Forward-looking Process Mining

Mahsa Pourbafrani
Process and Data Science Group, RWTH Aachen University

Outline

- Process Mining

  – How does process mining help organizations and businesses?

  – Process mining basics and insights (backward-looking process mining)

- Forward-Looking process mining

  – How to improve processes

    ▪ Turning insights into actions

  – Simulating and predicting business processes

- How to Analyze your processes

 – Conduct a Process Mining Project

- Real-world use cases

Process Mining

Example: Process Mining @ Companies

- Process mining usage in companies:

- Siemens
  - Millions of savings by reducing rework, process unification, etc.
  - O2C example: more than 30M cases, 300M events, and 900K variants.

- Vanderlande: baggage handling, warehousing, post and parcels.

- BMW: finance, production, distribution, actual product usage, aftersales, warranty, customs, etc.
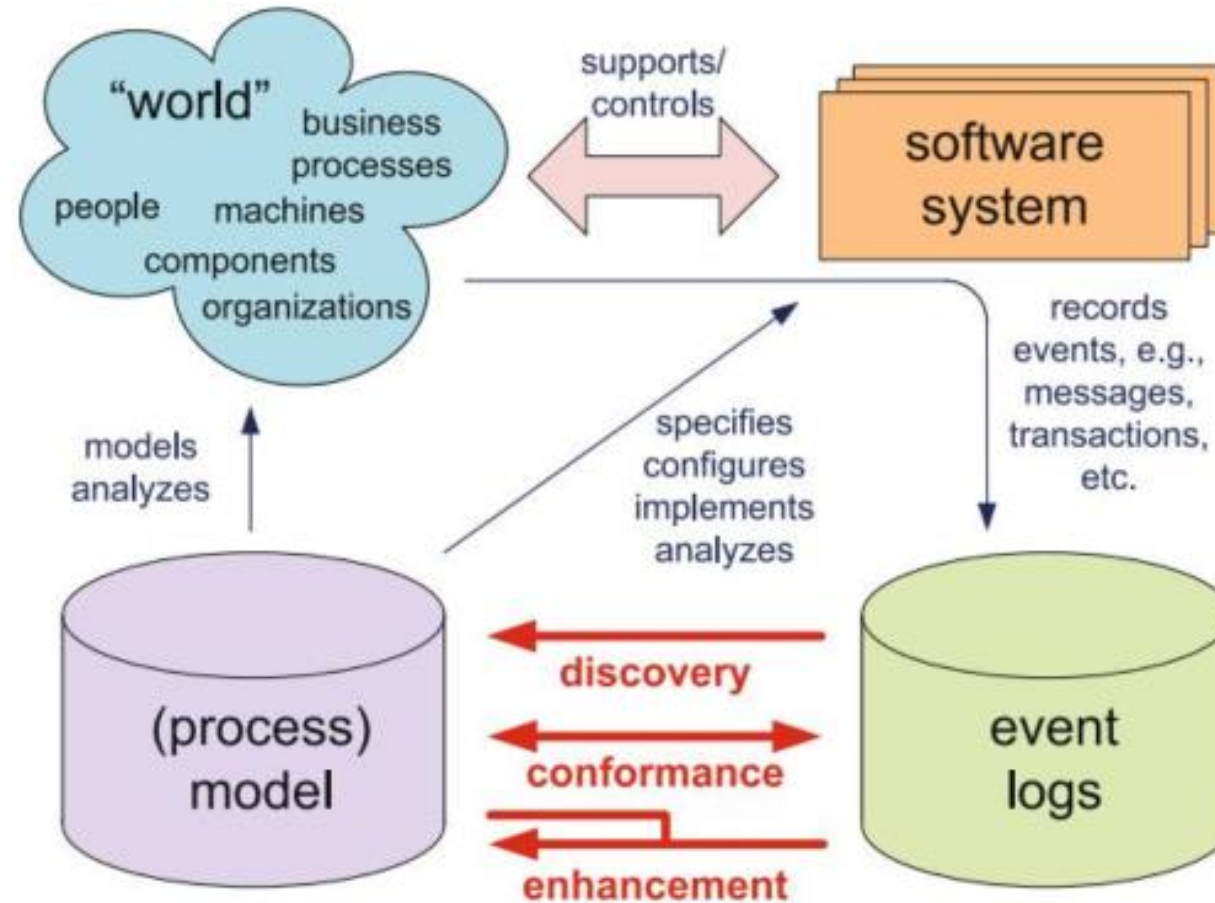
Positioning Process Mining
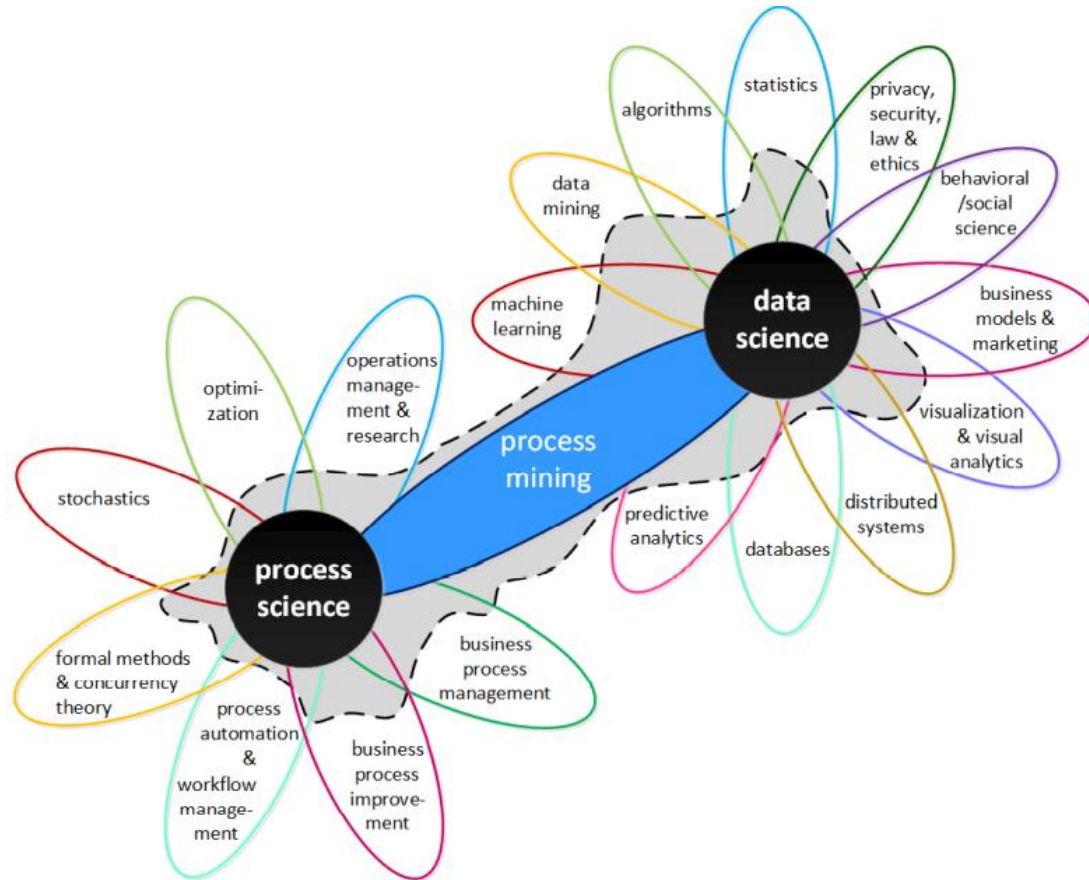
Improving operational processes

User-based Process management:

BPM, simulation, user-based modeling

Data-driven process management and improvement:

extensive insights supported by reality

Chair of Process and Data Science

RWTH AACHEN UNIVERSITY

General Overview of Process Mining

Wil M.P. van der Aalst
Process Mining: Data Science in Action, Springer

At airports:

- Why do bags miss a plane?
- Why do I need to wait so long for my bags?
- When and why does the system break down?
- Am I using the available capacity properly?

At hospitals:

- How long do patients have to wait for the first appointment?
- Why are there always long queues at the X-rays dept. between 11.00-13.30 ?
- How often do we need to refuse patients?

At retailers and shops:

- When and why are we unable to deliver on the planned date?
- How quickly can we answer questions?
- What is causing late payments?

At service-based and accounting companies

- How can we help organizations to save costs?
- How can we help organizations to serve customers better?
- What are best practices?

©Wil M.P. van der Aalst

PADS Chair of Process and Data Science

RWTH AACHEN UNIVERSITY
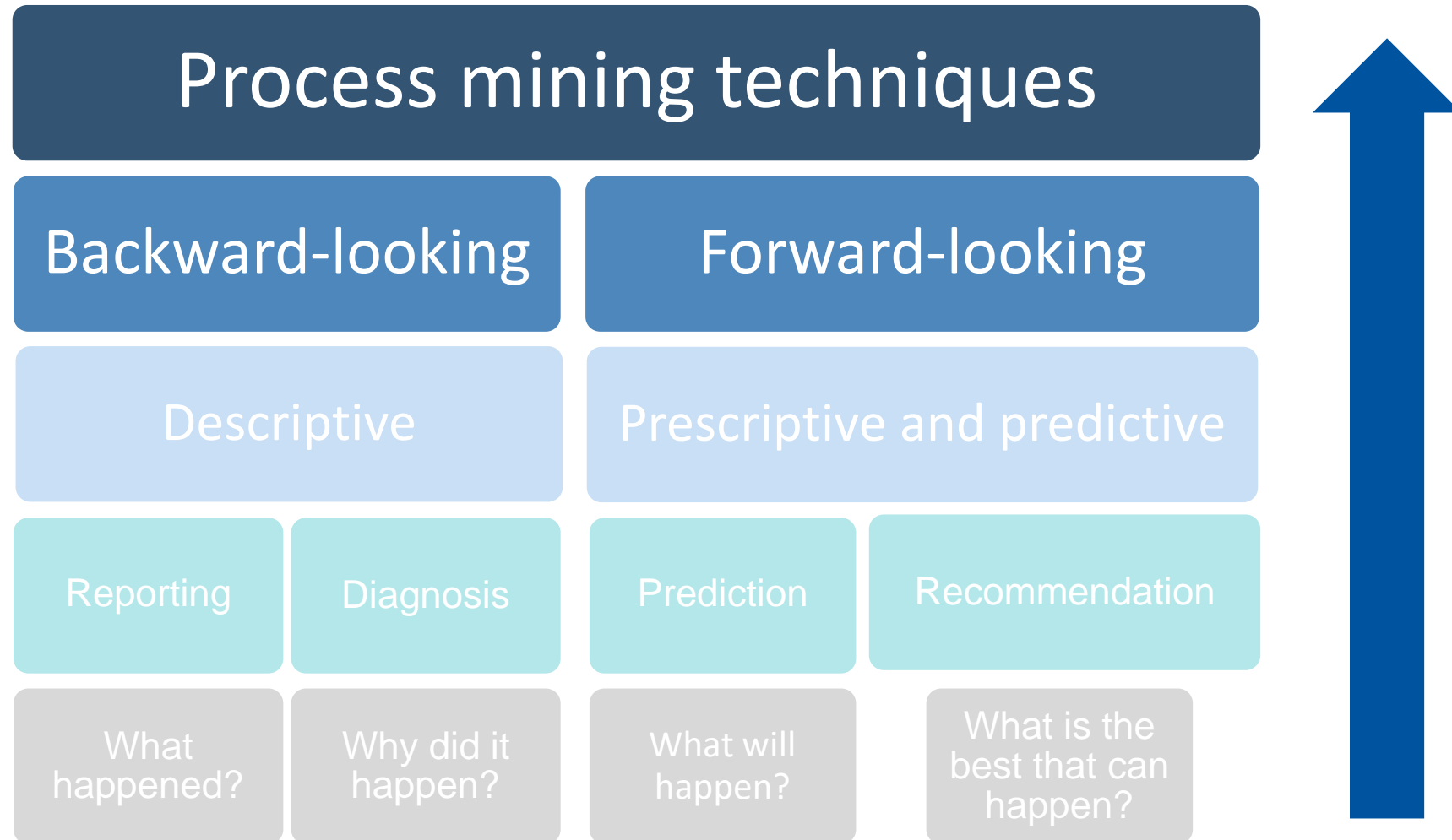
Process Mining Basics and Insights

