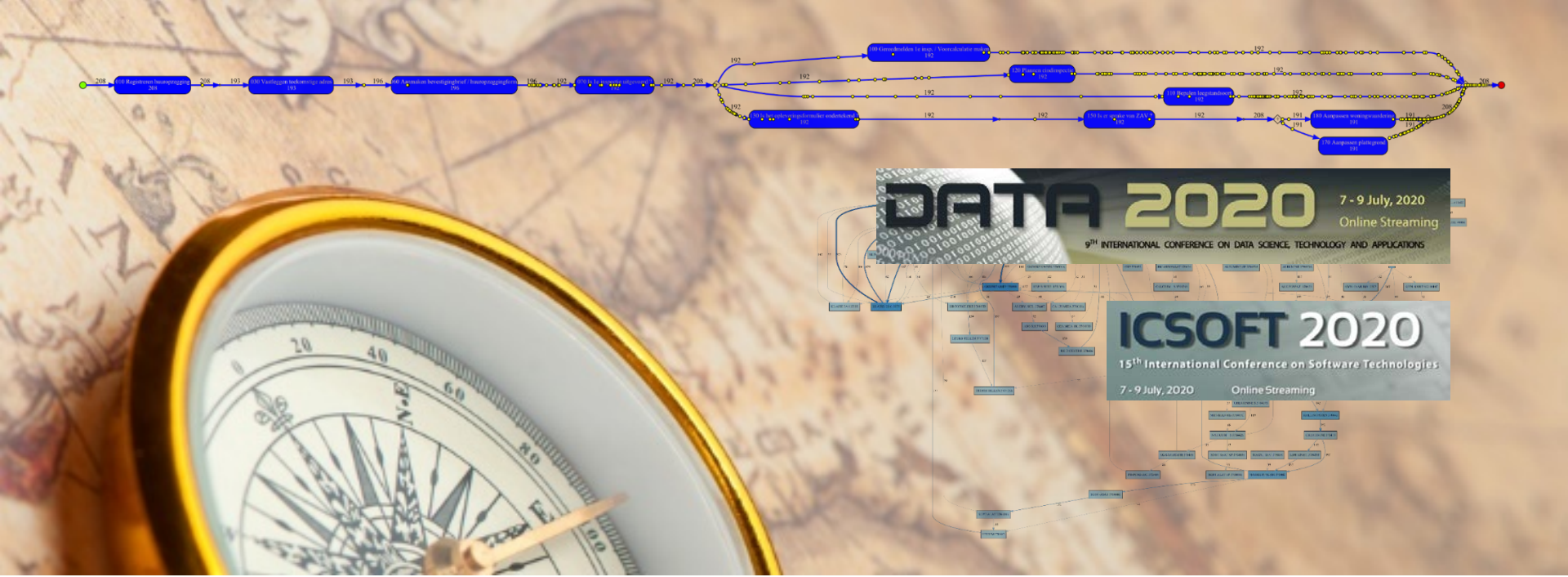

Process Mining as the Superglue between Data and Process Management

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9th International Conference on Data Science, Technology and Applications (DATA 2020)
15th International Conference on Software Technologies (ICSOFT 2020)
Lieusaint, Paris, France

Fraunhofer FIT
Alexander von Humboldt Stiftung/Foundation
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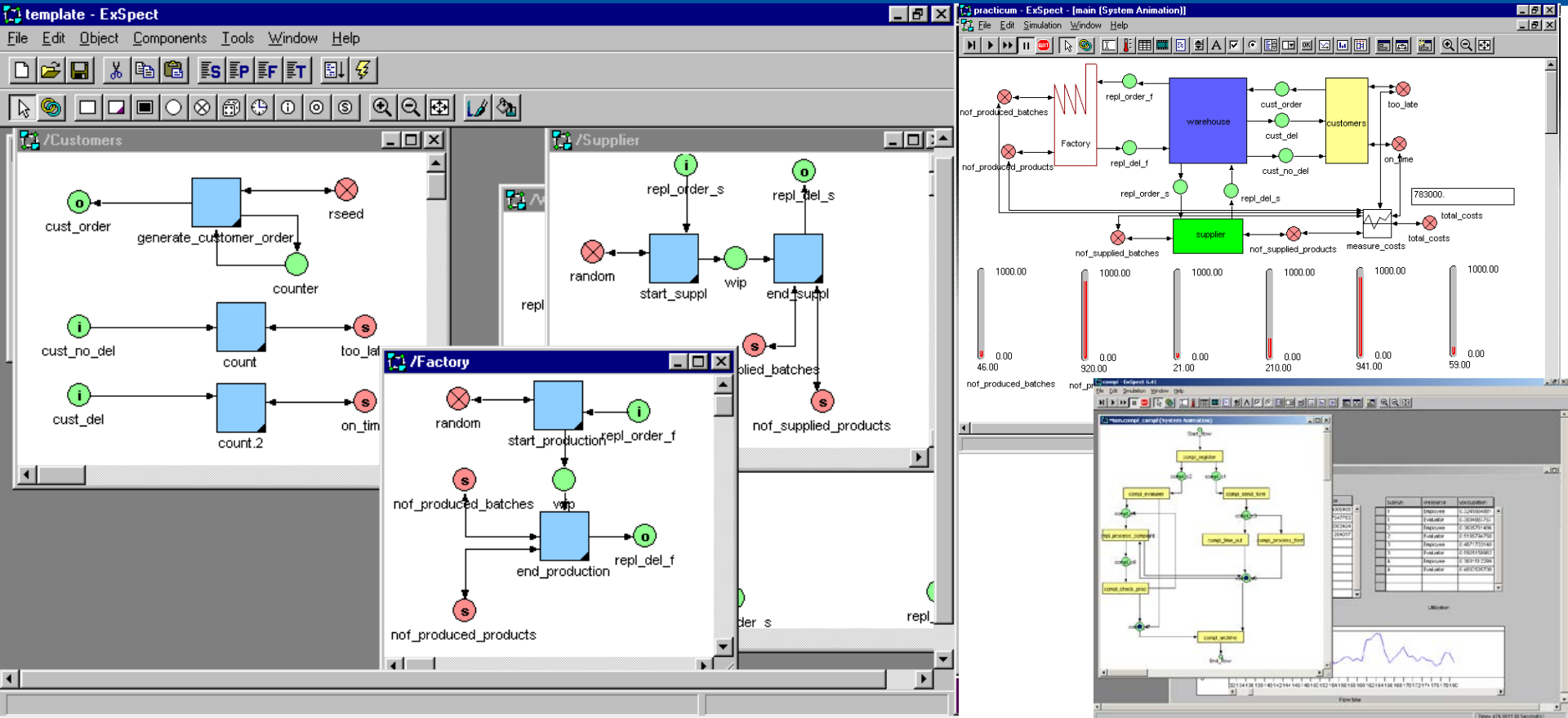
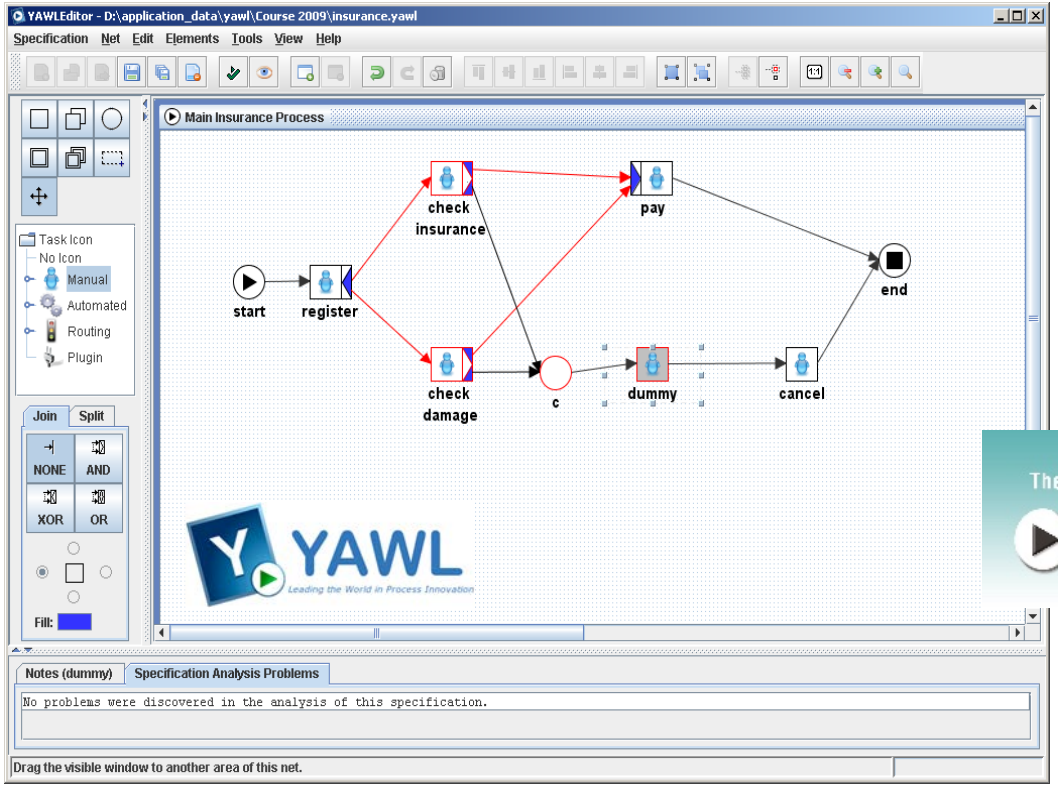
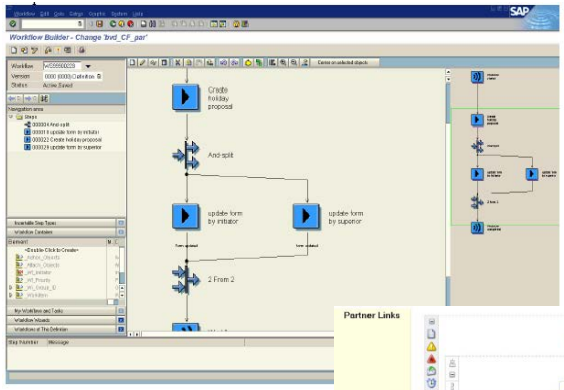
ExSpect: Executable Specification Tool

(1988-2000)

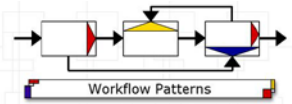


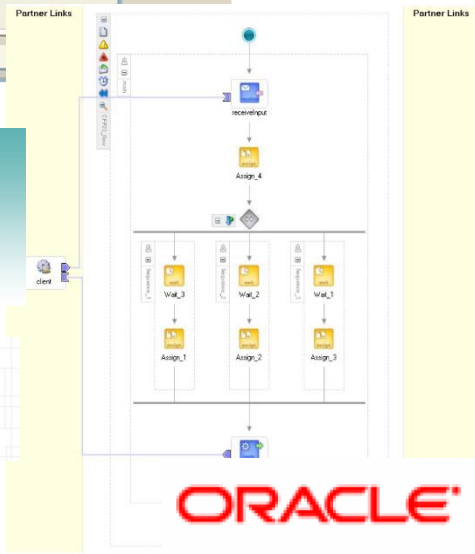
Workflow Management (YAWL, patterns, etc.)
(1994-2006)





