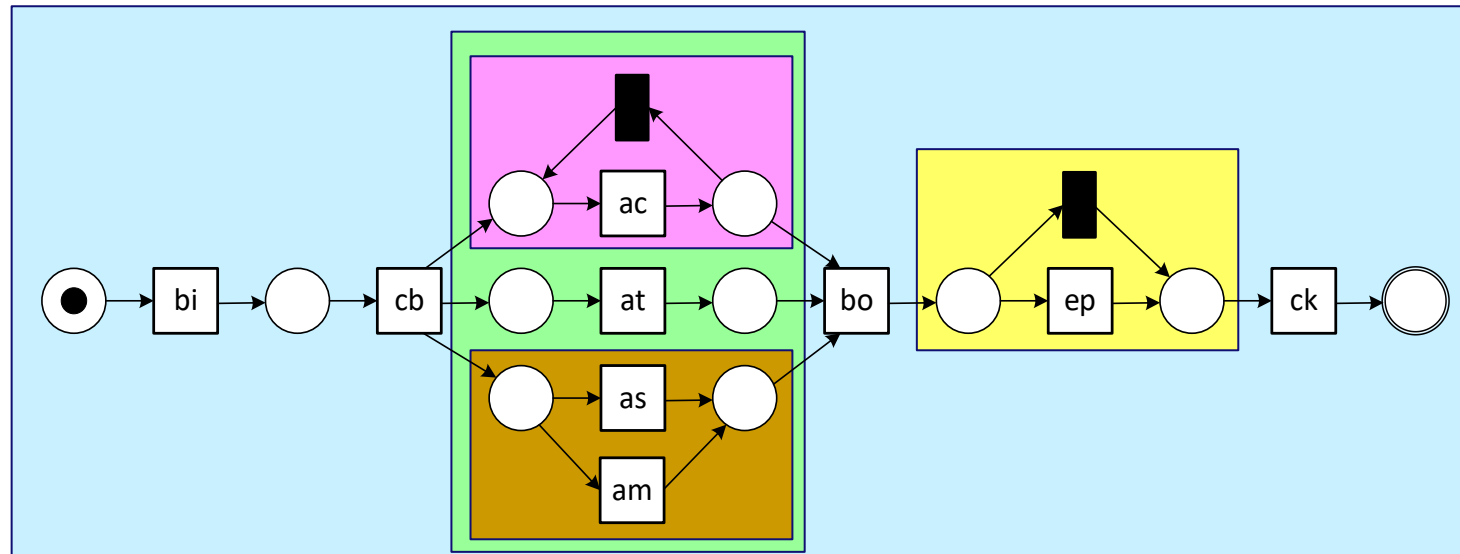
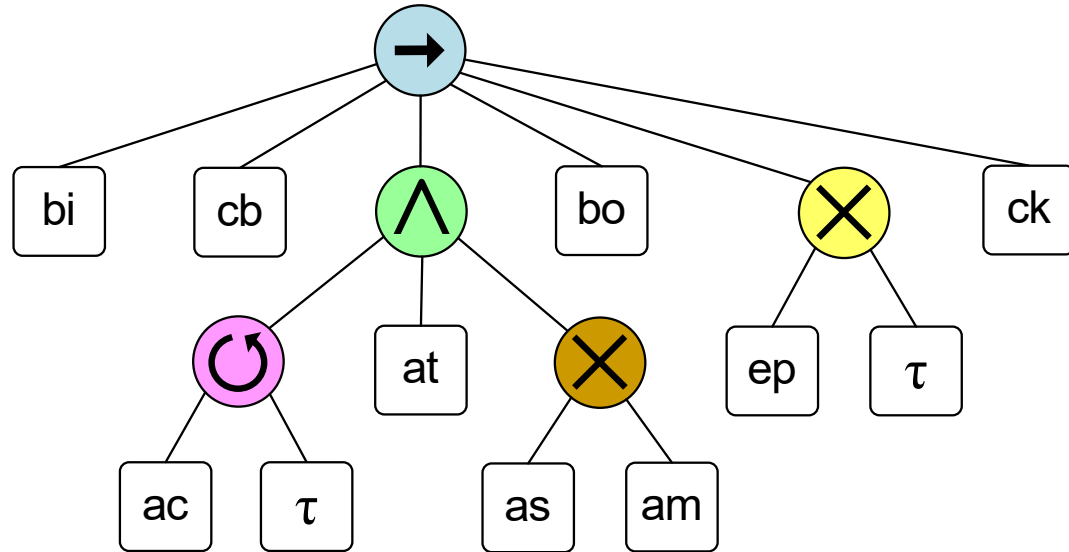


Four types of operators:

- $\rightarrow$ (sequential composition),
- $\times$ (exclusive choice),
- $\wedge$ (parallel composition), and
- $\curvearrowright$ (redo loop).

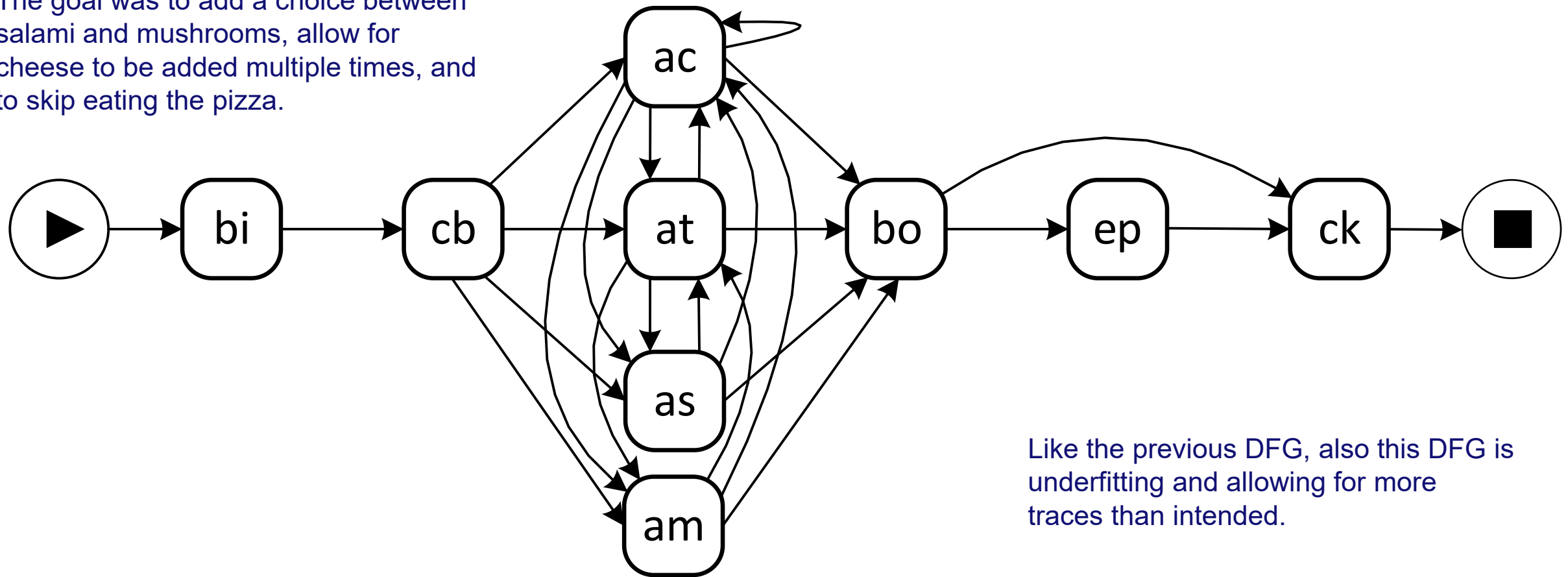
Same differences.

Semantics



The corresponding DFG

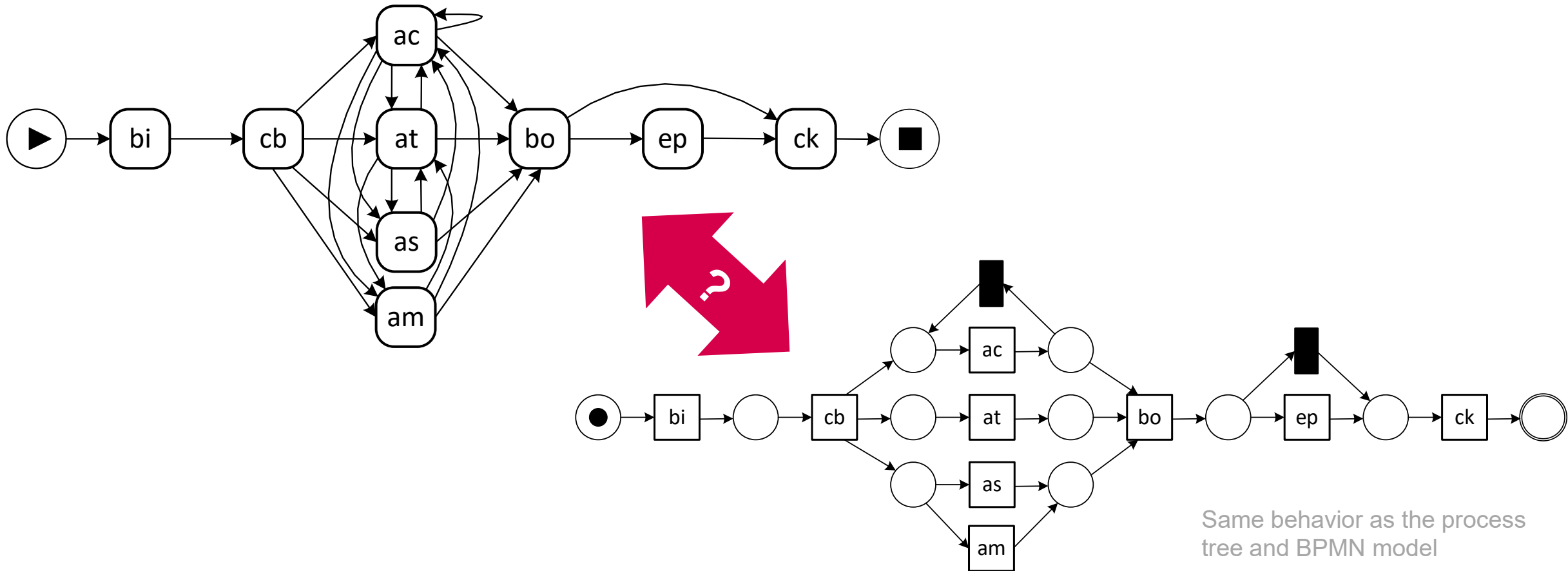
The goal was to add a choice between salami and mushrooms, allow for cheese to be added multiple times, and to skip eating the pizza.



Like the previous DFG, also this DFG is underfitting and allowing for more traces than intended.

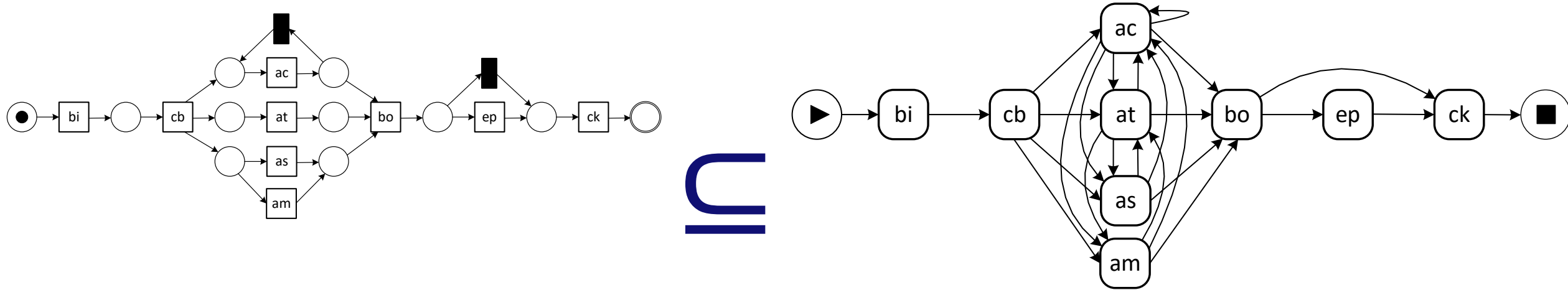
Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), add mushrooms (am), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

What are differences in behavior?



Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), add mushrooms (am), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

What are differences in behavior?



The DFG also allows for:

- Not adding cheese.
- Not adding tomato.
- Adding both salami and mushrooms.
- Adding tomato, salami, and mushrooms multiple times.

Using short names: buy ingredients (bi), create base (cb), add cheese (ac), add tomato (at), add salami (as), add mushrooms (am), bake in oven (bo), eat pizza (ep), and clean kitchen (ck).

Four types of basic process models

BPMN: The industry standard (here we just use a subset)

Petri nets: The oldest model for concurrent processes and the de facto standard in process mining research

Process trees: Frequently used in process mining because it is block structured and sound by construction

DFGs: Supported by all process mining tools (simple, but no concurrency)



Simplified event data used in the remainder

case	activity	timestamp	resource	customer
...	...	...	...	...
pizza-56	buy ingredients (<i>bi</i>)	18:10	Stefano	Valentina
pizza-57	buy ingredients (<i>bi</i>)	18:12	Stefano	Giulia
pizza-57	create base (<i>cb</i>)	18:16	Mario	Giulia
pizza-56	create base (<i>cb</i>)	18:19	Mario	Valentina
pizza-57	add tomato (<i>at</i>)	18:21	Mario	Giulia
pizza-57	add cheese (<i>ac</i>)	18:27	Mario	Giulia
pizza-56	add cheese (<i>ac</i>)	18:34	Mario	Valentina
pizza-56	add tomato (<i>at</i>)	18:44	Mario	Valentina
pizza-56	add salami (<i>as</i>)	18:45	Mario	Valentina
pizza-56	bake in oven (<i>bo</i>)	18:48	Stefano	Valentina
pizza-57	add salami (<i>as</i>)	18:50	Mario	Giulia
pizza-56	eat pizza (<i>ep</i>)	19:10	Valentina	Valentina
pizza-58	buy ingredients (<i>bi</i>)	19:17	Stefano	Laura
pizza-57	bake in oven (<i>bo</i>)	19:23	Stefano	Giulia
pizza-57	eat pizza (<i>ep</i>)	19:27	Giulia	Giulia
pizza-57	clean kitchen (<i>ck</i>)	19:44	Mario	Giulia
pizza-58	create base (<i>cb</i>)	19:48	Mario	Laura
pizza-58	add salami (<i>as</i>)	19:49	Mario	Laura
pizza-58	add tomato (<i>at</i>)	19:55	Mario	Laura
pizza-56	clean kitchen (<i>ck</i>)	20:08	Mario	Valentina
pizza-58	clean kitchen (<i>ck</i>)	20:51	Mario	Laura
...	...	...	...	...

normal event log (events with case, activity, time, etc. attributes)

case: pizza-56



case: pizza-57



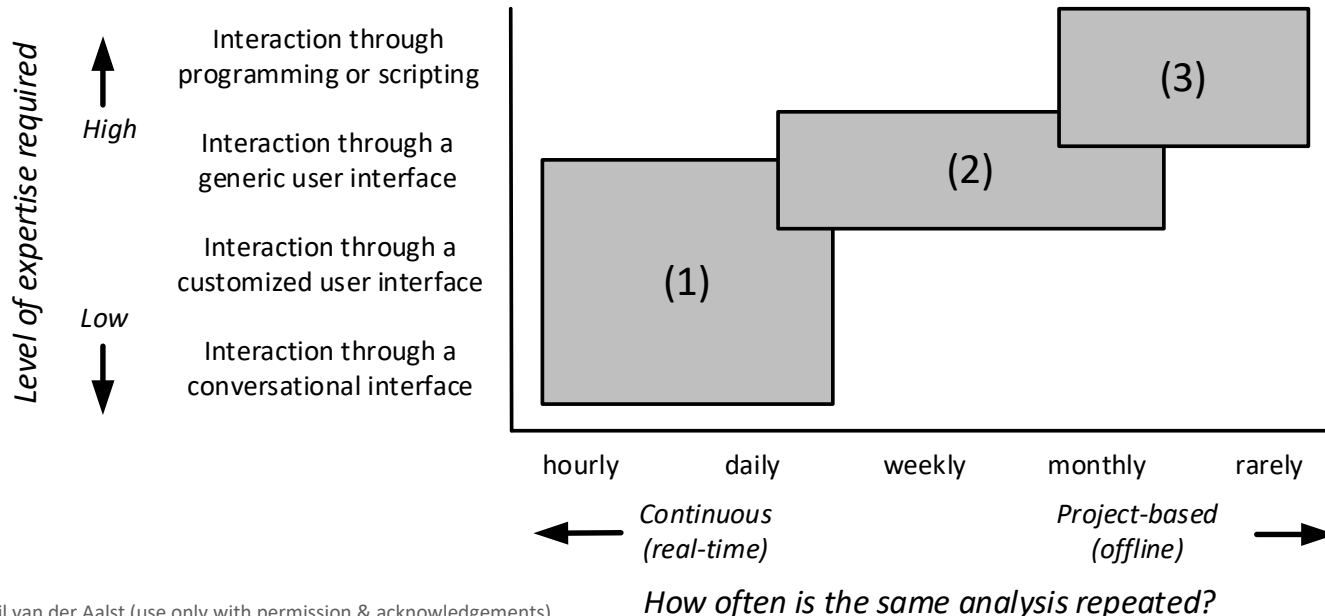
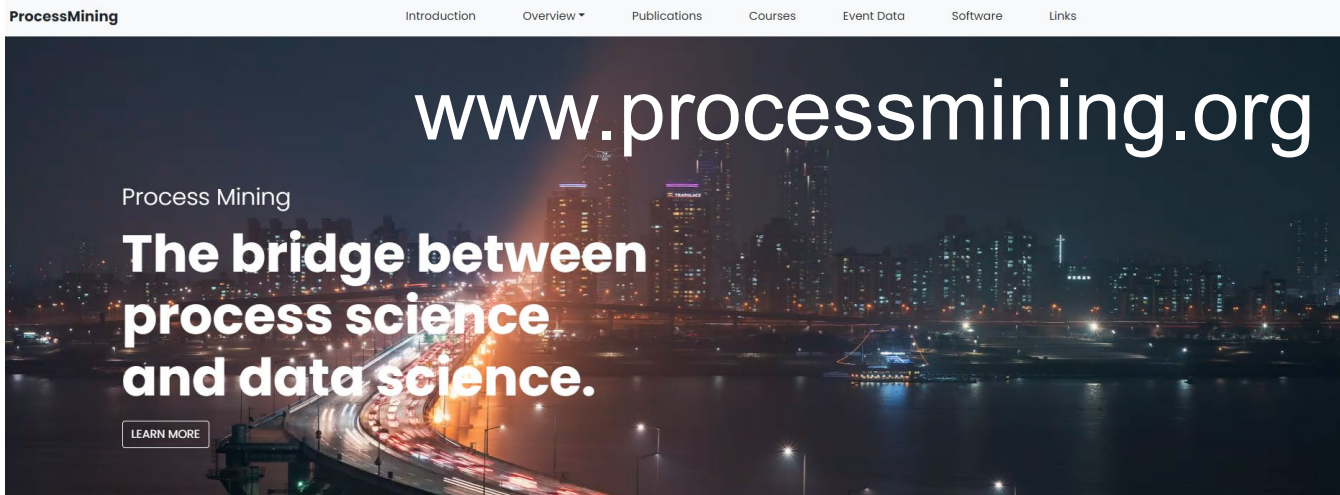
case: pizza-58



simplified event log (cases are represented as sequences of activities, ignoring all other attributes)