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

©Wil M.P. van der Aalst

P∆DS Chair of Process and Data Science

RWTHAACHEN UNIVERSITY

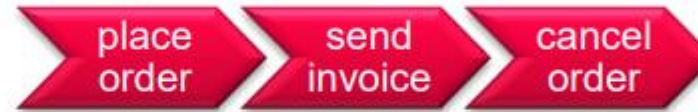| Case ID	Activity	Timestamp
6350	**place order**	**2018/02/13 14:29:45.000**
6351	place order	2018/02/13 16:17:37.000
6352	place order	2018/02/13 17:53:22.000
6352	send invoice	2018/02/19 09:20:28.000
6351	send invoice	2018/02/19 16:08:07.000
6350	**send invoice**	**2018/02/21 09:38:16.000**
6350	**pay**	**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

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

One Process Instance

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

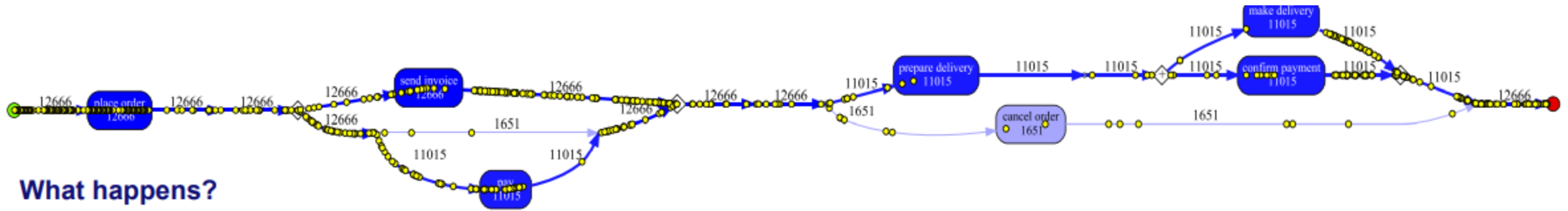place order → send invoice → pay → prepare delivery → make delivery → confirm payment

Order 6351

place order → send invoice → cancel order

©Wil M.P. van der Aalst

Single Process Instance

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

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

Order 6351

place order → send invoice → cancel order

Order 6352

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

©Wil M.P. van der Aalst

Cases and Variants

71,043 events
12,666 cases
7 activities

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

©Wil M.P. van der Aalst

What happens?

Where are the bottlenecks?
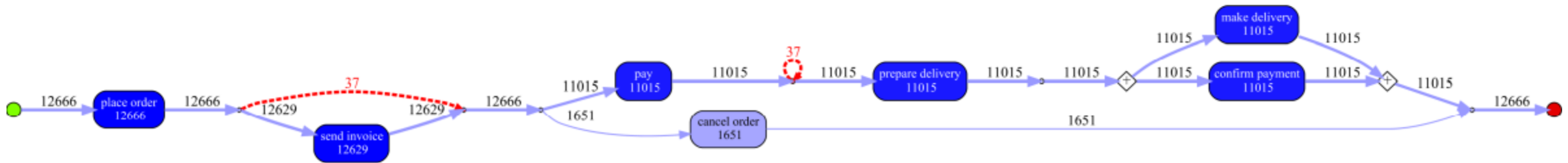
Where do we deviate from the happy path?
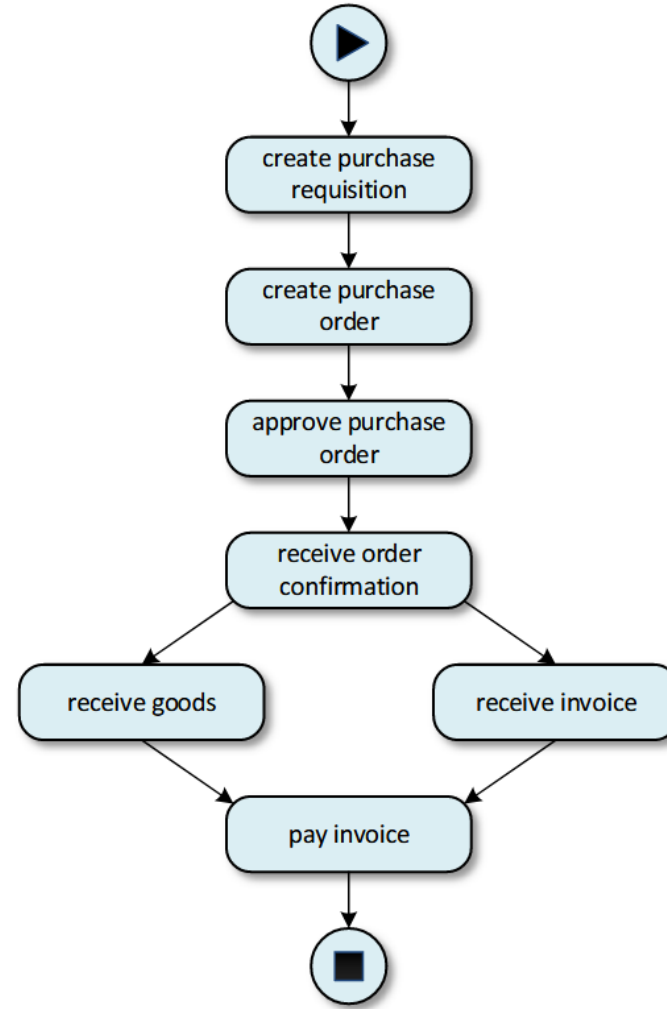
Answer to What Questions!

©Wil M.P. van der Aalst

- What happened?
  - Discovery:
    - 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

| 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
...	...	....	...	...	...	...	...

*©Wil M.P. van der Aalst*

Event log of purchase to pay

Sample Scenarios

- One of the many variations.

  - Changing prices result in lots of extra work and significant delays.

8% of cases

price change
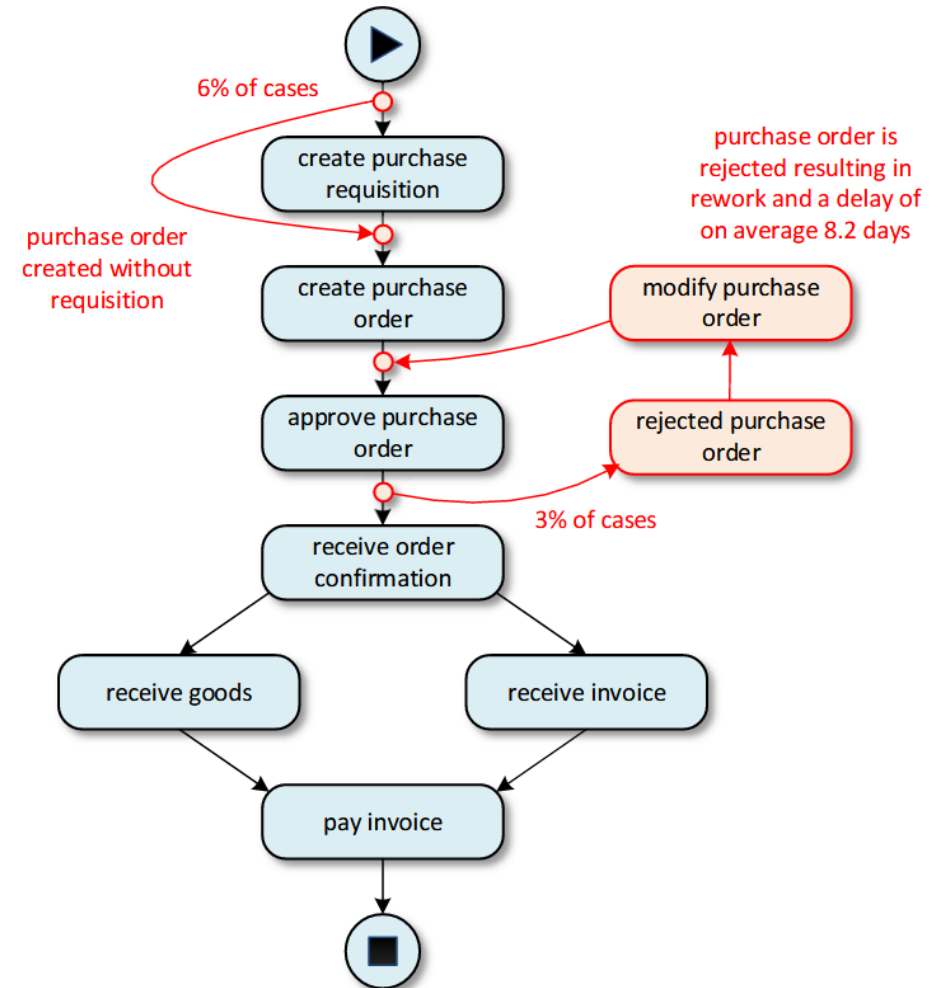
adds (on average)
a delay of 4.5 days
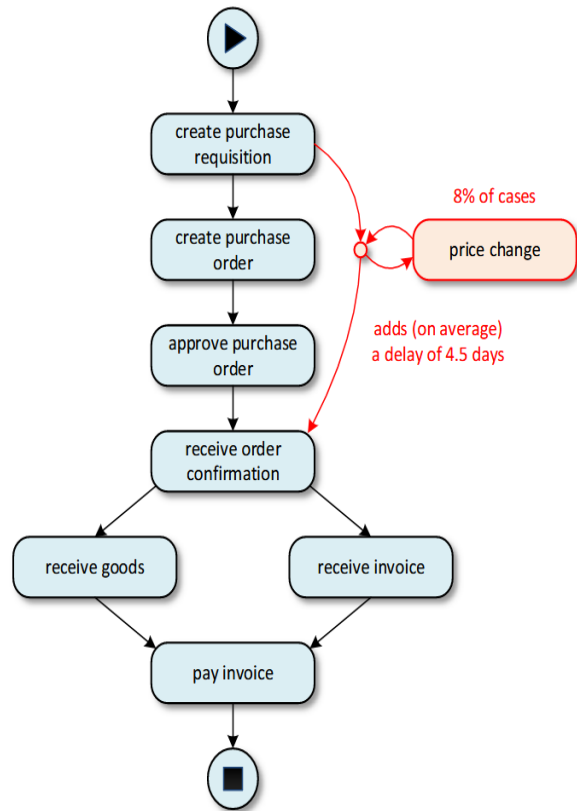
©Wil M.P. van der Aalst