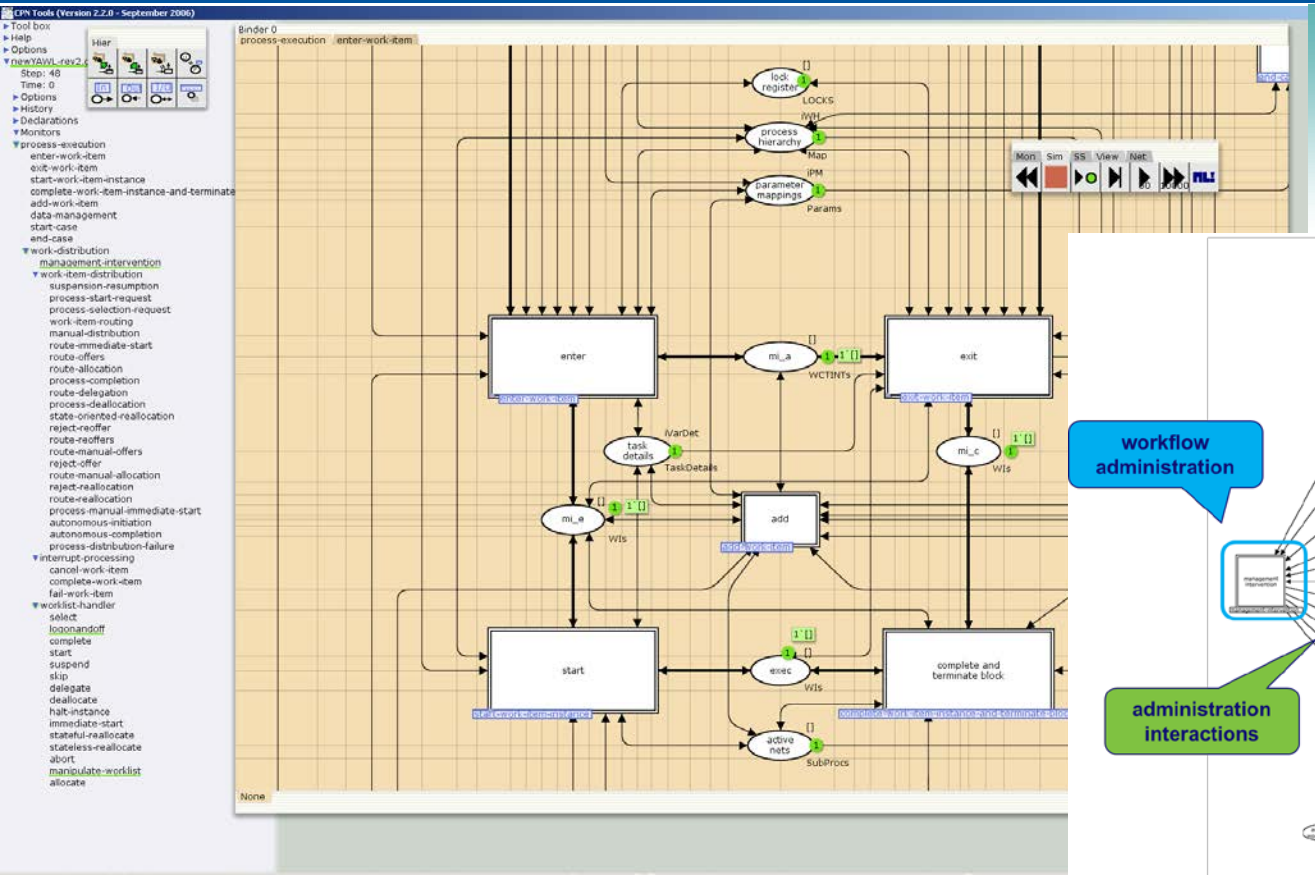
SAP

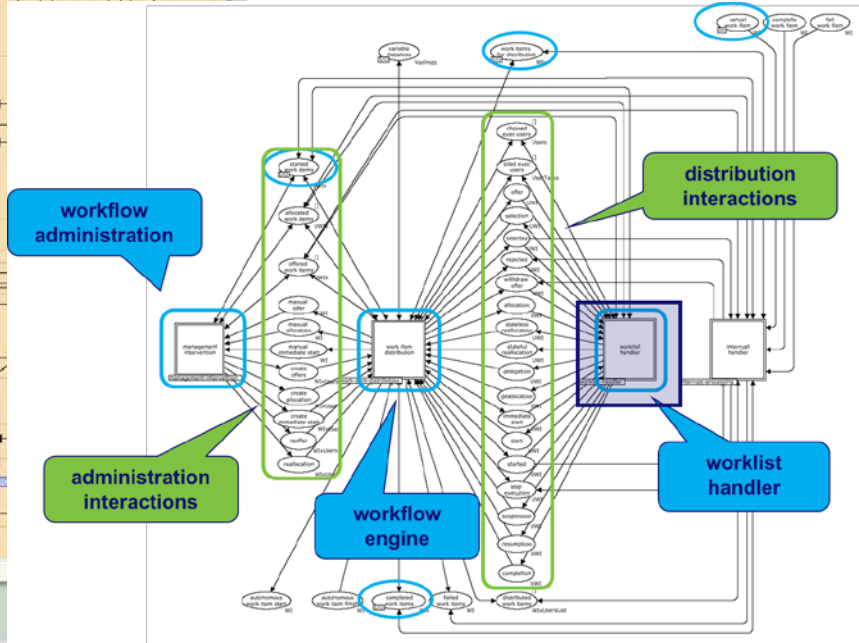




ORACLE

YAWL Specification in CPN Tools



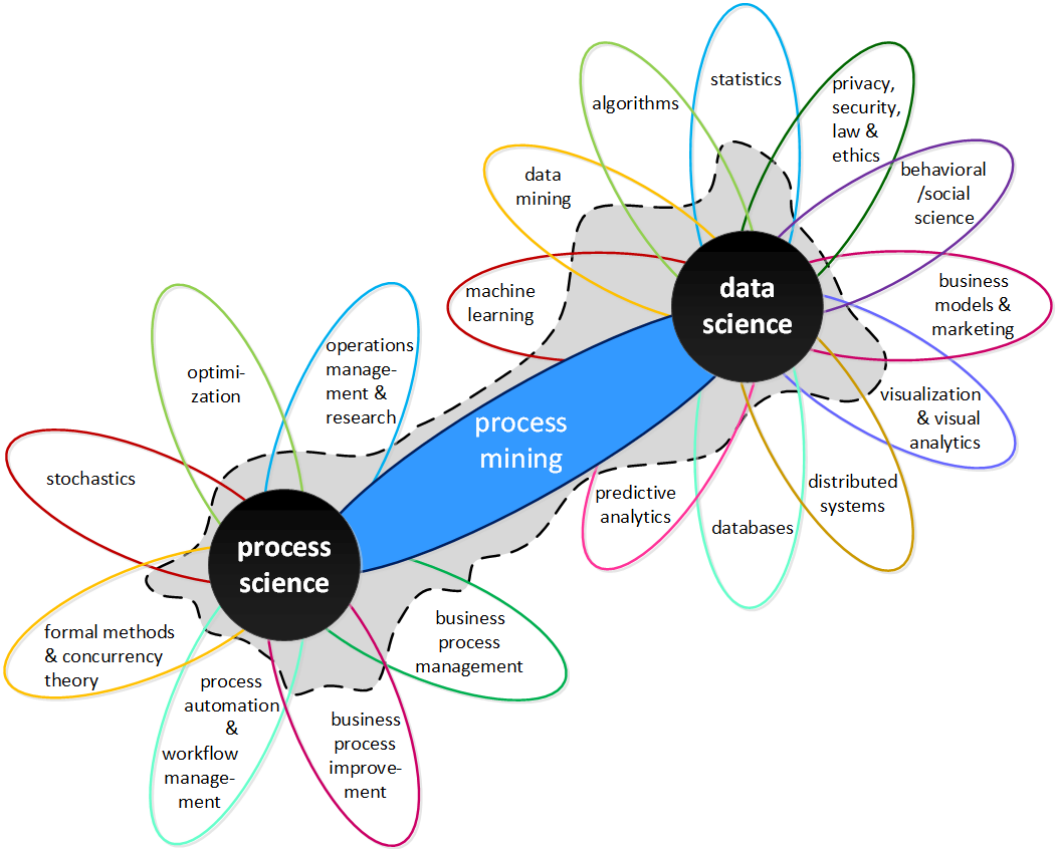


Great, but most behavioral models suck!

- It seems impossible to (perfectly) capture *real* systems and processes in formal models.
- Workflow management and business process management systems (driven by models) *failed* to support most of the real-live processes.

Yet, process orientation remains important and event data have become widely available.

Process Mining
Bridging Data Science and Process Science



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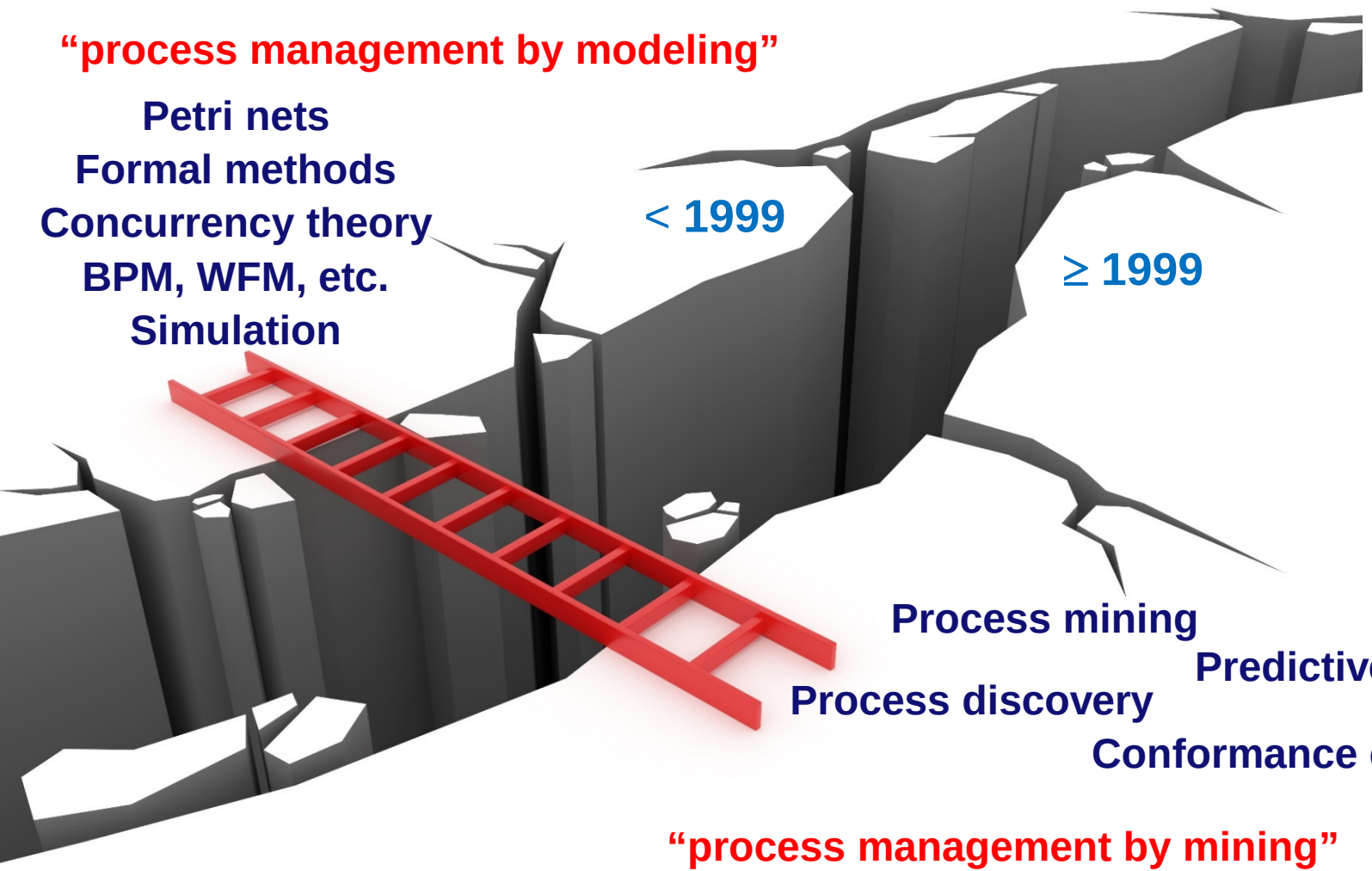

“process management by modeling”

Petri nets
Formal methods
Concurrency theory
BPM, WFM, etc.
Simulation

< 1999

≥ 1999

Process mining
Predictive analytics
Process discovery
Conformance checking

“process management by mining”

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Milestones

- 1999 start of process mining research at TU/e
- 2000-2002 Alpha and Heuristic miner
- 2004 first version of ProM
- 2004-2006 token-based conformance checking, organization mining, decision mining, etc.
- 2007 first process mining company (Futura PI)
- 2010 alignment-based conformance checking
- 2011 founding of Celonis
- 2011 first process mining book
- 2014 Coursera process mining MOOC
- 2016 “Process mining data science in action” book
- 2018 Market Guide for Process Mining by Gartner
- 2018 30+ process mining companies
- 2018 Celonis becomes a Unicorn
- 2019 ICPM 2019: First PM conf.

20 years of process mining

Over 30 process mining vendors today

Etc.

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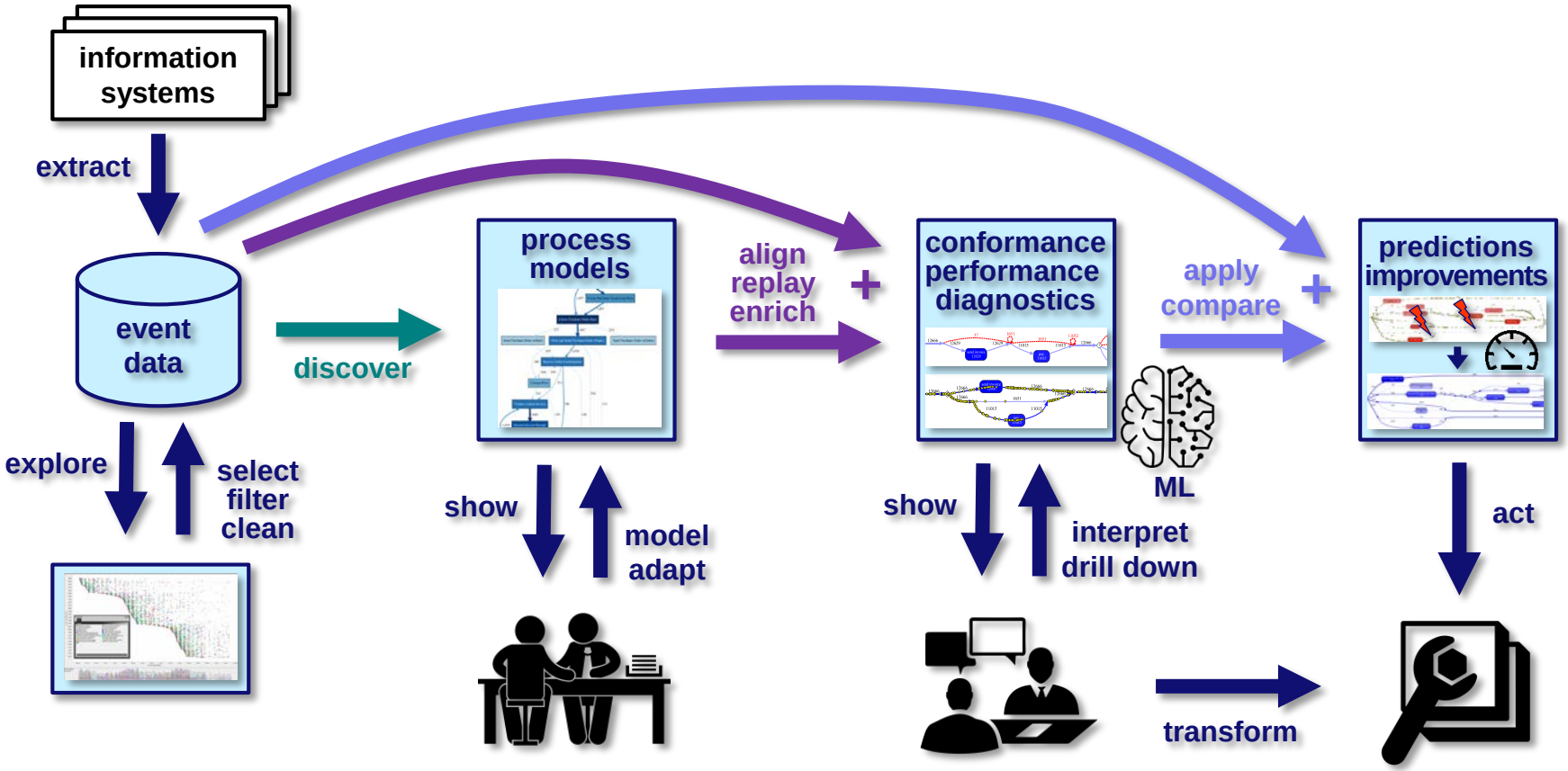

Chair of Process and Data Science

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

Chair of Process and Data Science

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
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6245	make delivery	Michael	2018/02/13 15:14:04.000	APPLE iPhone 6 16 GB	639,00 €	3	NL-7905AX-38
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6212	prepare delivery	Sophia	2018/02/13 15:43:39.000	HUAWEI P8 Lite	234,00 €	1	NL-7905AX-38
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6246	confirm payment	Jack	2018/02/13 15:56:03.000	SAMSUNG Galaxy S6 32 GB	543.99 €	3	NL-7833HT-15
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6265	confirm payment	Lily	2018/02/13 16:55:55.000	SAMSUNG Galaxy S4	329,00 €	4	NL-9521GC-32
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6352	place order	Aiden	2018/02/13 17:53:22.000	APPLE iPhone 6 16 GB	639,00 €	2	NL-9514BV-16
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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

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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

Chair of Process and Data Science

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

Case ID	Activity	Timestamp
6350	place order	2018/02/13 14:29:45.000
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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

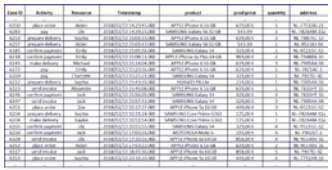
Order 6351

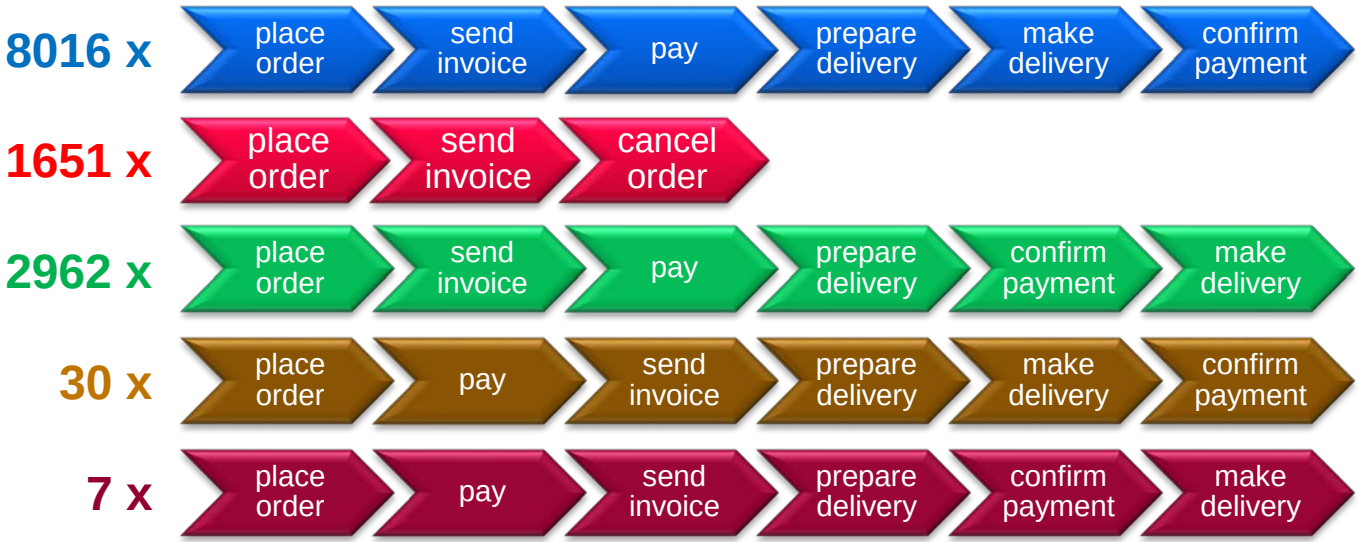
Order 6352

Chair of Process and Data Science

Let’s look at the whole event log again

71,043 events
12,666 cases
7 activities





Using the whole event log

8016 x place order → send invoice → pay → prepare delivery → make delivery → confirm payment