Software

Many process mining tools are available



- Interaction through programming or scripting
- Interaction through a generic user interface
- Interaction through a customized user interface
- Interaction through a conversational interface

- Continuous (real-time)
- Project-based (offline)

- Case-centric
- Object-centric

- Transition systems / Markov models
- Directly-Follows Graphs (DFGs)
- Petri nets / workflow nets
- Process trees
- Business Process Modeling Notation (BPMN)

- Data ingestion
- Event data visualization
- Event data querying and filtering
- Process discovery
- Process modeling
- Conformance checking
- Performance analysis
- Comparative analysis
- Decision mining
- Resource and organizational mining
- Simulation-based analysis
- Dashboarding and process monitoring
- Reporting and documentation
- Conversational process mining
- Action-oriented process mining

- On premise
- Private cloud
- Multi-tenant cloud
- Limited scale
- Extended scale
- Enterprise scale
- Hyperscale

Two example tools used to illustrate the concepts



open source
academic
local installation
single user
for data/process experts



closed source
commercial
cloud based
multiple users
also for non-experts

Many more tools, e.g.,



Object-Centric
Process Querying

Exploring object-centric process data made easy.

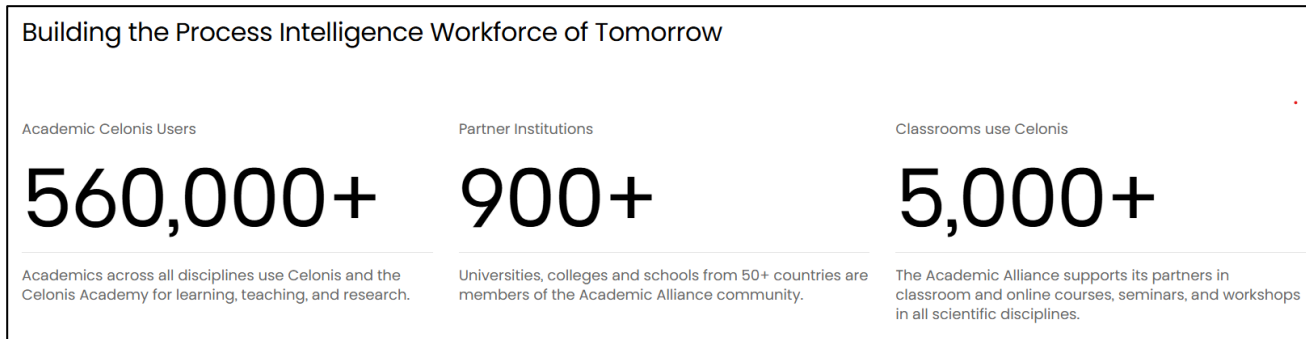


Chair of Process
and Data Science

Getting the software

I assume you have watched the videos!

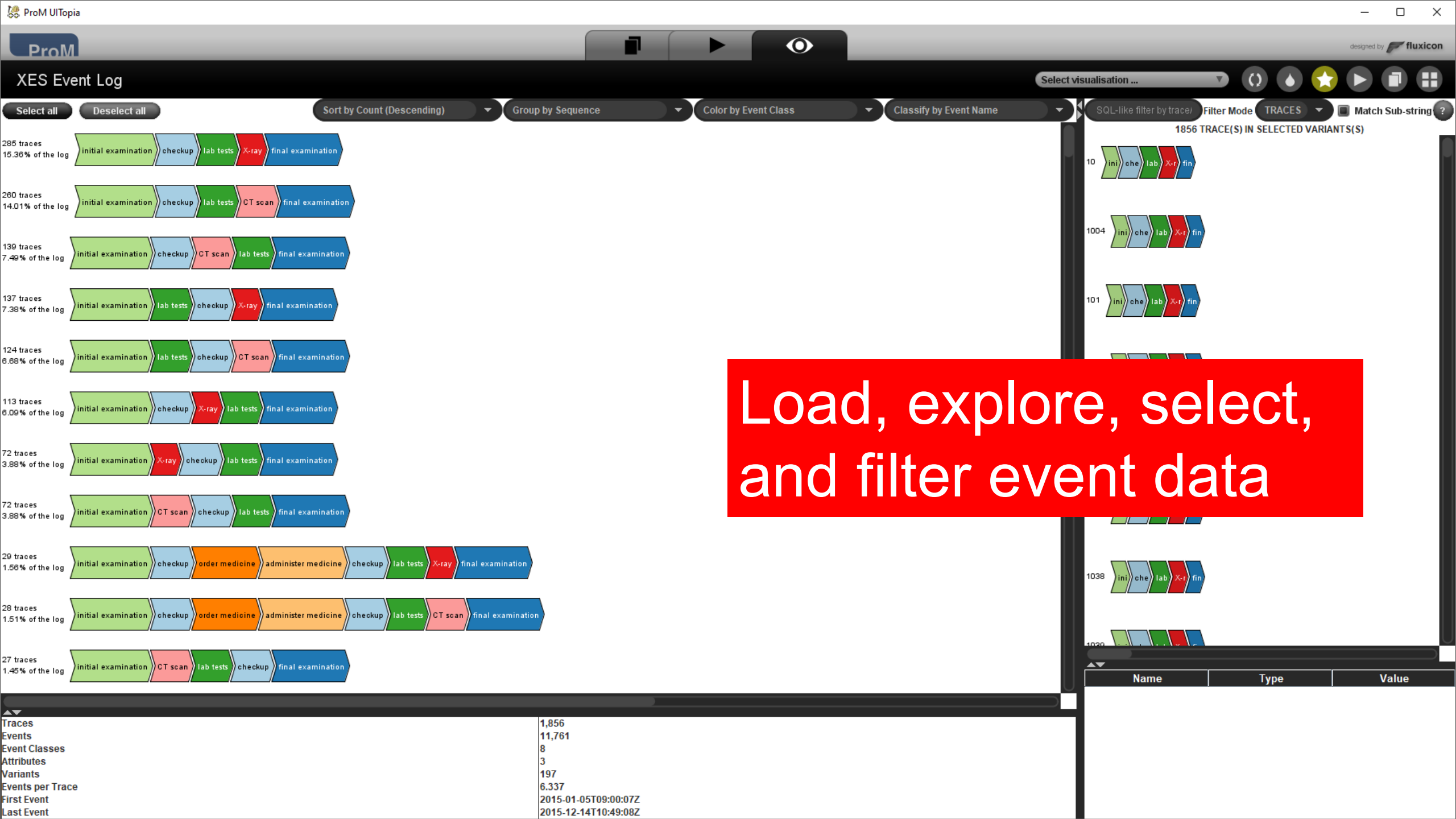
- **ProM**: download from www.promtools.org. Please install ProM 6.15 or ProM Lite 1.4. ProM requires Java 8. If you encounter issues, you may use the Docker setup described in the video
- **Celonis**: get access via: signup.celonis.com. See academy.celonis.com for additional resources:



Example of an open-source tool: ProM

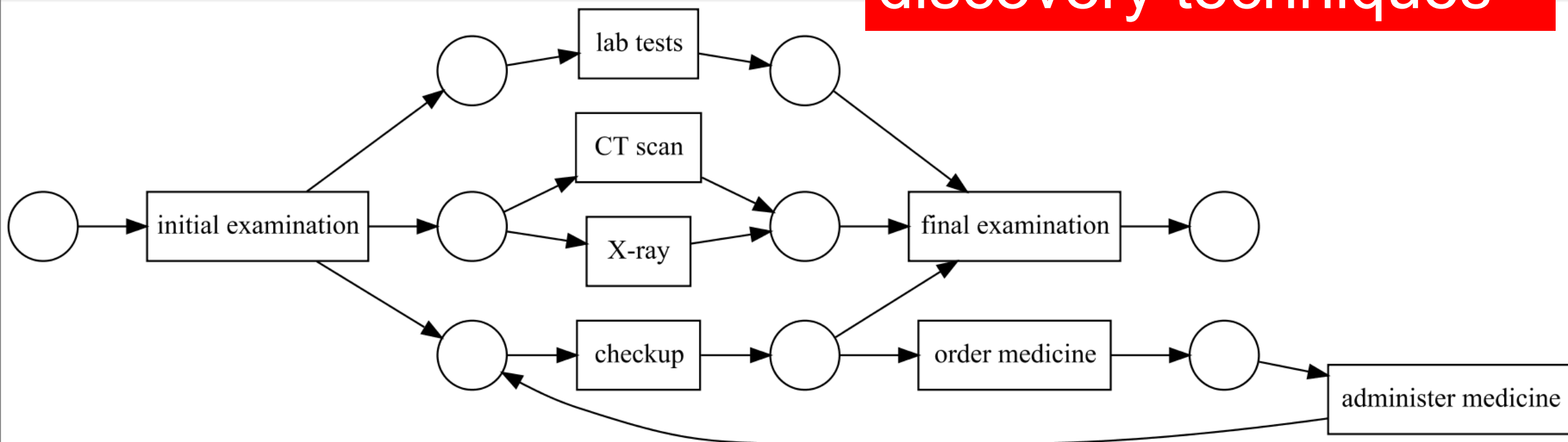
- For a long time, the de facto standard tool for process mining. Created to avoid reinventing the wheel in science.
- ProM 1.1, released in 2004, had 29 plug-ins.
- ProM 6.15 has over 1500 plug-ins.
- Different flavors: **ProM**, **ProM Lite**, **Nightly Builds**, **RapidProM**.
- GNU Public License (**GPL**) for core and Lesser GNU Public License (**L-GPL**) for most of the plug-ins.



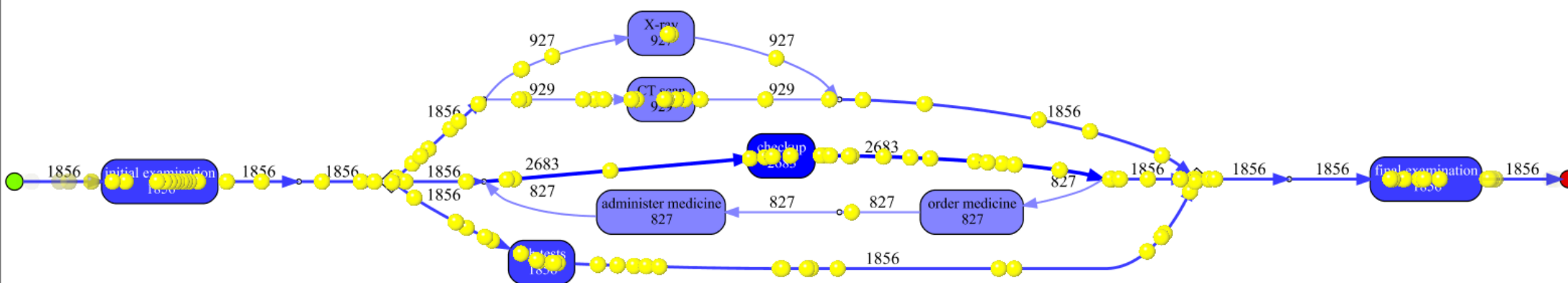




Dozens of process
discovery techniques



Animation on top of discovered models



activities:

paths:



1

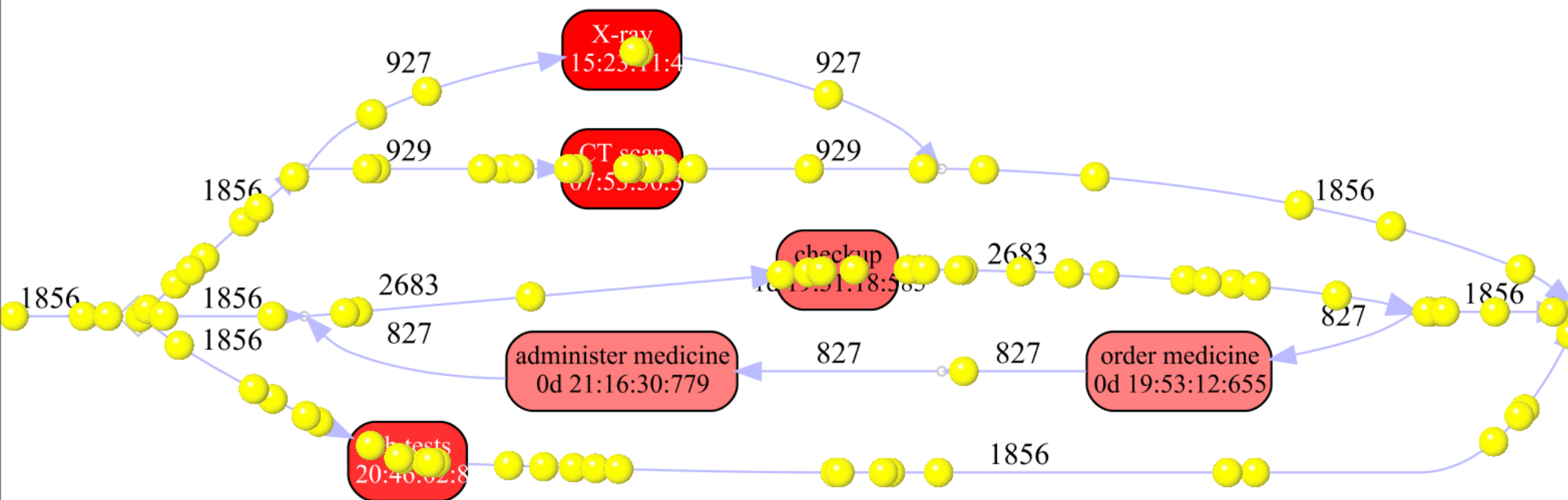
0.8

Classifier	conceptname
Miner	pre-mining filters
Miner	default miner (IMf)
Show	edit model
Show	paths
Show	trace colouring
Show	highlighting filters
Show	traces
Show	data analysis
Show	export log
Show	export model
Show	export ..

time: 30-03-2015 22:40:44:066

Highlighting all traces.