- Pay before receipt

  - Goods are paid before they have been received.

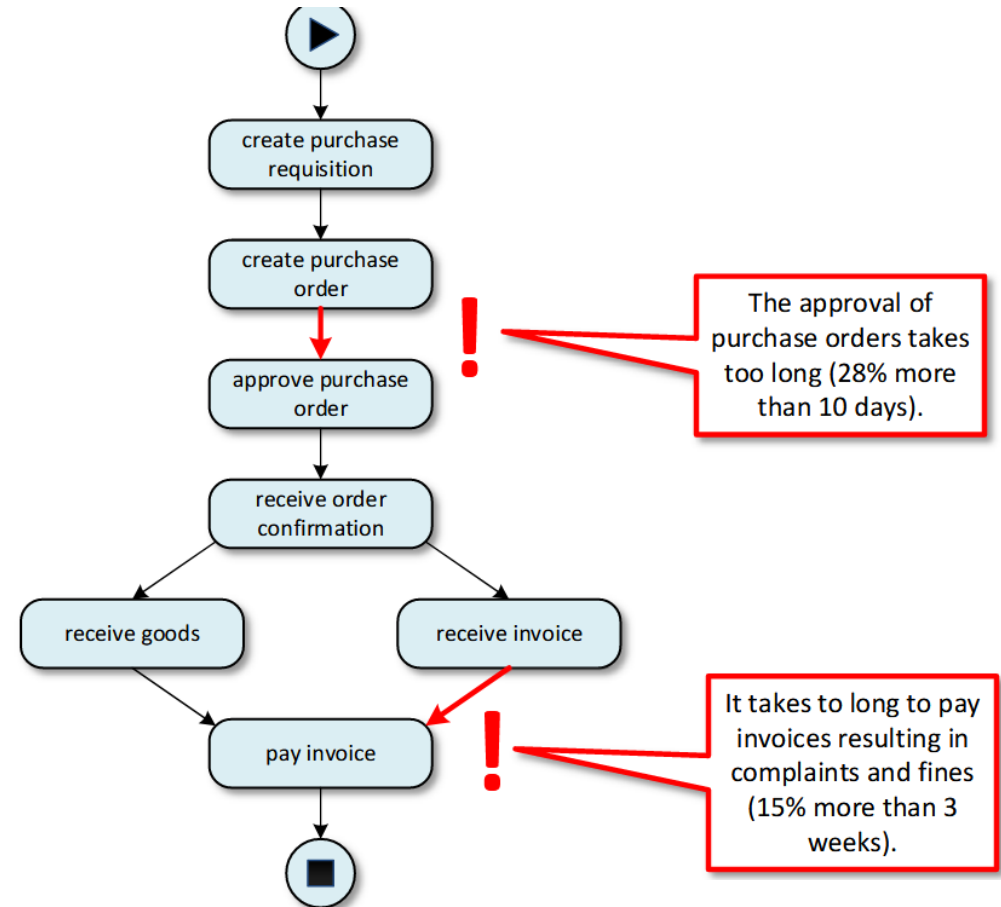 - Goods arrived too late or not at all. May indicate fraud!

2% of cases

goods are paid but
never received
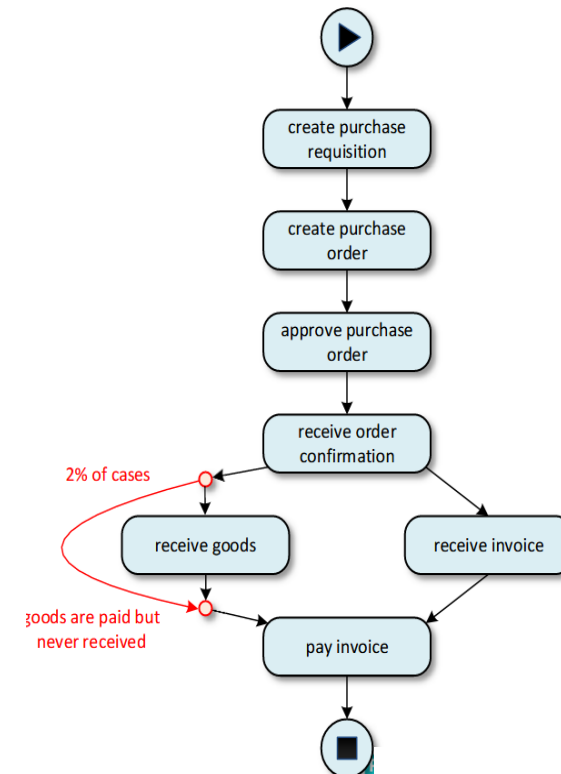
Two additional variations

- Two additional variations

  - Orders created without requisition.

  - Rejected orders generating rework.

6% of cases

purchase order
created without
requisition

purchase order is
rejected resulting in
rework and a delay of
on average 8.2 days

create purchase
requisition

create purchase
order

modify purchase
order

approve purchase
order

rejected purchase
order

3% of cases

receive order
confirmation

receive goods

receive invoice

pay invoice

Performance Problems

- Performance problems

  - Delays inside the process.

  - Excessive flow times.

  - Not meeting Service Level Agreements (SLAs).

create purchase requisition

create purchase order

approve purchase order

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

receive order confirmation

receive goods

receive invoice

pay invoice

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

©Wil M.P. van der Aalst

Compliance Problems

- Compliance problems Activities may be:

  - skipped

  - done too early or too late

  - done by the wrong person

  - should not have happened at all

©Wil M.P. van der Aalst

Orders are created without a purchase requisition.

Invoices are paid before the goods arrive.
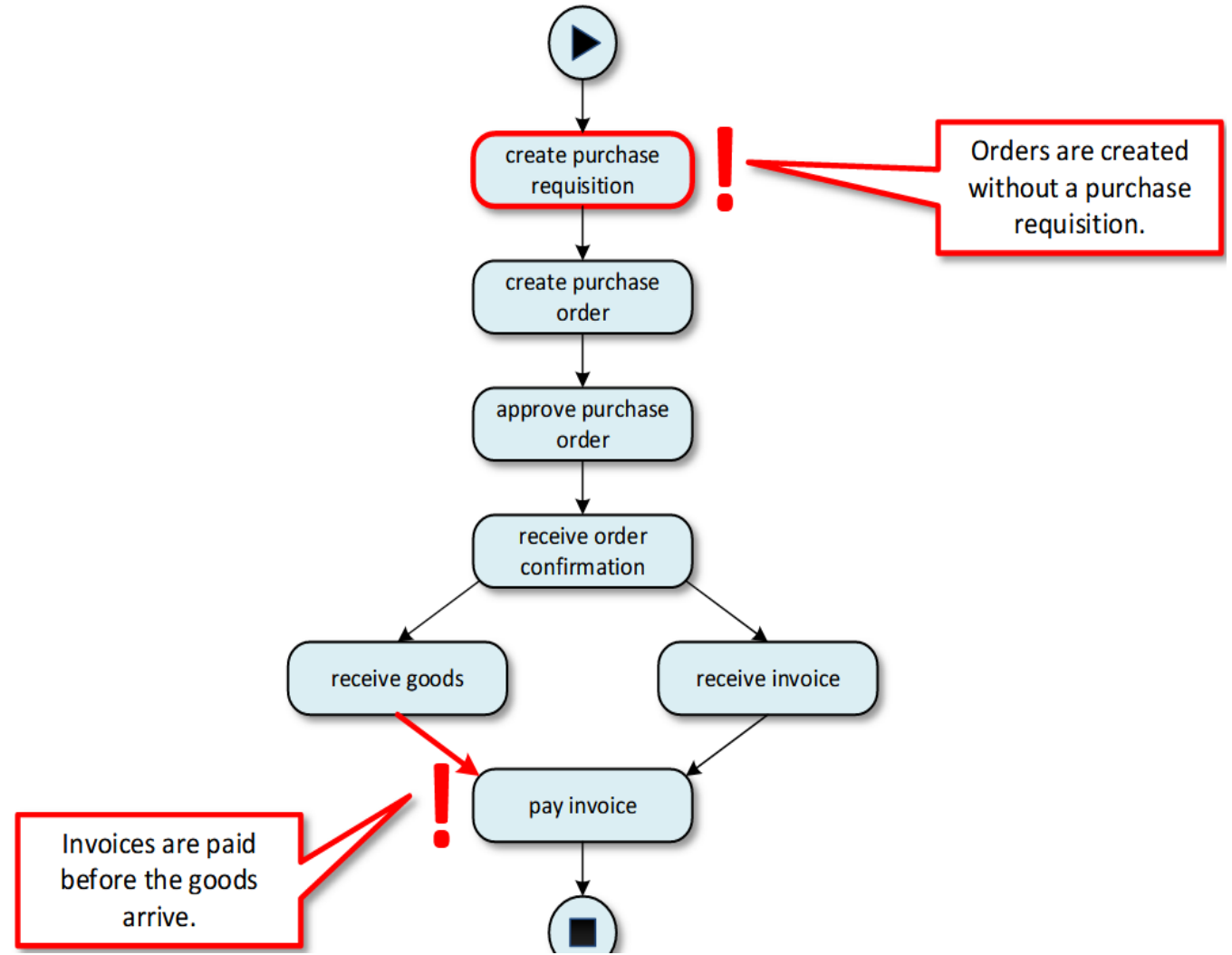
Forward-Looking Process Mining

Introduction

- Most process mining techniques are backward-looking!