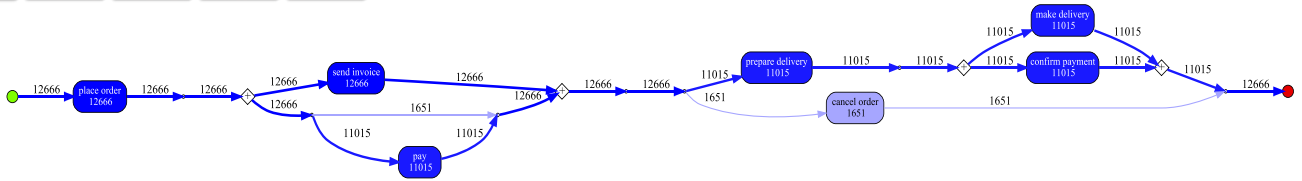
1651 x place order → send invoice → cancel order

2962 x place order → send invoice → pay → prepare delivery → confirm payment → make delivery

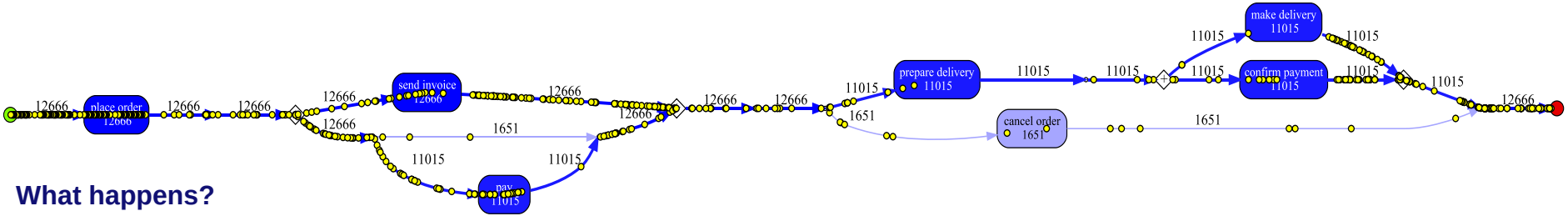
30 x place order → pay → send invoice → prepare delivery → make delivery → confirm payment

7 x place order → pay → send invoice → prepare delivery → confirm payment → make delivery

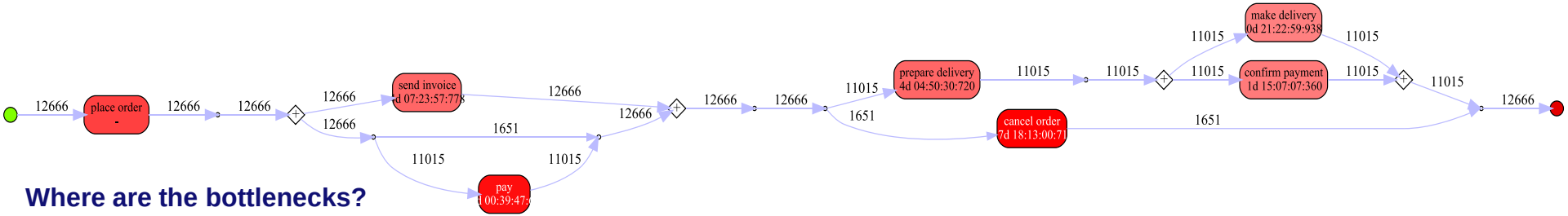
No modeling needed!



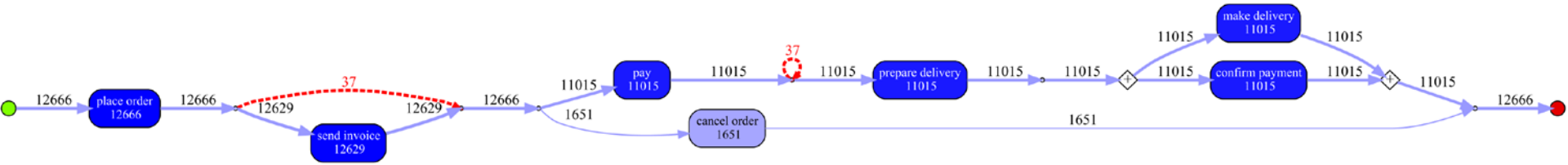
Performance and Compliance



What happens?



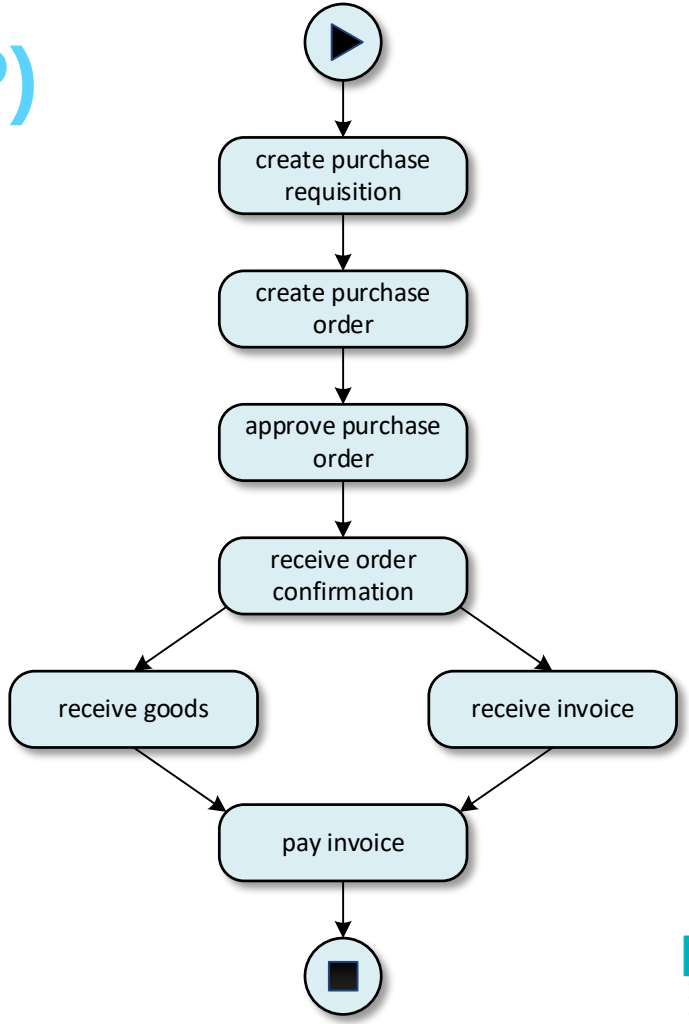
Where are the bottlenecks?



Where do we deviate from the happy path?

Purchase-to-Pay (P2P)

- **Simple process found in almost any organization.**
- **Data available in e.g. SAP.**
- **Most cases follow the so-called “happy path”.**
- **80/20 rule applies.**



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67k of 67k cases selected

100%

EDIT

Reset selections

Zoom

Activities

List view

100%

of activities

Reset

Less

More

Connections

List view

100%

of connections

Reset

Less

More

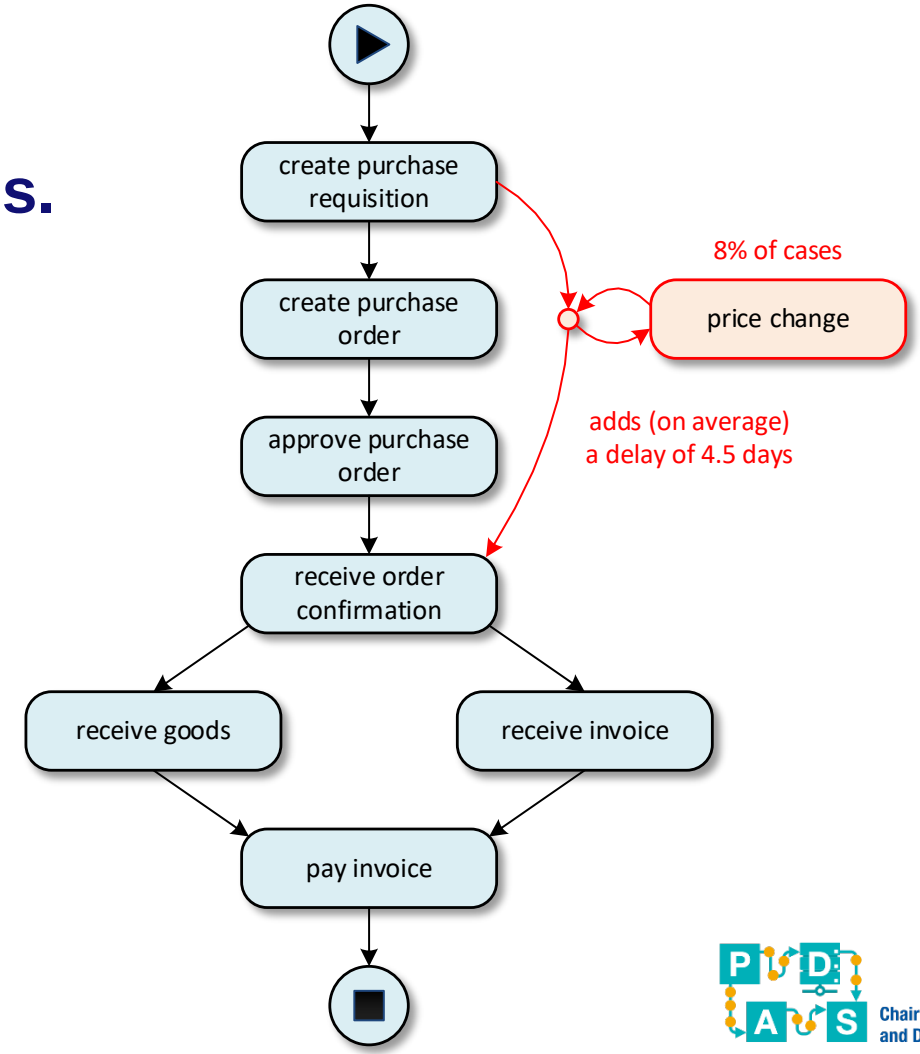
Fixed layout

Real process may look like this:
700,000 cases may exhibit 7,000 unique variants

Process Explorer | Case Explorer | Process overview | Purchasing Overview | Throughput Times | Changes | New App 7

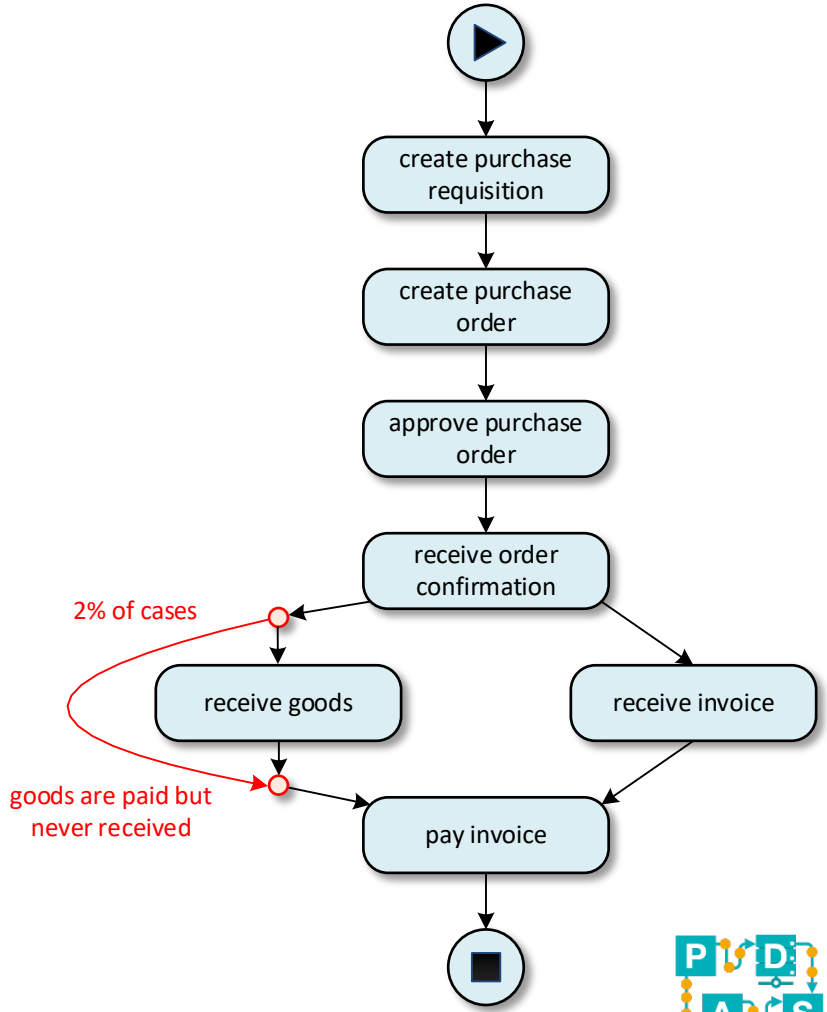
Price changes

- **One of the many variations.**
- **Changing prices result in lots of extra work and significant delays.**