Bottleneck analysis



activities:

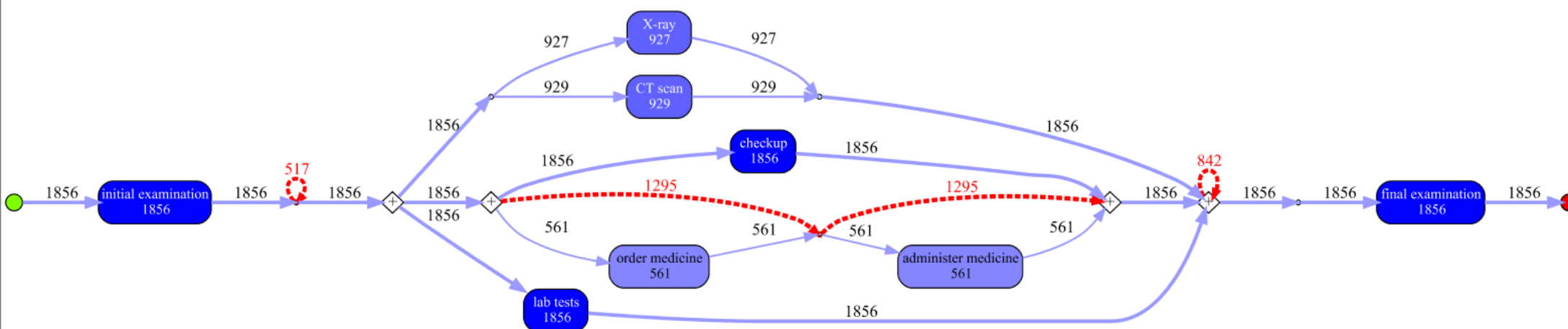
paths:

Classifier	conceptname
Miner	pre-mining filters
Show	default miner (IMf)
	edit model
	paths and sojourn times
	trace colouring
	highlighting filters
	traces
	data analysis
	export log
	export model
	export ..

time: 30-03-2015 22:40:44:066

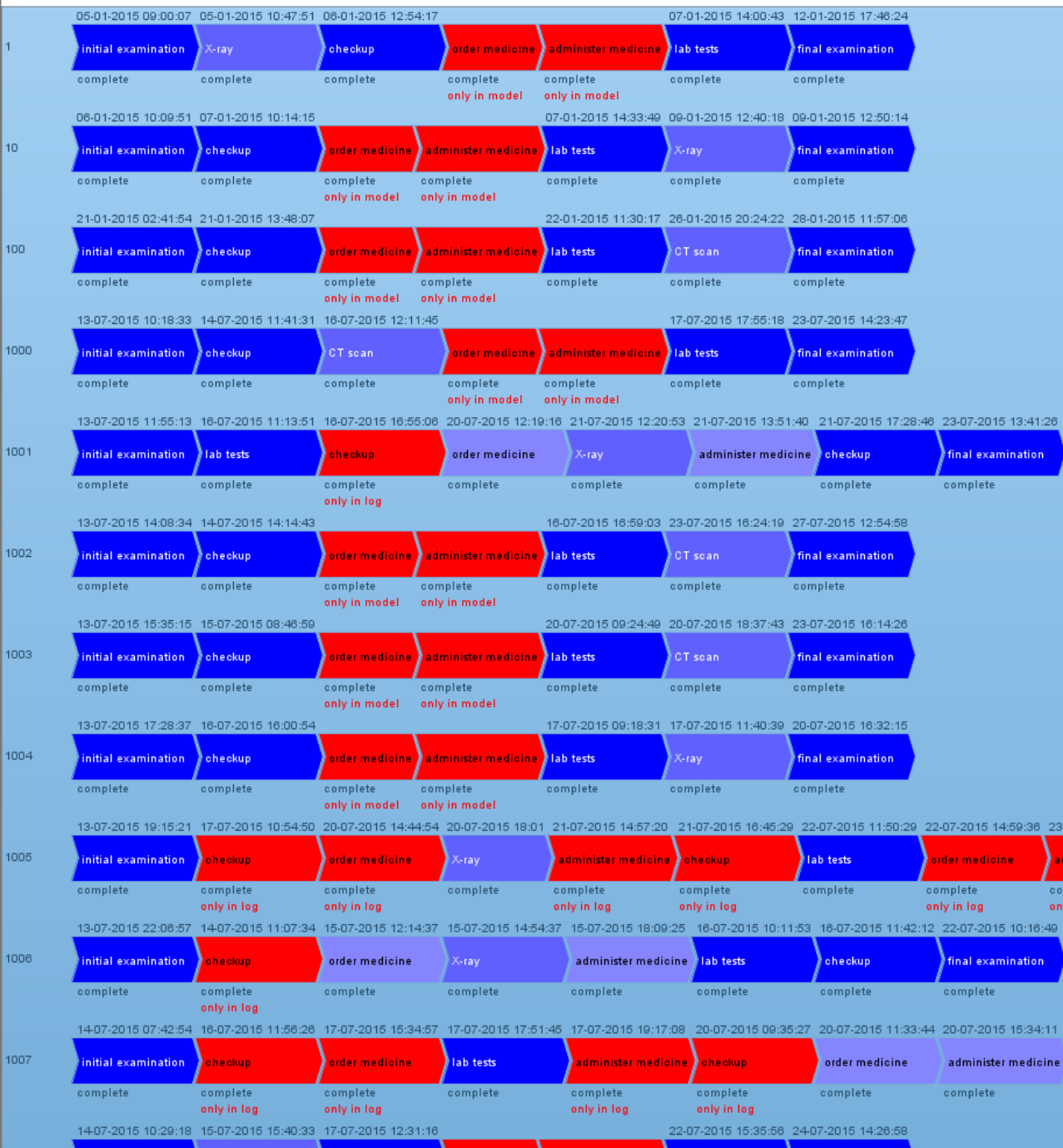
Highlighting all traces.

Conformance checking

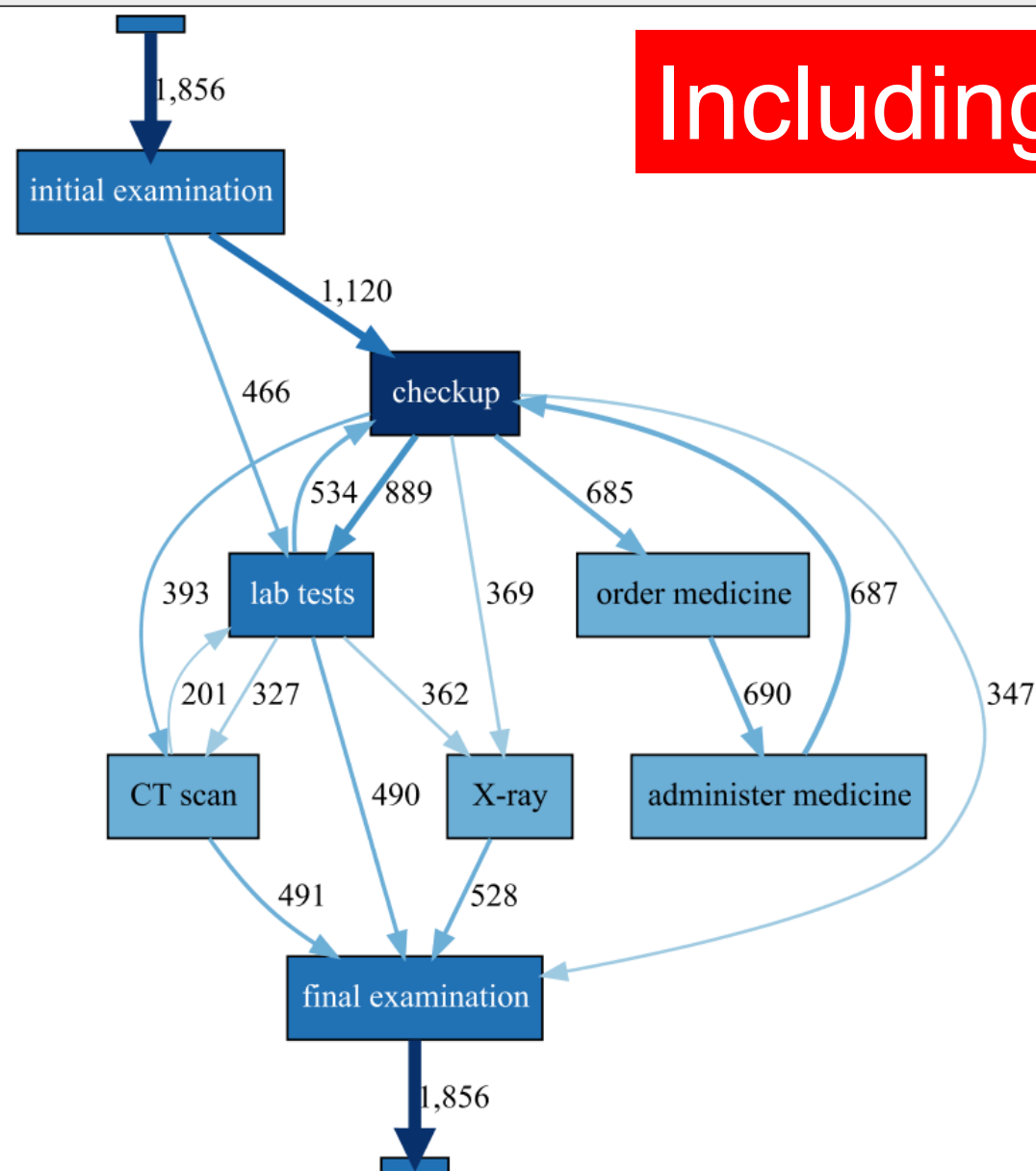


activities: 1 paths: 1

Classifier	conceptname
Miner	pre-mining filters
Miner	default miner (IMf)
Show	edit model
Show	paths and deviations
Show	trace colouring
Show	highlighting filters
Show	traces
Show	data analysis
Show	export log
Show	export model
Show	export ..



Conformance checking



Including DFGs

INPUT: TRACES

attribute = "value" (use right click to view available attribut

Using 1,856/1,856 traces, 15,473/15,473 events

OUTPUT: PROCESS MODEL

Directly-follows Graph

Export model

SELECTED HEURISTICS

OPTIONS & THRESHOLDS

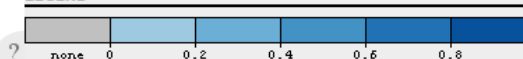
Frequency:

0.1

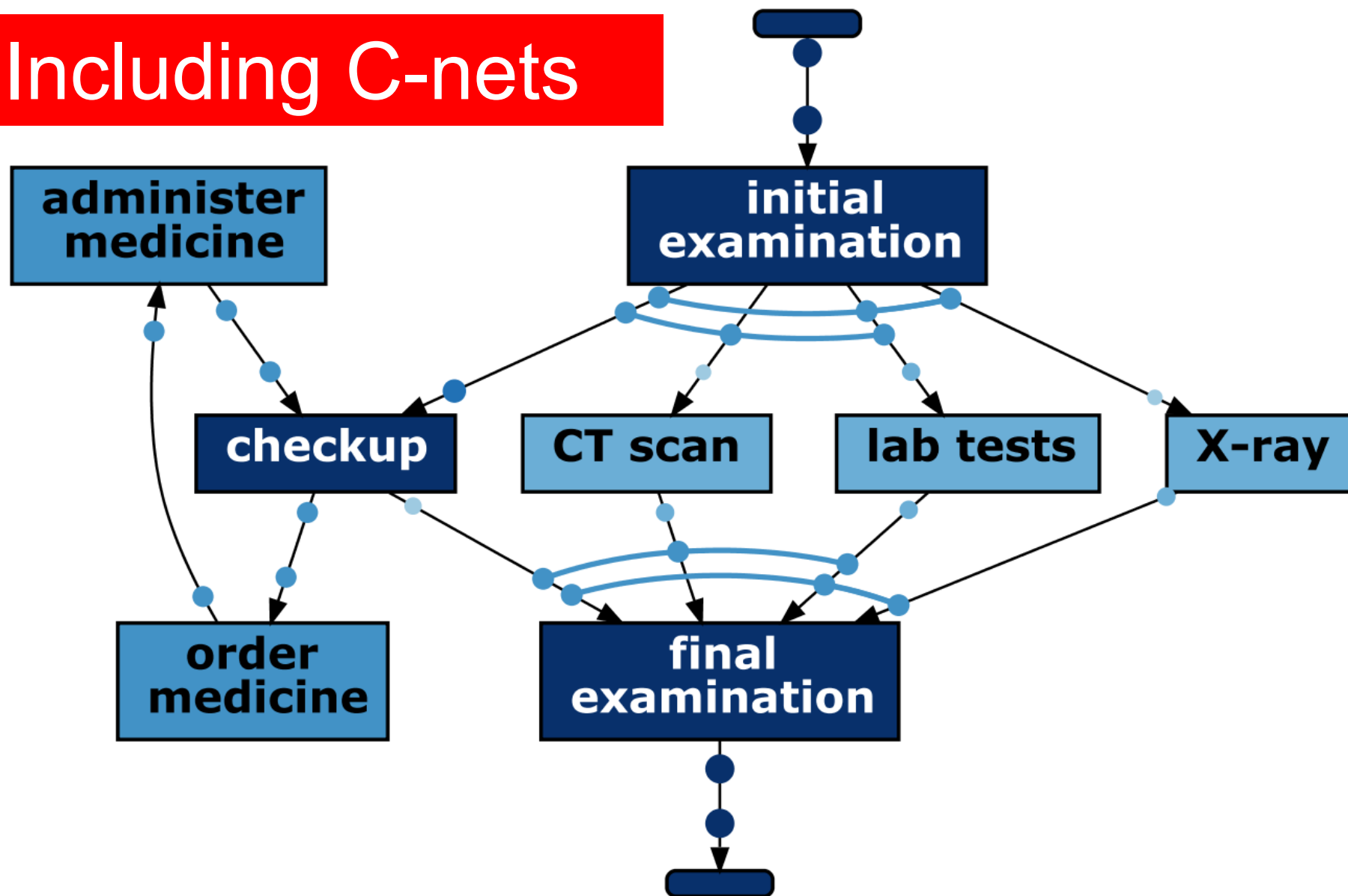
Using 18/35 directly-follows relations occurring at least 186 times

Expert Options

LEGEND



Including C-nets



INPUT: TRACES

attribute = "value" (use right click to view available attributes) ?

Using 1,856/1,856 traces, 15,473/15,473 events

OUTPUT: PROCESS MODEL

Causal net (C-net)

Export model

SELECTED HEURISTICS

Dependency Heuristic

Flexible Heuristics Miner

Conditional Heuristic

C4.5 (Cohen's Kappa)

Bindings Heuristic

Nearest Activity (FHM)

Conformance Heuristic

None

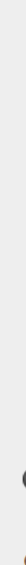
OPTIONS & THRESHOLDS

Frequency:

Dependency:

Bindings:

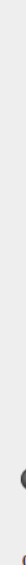
Conditions:



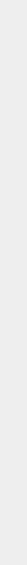
0.1



0.9



0.1



0.5

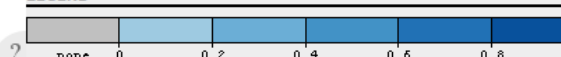
Using 18/35 directly-follows relations occurring at least 186 times

☒ Long Term Dependencies

Data-aware Config

☒ All Tasks Connected☒ Expert Options☒ Accepted Connected

LEGEND



Windows

[ProM Lite 1.3 with 64-bit JRE8](#)[ProM Lite 1.3 with 32-bit JRE8](#)[ProM Lite 1.3 without JRE8](#)[ProM 6.11 with 64-bit JRE8](#)[ProM 6.11 with 32-bit JRE8](#)[ProM 6.11 without JRE8](#)[RapidProM](#)[ProM 5.2](#)

Other platforms

[ProM Lite 1.3](#)[ProM 6.11](#)[RapidProM](#)[ProM 5.2](#)

Licenses

[ProM 6 framework license](#)[ProM 6 package licenses](#)

Documents

[Example log files](#)[ProM 6 getting started](#)[ProM 6 tutorial](#)

ProM Tools

Processes are an integral part of today's world, driving services and internal functionalities in businesses, governmental bodies, and organizations around the globe. While there are plenty of systems available for supporting the execution of such processes, the current practices for monitoring and analyzing this execution in the organizational reality still leaves a lot to be desired. **Process Mining** is able to fill that gap, providing revolutionary means for the analysis and monitoring of real-life processes.

Process Mining research is concerned with the **extraction of knowledge about a (business) process from its process execution logs**. Process Mining strives to gain insight into various perspectives, such as the process (or control flow) perspective, the performance, data, and organizational perspective (The processmining.org web site has more in-depth information and scientific publications available).

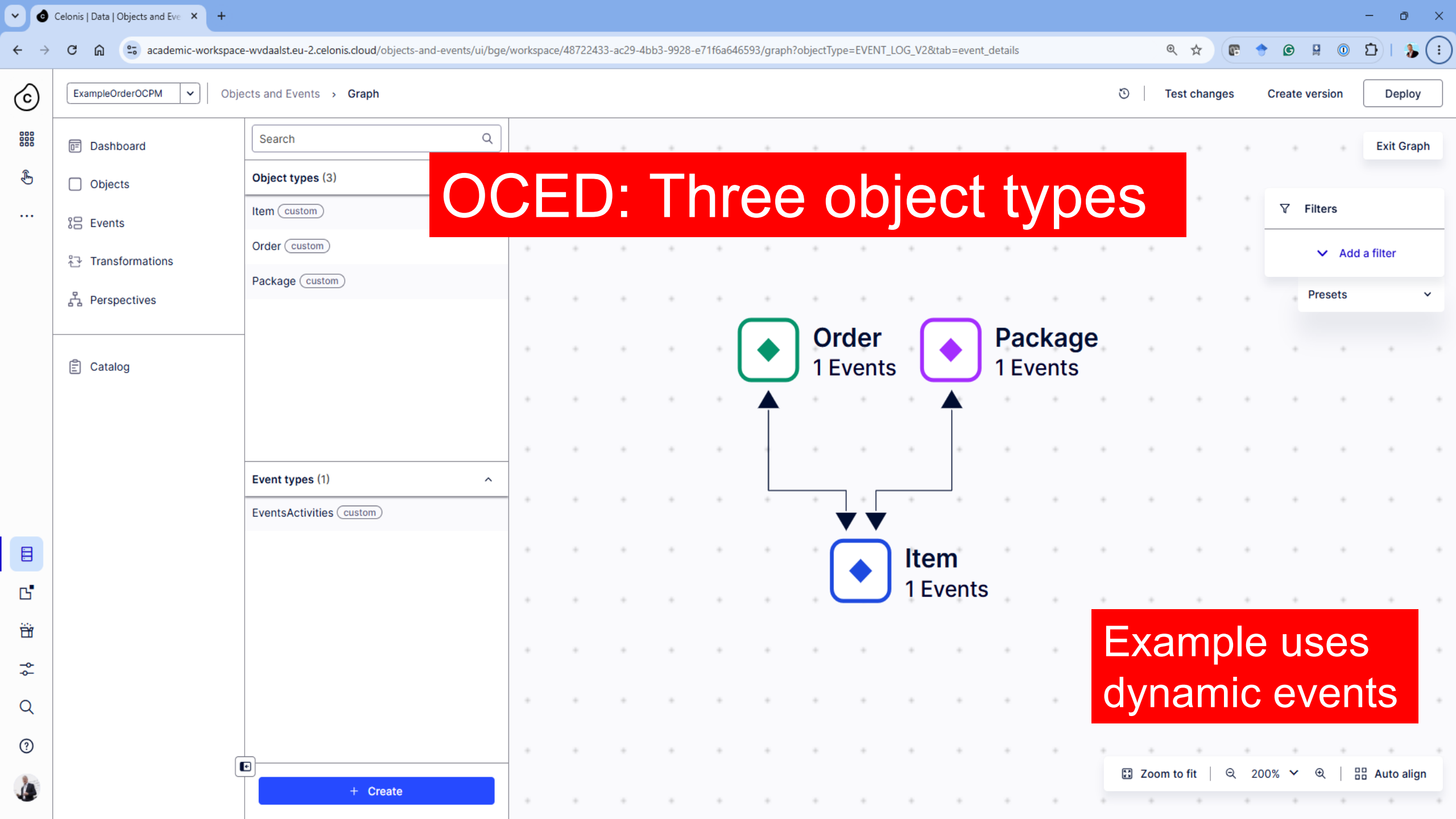
ProM is an **extensible** framework that supports a wide variety of process mining techniques in the form of plug-ins. It is **platform** port **practical**

These were just 5 of 1500 plug-ins, just try some more yourself.