- Forward-looking process mining put the provided insights into actions

Backward-looking process mining

Forward-looking process mining
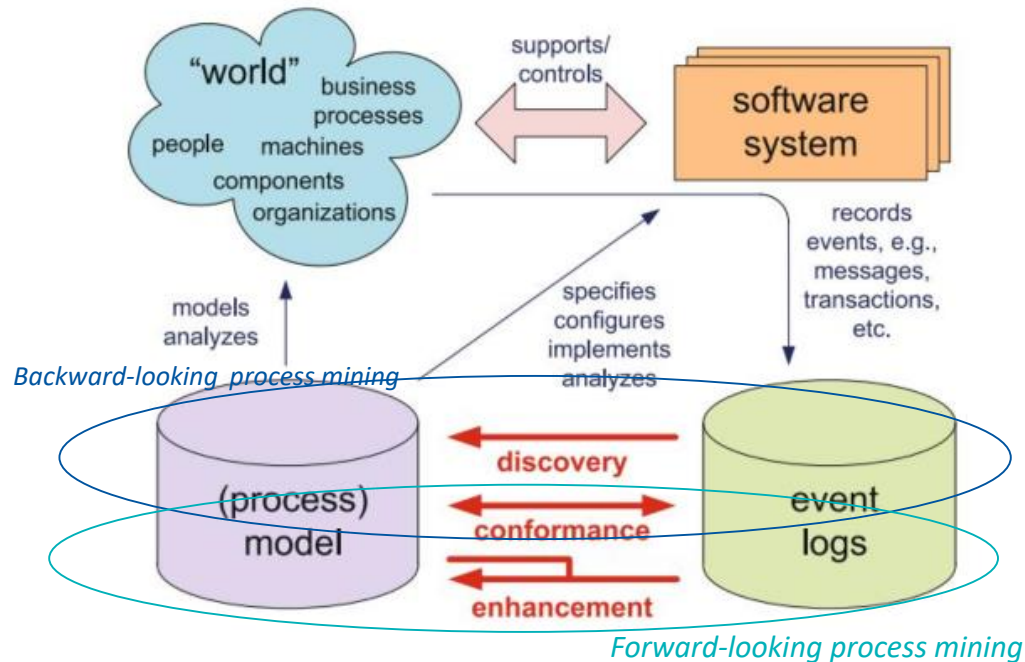
Wil M.P. van der Aalst
Process Mining: Data Science in Action, Springer

Process mining techniques			
Backward-looking		**Forward-looking**	
Descriptive		Prescriptive and predictive	
Reporting	Diagnosis	Prediction	Recommendation
What happened?	Why did it happen?	What will happen?	What is the best that can happen?

- Prescriptive techniques

  - Simulations

    - Using Discrete Event Simulation Techniques

      - In-depth knowledge of the process

    - Aggregated Simulation Techniques

      - At the strategical level

- Predictive techniques

  - Prediction

    - Using machine learning techniques

    - Abstraction level:

      - At the instance level

   - Short Term Predictions
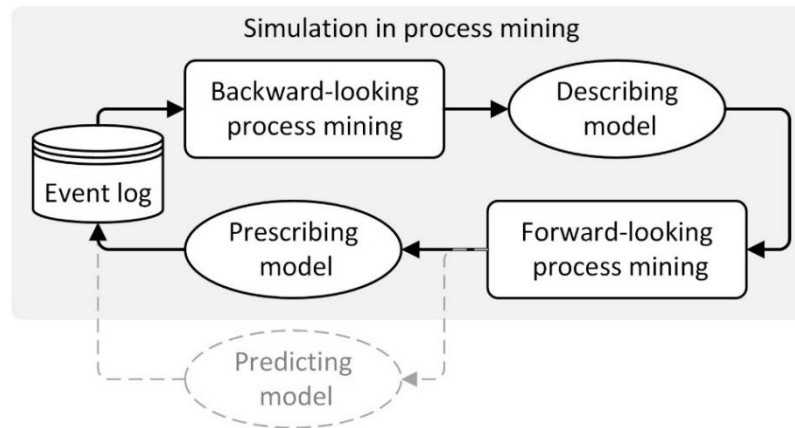
Businesses Need Digital Shadows

- Business processes are an excellent example of the digital shadow that a company requires

  - This shadow should be proactive and actively assist the real business processes in making confident decisions:

    - Strategic, high-level, and short-term decisions

    - Making business process models executable is the key to creating a supportive digital shadow of businesses
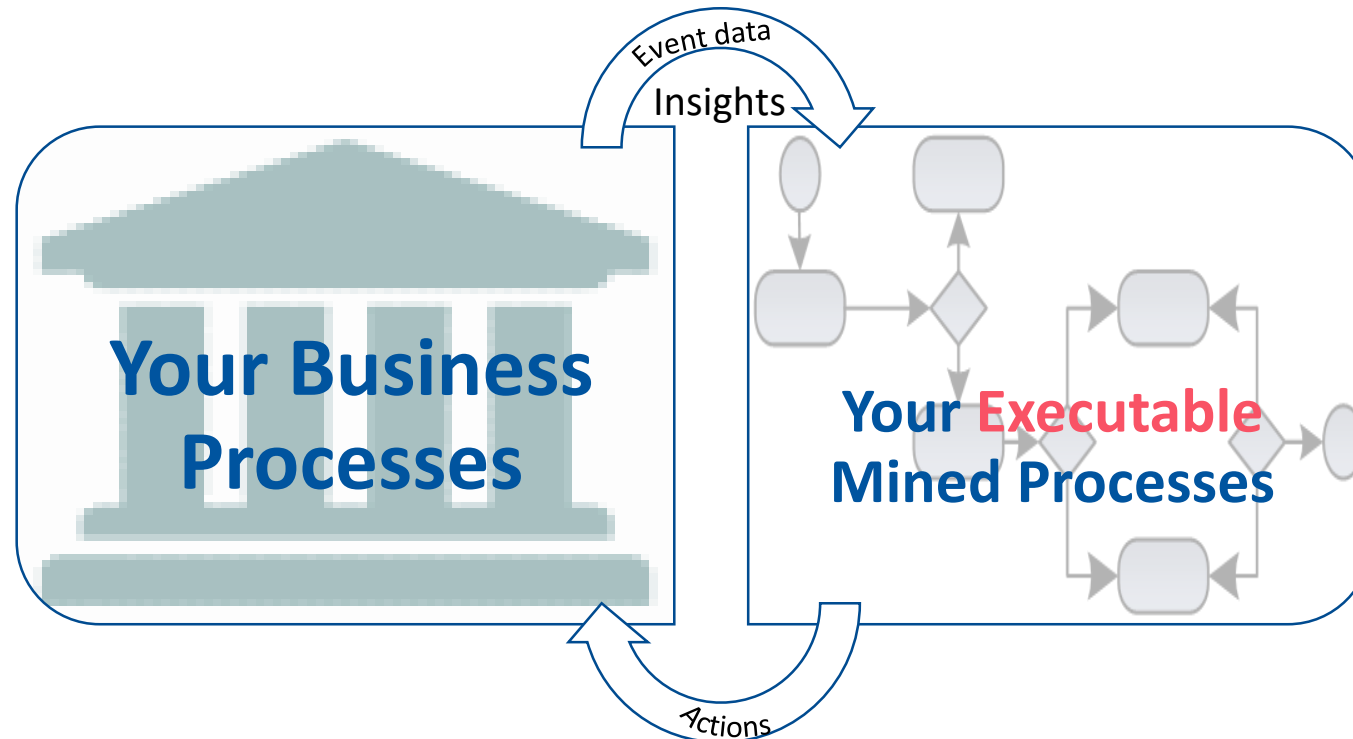
Simulation in Process Mining

- The combination of process mining and simulation allows for forward-looking approaches to answer
  - "What if?" questions

- Capturing the reality well using fine-grained simulation models is difficult

Process Mining Simulation
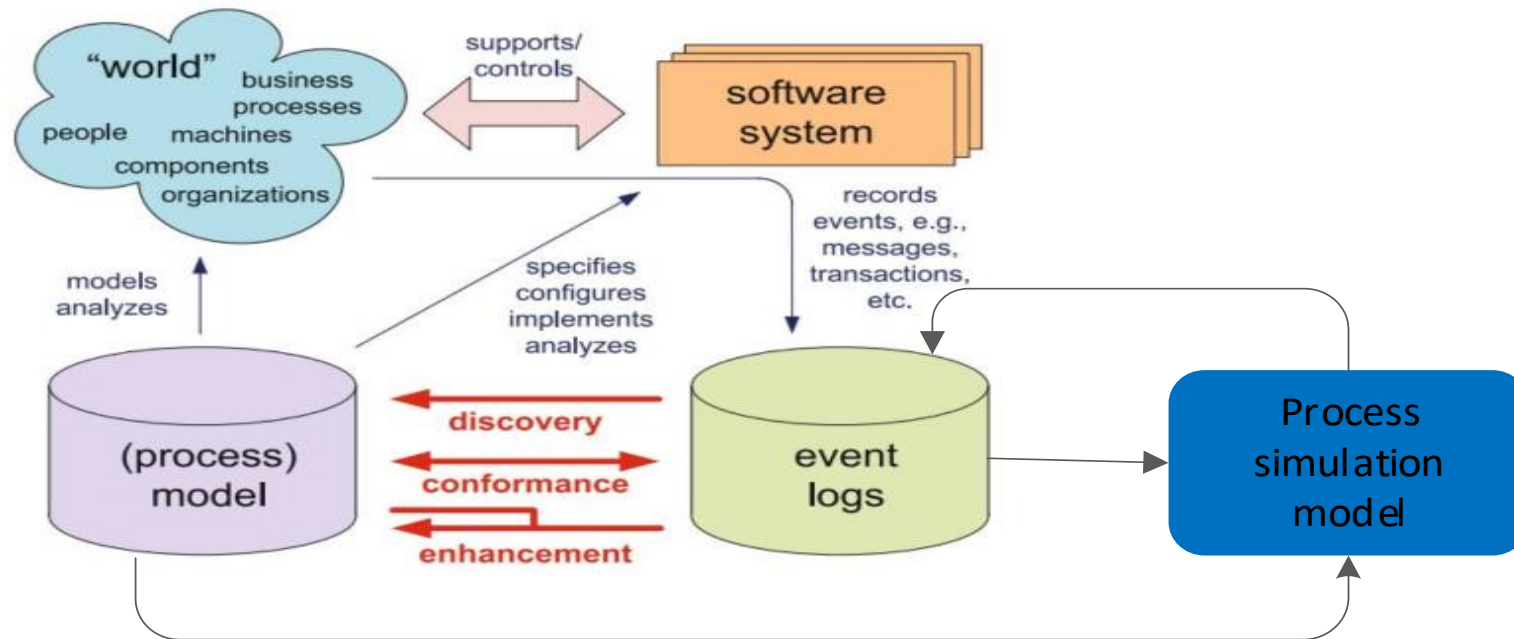
Discovery
- Process model-Activity-flow