Pay before receipt

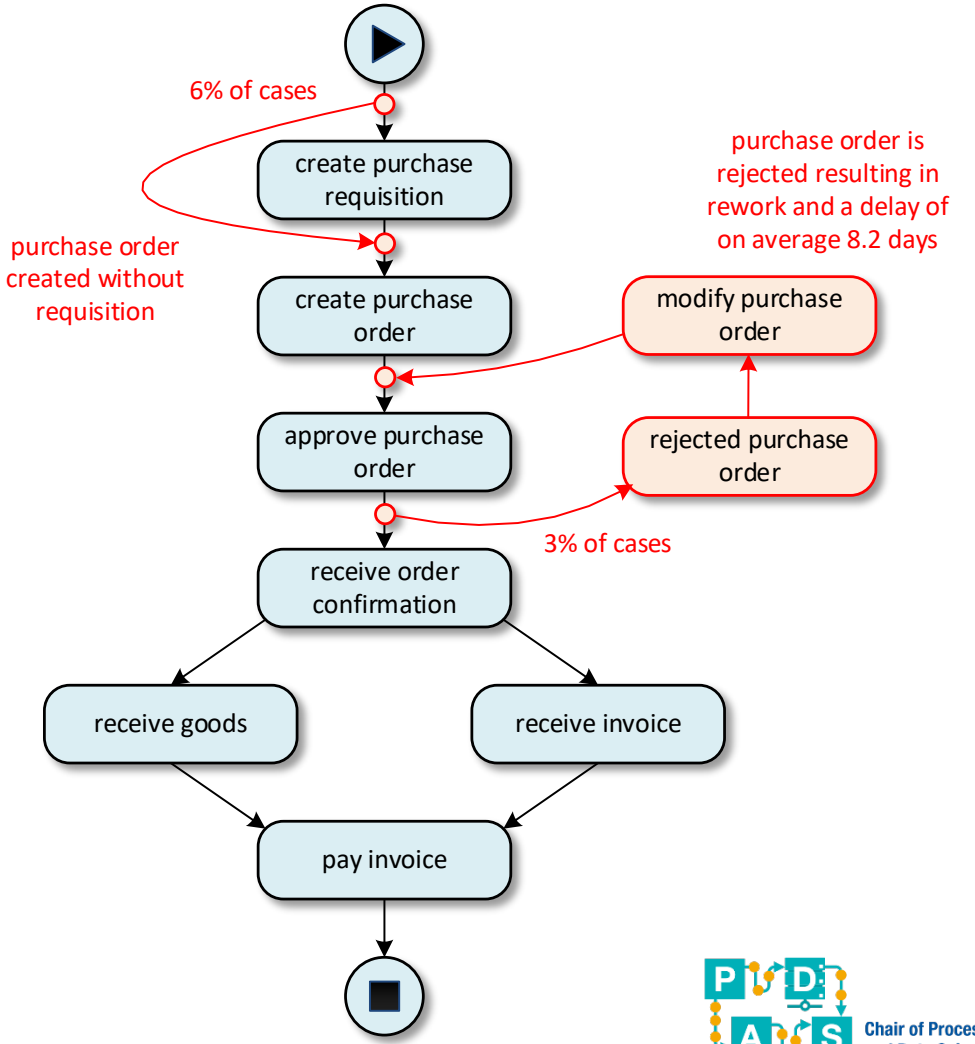
- **Goods are paid before they have been received.**
- **Goods arrived too late or not at all.**
- **May indicate fraud.**



Two additional variations

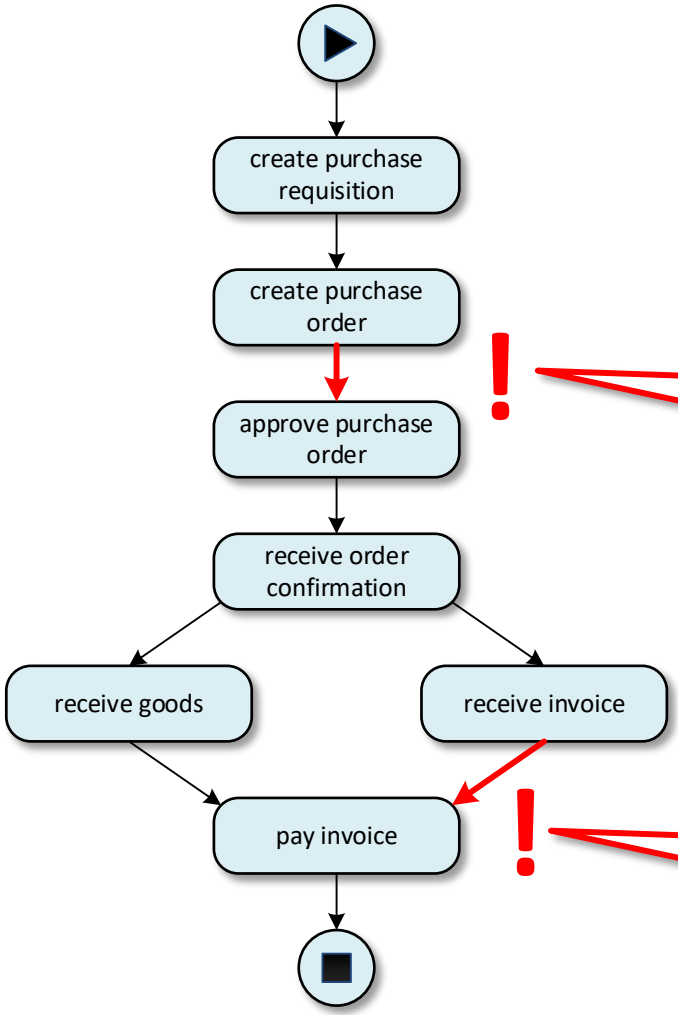
- **Orders created without requisition.**
- **Rejected orders generating rework.**

- **7000-4 = 6996 variants to go …**
- **Can be sorted based on frequency or impact.**



Performance problems

- **Delays inside the process.**
- **Excessive flow times.**
- **Not meeting Service Level Agreements (SLAs).**



Drill down to event data and uncover the root causes.

The approval of purchase orders takes too long (28% more than 10 days).

It takes to long to pay invoices resulting in complaints and fines (15% more than 3 weeks).

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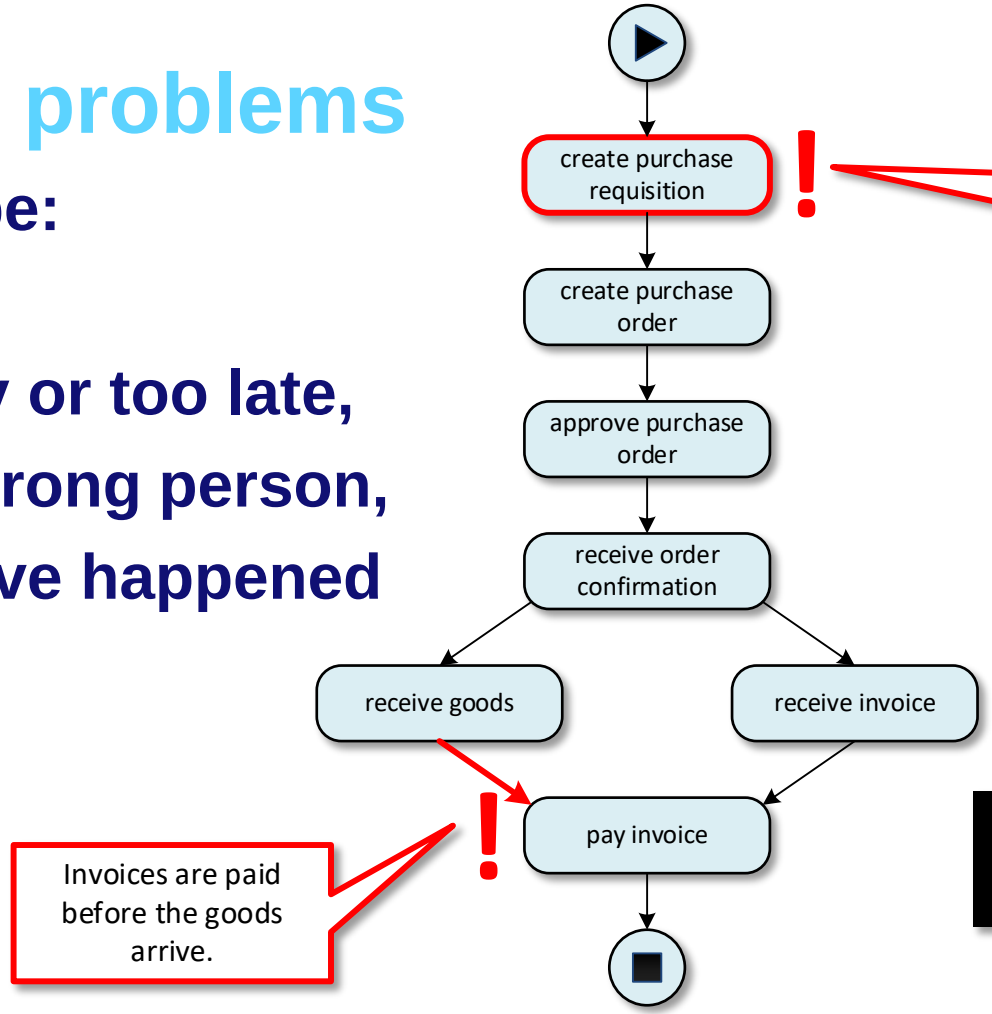
Compliance problems

Activities may be:

- **skipped,**
- **done too early or too late,**
- **done by the wrong person,**
- **should not have happened at all.**



Drill down to event data and uncover the root causes.

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Example: Process Mining @ Siemens

(thanks to Lars Reinkemeyer, head of process mining Siemens)

- **> 6000 active Celonis users (P2P, O2C, etc.)**
- **Millions of savings by reducing rework, process unification, etc.**
- **Improved reliability and responsiveness.**
- **At an amazing scale, e.g., Order to Cash (O2C) process with >30M cases, >300M events, and >900K variants.**

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Other examples (beyond P2P and O2C)

- **Vanderlande**: baggage handling, warehousing, post and parcels.
- **BMW**: finance, production, distribution, actual product usage, aftersales, warranty, customs, etc.

Potential applications are everywhere!

- Finance
- Logistics
- Government
- Production
- E-learning
- Healthcare
- Energy
- Transport
- ….

- Process improvement
- Customer journey analysis
- Compliance (auditing)
- Robotic process automation
- Digital twins
- …

On the Pareto Principle in Process Mining

"How to see the hidden structures?"

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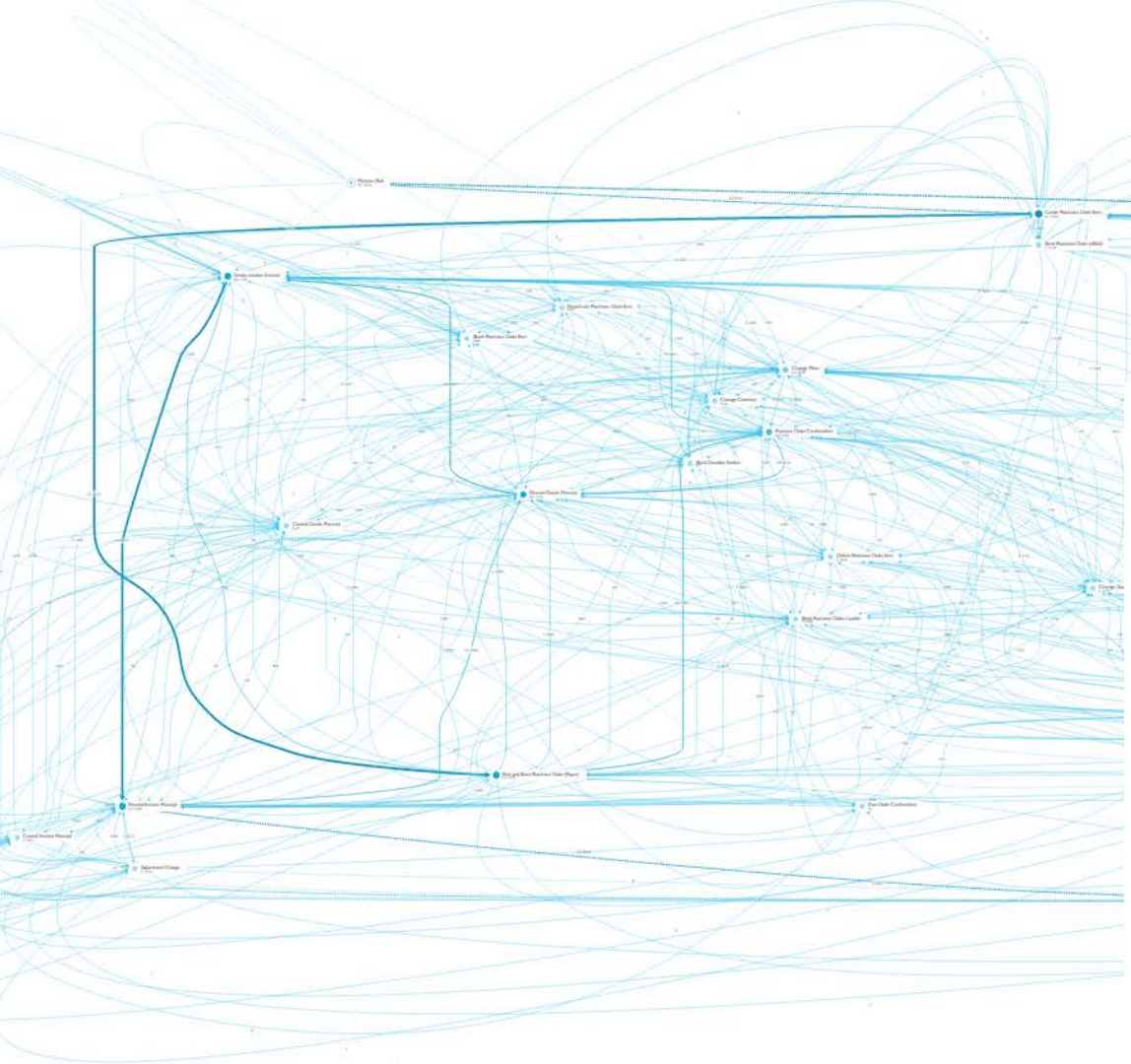

On the Pareto Principle in Process Mining, Task Mining, and Robotic Process Automation

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Keywords: Process Mining, Task Mining, Robotic Process Automation, Pareto Distribution

Abstract: Process mining is able to reveal how people and organizations really function. Often reality is very different and less structured than expected. Process discovery exposes the variability of real-life processes. Conformance checking is able to pinpoint and diagnose compliance problems. Task mining exploits user-interaction data to enrich traditional event data. All these different forms of process mining can and should support Robotic Process Automation (RPA) initiatives. Process mining can be used to decide what to automate and to monitor the cooperation between software robots, people, and traditional information systems. In the process of deciding what to automate, the Pareto principle plays an important role. Often 80% of the behavior in the event data is described by 20% of the trace variants or activities. An organization can use such insights to "pick its automation battles", e.g., analyzing the economic and practical feasibility of RPA opportunities before implementation. This paper discusses how to leverage the Pareto principle in RPA and other process automation initiatives.