Example of a commercial tool: Celonis

- Most successful commercial process mining tool.
- Celonis was **founded in 2011** by Alex, Basti, and Martin.
- Characteristics:
 - The first process mining tool **aiming at non data-scientists** (using dashboards, cloud, apps, adapters).
 - **Highly scalable** (SaolaDB in-memory database).
 - **Process Query Language (PQL)** is at the core.
 - The first to support **action-oriented process mining** (Integromat/Make connects to 1000+ systems).
 - Fully object-centric



Your System Data Sources

Celonis Data Integration

File Uploads

Drop files here or [Select Files](#)

File upload limit: 1GB

Files

Filters: Status

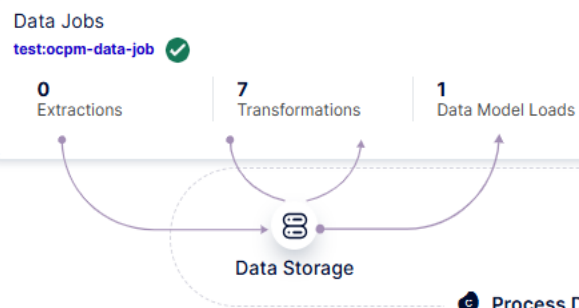
Table Name	Type	Data Connection	Date	File Count	Status	Errors	Action
E2O_order	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
Events	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
E2O_package	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
E2O_item	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
OT_package	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
OT_order	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		
OT_item	Flat File	[Default]	6/21/26, 4:50 PM	0	✓		

ExampleOrderOCPM

Data Processing

Output

Create Schedule →

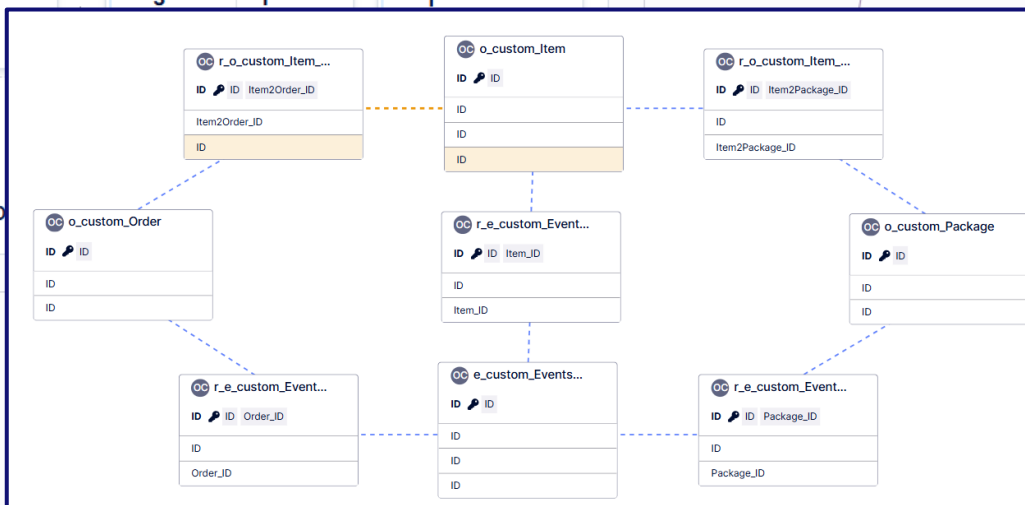
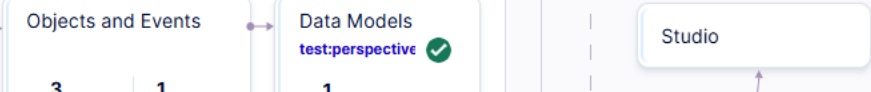


Loaded Data Model

Table sync ✓ >

Data load progress ✓ ▾

Table name	Loaded rows
e_custom_EventsActivities	2,244
o_custom_Item	791
o_custom_Order	200
o_custom_Package	128
r_e_custom_EventsActivities_Item	3,522
r_e_custom_EventsActivities_Order	663
r_e_custom_EventsActivities_Package	432
r_o_custom_Item_Item2Order	791
r_o_custom_Item_Item2Package	791



Data integration: from raw data files to a loaded data model

Search

All (4) Pam Widget (2) Knowledge

New asset

BPMN-Happy

BPMN-Full

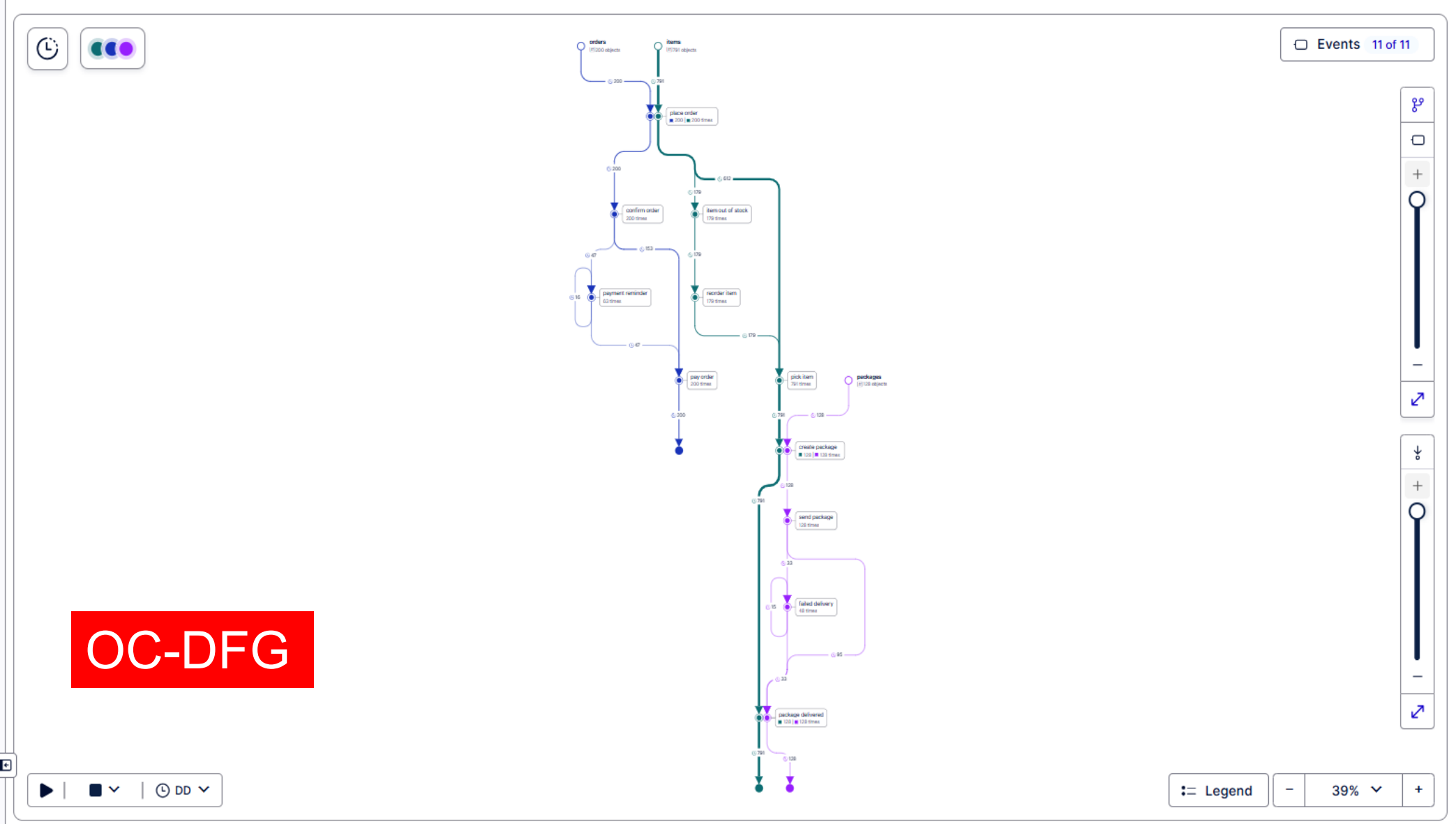
OC-DFG

test:perspective_custom_Orders...

OC-DFG

100%

Events 11 of 11



Grid icon

Hand icon

More icon

Table icon

Diagram icon

Settings icon

Search icon

Help icon

User profile icon

Play button

Stop button

DD button

Legend

39%

Celonis | OC-DFG | default | Exa

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/8ad1b787-6438-43cc-ac41-94a6e668ea7f/packages/0bb45c78-82ea-425e-822a-22d48462fefe/nodes/230d0fd6-6a45-47e9-...

Studio > ExampleOCPMOrders > default

SearchCTRL / 1 4 Create version Deploy

Search

All (4) Pam Widget (2) Knowledge

New asset

BPMN-Happy

BPMN-Full

OC-DFG

test:perspective_custom_Orders...

OC-DFG

pick item 791 times

create package 128 | 128 times

pay order 200 times

100%

Events 11 of 11

packages # 128 objects

Legend 200%

pay order 200 times

pick item 791 times

create package 128 | 128 times

200

791

128

celonis | BPMN-Full | default | E

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/8ad1b787-6438-43cc-ac41-94a6e668ea7f/packages/0bb45c78-82ea-425e-822a-22d48462fefe/nodes/285db3ca-cd76-4ef8-...

Studio > ExampleOCPMOrders > default

Search

All (4) Pam Widget (2) Knowledge

New asset

BPMN-Happy

BPMN-Full

OC-DFG

test:perspective_custom_Orders...

Deviations

Variants

Allowed deviations

Explore deviations

Conformance rate

items 100%

orders 100%

Show all

Deviations (0)

Congratulations! Your data has no deviations and conditions. It is 100% compliant.

Items

orders

packages

place order

confirm order

payment reminder

pay order

create package

send package

failed delivery

package delivered

item out of stock

reorder item

pick item

Filters

Select the data you want to compare to the target model.

Add a filter

Data & Coverage Info

items 100%

orders 100%

packages 100%

Legend

30%

OC-BPMN with 100% recall/fitness

celonis | BPMN-Happy | default

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/8ad1b787-6438-43cc-ac41-94a6e668ea7f/packages/0bb45c78-82ea-425e-822a-22d48462fefe/nodes/2bb4fc7e-22e4-4b2d-...

Studio > ExampleOCPMOrders > default

Search

All (4) Pam Widget (2) Knowledge

New asset

BPMN-Happy

BPMN-Full

OC-DFG

test:perspective_custom_Orders...

Deviations

Variants

Allowed deviations

Explore deviations

Conformance rate

items 77.37%

orders 76.50%

Show all

Deviations (4)

Search

Unexpected event

item out of stock

179 (22.63%) items | +15 days TPT

Unexpected event

reorder item

179 (22.63%) items | +15 days TPT

Unexpected event

payment reminder

47 (23.50%) orders | +20 days TPT

Unexpected event

#

items

orders

place order

pick item

packages

confirm order

create package

pay order

send package

package delivered

Filters

Select the data you want to compare to the target model.

Add a filter

Data & Coverage Info

items 100%

orders 100%

packages 100%

Legend

50%

OC-BPMN for the happy path

celonis | BPMN-Happy | default

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/8ad1b787-6438-43cc-ac41-94a6e668ea7f/packages/0bb45c78-82ea-425e-822a-22d48462fe/nodes/2bb4fc7e-22e4-4b2d-...

Search CTRL / 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000

Studio > ExampleOCPMOrders > default

Search

All (4) Pam Widget (2) Knowledge

New asset

BPMN-Happy

BPMN-Full

OC-DFG

test:perspective_custom_Orders...

Deviations

Variants

Allowed deviations

Unexpected event
failed delivery

Filter on this behavior

Deviations (1) packages

Unexpected flow between send package and package delivered

Unexpected event: failed delivery

33 (100%) cases | +20 hours TPT

pick item
791

packages

create package
128

send package
128

failed delivery

package delivered
128

Filters

Select the data you want to compare to the target model.

Add a filter

Data & Coverage Info

items 100%

orders 100%

packages 100%

Legend

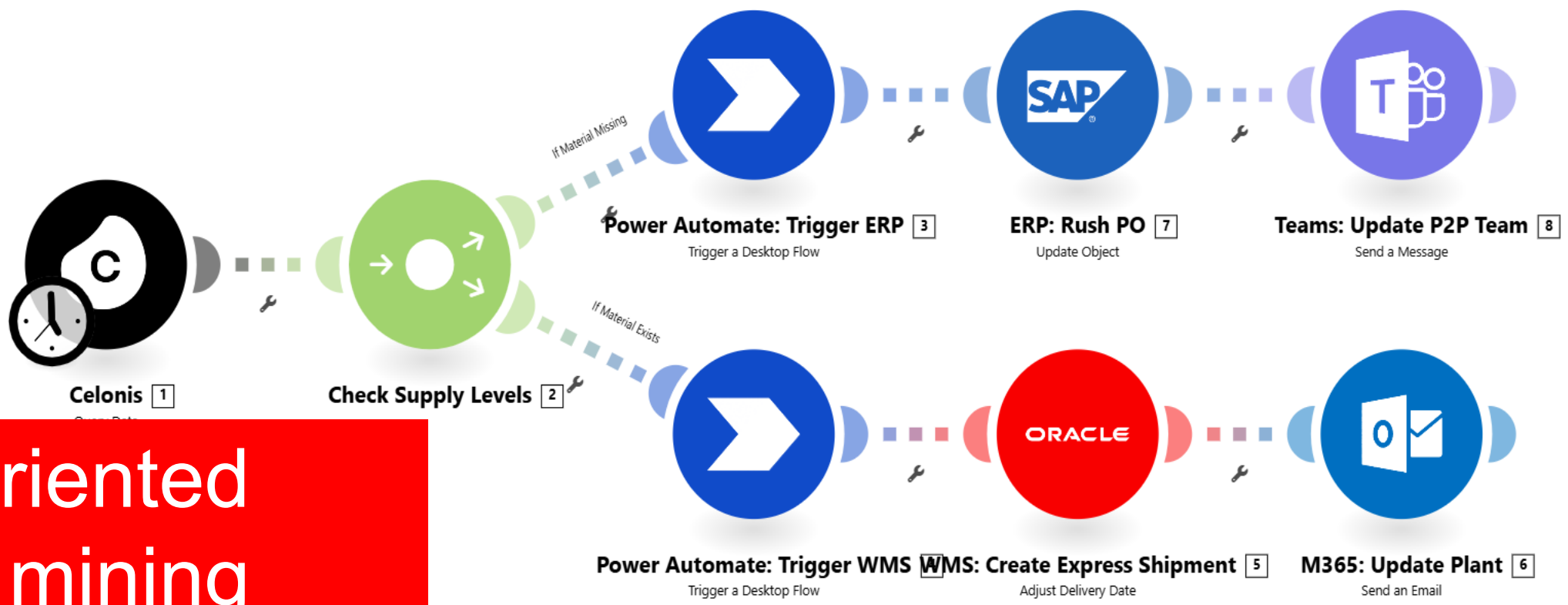
60%

Investigating a particular deviation

- Material Availability (MSFT PAD)
- Material Availability
- Alternative Routing
- Create Invoice
- OTD Prediction

Material Availability (RPA) material-available-msft-pad-

Version Control Inputs Explain Flow Auto-Align Help Settings Blueprint



Action-oriented
process mining



Power Automate: Trigger WMS  **WMS: Create Express Shipment**  **M365: Update Plant** 

File Uploads

ABAP

CSV

GZ

JSON

PARQ

XES

XLS

XLSX

ZIP

.7z

Drop files here or

Select Files

File upload limit: 1GB

Files

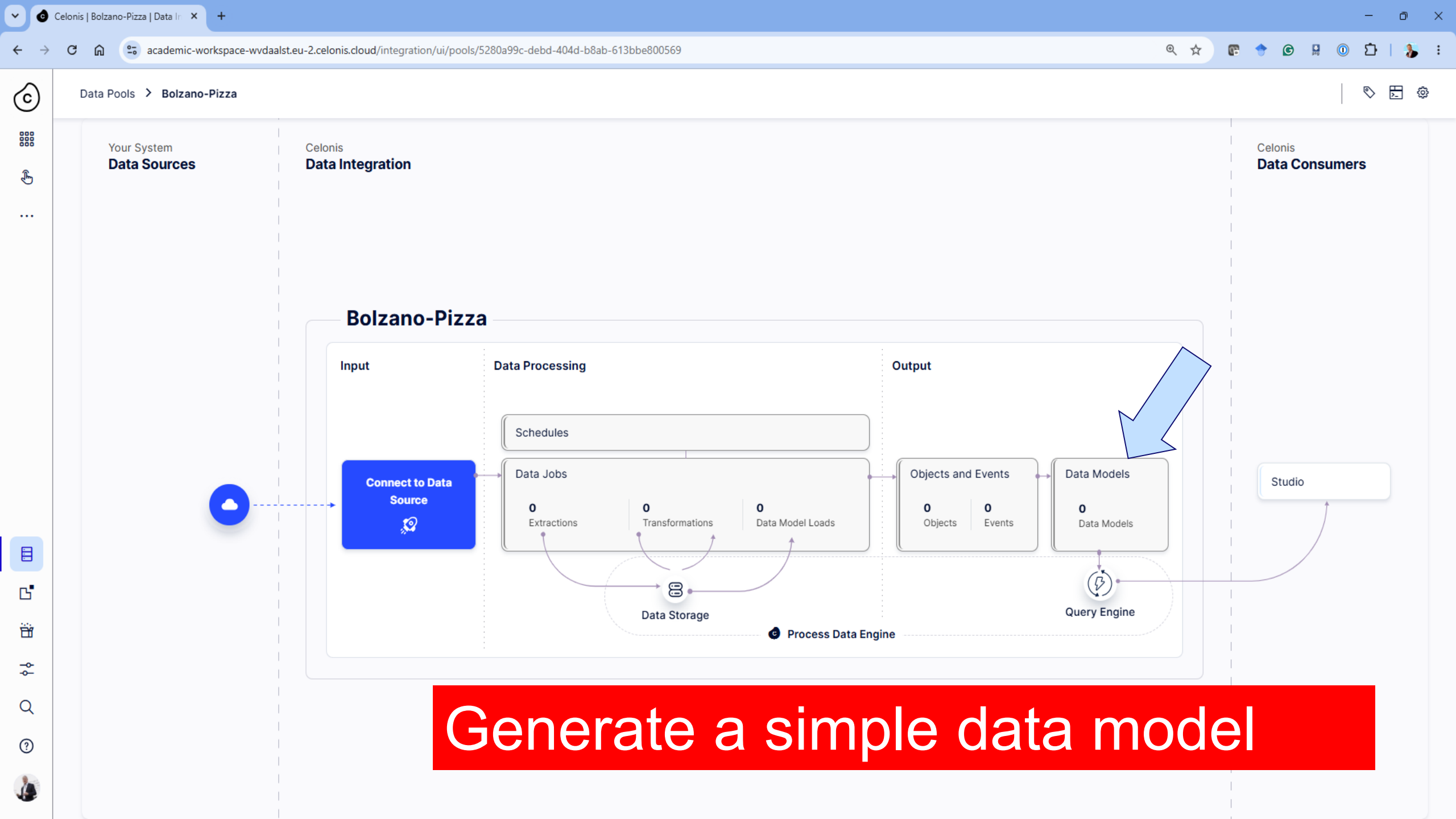
Filters:

Status

Table Name	Type	Data Connection	Date	File Count	Status	Errors	Action
pizza-log	Flat File	[Global]	6/28/26, 5:17 PM	1	✓		⋮

Load a CSV (or XES)

case	activity	time
1	take order	11/4/2025 14:21
1	create base	11/4/2025 14:32
1	add tomato	11/4/2025 14:34
1	add salami	11/4/2025 14:34
1	add cheese	11/4/2025 14:35
1	bake in oven	11/4/2025 14:36
1	eat pizza	11/4/2025 14:40
1	clean kitchen	11/4/2025 14:48
2	take order	11/4/2025 19:07
2	create base	11/4/2025 19:18
2	add tomato	11/4/2025 19:19
2	add mushrooms	11/4/2025 19:19
2	add cheese	11/4/2025 19:19





Tables

Available items (1)

Select all

Search

🔍

pizza-log

+

Selected items (0)

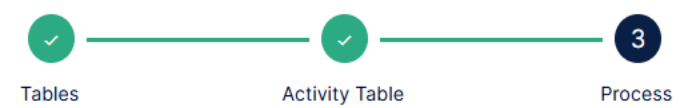
Clear all

Search

🔍

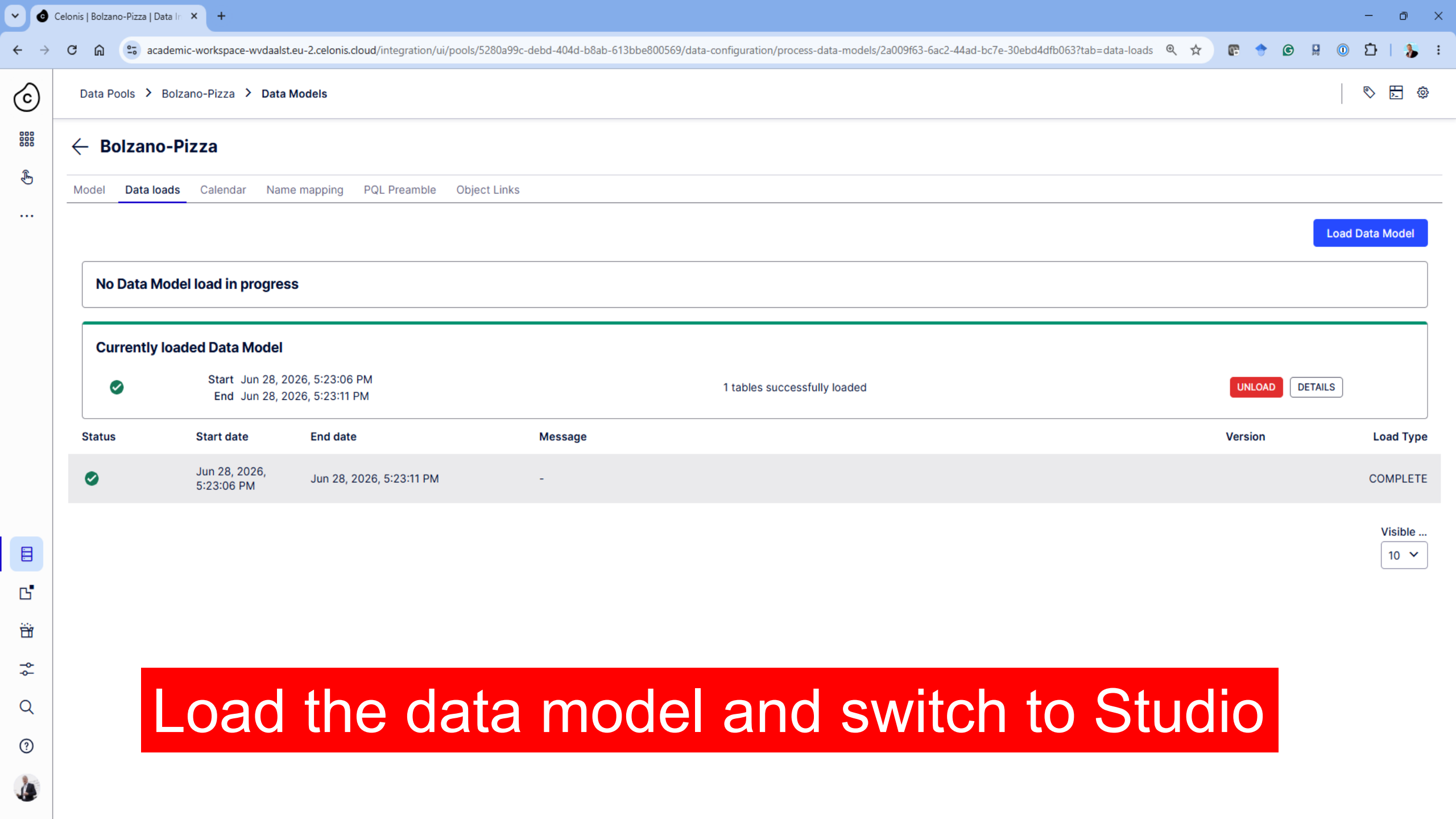
There are no selected items. Add some from the list of available items.

[Data Pools](#) > [Bolzano-Pizza](#) > [Data Models](#)



Process
Step 4/4: Select sorting column (optional) | Skip step
Click on the column that contains the sorting information for each activity. Sorting information is used to determine the order of activities which have the exact same timestamp. Not all source systems provide sorting information.

123	CASE	ABC	ACTIVITY	DATE	TIME	DATE	_CELONIS_CHANG...
1			add cheese	Nov 4, 2025, 3:35:01 ...		Jun 28, 2026, 5:17:19 ...	
1			add salami	Nov 4, 2025, 3:34:36 ...		Jun 28, 2026, 5:17:19 ...	
1			add tomato	Nov 4, 2025, 3:34:02 ...		Jun 28, 2026, 5:17:19 ...	
1			bake in oven	Nov 4, 2025, 3:36:41 ...		Jun 28, 2026, 5:17:19 ...	
1			clean kitchen	Nov 4, 2025, 3:48:27 ...		Jun 28, 2026, 5:17:19 ...	
1			create base	Nov 4, 2025, 3:32:07 ...		Jun 28, 2026, 5:17:19 ...	
1			eat pizza	Nov 4, 2025, 3:40:08 ...		Jun 28, 2026, 5:17:19 ...	
1			take order	Nov 4, 2025, 3:21:34 ...		Jun 28, 2026, 5:17:19 ...	
2			add cheese	Nov 4, 2025, 8:19:41 PM		Jun 28, 2026, 5:17:19 ...	
2			add mushrooms	Nov 4, 2025, 8:19:37 P...		Jun 28, 2026, 5:17:19 ...	
2			add tomato	Nov 4, 2025, 8:19:12 PM		Jun 28, 2026, 5:17:19 ...	
2			bake in oven	Nov 4, 2025, 8:21:10 PM		Jun 28, 2026, 5:17:19 ...	
2			clean kitchen	Nov 4, 2025, 8:25:48 ...		Jun 28, 2026, 5:17:19 ...	
2			create base	Nov 4, 2025, 8:18:06 ...		Jun 28, 2026, 5:17:19 ...	



Load Data Model

No Data Model load in progress

Currently loaded Data Model



Start Jun 28, 2026, 5:23:06 PM
End Jun 28, 2026, 5:23:11 PM

1 tables successfully loaded

UNLOAD

DETAILS

Status	Start date	End date	Message	Version	Load Type
✓	Jun 28, 2026, 5:23:06 PM	Jun 28, 2026, 5:23:11 PM	-		COMPLETE

Visible ...

10

Load the data model and switch to Studio

Create a new space in Studio

Create space

A space helps you organise packages in a meaningful way, for the right audience.

Space Icon

Space Name

 ▼

Bolzano-Pizza

Suggested Data Models

Optional ⓘ

 Bolzano-Pizza X

▼

☐	test:perspective_custom_...	✓	Object-centric	OCPM-Simple-CSV
☐	perspective_custom_Pers...	✓	Object-centric	Erin-1
☐	test:perspective_custom_...	✓	Object-centric	Erin-1
☐	test:perspective_custom_...	✓	Object-centric	ExampleOrderOCPM
☒	Bolzano-Pizza	✓	Case-centric	Bolzano-Pizza
☐	test:perspective_cust...			AirportOCPM
☐	test:perspective_cust...			Timothy Smith
☐	Academic Template - Goo...	✗	Case-centric	Demo Processes
☐	Academic Template - Logi...	✗	Case-centric	Demo Processes
☐	Academic Template - Old ...	✗	Case-centric	Demo Processes

Name: Bolzano-Pizza

Parent Data Pool: Bolzano-Pizza

Data model status: Loaded

Type: Case-centric

Create package

Using packages is the most effective way to organize your work in meaningful ways. Use packages to maintain, build, and deploy your assets.

Package name

Default

Description Optional

Initial content ⓘ


View


Automation


Empty package

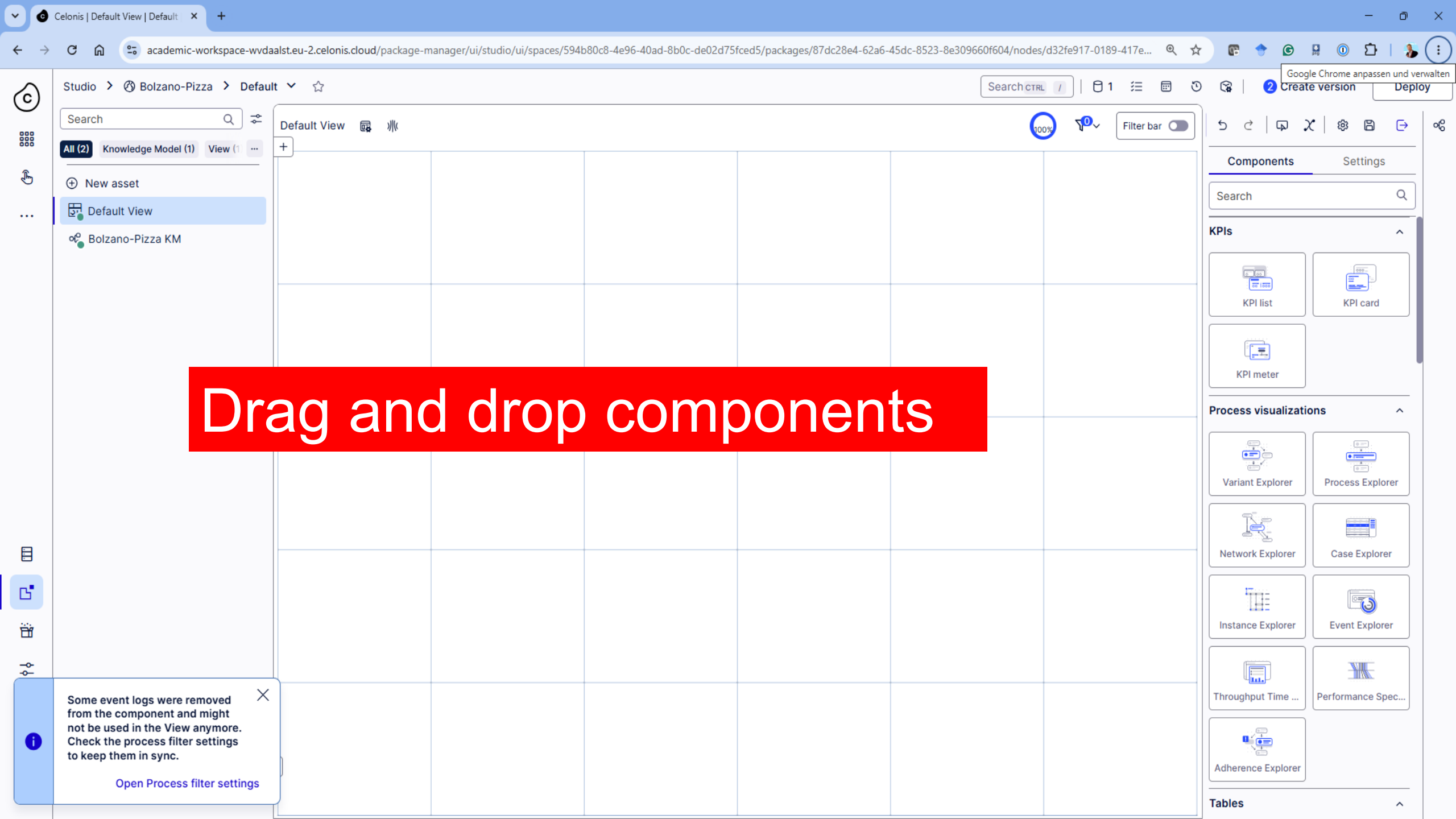
Data Model

Bolzano-Pizza

Advanced Settings

Cancel

Create



Drag and drop components

A DFG



Celonis | Default View | Default

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/594b80c8-4e96-40ad-8b0c-de02d75fcd5/packages/87dc28e4-62a6-45dc-8523-8e309660f604/nodes/d32fe917-0189-417e...

Studio > Bolzano-Pizza > Default

Search

All (2) Knowledge Model (1) View (1)

New asset

Default View

Bolzano-Pizza KM

Default View

Case Frequency

Activity Frequency

Throughput Time (Avg)

Throughput Time (Median)

Throughput Time (Trimmed Mean)

Start

take order

create base

add cheese

add tomato

add mushrooms

add salami

bake in oven

eat pizza

clean kitchen

End

Activities 9 of 9

100%

Legend

61%

Select annotation

Celonis | Default View | Default

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/594b80c8-4e96-40ad-8b0c-de02d75fcd5/packages/87dc28e4-62a6-45dc-8523-8e309660f604/nodes/d32fe917-0189-417e...

Studio > Bolzano-Pizza > Default

Search

1 2 Create version Deploy

All (2) Knowledge Model (1) View (1)

New asset

Default View

Bolzano-Pizza KM

Default View

100%

Activities 9 of 9

Legend 159%

add cheese
1.28K

add mushrooms
640

add tomato
1.28K

2 min

2 min

3 min

2 min

1 min

2 min

3 min

57 s

2 min

1 min

2 min

2 min

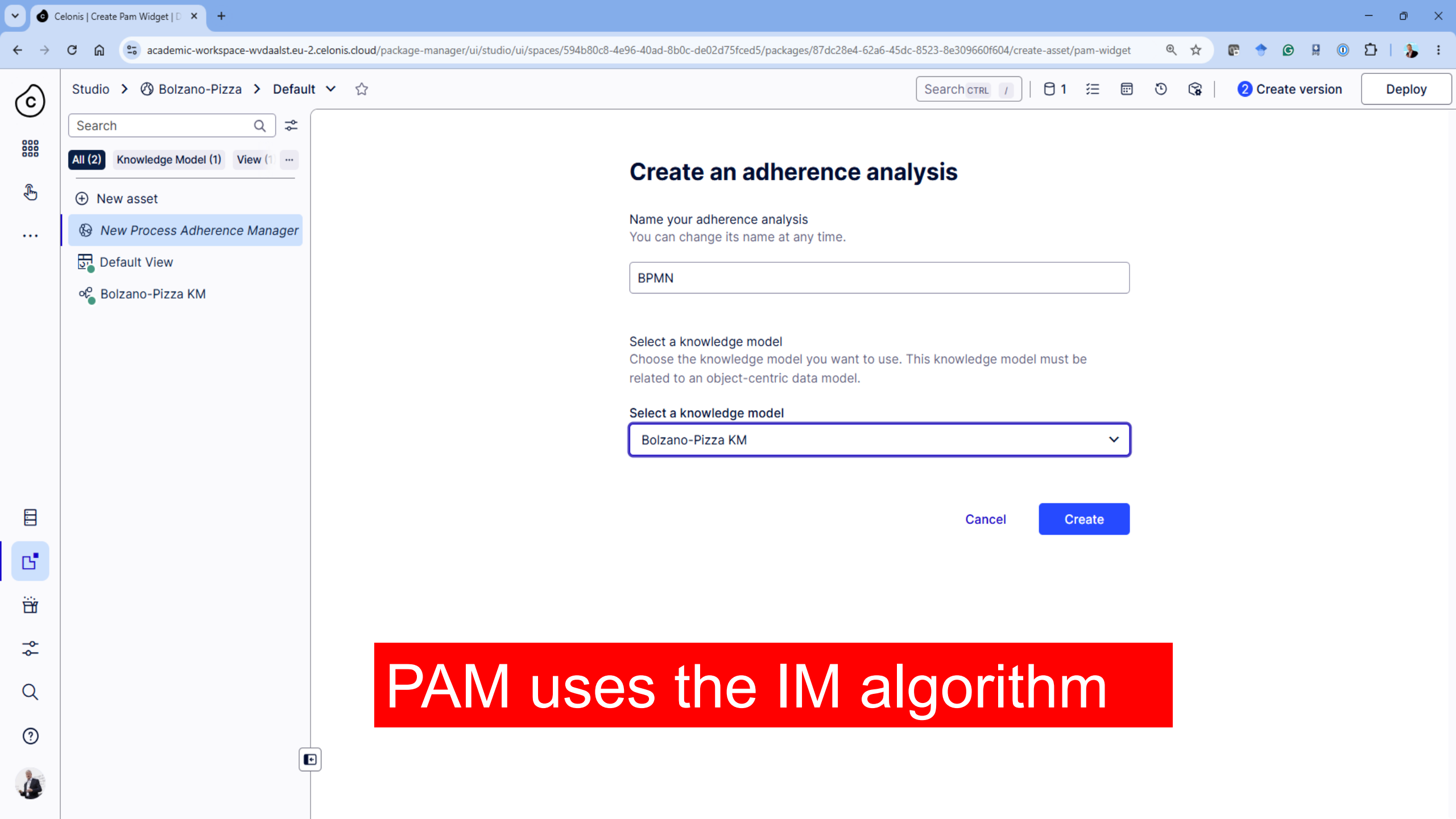
2 min

5 min

6 min

29 s

1 min



Create an adherence analysis

Name your adherence analysis
You can change its name at any time.