Conformance
- Case types
  - Specific flow type
- Redo activities

Performance analysis and Social Network analysis
- Case analysis
  - Type
  - Priority
  - Arrival rate
- Activity
  - Activity duration
  - Activity capacity
  - Required resources
  - Bottleneck activity
- Resources
  - Duration
  - Type
  - Numbers for type
  - Batching
- Roles
  - Type (dep)
  - Numbers in dep
- Queue mining

Decision Mining
- Design choices in the activity-flow
- Design choices in resource allocation
- Priority for case serving in queue

Business Process Simulation

Model Blocks
- Flow objects
- Activities
- Routing activities
- Resources
- Resource Schedules
- Decision logic
- For complex routing activities
- For resource assignment
- Interruptions
- User defined distributions and functions

Modeling activity constructs
- Arrivals
- Queuing
- Branching
- Assembly
- Disassembly
- Batching
- Unbatching
- Creation
- Cloning
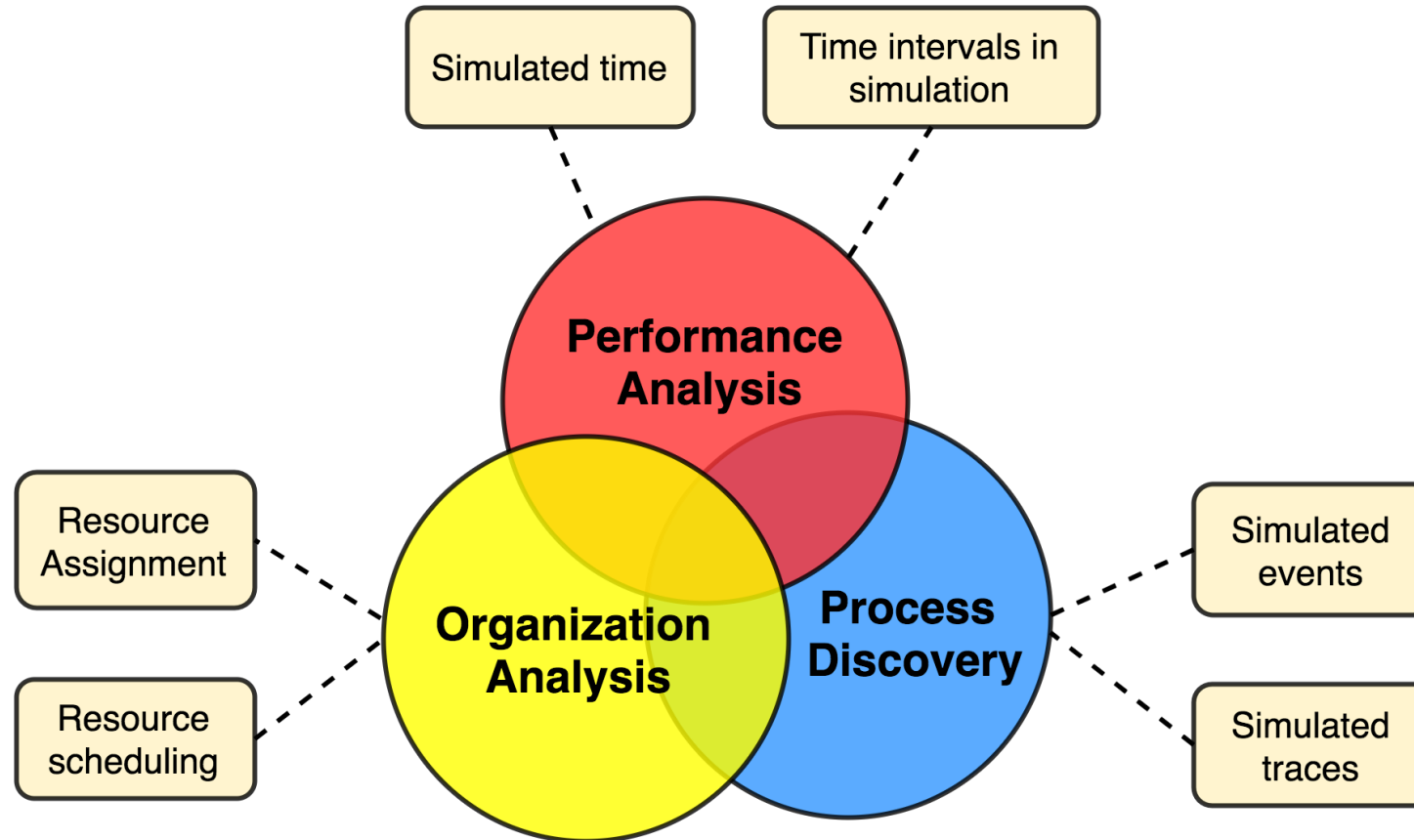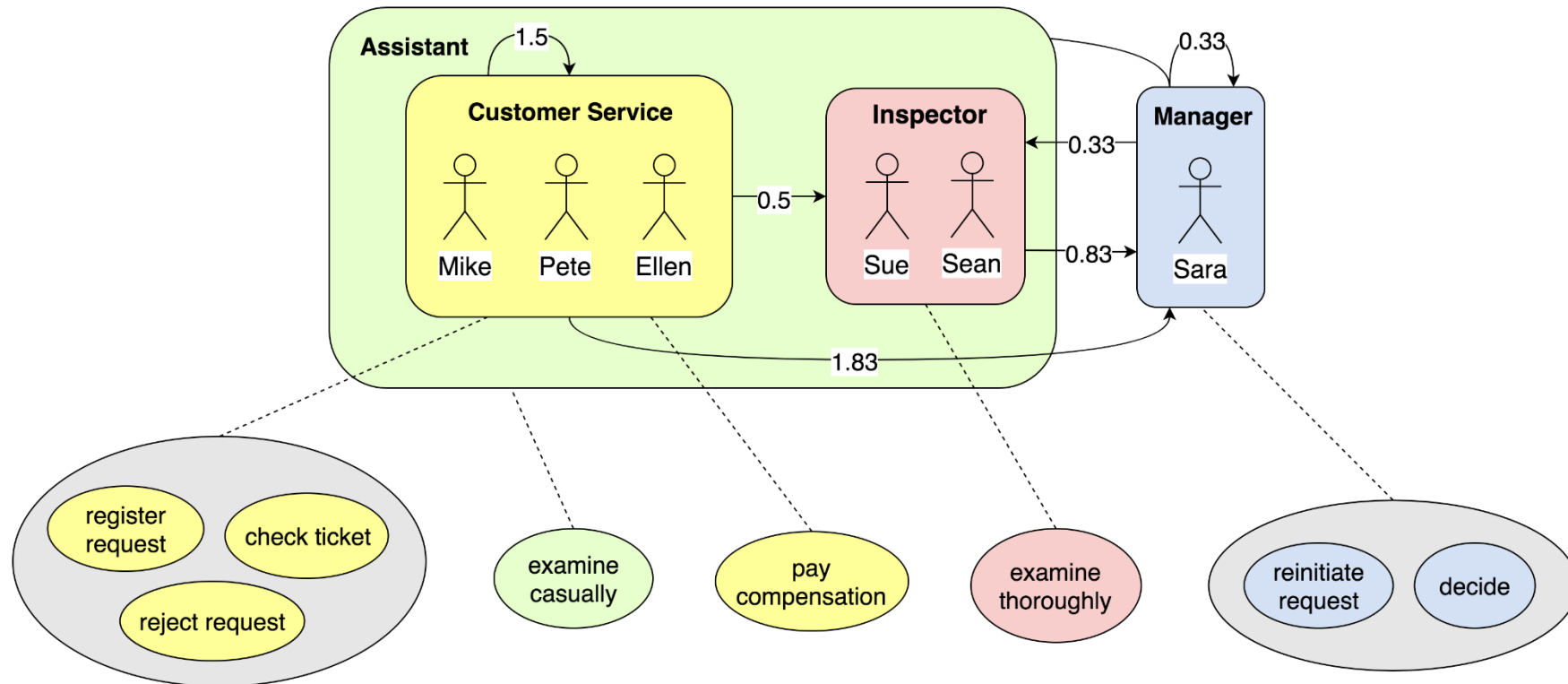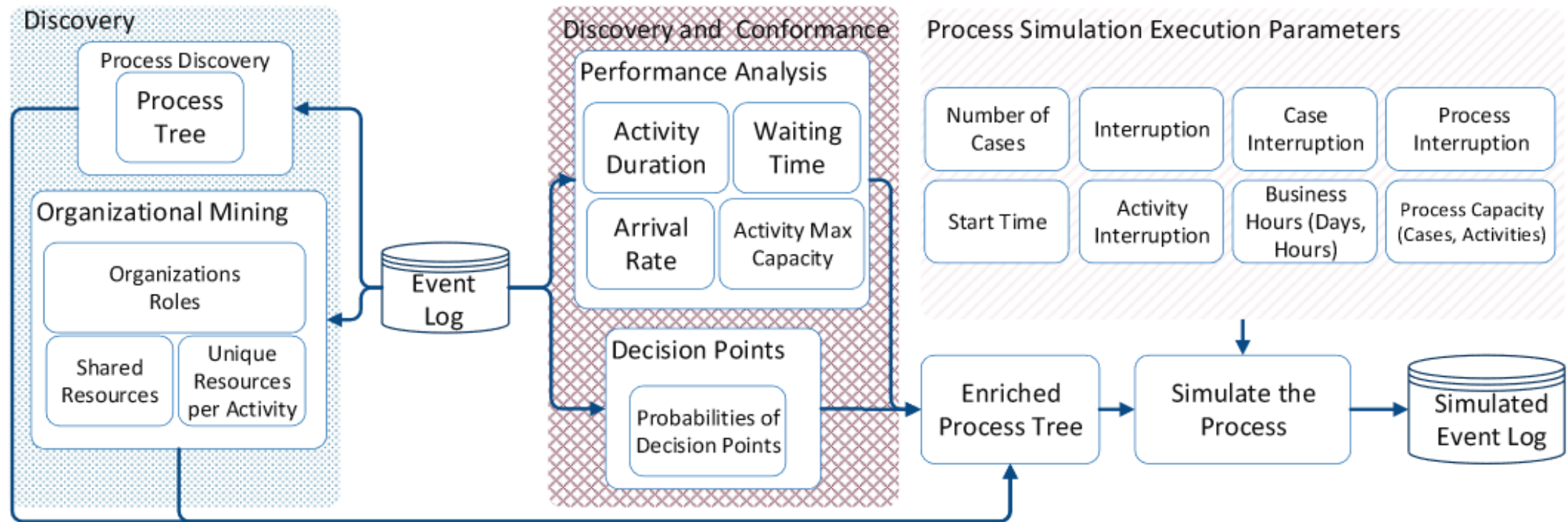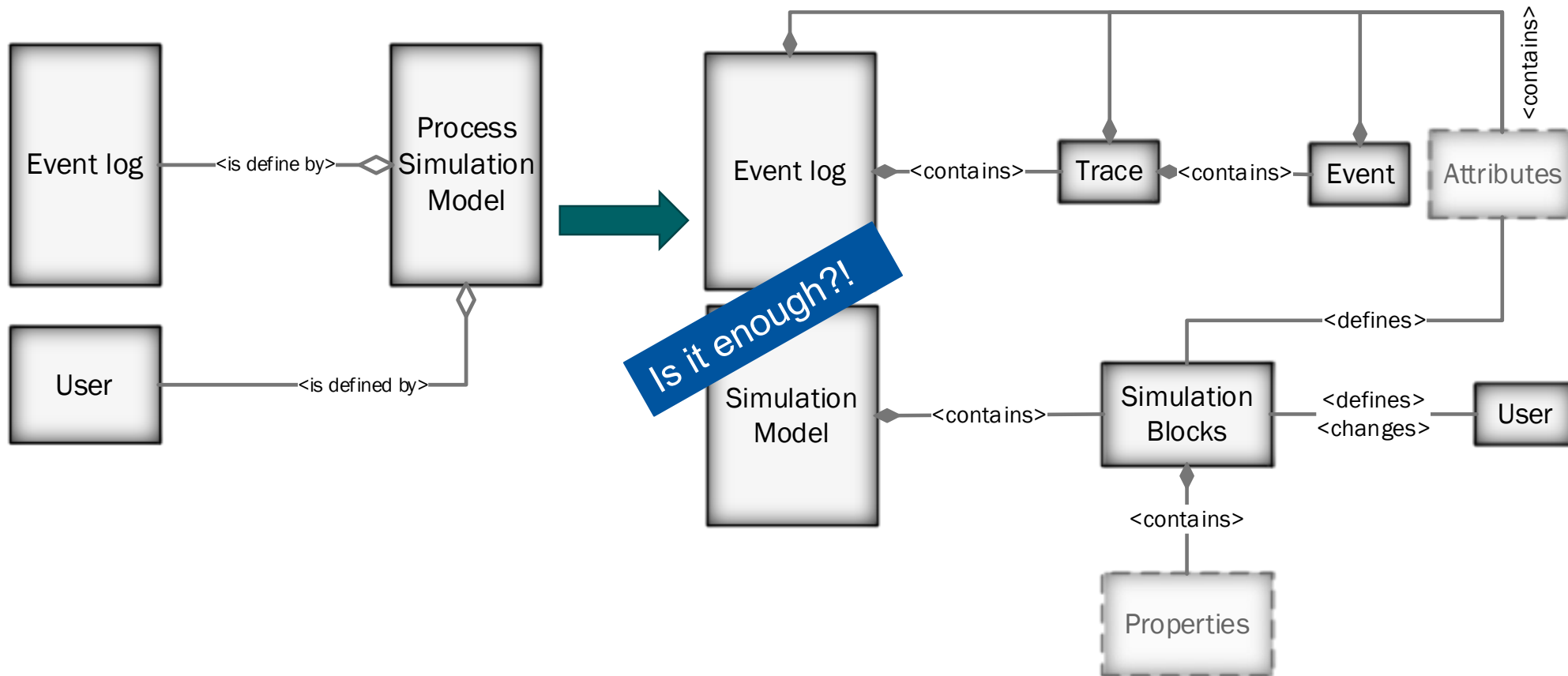
The cornerstone of the further simulation