1 INTRODUCTION

The Pareto principle, also called the 80/20 rule, states that for many phenomena, 80% of the outcomes (e.g., effects, outputs, or values) come from 20% of the causes (e.g., inputs, resources, or activities). The principle has been named after Vilfredo Pareto (1848-1923), an Italian economist, who noted already in 1896 that about 80% of the land in Italy belonged to 20% of the people (Pareto, 1896). The same 80/20 distribution was witnessed for other countries. George Kingsley Zipf (1902-1950) witnessed a simi-

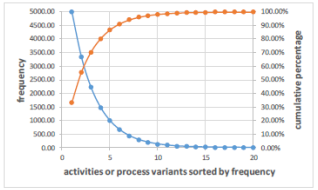
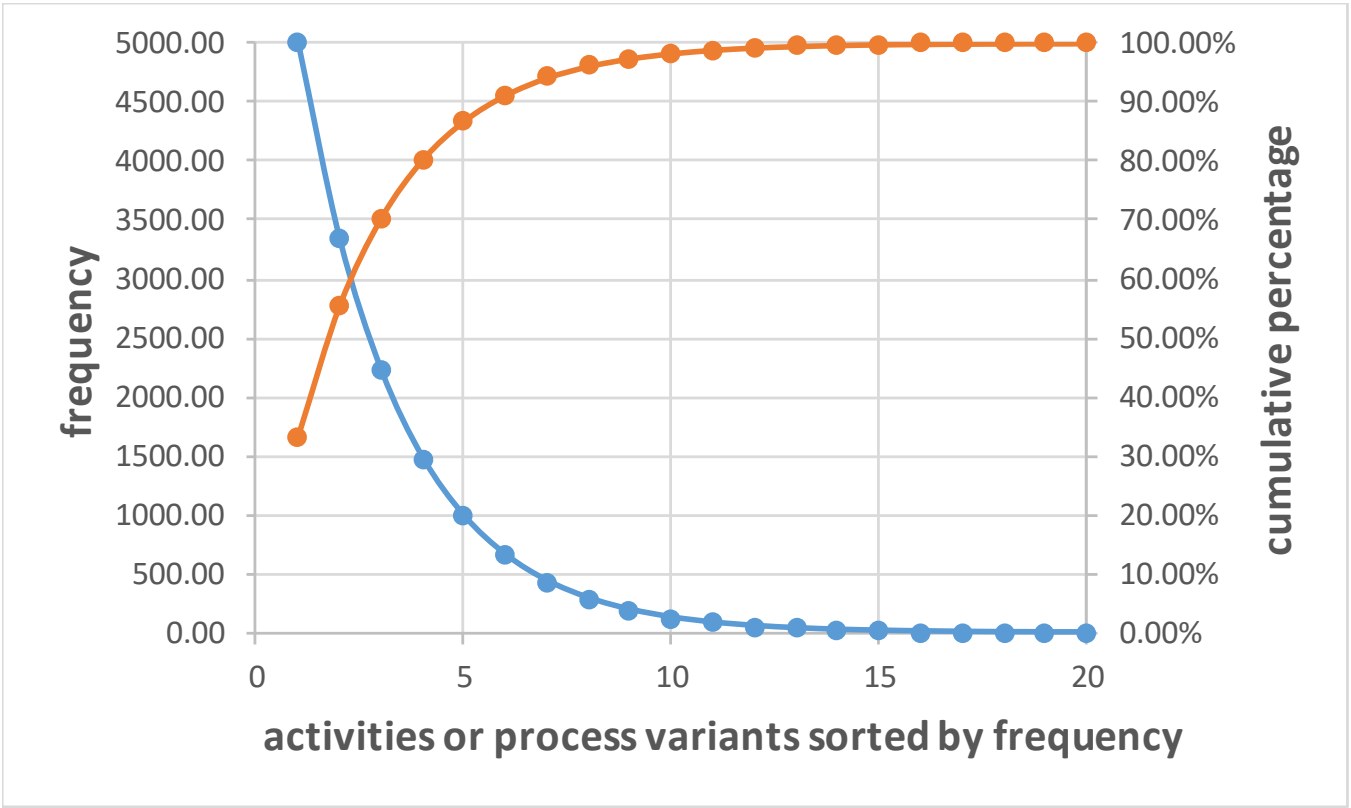
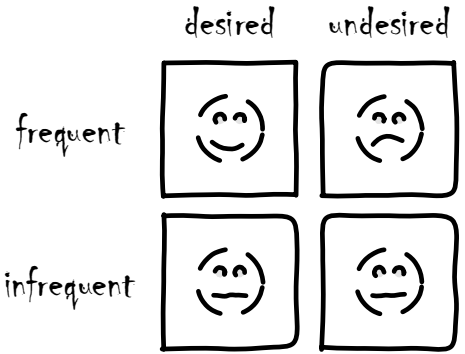


Figure 1: Illustration of the Pareto principle: 20% of the

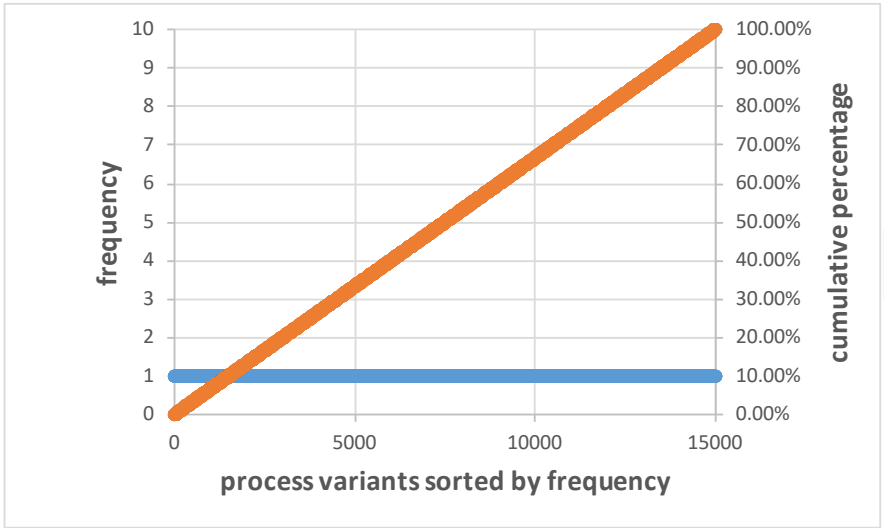
The Pareto distribution in event logs



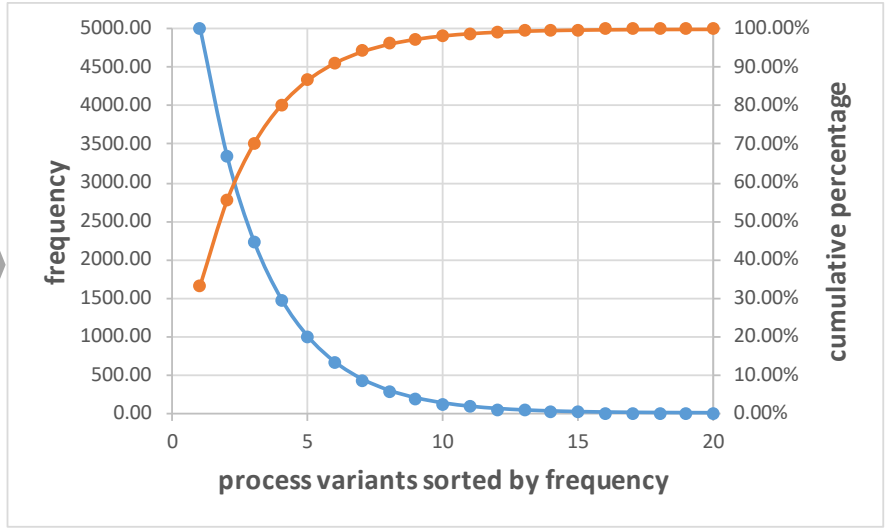


What if all traces are unique?

Trace variant distribution before activity-based filtering: Since all 14992 variants are unique we cannot filter in a meaningful way.



Trace variant distribution after activity-based filtering: Now we can exploit the Pareto-like distribution to filter trace variants.



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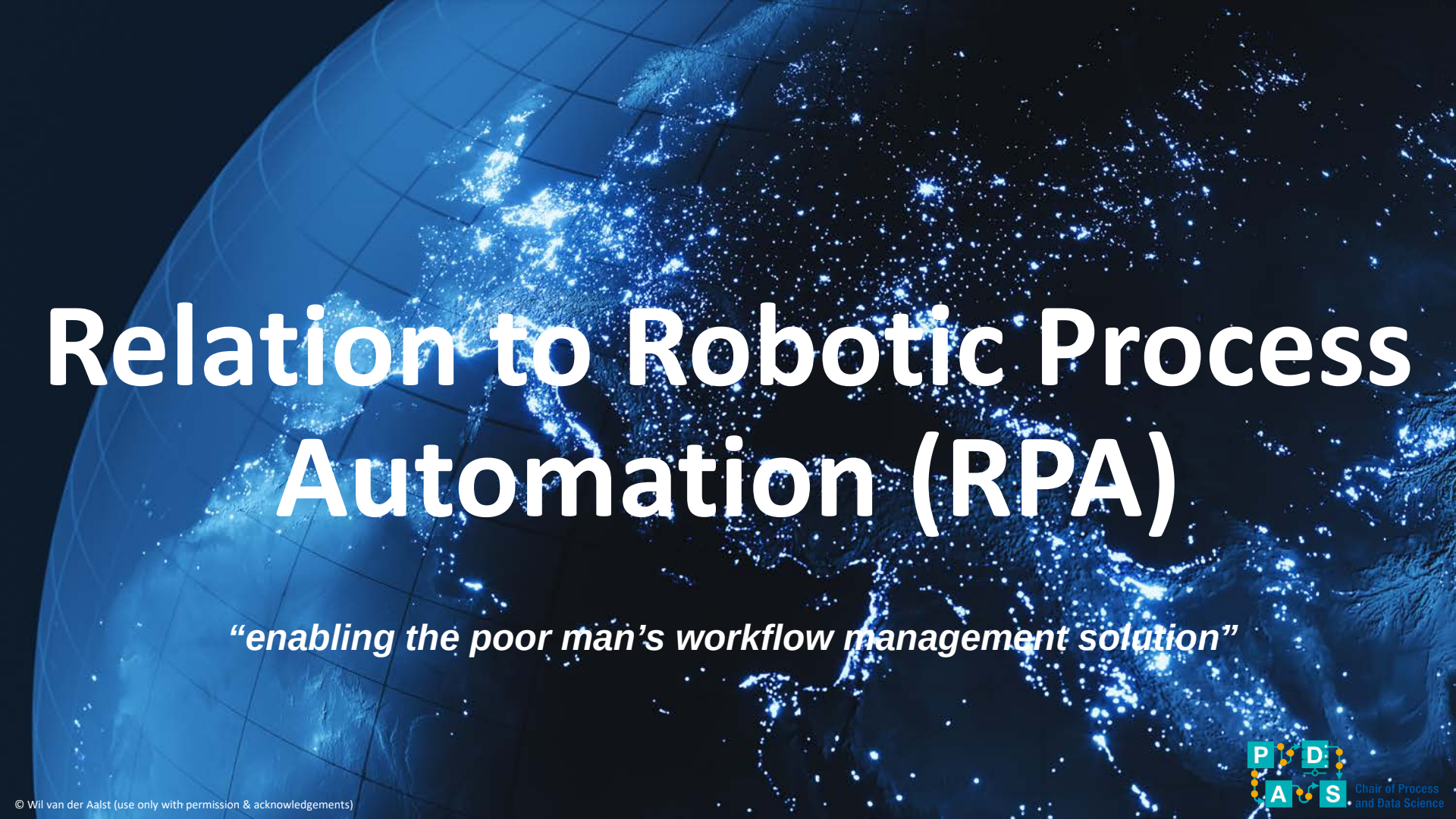

Relation to Robotic Process Automation (RPA)

“enabling the poor man’s workflow management solution”

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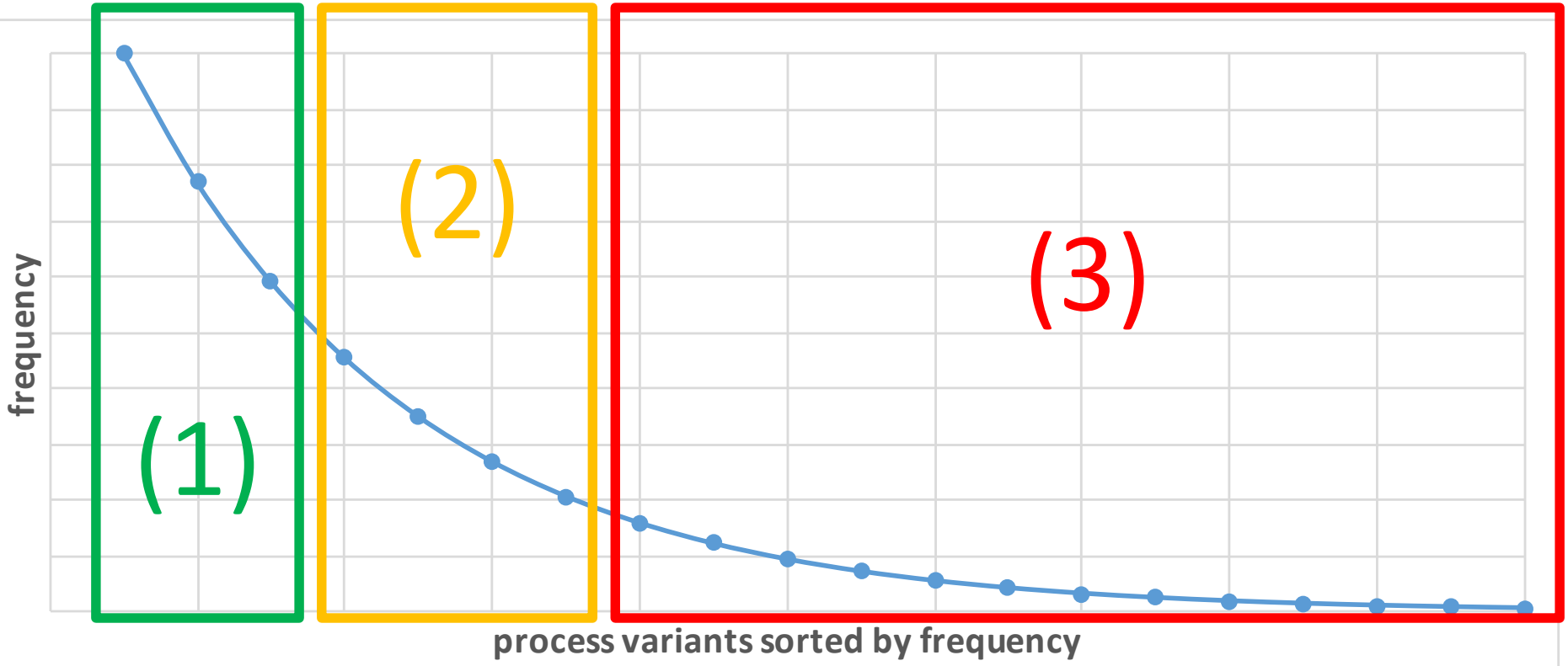
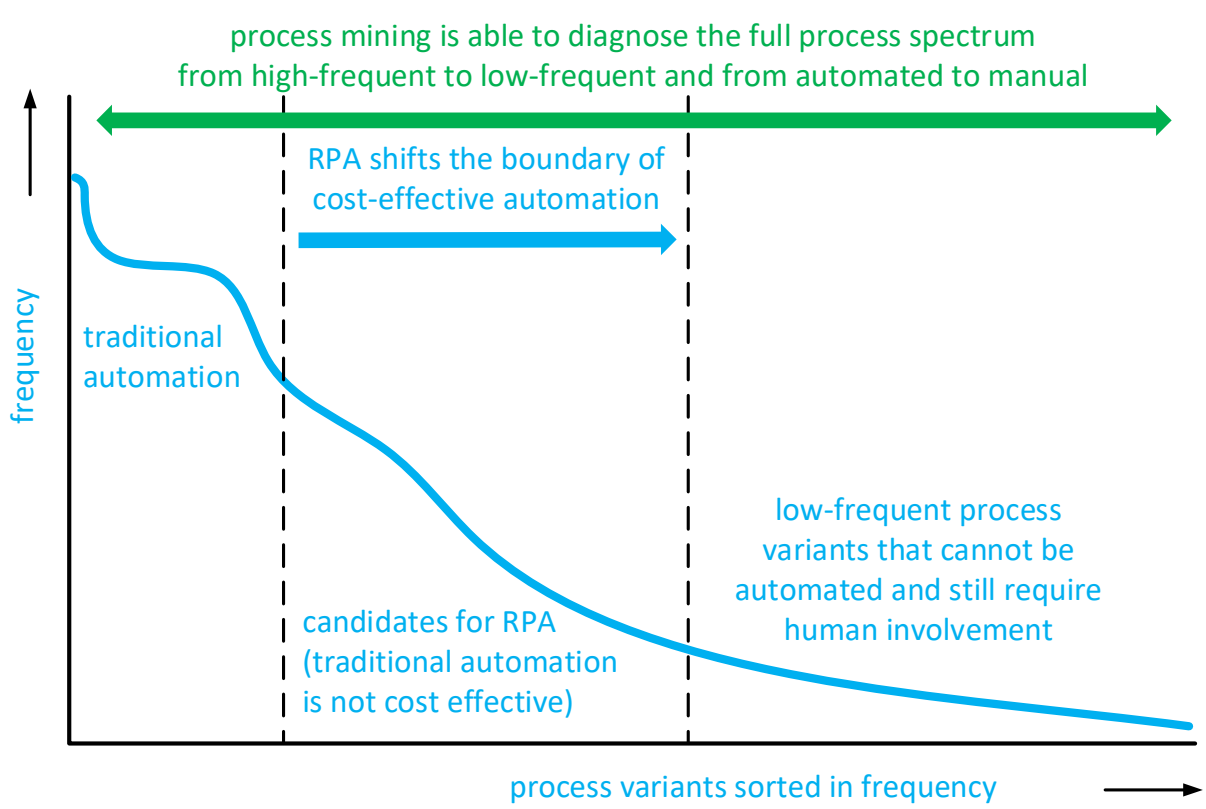
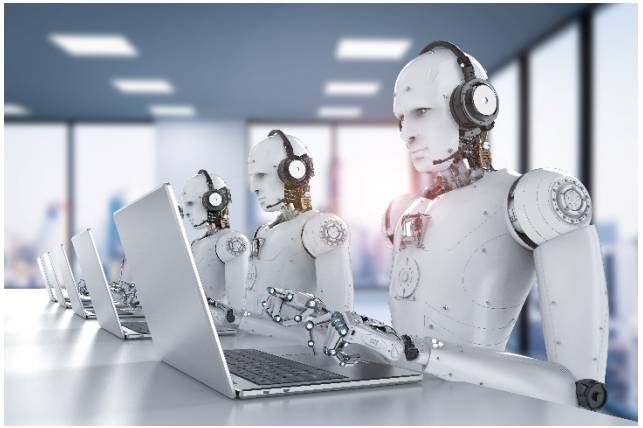
How to pick your automation battles?