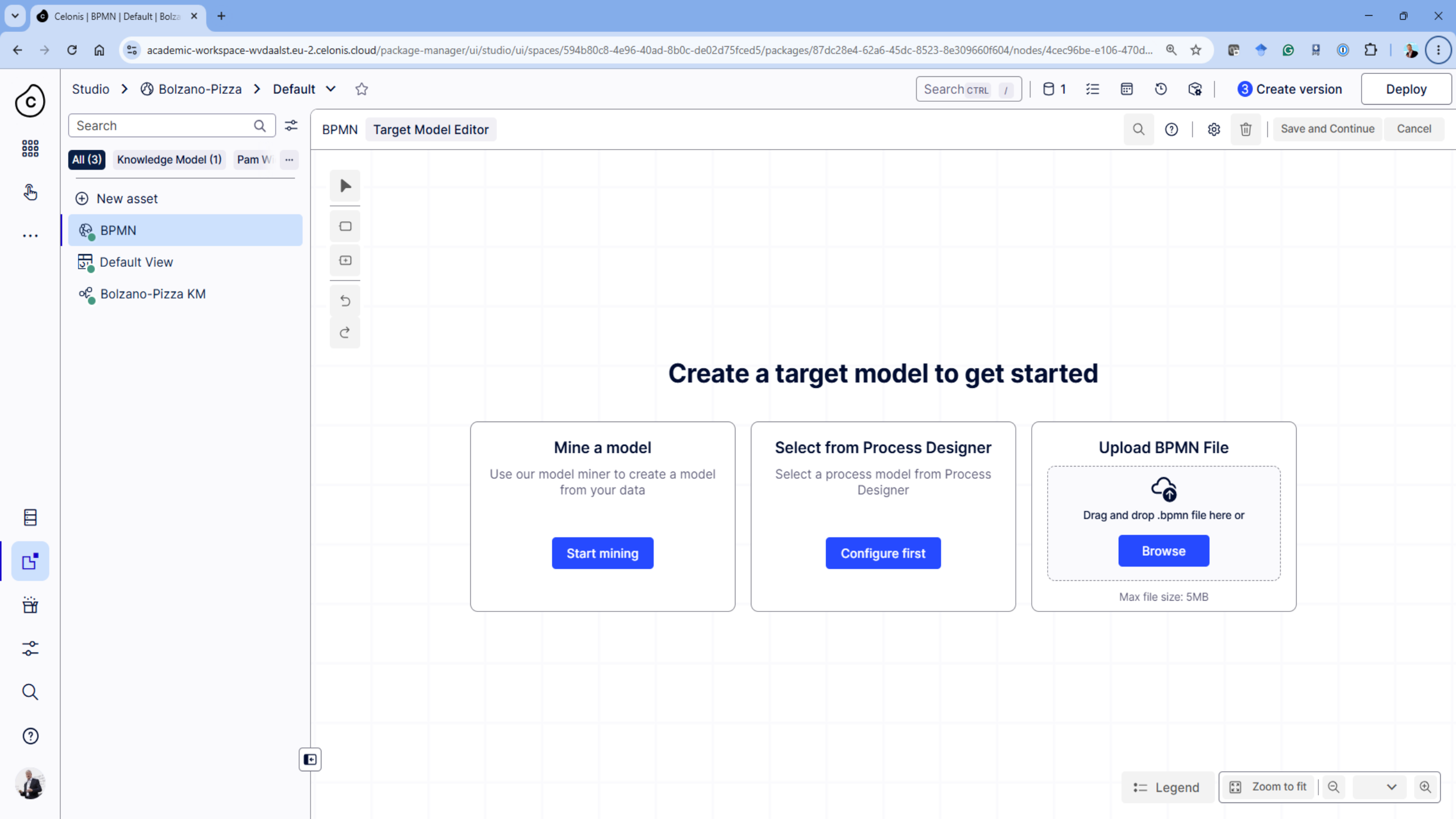
Select a knowledge model
Choose the knowledge model you want to use. This knowledge model must be related to an object-centric data model.

Select a knowledge model

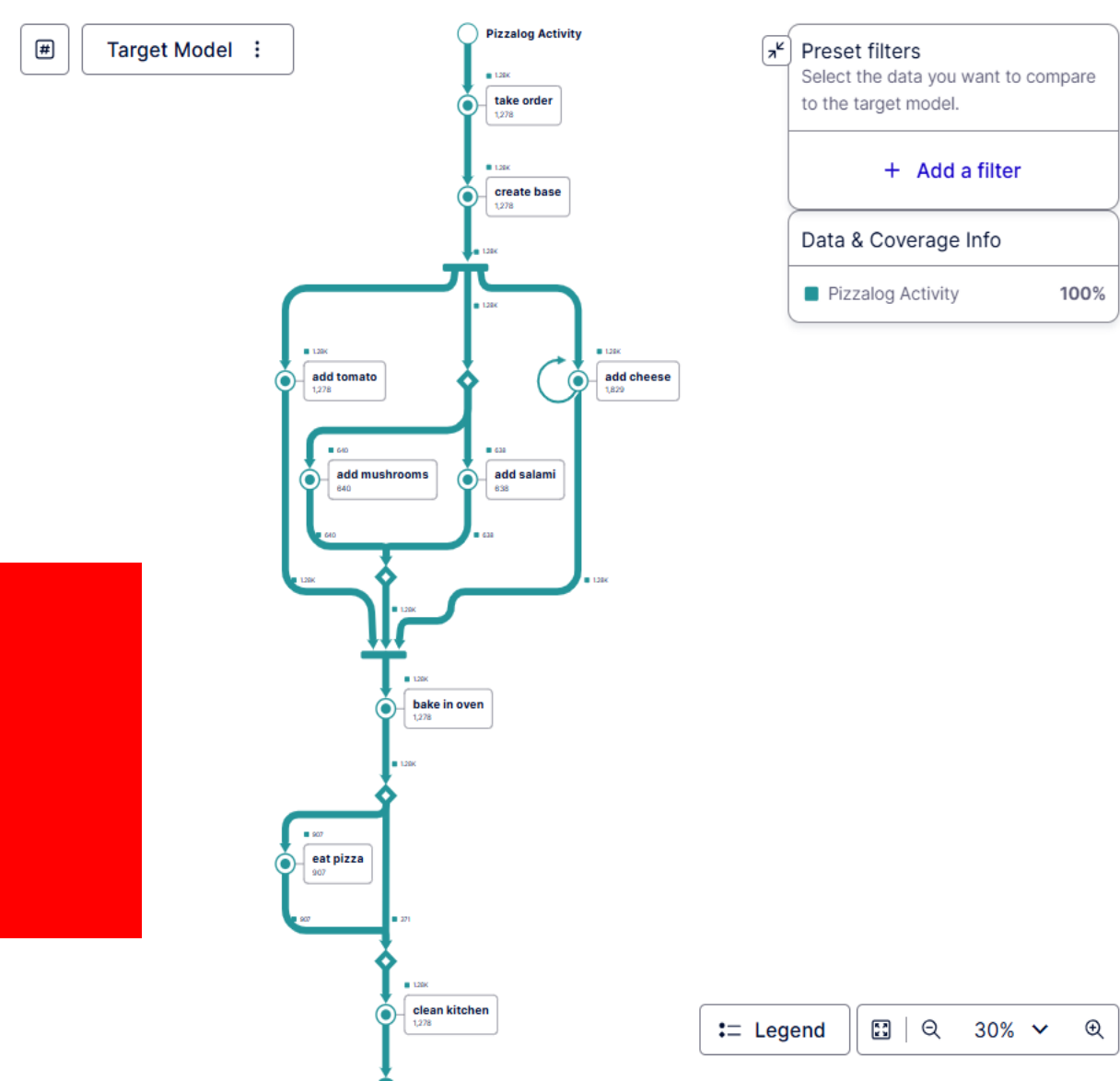
Cancel

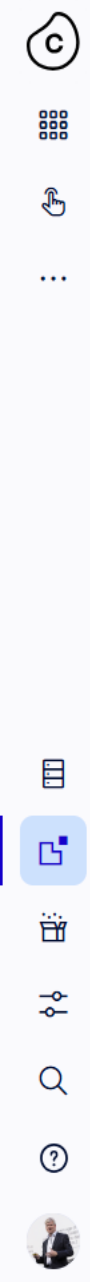
Create

PAM uses the IM algorithm



If all variants are selected, there will be 100% conformance.





BPMN

Deviations

Variants

Allowed deviations

Explore deviations

Conformance rate
Pizzalog Activity 100%

Deviations (0)

Congratulations! Your data has no deviations and conditions. It is 100% compliant.

Throughput time filter

Event log

Pizzalog Activity

from: take order First

to: clean kitchen Last

avg. 0.0391 days med. 0 days min. 0 days max. 0 days

Frequency

Time

0 to 2 days

1.28K of 1.28K... 100% are sele... Cancel Apply filter

Filters

Select the data you want to compare to the target model.

+ Add a filter

Data & Coverage Info

Pizzalog Activity 100%

Legend

30%

Time analysis

Select
variants
with
salami
and
eaten

Happy BPMN Model Miner

< Custom process variants

Select variants to build your model. You can use the search criteria to find the relevant variants.

6 Selected variants

[Clear all](#)

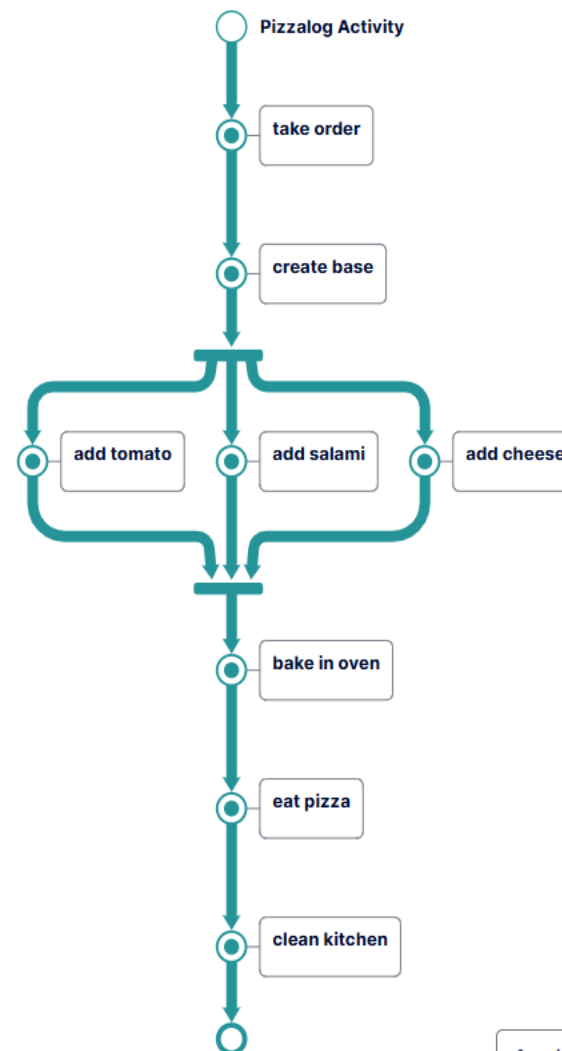
	#	Count	Coverage	Avg TPT	#Steps
✓	#2	63	0.61%	55 minutes	8
✓	#5	57	0.55%	1 hours	8
✓	#7	49	0.47%	1 hours	8
✓	#9	47	0.45%	60 minutes	8
✓	#10	45	0.43%	49 minutes	8
✓	#11	43	0.41%	55 minutes	8

Additional variants

Throughput time Event flow

Event log attribute Include event (1)

	#	Count	Coverage	Avg TPT	#Steps
+	#14	31	0.30%	26 minutes	7
+	#15	29	0.28%	35 minutes	7
+	#17	26	0.25%	1 hours	9
+	#22	19	0.18%	17 minutes	7
+	#21	19	0.18%	30 minutes	7
+	#23	18	0.17%	49 minutes	8



Legend

Zoom to fit

40%

Zoom in Zoom out

Celonis | Happy BPMN | Default

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/594b80c8-4e96-40ad-8b0c-de02d75fcd5/packages/87dc28e4-62a6-45dc-8523-8e309660f604/nodes/5b5ebff6-f601-44b5-...

Studio > Bolzano-Pizza > Default

Search CTRL / | 1 | | | | | 4 Create version Deploy

Search

All (4) Pam Widget (2) Knowledge M ...

+ New asset

Happy BPMN

BPMN

Default View

Bolzano-Pizza KM

Deviations

1 2 3 Variants

Allowed deviations

Missing event
eat pizza

Filter on this behavior

Deviations (1) Pizzalog Activity

Event missing between bake in oven and clean kitchen

Missing event: eat pizza

371 (100%) cases | -18 minutes TPT

Target Model

Preset filters

Select the data you want to compare to the target model.

+ Add a filter

Data & Coverage Info

Pizzalog Activity 100%

Pizzalog Activity

take order 1,278

create base 1,278

add tomato 1,278

add salami 838

add cheese 1,829

bake in oven 1,278

eat pizza 907

clean kitchen 1,278

Legend

30%

Zoom in on problem that not all pizzas are eaten.

Process visualizations



Variant Explorer



Process Explorer



Network Explorer



Case Explorer



Instance Explorer



Event Explorer



Throughput Time ...



Performance Spec...



Adherence Explorer

Tables



Table



Condition list



Pivot table

Category charts



Bar



Pie



Treemap



Stacked bar



Grouped bar



Bar and point

Time series charts



Line



Column



Grouped column



Column and line



Stacked column



Area



Stacked Area

Distribution charts



Histogram



Boxplot

Advanced charts



World map



Sankey



Waterfall

Filter components



Filter dropdown



Date range



Quick filters



Search

A small selection of the components you can drag and drop in a view's window to create your own "process apps".

Process
Analytics
Chair of Process
and Data Science

RWTH AACHEN
UNIVERSITY

Celonis | View | Default | Bolzano

academic-workspace-wvdaalst.eu-2.celonis.cloud/package-manager/ui/studio/ui/spaces/594b80c8-4e96-40ad-8b0c-de02d75fcd5/packages/87dc28e4-62a6-45dc-8523-8e309660f604/nodes/d42baa76-2a38-4105...