Sample Organizational Model

- Visualize the clusters of resource and the correlation between them.
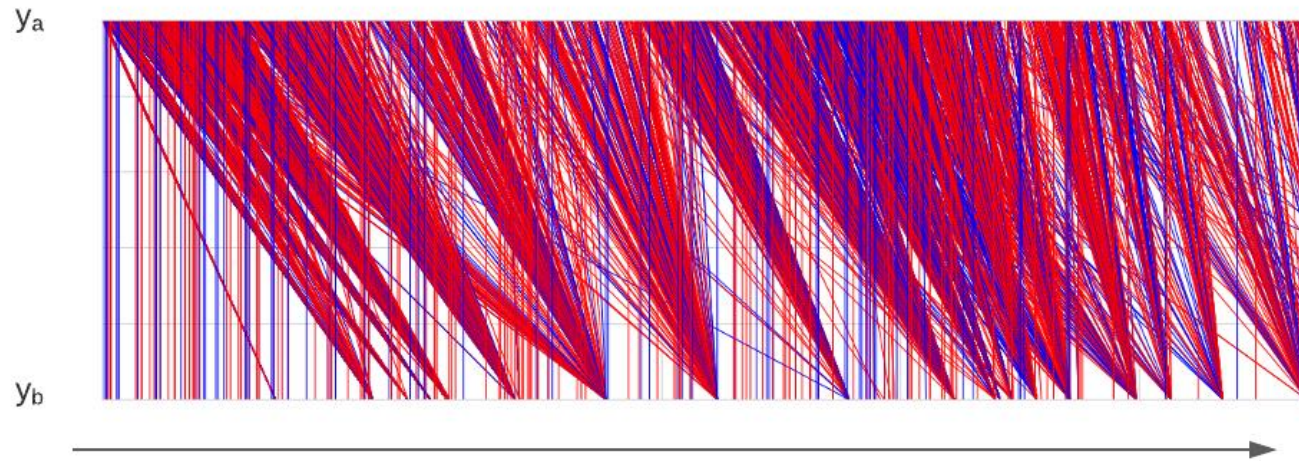
- **For example:**

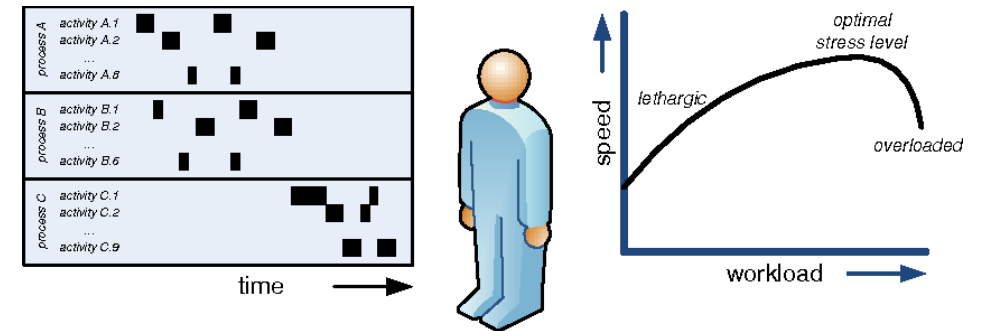# A sample Simulation of Processes

Is that Enough?! Why?