Revisiting the Pareto distribution



How to pick your automation battles? The RPA connection





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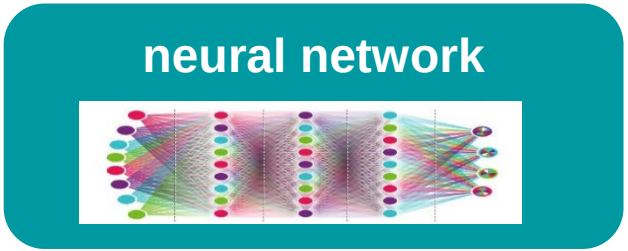
Process mining is very different!

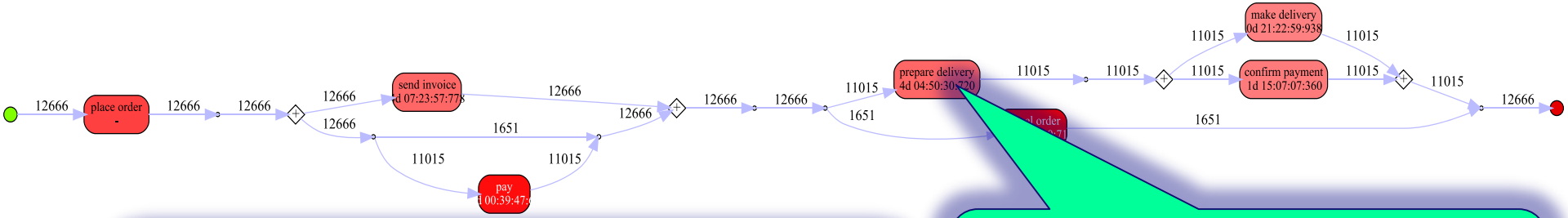
The core process mining techniques and tools do not use techniques from machine learning, artificial intelligence, data mining, etc.



“dog”

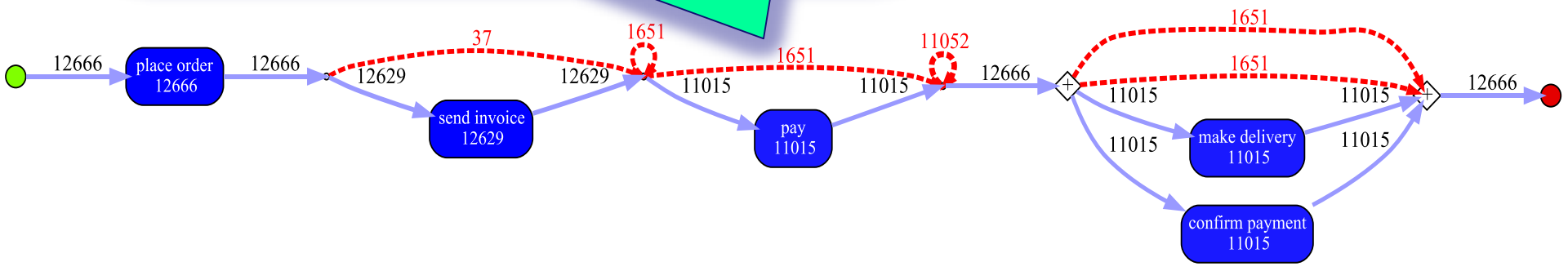
- **The model needs to be visible and understandable by stakeholders.**
- **Process owners are not going to label training examples.**

However, …
PM can be used to generate ML problems



Why are payments skipped?
What do these cases have in common?
Can we predict such deviations?

Why is the bottleneck here?
What is causing it?
Can we predict such delays?



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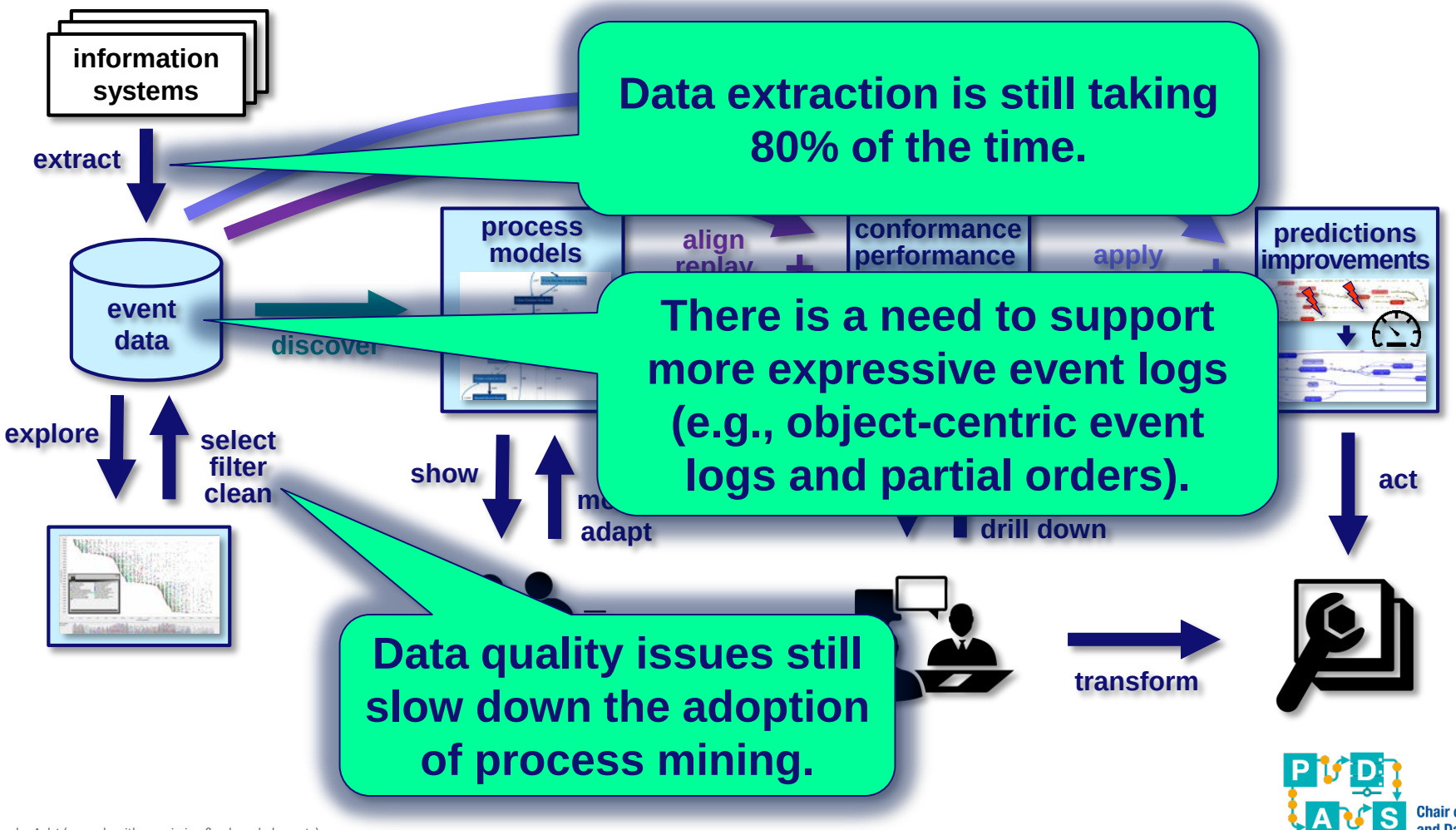

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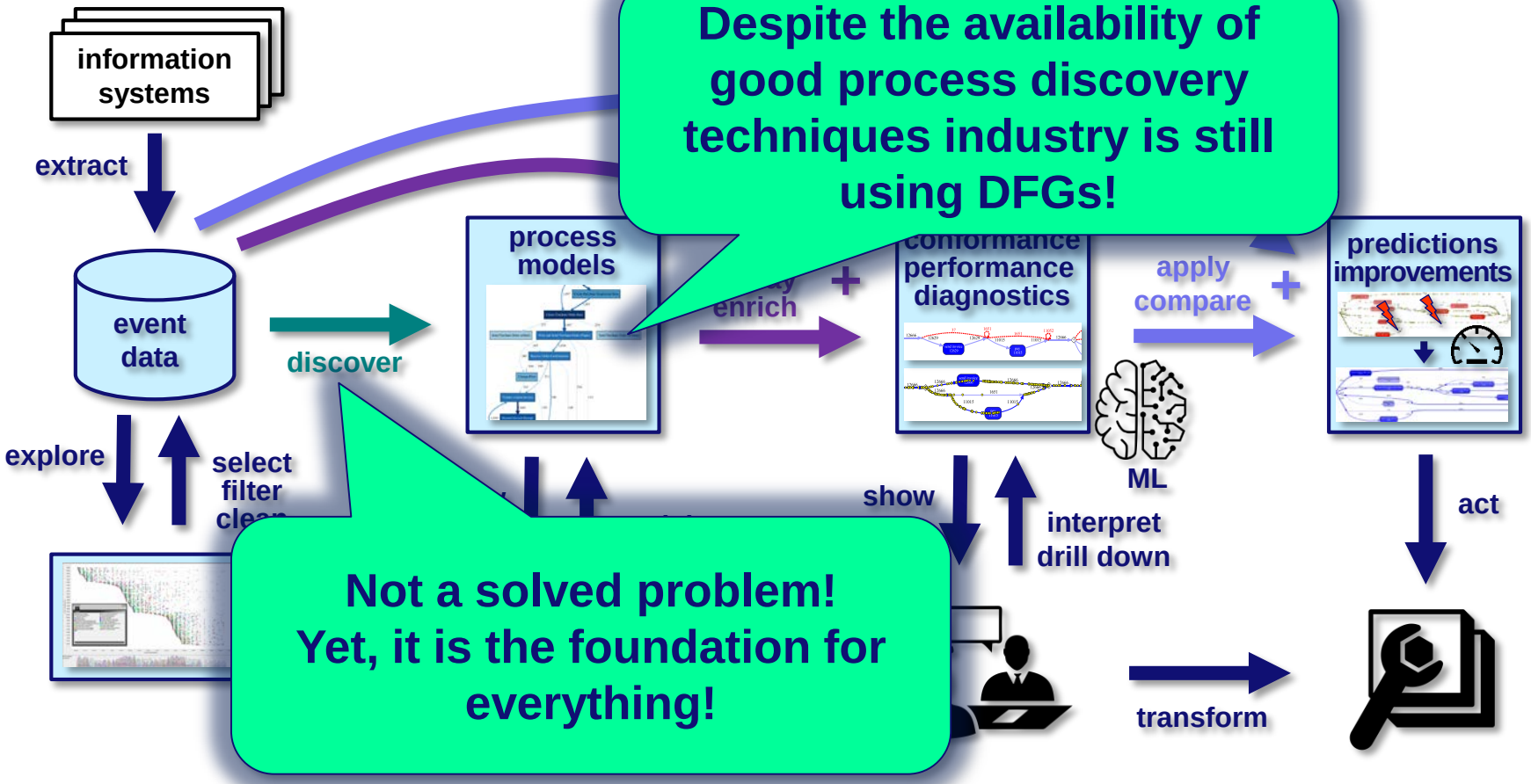

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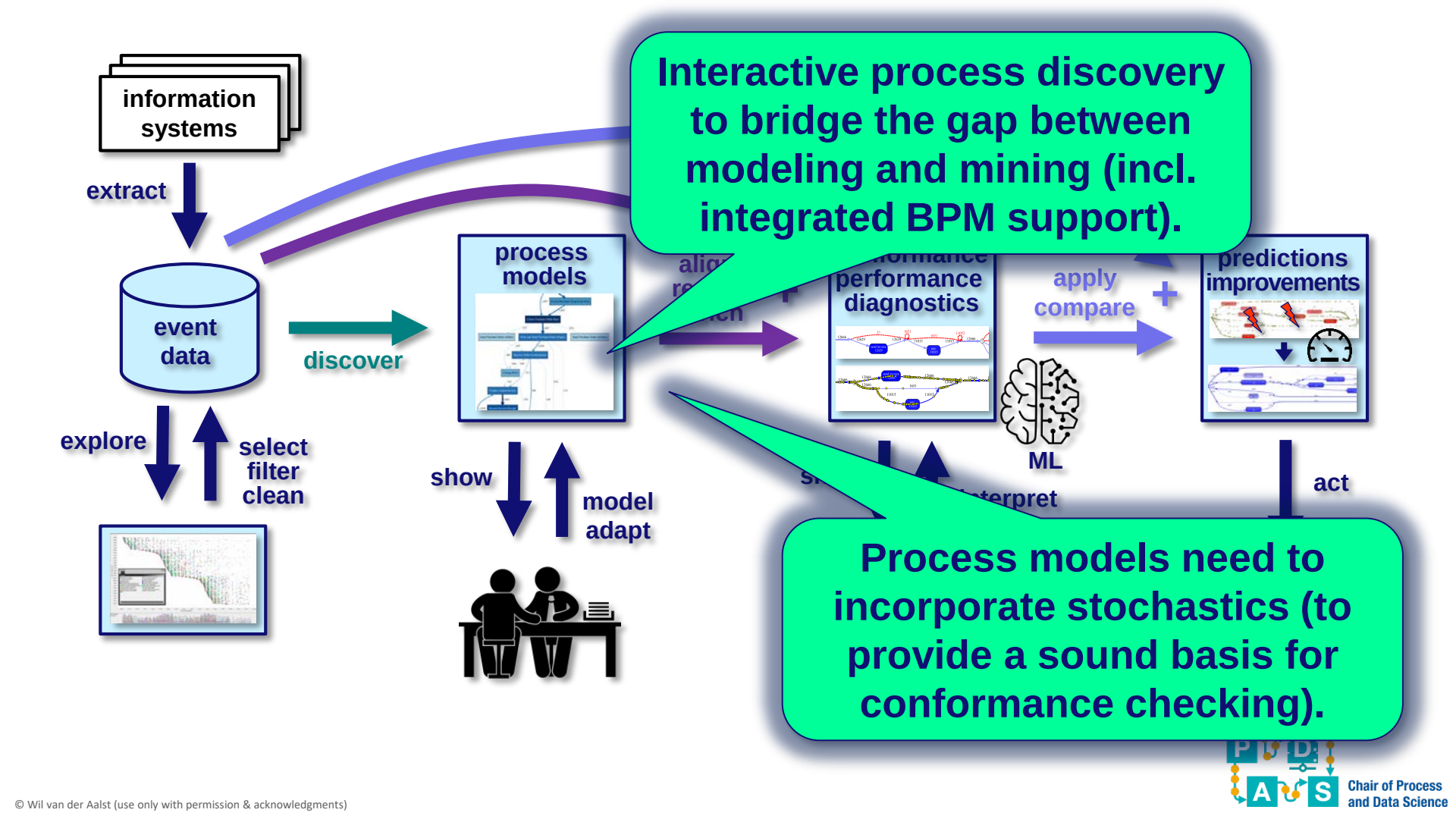