Studio > Bolzano-Pizza > Default

Search

All (5) Pam Widget (2) View (2)

New asset

View

Happy BPMN

BPMN

Default View

Bolzano-Pizza KM

View

100%

Case	Conforms to BPMN	Conforms to Happy BPMN	PU_COUNT	PU_MIN	PU_MAX
1	1	1	8	11/04/25, 2:21 PM	11/04/25, 2:48 PM
2	1	0	7	11/04/25, 7:07 PM	11/04/25, 7:25 PM
3	1	0	8	11/04/25, 9:01 PM	11/04/25, 9:35 PM
4	1	0	7	11/05/25, 1:30 PM	11/05/25, 1:41 PM
5	1	0	8	11/05/25, 6:35 PM	11/05/25, 7:50 PM
6	1	0	9	11/05/25, 8:58 PM	11/06/25, 12:08 AM
7	1	1	8	11/06/25, 2:03 PM	11/06/25, 2:24 PM
8	1	0	8	11/06/25, 6:05 PM	11/06/25, 6:29 PM
9	1	0	8	11/06/25, 7:21 PM	11/06/25, 7:48 PM
10	1	0	7	11/06/25, 8:54 PM	11/06/25, 10:06 PM
11	1	0	7	11/07/25, 1:16 PM	11/07/25, 1:31 PM
12	1	0	8	11/07/25, 2:37 PM	11/07/25, 4:05 PM
13	1	0	9	11/07/25, 6:37 PM	11/07/25, 6:58 PM
			8	11/07/25, 8:08 PM	11/07/25, 8:36 PM
			8	11/07/25, 9:12 PM	11/07/25, 9:30 PM
			9	11/08/25, 12:14 PM	11/08/25, 12:39 PM
17	1	0	9	11/08/25, 12:56 PM	11/08/25, 2:11 PM
18	1	0	8	11/08/25, 2:16 PM	11/08/25, 2:27 PM
19	1	0	10	11/08/25, 3:50 PM	11/08/25, 4:50 PM

Create any table using PQL

Throughput times

Event Log ⓘ

Pizzalog Activity

Default

from take order

to clean kitchen

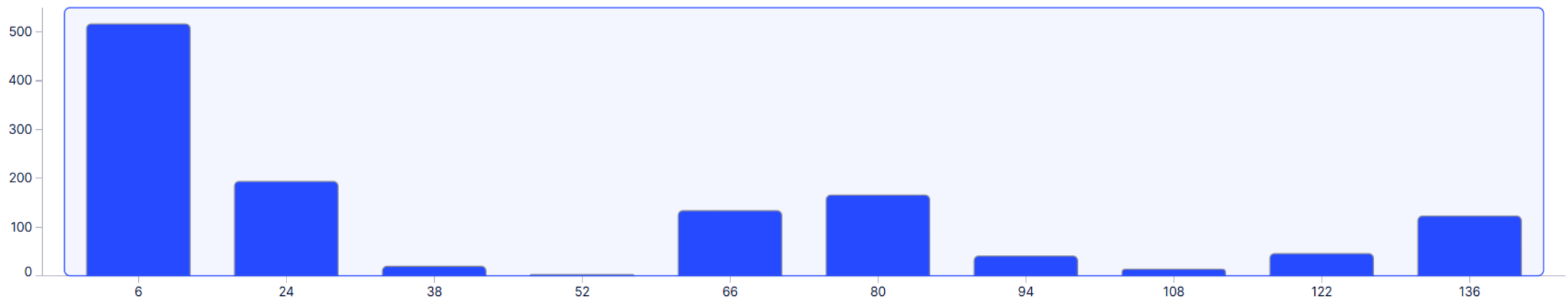
avg.
56.3 minutes

med.
28.9 minutes

min.
6.42 minutes

max.
515 minutes

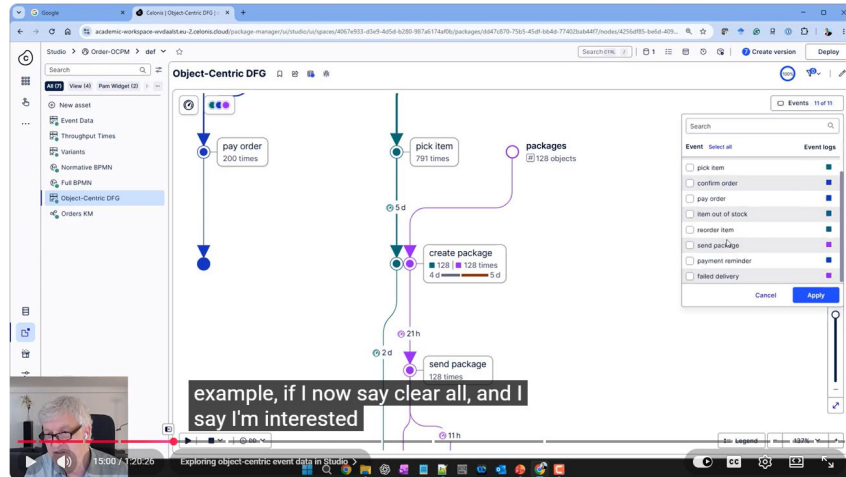
↑ Frequency



Time →

6 to 516 minutes

Video: Includes loading more realistic data sets



Contents:

- 0:00 How to get access to the Celonis software
- 1:55 Brief overview of process mining tools
- 6:25 Overview of demo
- 9:40 Exploring object-centric event data in Studio
- 20:18 Loading the Pizza dataset from scratch using a CSV or XES file
- 23:30 Building your first analysis: process discovery, conformance checking, etc.
- 35:30 Loading another data set consisting of a case table and an event table
- 40:24 Analyzing order data: process discovery, conformance checking, creating tables for ML, etc.
- 51:24 Loading object-centric event data and creating an object-centric data model
- 1:10:16 Building a new object-centric analysis from scratch using the new object-centric data model
- 1:13:51 Creating an object-centric DFG
- 1:15:33 Discovering an object-centric BPMN
- 1:17:45 Conformance checking using a normative object-centric BPMN
- 1:19:40 Learn more?

As mentioned before, make sure to install ProM, get access to Celonis, and to download the datasets

<https://www.vdaalst.com/courses/pmdata2026.zip>. Watch the videos mentioned before: ProM

<https://www.youtube.com/watch?v=rmpWqyHGRm4> and Celonis

<https://www.youtube.com/watch?v=zd7amuEC028>

Also check out OCPQ

Object-Centric
Process Querying

Exploring object-centric process data made easy.



OC PQ (App)



OCPQ
OCEL loaded
21008 Events
10840 Objects

Extraction Blueprints

OCEL Info

Relationship Graph

Path Schemas

OCPQ (Queries)

OC-DECLARE

Load another dataset

Update
available 0.12.1
Current version: 0.12.0
Download 0.12.1

OCEL Info

11 Event Types
6 Object Types

OCEL Counts

Events (21,008)

pick item	7,659
confirm order	2,000
pay order	2,000
place order	2,000
item out of stock	1,544
reorder item	1,544
create package	1,128
package delivered	1,128
send package	1,128
payment reminder	566

Click a type for its attributes

Objects (10,840)

items	7,659
orders	2,000
packages	1,128
products	20
employees	18
customers	15

Export OCEL:

[JSON](#) [XML](#) [SQLite](#)

[Unload Dataset](#)



Chair of Process
and Data Science

<https://ocpq.aarkue.eu/>



OCPQ

OCEL loaded
21008 Events
10840 Objects

Beta

Extraction Blueprints

OCEL Info

Relationship Graph

OCPQ (Queries)

OC-DECLARE

Load another dataset

v0.10.1

Local Backend

Backend online

1 Queries...

+ Add

New Constraint (1)

No description

New Constraint (1)

Description

Selected Query

Query Info

1 Nodes, 0 Edges

3.08% ∞ Violations
(236 of 7659)

Object Variables +

#7659

o1: orders

o2: items

Event Variables +

e1: place order

e2: package delivered

Filters +

e1 $\hookrightarrow$ o1

e2 $\hookrightarrow$ o2

o1 $\hookrightarrow$ o2

Labels +

Constraints +

e1 $\rightarrow$ e2 $-\infty - 4w$

3.08%
236

3% of the
items are
delivered
too late

+

-

$\ll$

$\gg$



Object Variables + #7659

 **o1**: orders

 **o2**: items

Event Variables +

 **e1**: place order

 **e2**: package delivered

Filters +

 **e1**   **o1**

 **e2**   **o2**

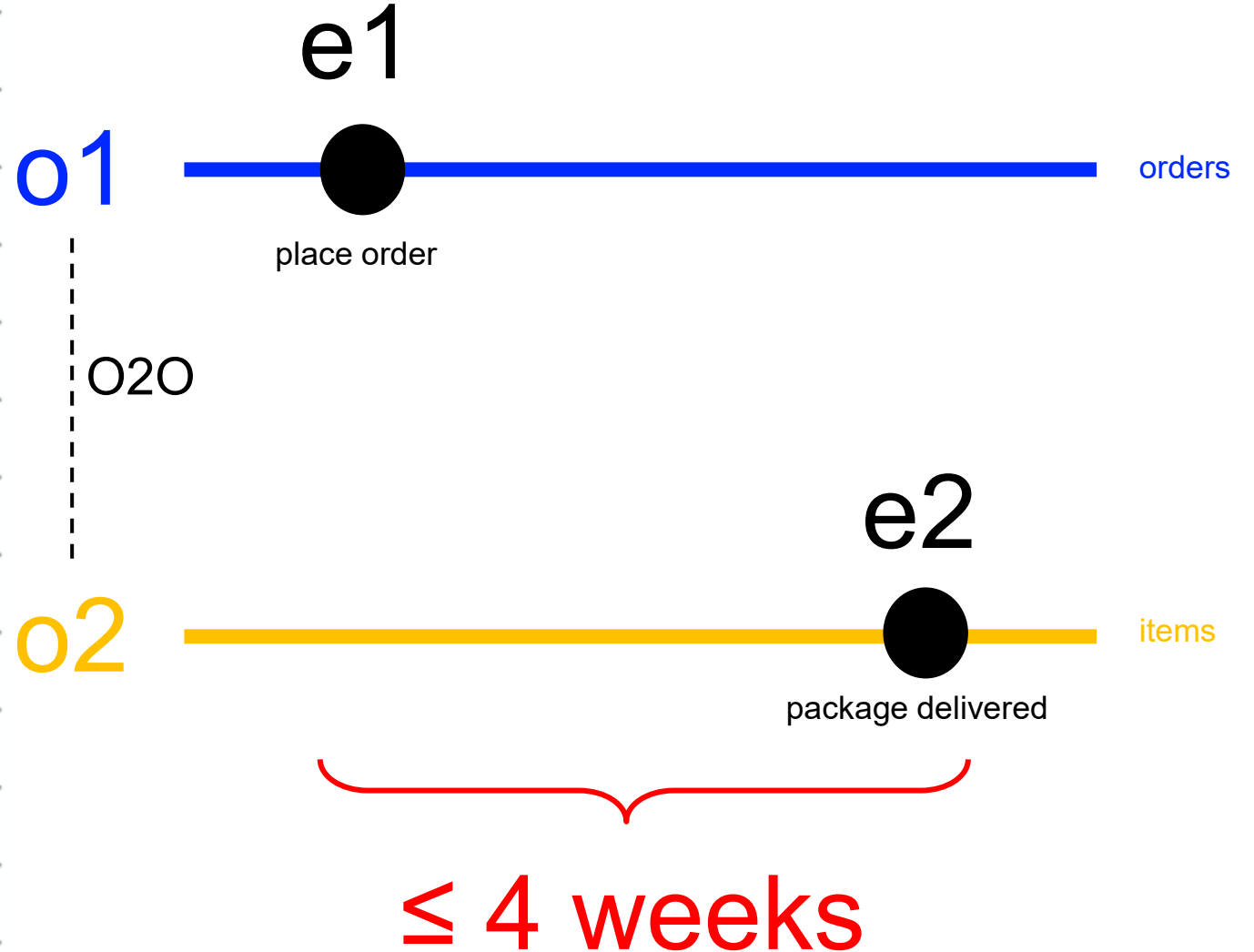
 **o1**   **o2**

Labels +

Constraints +

 **e1** →  **e2** -∞ - 4w


3.08%
236



Output Bindings

7659 Bindings
236 Violations

o1	o2	o3	e1	e2	price of order	weight of product	Violation any
o-990001	i-880001	Echo	place_o-990001	deliver_p-660001	1353.98	0.78	☐
o-990001	i-880002	Echo	place_o-990001	deliver_p-660001	1353.98	0.78	☐
o-990001	i-880003	iPhone 11 Pro	place_o-990001	deliver_p-660001	1353.98	0.188	☐
o-990002	i-880004	MacBook Pro	place_o-990002	deliver_p-660001	3083	1.37	☐
o-990002	i-880005	Kindle Paperwhite	place_o-990002	deliver_p-660001	3083	0.495	☐
o-990002	i-880006	iPad mini	place_o-990002	deliver_p-660001	3083	0.28	☐
o-990003	i-880007	Fire Stick	place_o-990003	deliver_p-660018	3599.99	0.2	☐
o-990003	i-880008	iPhone 8	place_o-990003	deliver_p-660003	3599.99	0.21	☐
o-990003	i-880009	iPad Pro	place_o-990003	deliver_p-660003	3599.99	0.483	☐
o-990003	i-880010	iPhone X	place_o-990003	deliver_p-660003	3599.99	0.172	☐
o-990003	i-880011	Kindle Paperwhite	place_o-990003	deliver_p-660003	3599.99	0.495	☐
o-990003	i-880012	iPad Pro	place_o-990003	deliver_p-660003	3599.99	0.483	☐
o-990004	i-880013	Echo	place_o-990004	deliver_p-660002	2241.95	0.78	☐
o-990004	i-880014	Kindle Paperwhite	place_o-990004	deliver_p-660002	2241.95	0.495	☐
o-990004	i-880015	Echo Show 8	place_o-990004	deliver_p-660002	2241.95	0.98	☐
o-990004	i-880016	Echo Show 8	place_o-990004	deliver_p-660014	2241.95	0.98	☐
o-990004	i-880017	iPhone 8	place_o-990004	deliver_p-660002	2241.95	0.21	☐
o-990004	i-880018	iPad Pro	place_o-990004	deliver_p-660014	2241.95	0.483	☐
o-990004	i-880019	Fire Stick 4K	place_o-990004	deliver_p-660002	2241.95	0.28	☐
o-990004	i-880020	Echo Dot	place_o-990004	deliver_p-660002	2241.95	0.38	☐
o-990005	i-880021	MacBook Air	place_o-990005	deliver_p-660001	3049.98	1.25	☐

Rows per page 50

Page 1 of 154

Selected Query

y-text

Query Info

1 Nodes, 0 Edges

3.08% Violations
(236 of 7659)

Object Variables +

#7659

o1: orders

o2: items

o3: products

Event Variables +

e1: place order

e2: package delivered

Filters +

e1 o1

e2 o2

o1 o2

o2 o3

Labels +

price of order o1.attr('price')

weight of product o3.attr('weight')

Constraints +

e1 e2 -∞ - 4w

3.08%
236

7659 rows, one for each binding

Output Bindings

7659 Bindings

236 Violations

o1	o2	o3	e1	e2	price of order	weight of product	Violation viol.
o-990026	i-880114	iPad	place_o-990026	deliver_p-660065	829.98	0.483	✓ e1 → e2
o-990031	i-880135	Fire Stick 4K	place_o-990031	deliver_p-660091	713.98	0.28	✓ e1 → e2
o-990036	i-880157	iPad	place_o-990036	deliver_p-660074	3488.99	0.483	✓ e1 → e2
o-990047	i-880202	Echo Show 8	place_o-990047	deliver_p-660121	8016.98	0.98	✓ e1 → e2
o-990061	i-880261	MacBook Air	place_o-990061	deliver_p-660108	7482	1.25	✓ e1 → e2
o-990061	i-880262	MacBook Pro	place_o-990061	deliver_p-660108	7482	1.37	✓ e1 → e2
o-990078	i-880330	iPhone X	place_o-990078	deliver_p-660120	1482.98	0.172	✓ e1 → e2
o-990085	i-880361	iPad Air	place_o-990085	deliver_p-660132	5207.97	0.44	✓ e1 → e2
o-990087	i-880377	Fire Stick	place_o-990087	deliver_p-660165	2380.97	0.2	✓ e1 → e2
o-990094	i-880408	Echo Dot	place_o-990094	deliver_p-660147	1283.98	0.38	✓ e1 → e2
o-990103	i-880434	iPad	place_o-990103	deliver_p-660136	3797.98	0.483	✓ e1 → e2
o-990109	i-880469	MacBook Air	place_o-990109	deliver_p-660146	2324.98	1.25	✓ e1 → e2
o-990114	i-880484	Echo Plus	place_o-990114	deliver_p-660149	5374.96	1.28	✓ e1 → e2
o-990114	i-880488	Kindle	place_o-990114	deliver_p-660169	5374.96	0.483	✓ e1 → e2
o-990133	i-880545	MacBook Air	place_o-990133	deliver_p-660152	6630.95	1.25	✓ e1 → e2
o-990153	i-880626	Echo Show 8	place_o-990153	deliver_p-660169	2341.97	0.98	✓ e1 → e2
o-990153	i-880627	iPad Pro	place_o-990153	deliver_p-660185	2341.97	0.483	✓ e1 → e2
o-990160	i-880662	iPad mini	place_o-990160	deliver_p-660175	892.96	0.28	✓ e1 → e2
o-990183	i-880753	iPhone 11	place_o-990183	deliver_p-660196	5769.98	0.166	✓ e1 → e2
o-990190	i-880786	iPad mini	place_o-990190	deliver_p-660201	2541.97	0.28	✓ e1 → e2
o-990197	i-880814	MacBook Air	place_o-990197	deliver_p-660240	3479.97	1.25	✓ e1 → e2

Rows per page 50

Page 1 of 5

Selected Query

query-text

Query Info

1 Nodes, 0 Edges

3.08% Violations
(236 of 7659)

Object Variables + #7659

o1: orders

o2: items

o3: products

Event Variables +

e1: place order

e2: package delivered

Filters +

e1 o1

e2 o2

o1 o2

o2 o3

Labels +

price of order o1.attr('price')

weight of product o3.attr('weight')

Constraints +

e1 → e2 -∞ - 4w

3.08%
236

236 rows, one for each binding corresponding to a violation

**OCPQ**

OCEL loaded

21008 Events

10840 Objects

Extraction Blueprints

OCEL Info

Relationship Graph

Path Schemas

OCPQ (Queries)

OC-DECLARE

Load another dataset

v0.12.1

Local Backend

Backend online

OC-DECLARE Model**New Constraint (1)**

Add Discover Evaluate Clear Layout Export

OBJECT TYPES

customers employees items

orders packages products

ACTIVITIES

11/11 shown

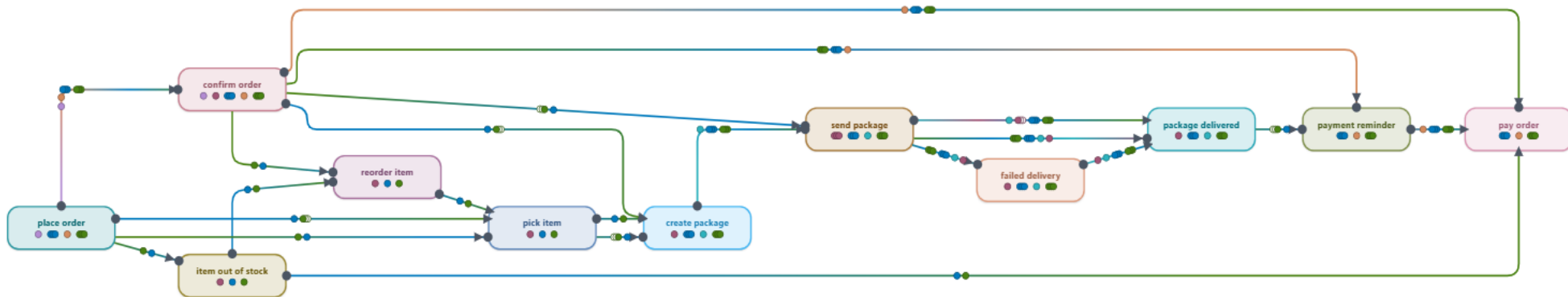
→ EF ← EP → EF+EP

each any all

1..1 0..1 1..* 0..*

25 arcs

OC-Declare





OC-PQ

OCEL loaded
21008 Events
10840 Objects

Extraction Blueprints

OCEL Info

Relationship Graph

Path Schemas

OC-PQ (Queries)