- 2 resources for one activity
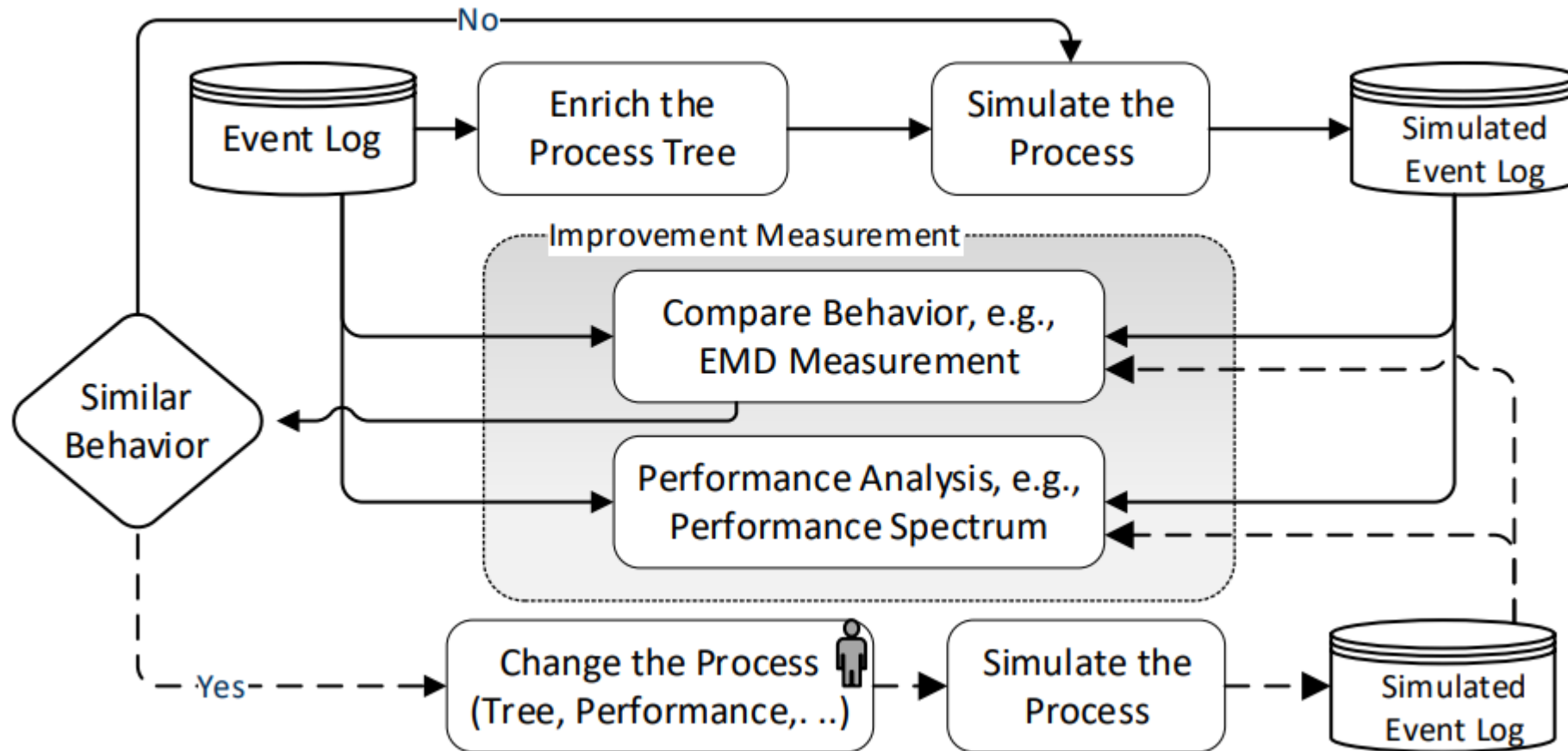
- Different patterns of handling cases!
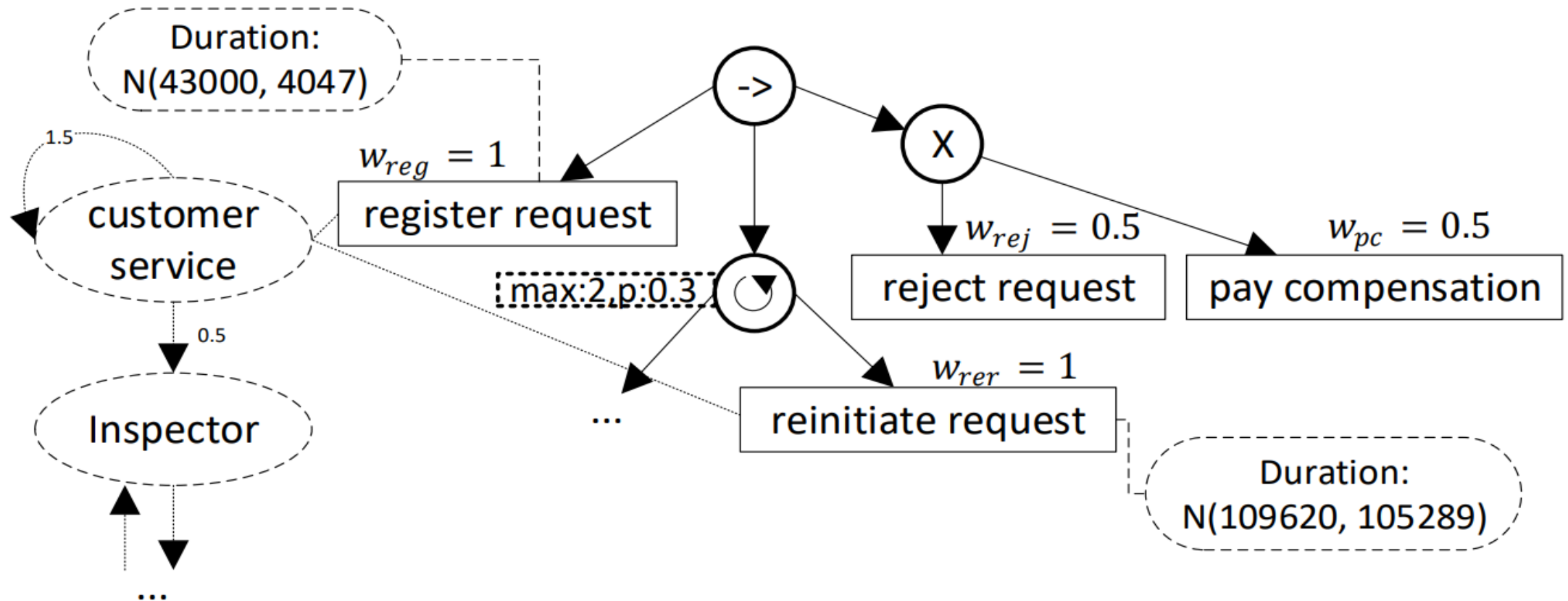
- What about different speed of resources?

The "Yerkes-Dodson Law of Arousal" describes the phenomenon that people work at different speeds based on their workload
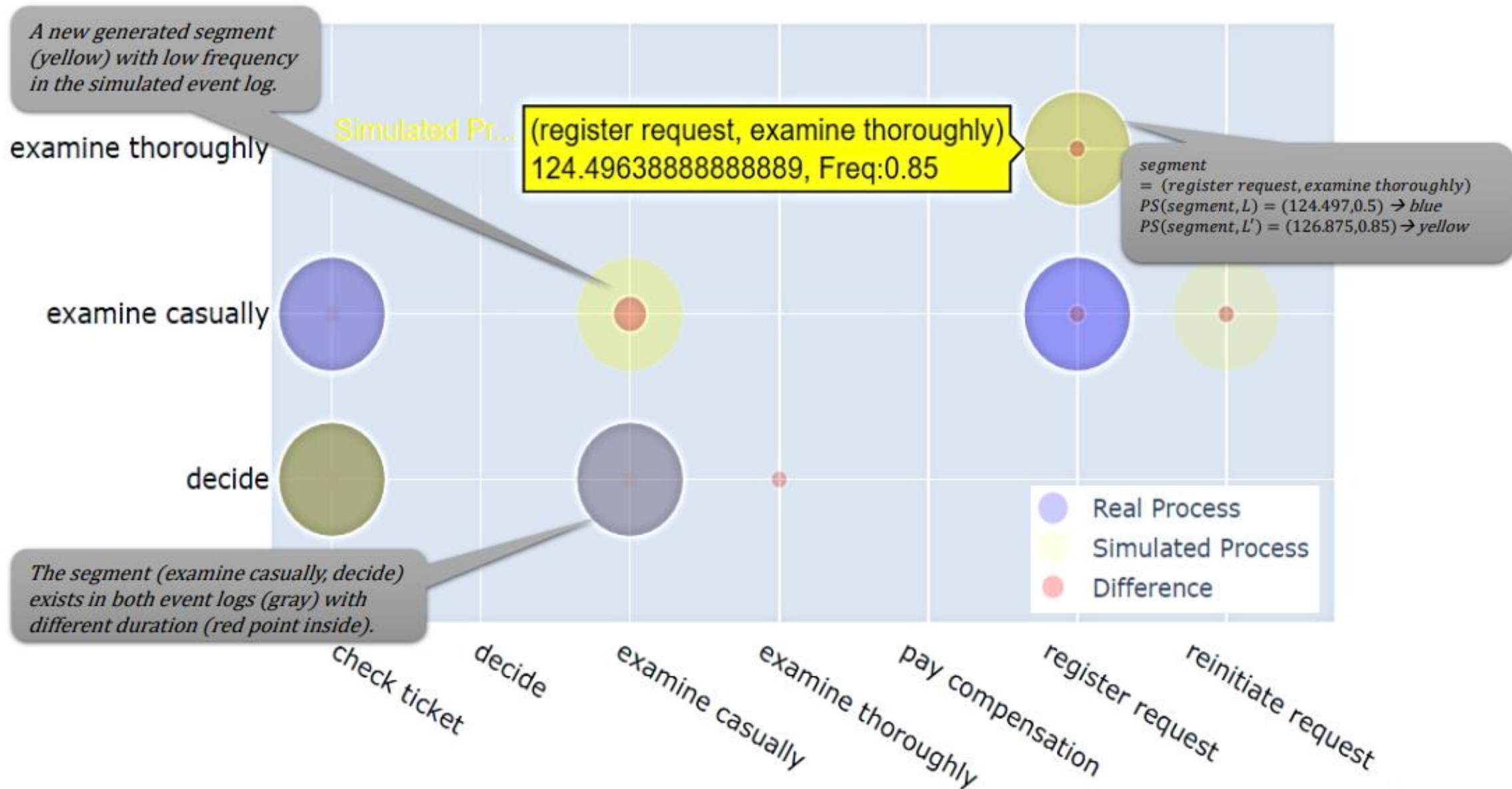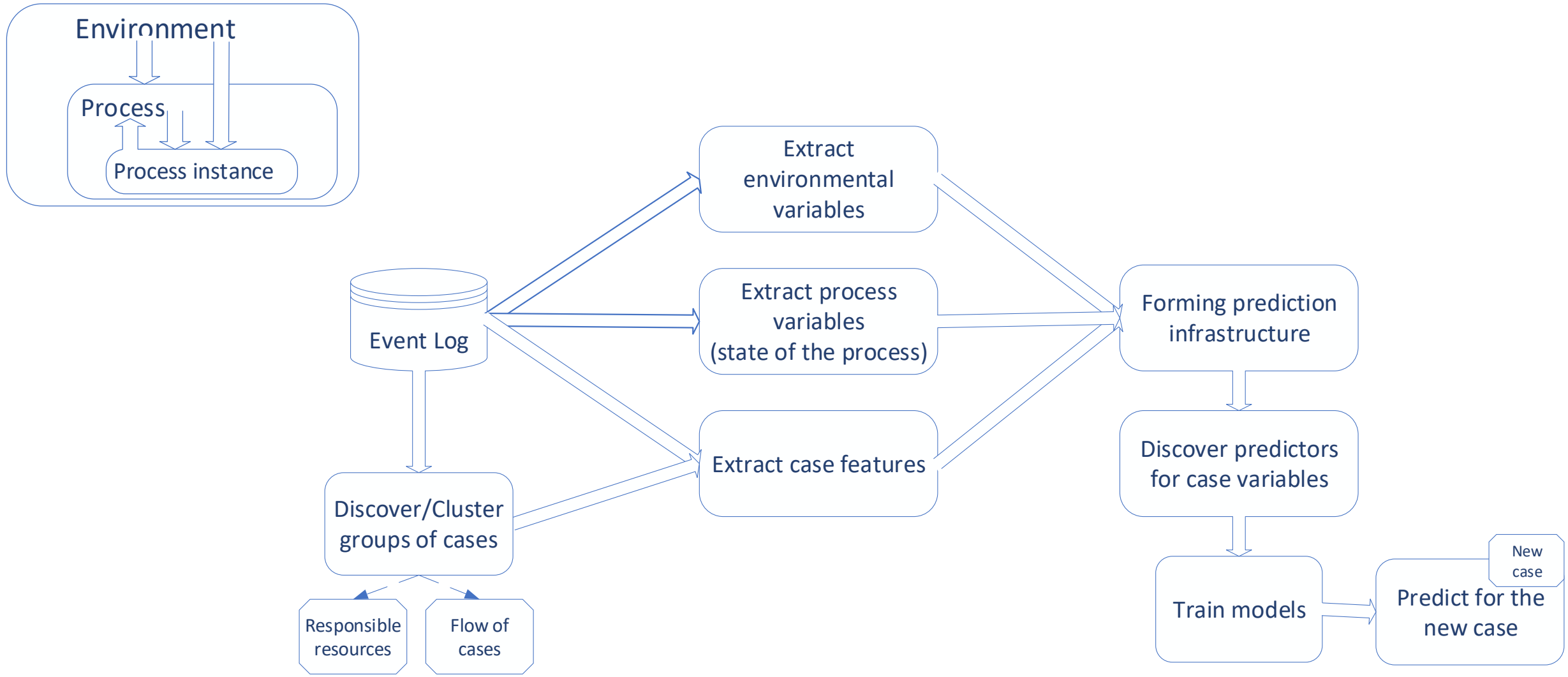
Aggregated performance spectrum comparison of the simulated and real event logs