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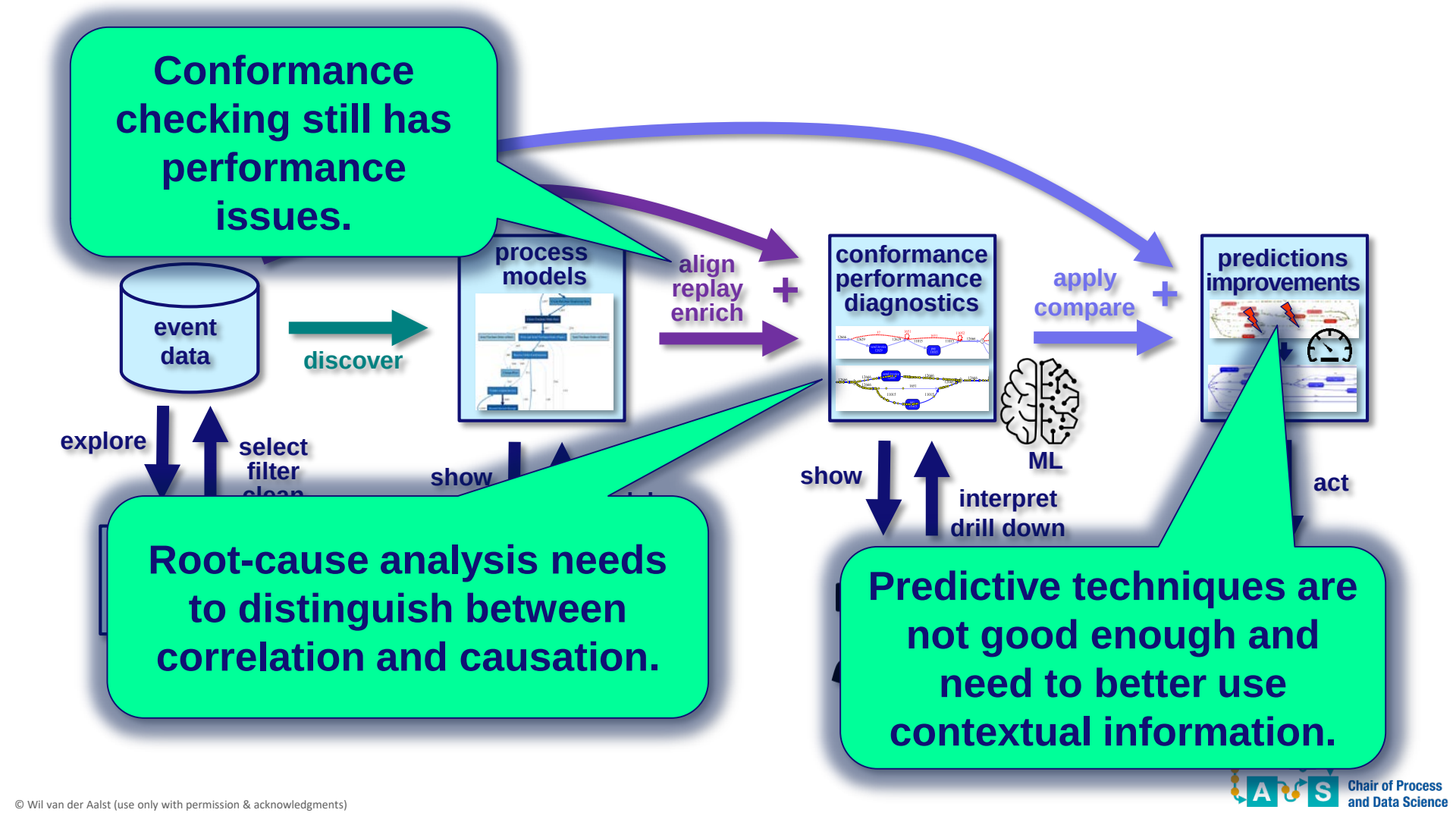

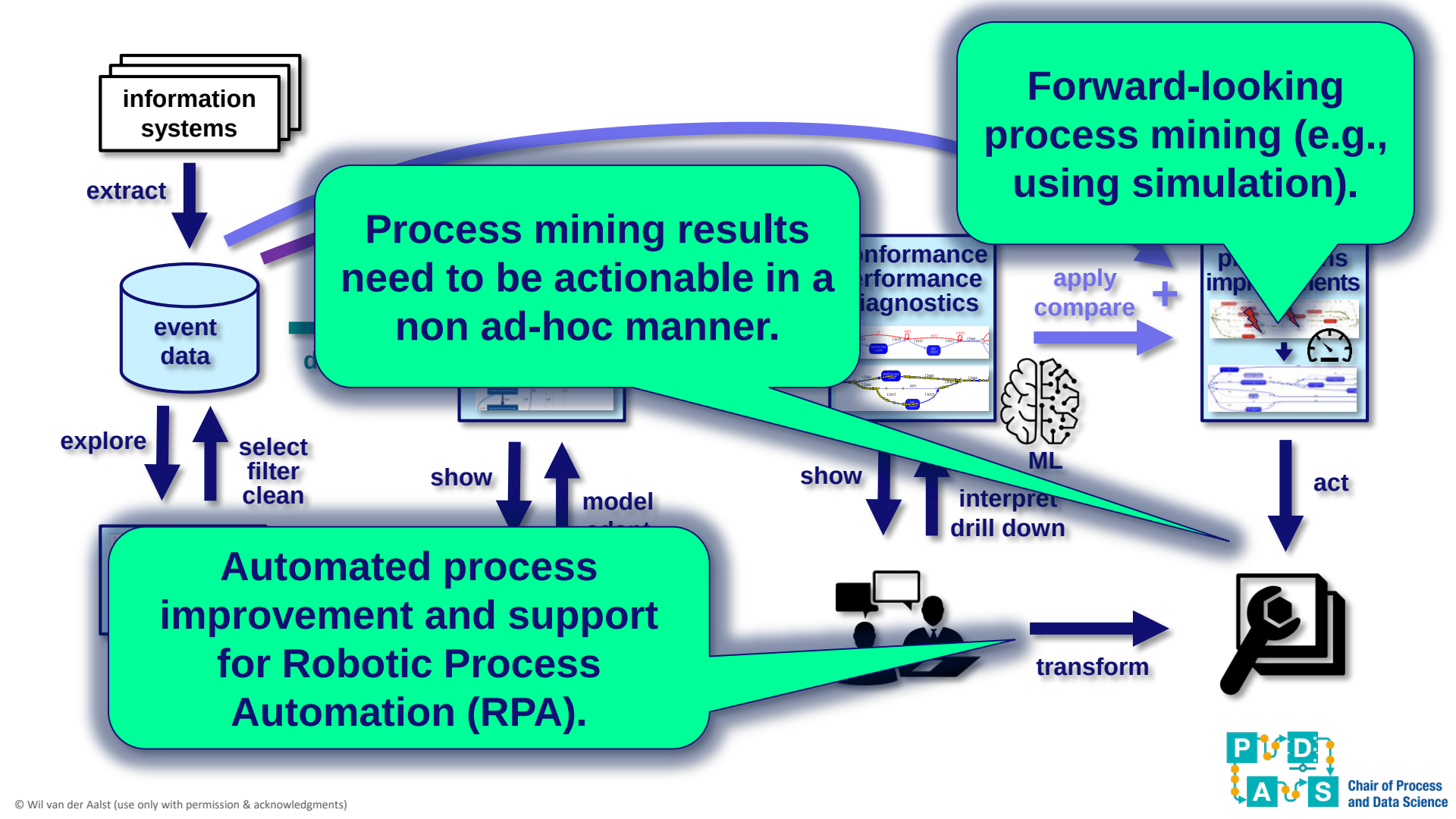

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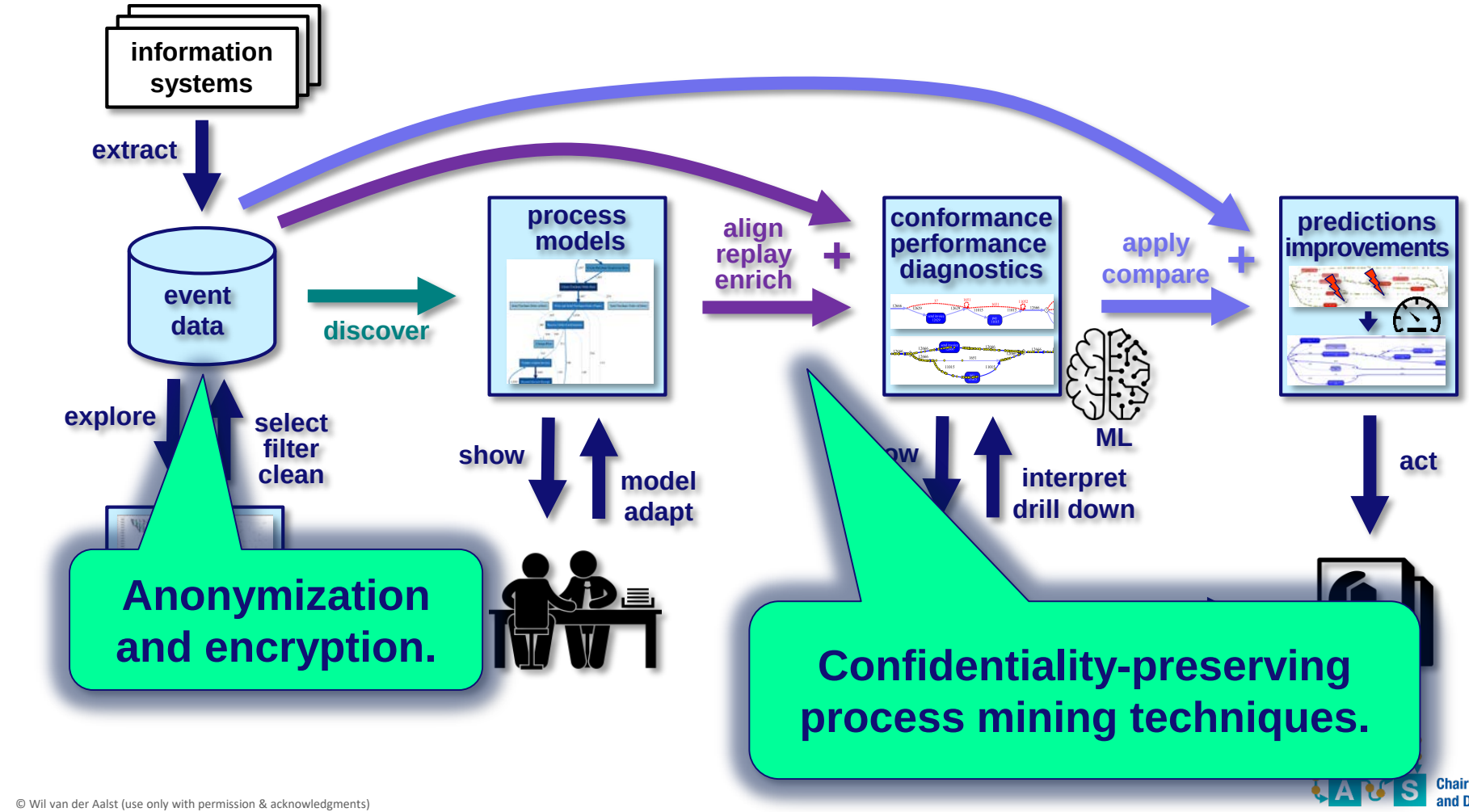

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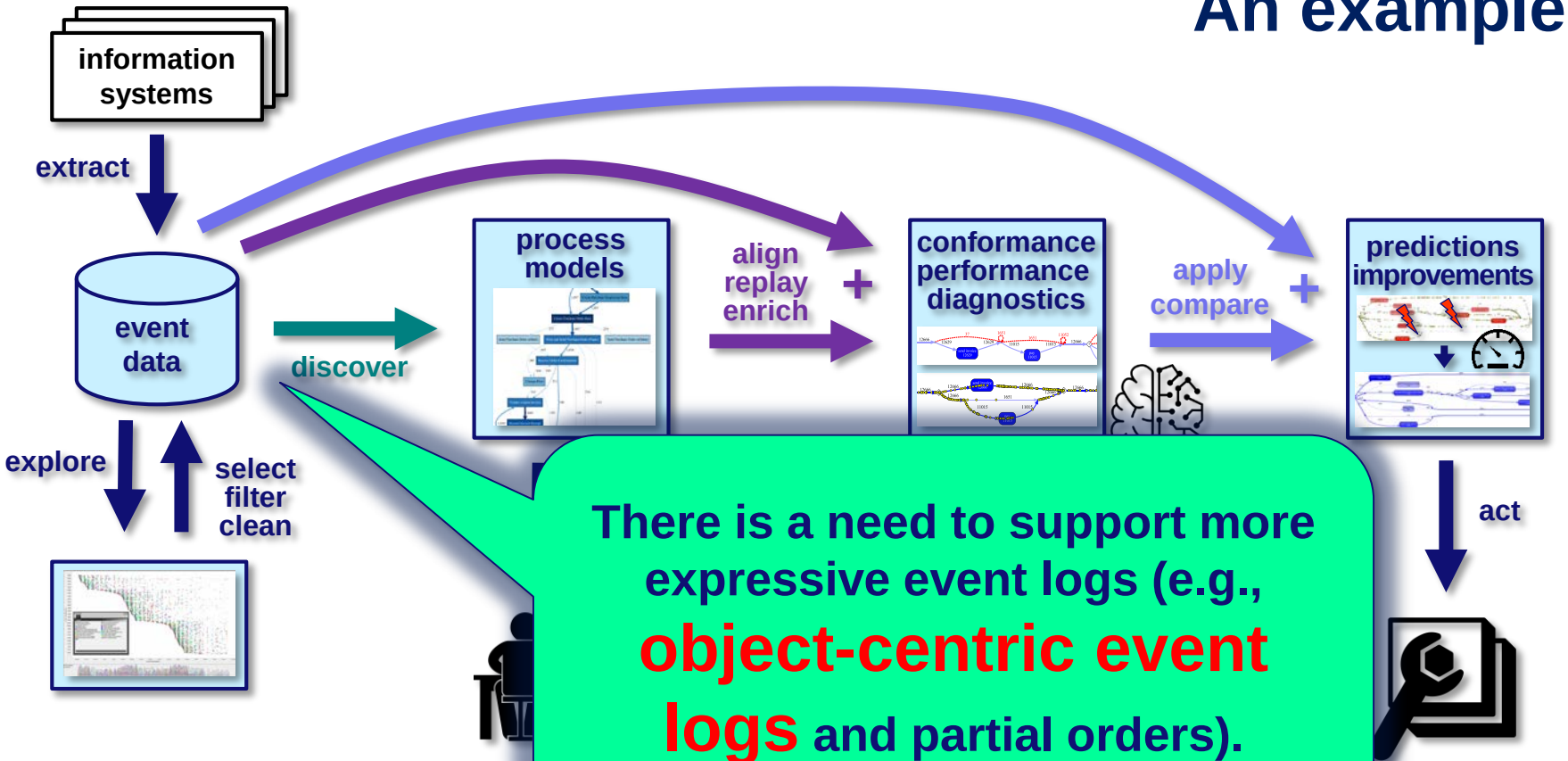
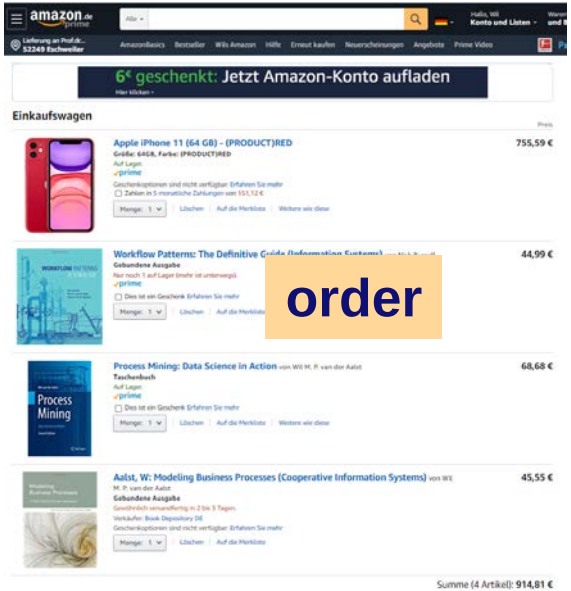
An example