OC-DECLARE

Load another dataset

v0.12.1

Local Backend

Backend online

OC-DECLARE Model

New Constraint (1)

+ Add Discover Evaluate Clear Layout Export

OBJECT TYPES

customers employees items

orders packages products

ACTIVITIES

11/11 shown

EF EP EF+EP

each any all

1..1 0..1 1..* 0..*

25 arcs

EF EP Both

send package → package delivered

EF count 1 - max ≥ 1

Objects

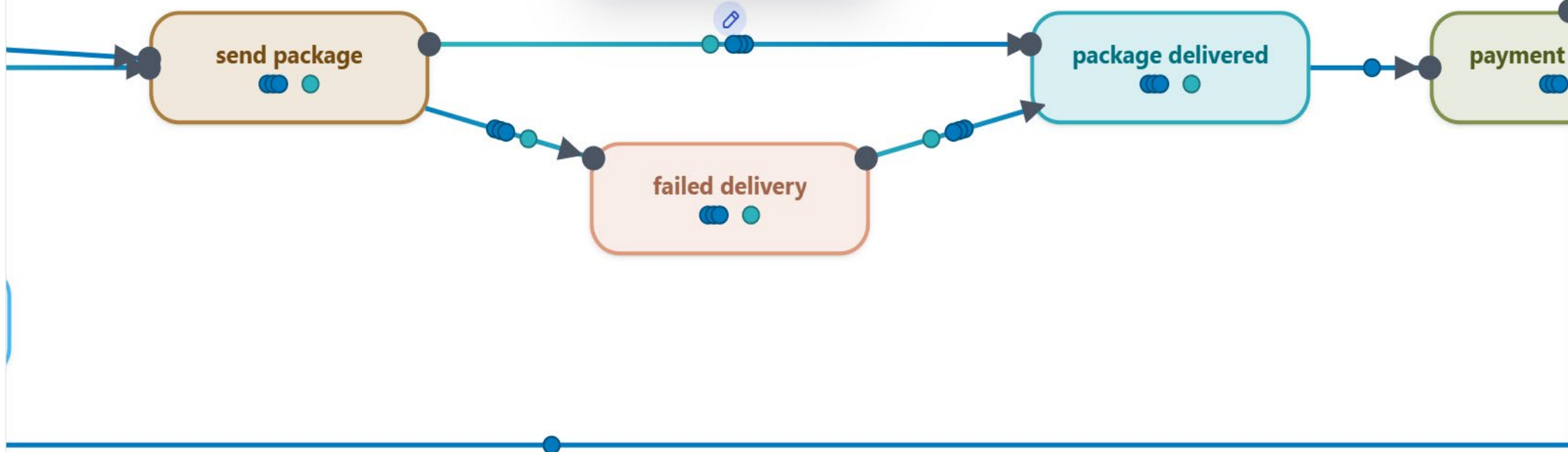
each packages ×

all items ×

any —

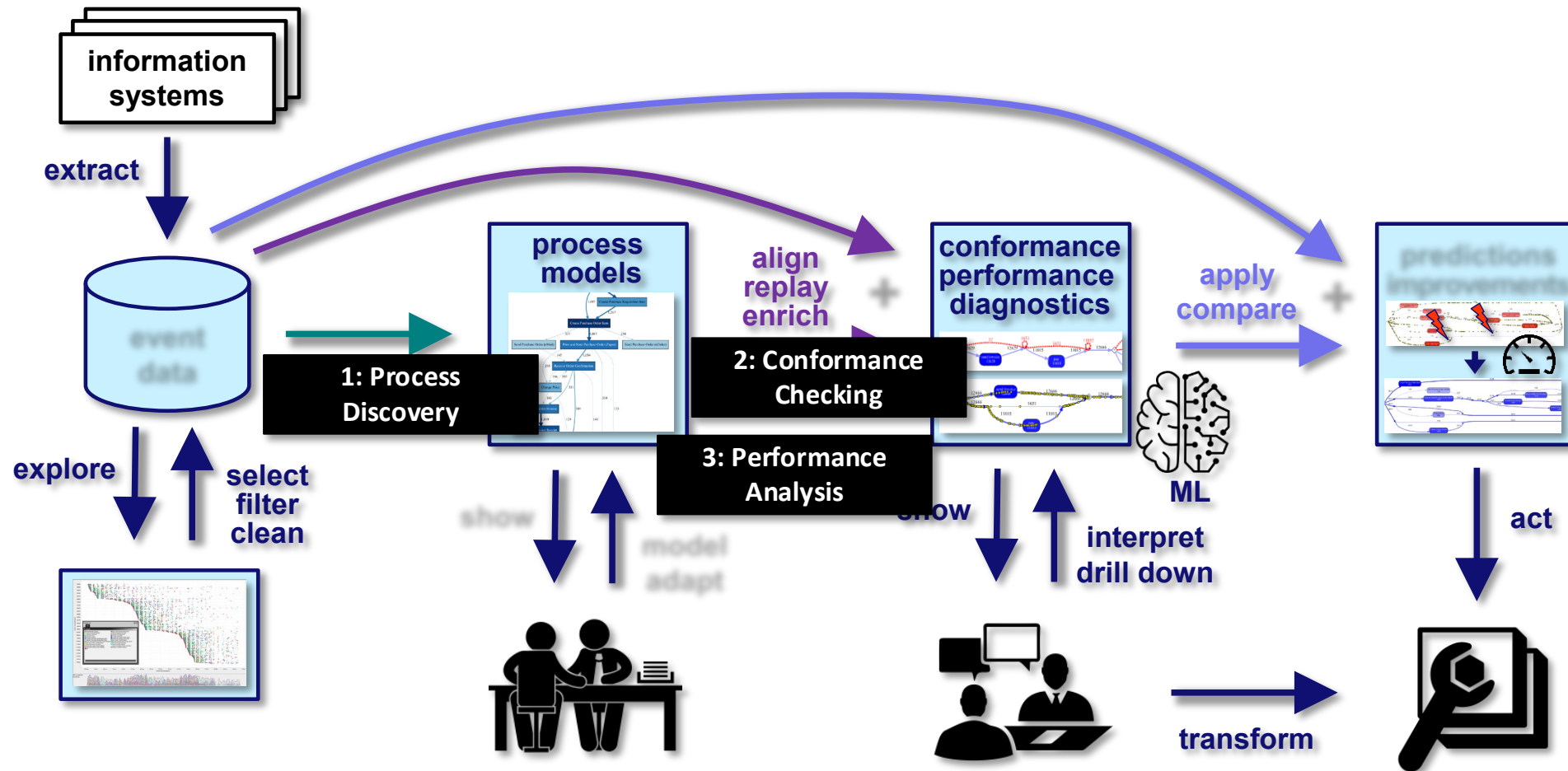
each all any Simple O2O

object type + Add

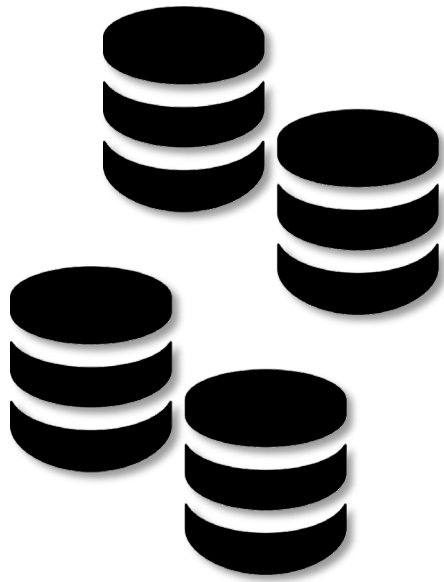


Summary and Outlook

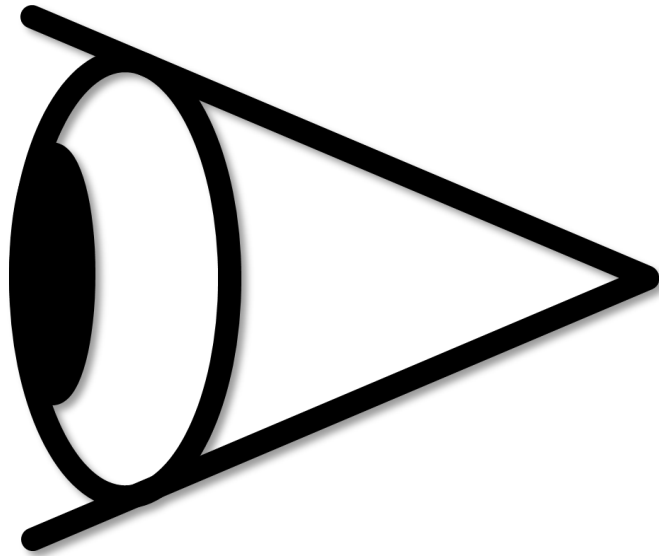
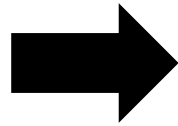
Next



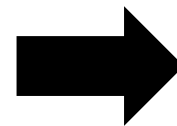
Process models and event data provide the context to look at processes and apply machine learning algorithms



complex reality

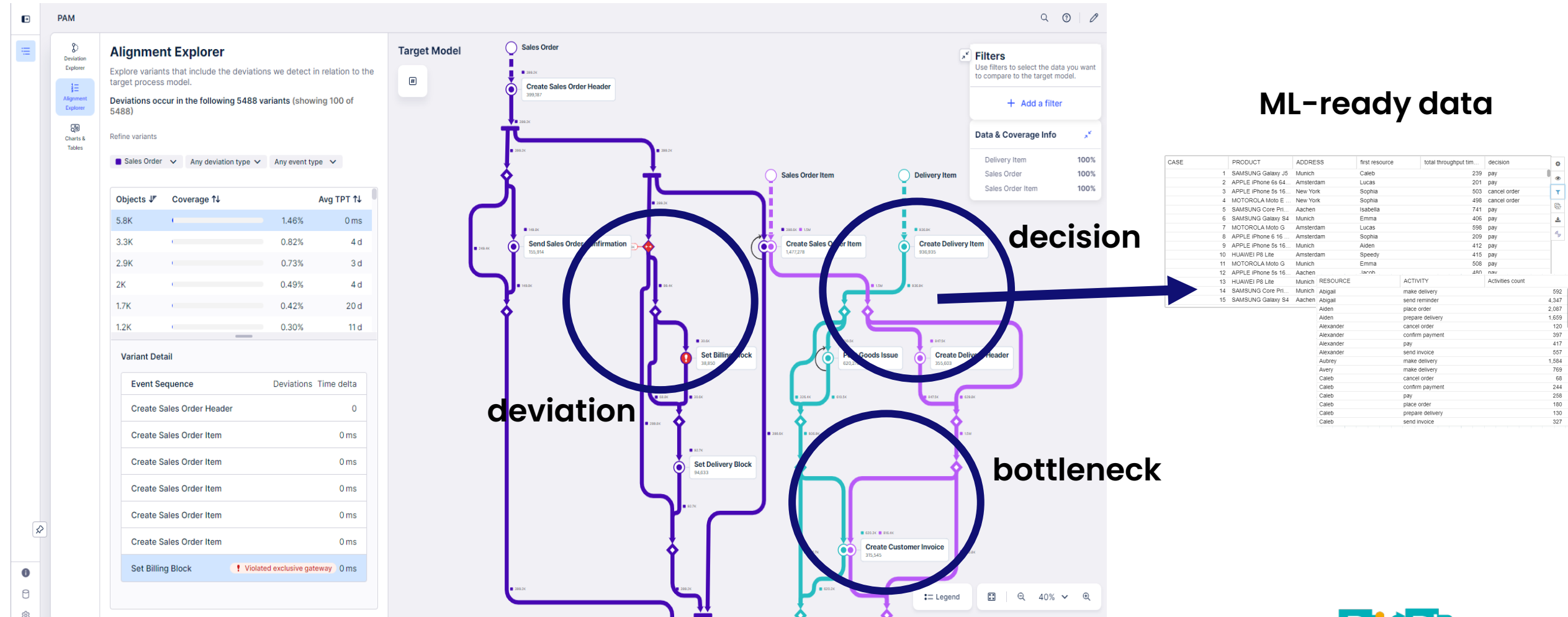


event data and process models

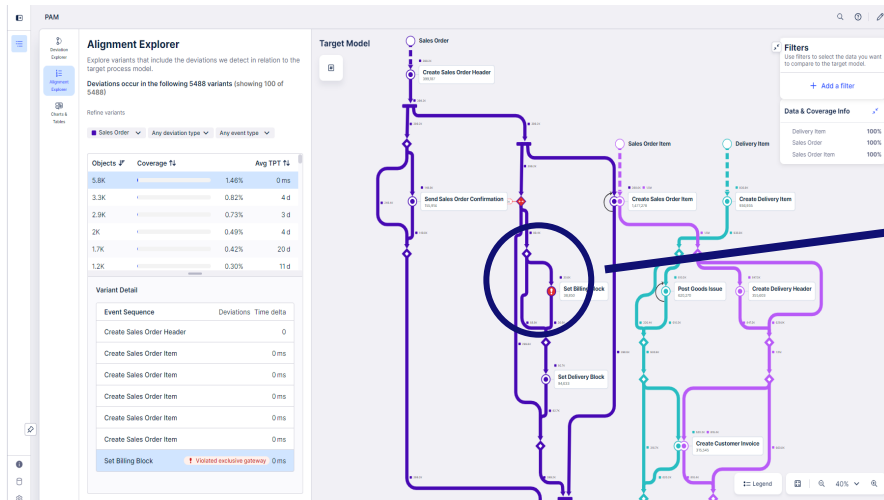


machine learning

Generating “Machine Learning Problems” for “Process Problems”

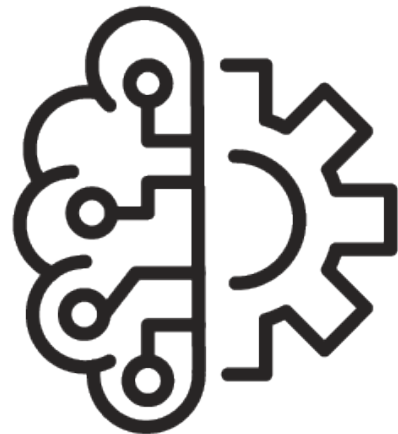


Can be used to answer any process-related problem! (if there is enough data)



CASE	PRODUCT	ADDRESS	first resource	total throughput tim.	decision
1	SAMSUNG Galaxy J5	Munich	Caleb	239	pay
2	APPLE iPhone 5s 64	Amsterdam	Lucas	201	pay
3	APPLE iPhone 5s 16	New York	Sophia	503	cancel order
4	MOTOROLA Moto E	New York	Sophia	498	cancel order
5	SAMSUNG Core Pti	Aachen	Isabella	741	pay
6	SAMSUNG Galaxy S4	Munich	Emma	406	pay
7	MOTOROLA Moto G	Amsterdam	Lucas	598	pay
8	APPLE iPhone 6 16	Amsterdam	Sophia	209	pay
9	APPLE iPhone 5s 16	Munich	Aiden	412	pay
10	HUAWEI P8 Lite	Amsterdam	Speedy	415	pay
11	MOTOROLA Moto G	Munich	Emma	508	pay
12	APPLE iPhone 5s 16	Aachen	Emma	480	rev
13	HUAWEI P8 Lite	Munich	Jacob		
14	SAMSUNG Core Pti	Munich			
15	SAMSUNG Galaxy S4	Aachen			

RESOURCE	ACTIVITY	Activities count
Abigail	make delivery	592
Abigail	send reminder	4,347
Aiden	place order	2,087
Aiden	prepare delivery	1,659
Alexander	cancel order	120
Alexander	confirm payment	397
Alexander	pay	417
Alexander	send invoice	357
Aubrey	make delivery	1,584
Avery	make delivery	769
Caleb	cancel order	68
Caleb	confirm payment	244
Caleb	pay	258
Caleb	place order	180
Caleb	prepare delivery	130
Caleb	send invoice	327



- What is causing the bottleneck?
- Which orders are deviating?
- When will this product be delivered?
- Will we meet our SLA tomorrow?

The real challenge

WE ARE TOO BUSY TO APPLY PROCESS MINING



Websites

- www.processmining.org
- www.process-mining-summer-school.org
- www.tf-pm.org
- www.promtools.org
- www.celonis.com/academic-signup
- xes-standard.org
- ocel-standard.org
- www.pads.rwth-aachen.de
- www.vdaalst.com



Online courses

- **Coursera course “Process Mining: Data science in Action”**
Register via coursera.org/learn/process-mining (>175.000 participants since 2015).
- **Celonis/RWTH course “Process Mining: From Theory to Execution”**
Register via www.celonis.com/wils-process-mining-class.
- **edX course “A Hands-on Introduction to Process Mining”**
Register via RWTHx: www.edx.org/school/rwthx.
- **edX course “Object Centric Process Mining”**
Register via RWTHx: www.edx.org/school/rwthx.



Books (not intended to be complete)