Predicting the state of the newly arrived cases in the process

Sample data set based on event data

Case	Case Attr₁, age	…	Case Attrₙ	Case Duration	Case waiting time	Case Flow of activities	Group of the case for (similar responsible resources)	Group of the case (similar path, the flow of activities)	Day of the week	Hour of the day	Arrival rate	Number of cases in the process	Number of unique resources in the process	The average number of activities for each case	Average waiting time for each case	Number of the finished case in the process

The table spans three grouped headers: **Case features** (Case Attr₁ age … Case Attrₙ, Case Duration, Case waiting time, Case Flow of activities, Group of the case for (similar responsible resources), Group of the case (similar path, the flow of activities)), **Environmental variables** (Day of the week, Hour of the day), and **Process variables** (Arrival rate, Number of cases in the process, Number of unique resources in the process, The average number of activities for each case, Average waiting time for each case, Number of the finished case in the process).

Rows: 1, 2, …, n — with rows 2 onward grouped as **Training Data** and lower rows through n grouped as **Test Data**.

Analyzing your process
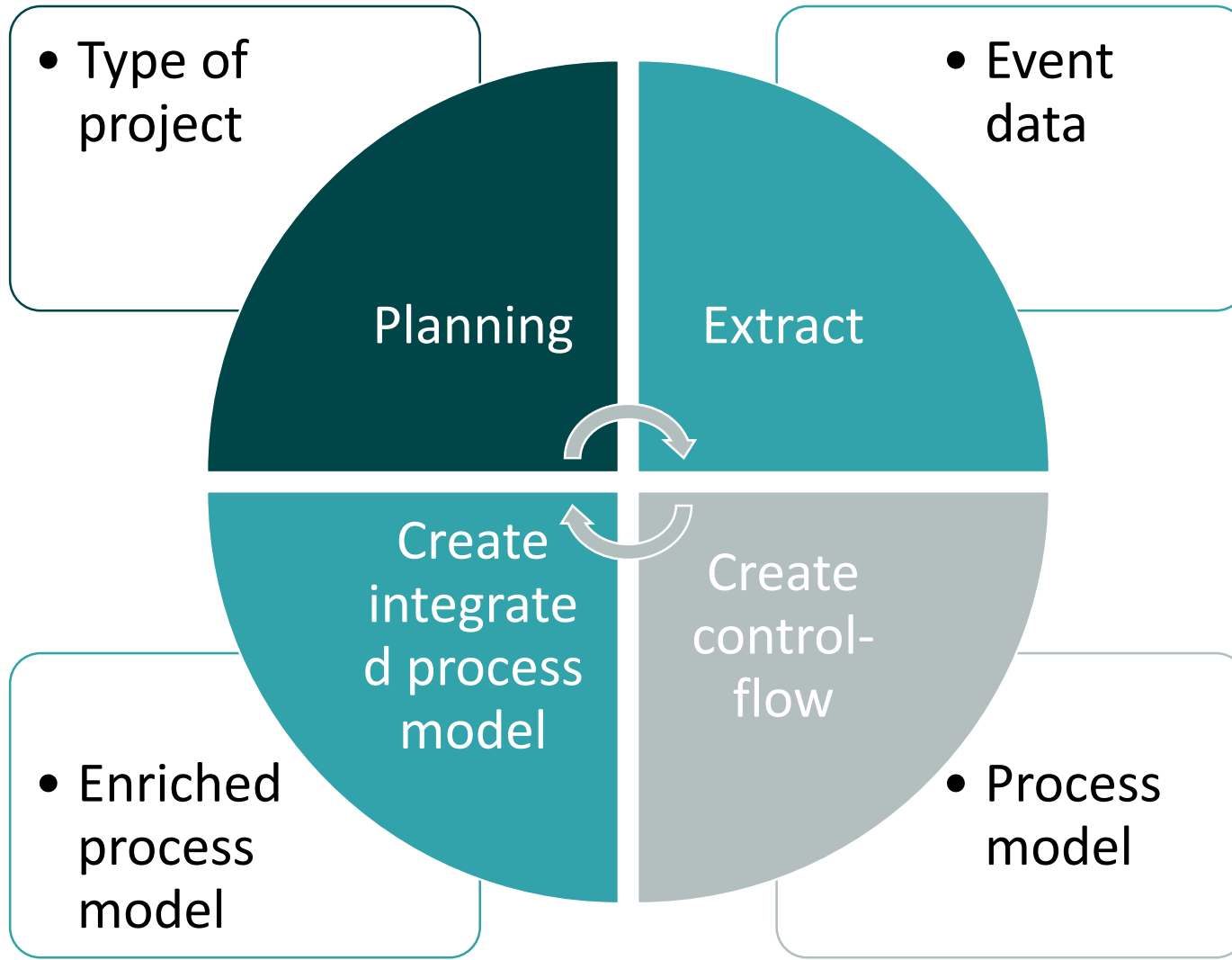
Conduct a Process Mining Project

- Goal:
  - Improve the process
    - KPIs
      - Time related
      - Costs related
      - Quality related
- Actions
  - Handle problems
  - Improving the process
  - Support the process
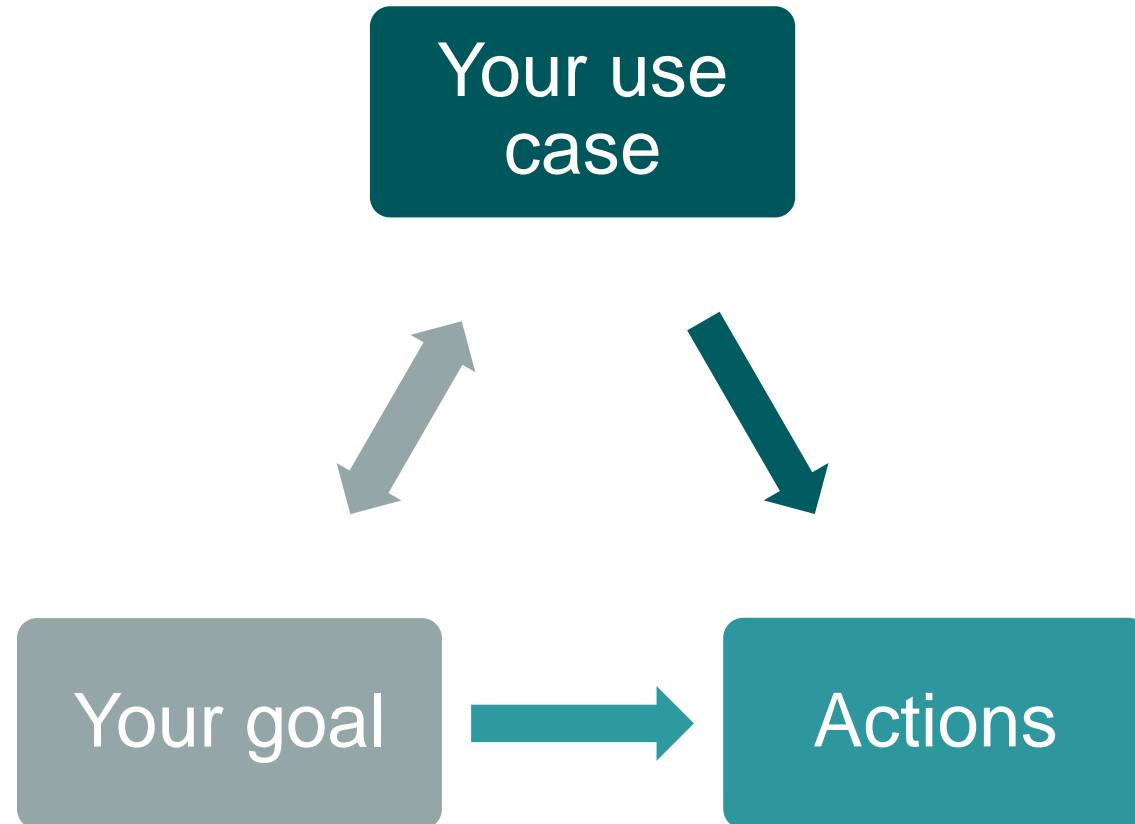
How to create a digital shadow of an organization

- Type of project

- Event data
  - Data driven (curiosity!)
  - Question driven (why?)
  - Goal driven (how?)

  - Present the whole process inside organization
  - Comprehensive process mimicking the real process
  - Make it executable!

Planning | Extract

Create integrated process model | Create control-flow

- Enriched process model

- Process model

  - LTE of event logs
  - Collect objectives, existing models and questions
  - Exploit existing domain knowledge

  - Discover process model
  - Discover organizational information
  - Discover performance and compliance state of the process

Chair of Process and Data Science

RWTH AACHEN UNIVERSITY

Thank you for your attention!

mahsa.bafrani@pads.rwth-aachen.de