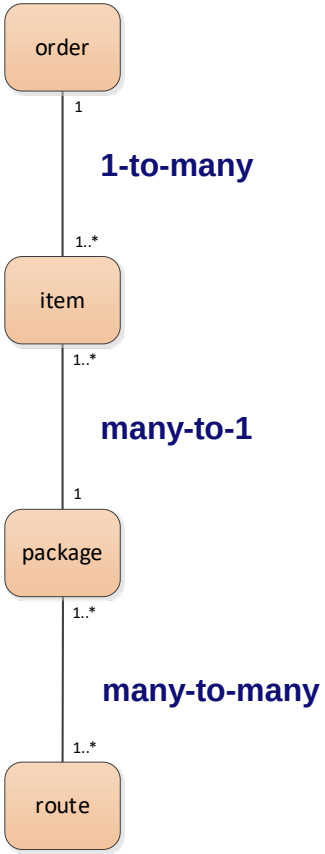
Chair of Process and Data Science

Example illustrating object-centric PM

item



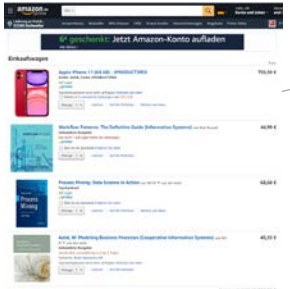
order



package

route

Example illustrating object-centric PM

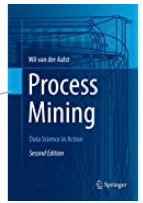


order1 order2 order3

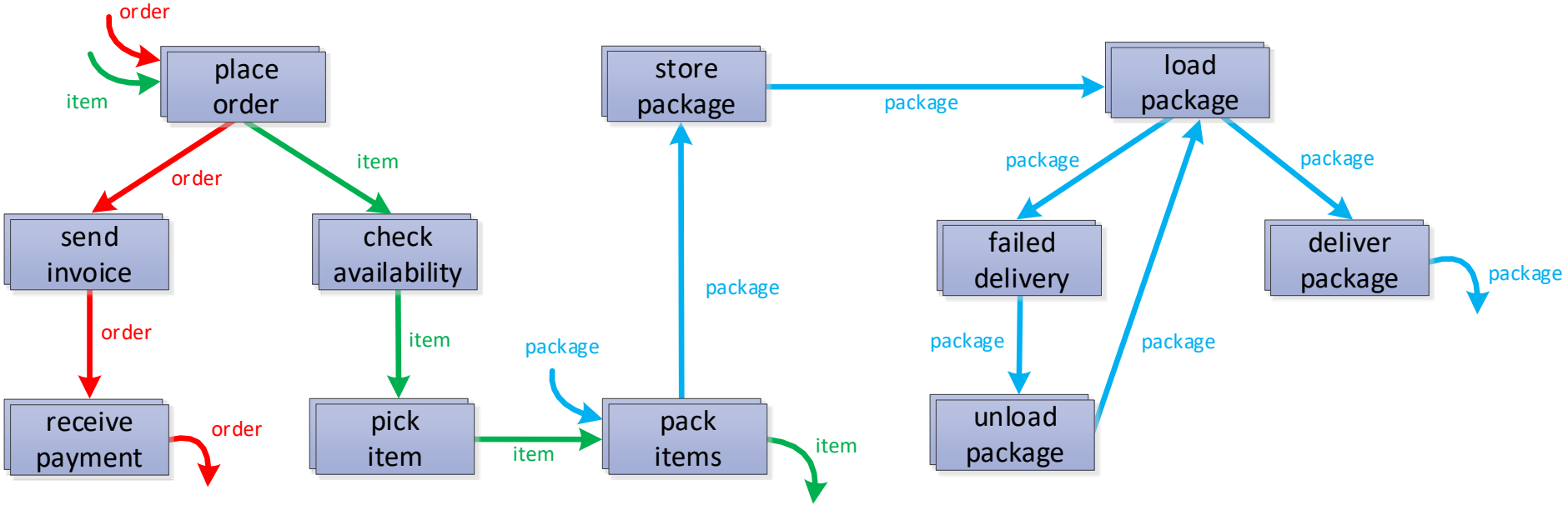
item1 item2 item3 item4 item5 item6 item7

package1 package2 package3 package4

route1 route2 route3



What is the case identifier?



See Wil van der Aalst: Object-Centric Process Mining: Dealing with Divergence and Convergence in Event Data. SEFM 2019, 3-25 https://doi.org/10.1007/978-3-030-30446-1_1

Object-Centric Process Mining (OCPM)

extract from data sources

Each row corresponds to an event which refers to one activity and any number of objects of (possibly many) different types.

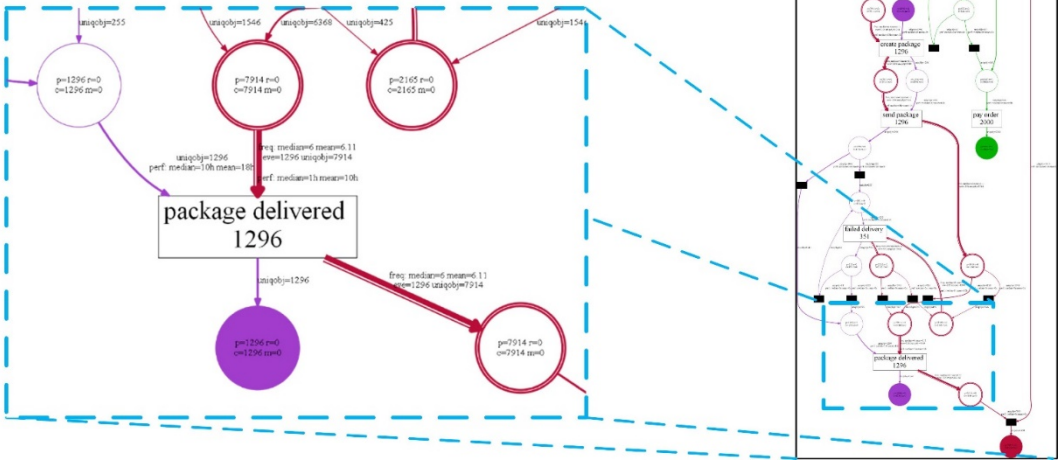
automatically discovered object-centric Petri net

object-centric event log

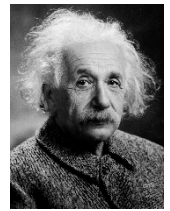
	activity	time	orders	items	packages	customers	products	price	weight
13501	place order	2019-12-24 17:27:18	{991269}	{884994,884995,884996,884997,884998}	{}	{Wil van der Aalst}	{Fire Stick 4K,Echo Show 5,Echo Plus,iPad mini,Echo Show 8}	€ 913,96	3,70
13502	pick item	2019-12-24 17:33:55	{961261}	{884956}	{}	{Christine Dobbert}	{Kindle Paperwhite}	€ 129,00	0,50
13503	pick item	2019-12-24 17:50:[illegible]			{}	{Wil van der Aalst}	{Fire Stick 4K}	€ 89,99	0,28
13504	pick item	2019-12-24 17:58:[illegible]			{}	{Kefang Ding}	{Fire Stick 4K}	€ 89,99	0,28
13505	pay order	2019-12-24 18:05:[illegible]		[illegible]860}	{}	{Mahsa Bafrani}	{Echo Studio,Kindle,MacBook Pro,MacBook Air}	€ 4.984,98	4583,00
13506	pick item	2019-12-24 18:18:30	{991237}	{884864}	{}	{Mahnaz Qafari}	{Kindle Paperwhite}	€ 129,00	0,50
13507	pick item	2019-12-24 18:19:53	{991182}	{884623}	{}	{Christine Dobbert}	{Echo Show 8}	€ 129,99	0,98
13508	pick item	2019-12-24 18:33:59	{991258}	{884940}	{}	{Tobias Brockhoff}	{iPad mini}	€ 449,00	0,28
13509	pay order	2019-12-24 18:47:07	{991261}	{884956,884957,884958,884959,884960,884961,884962}	{}	{Christine Dobbert}	{Kindle Paperwhite,iPad,Kindle,Echo Show 5,Echo Show 5,Echo Studio,Ki}	€ 1.168,95	5184,00
13510	place order	2019-12-24 19:14:23	{991270}	{884999}	{}	{Junxiang Gao}	{iPad mini}	€ 454,00	0,28
13511	item out of stock	2019-12-24 20:39:01	{991224}	{884803}	{}	{Wil van der Aalst}	{iPhone 8}	€ 529,00	0,21
13512	package delivered	2019-12-24 20:46:47	{991119,991030,991209,991254,991213,9	{884386,884020,884749,884930,884926,884925,884766,884927	{660784}	{Kefang Ding}	{iPad Air,Echo Dot,MacBook Pro,iPad Air,Kindle Paperwhite,iPad Air,iPad}	€ 6.829,99	4719,00
13513	place order	2019-12-24 22:08:21	{991271}	{885000,885001,885002,885003}	{}	{Mohammadreza Fani Sani}	{Fire Stick 4K,iPad,Kindle Paperwhite,iPad Air}	€ 1.394,99	1698,00
13514	pick item	2019-12-24 22:12:24	{991239}	{884874}	{}	{Tobias Brockhoff}	{Fire Stick}	€ 39,99	0,20
13515	place order	2019-12-25 08:08:00	{991272}	{885004,885005}	{}	{Mohammadreza Fani Sani}	{iPhone 11 Pro,iPad Pro}	€ 2.253,00	0,67
13516	[illegible]m order	2019-12-25 08:12:59	{991272}	{885004,885005}	{}	{Mohammadreza Fani Sani}	{iPhone 11 Pro,iPad Pro}	€ 2.253,00	0,67
13517	pay order	2019-12-25 09:13:08	{991244}	{884890,884891,884892}	{}	{Junxiang Gao}	{Kindle,Fire Stick 4K,Echo Plus}	€ 324,97	2043,00
13[illegible]	package delivered	2019-12-25 09:17:36	{991229,991130,991069,991226,991236}	{884824,884429,884173,884810,884859}	{660788}	{Mahsa Bafrani}	{Kindle,Echo Show 8,iPad Pro,Echo,MacBook Pro}	€ 3.908,97	4096,00

object-centric Petri net

One of the 21887 events:
- **activity**: package delivered
- **time**: 2019-12-24 20:46:47
- **orders involved**: {991119,991030,991209,991254, 991213,991206}
- **items involved**: {884386,884020,884749,884930, 884926,884925,884766,884927,884736}
- **packages involved**: {660784}
- **customers involved**: {Kefang Ding}
- **products involved**: {iPad Air,Echo Dot,MacBook Pro,iPad Air,Kindle Paperwhite,iPad Air,iPad Pro, iPad,iPhone 11 Pro}
- **total price**: € 6.829,99
- **total weight**: 4,719 KG



Everything should be made as simple as possible, but no simpler.



PM4PY

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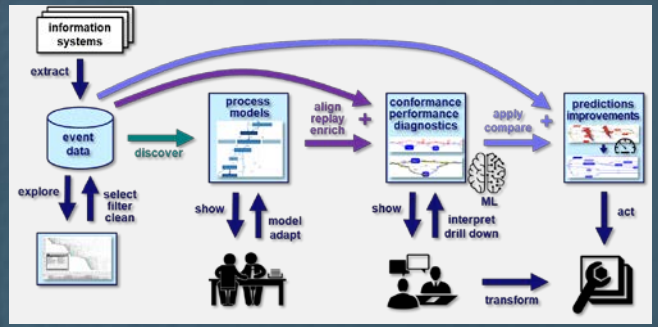
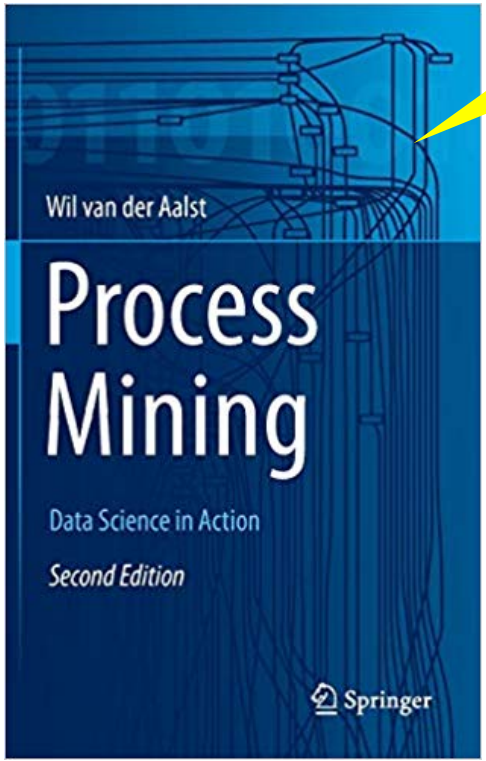
Make process mining repeatable and actionable, but …



free advice

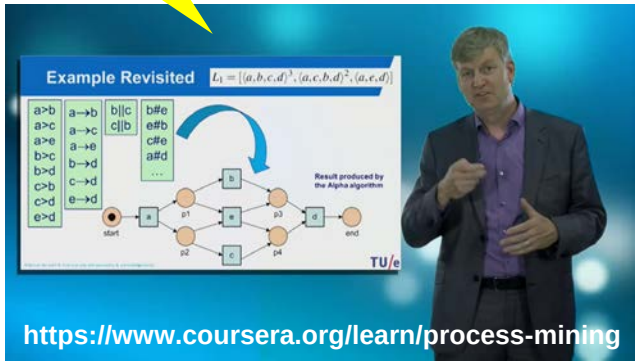

Business process hygiene
Typical excuses: privacy, data quality, workload, etc.
Are you sure you need to have a business case?

Learn more?



“PM Bible”

Over 125.000 participants



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