



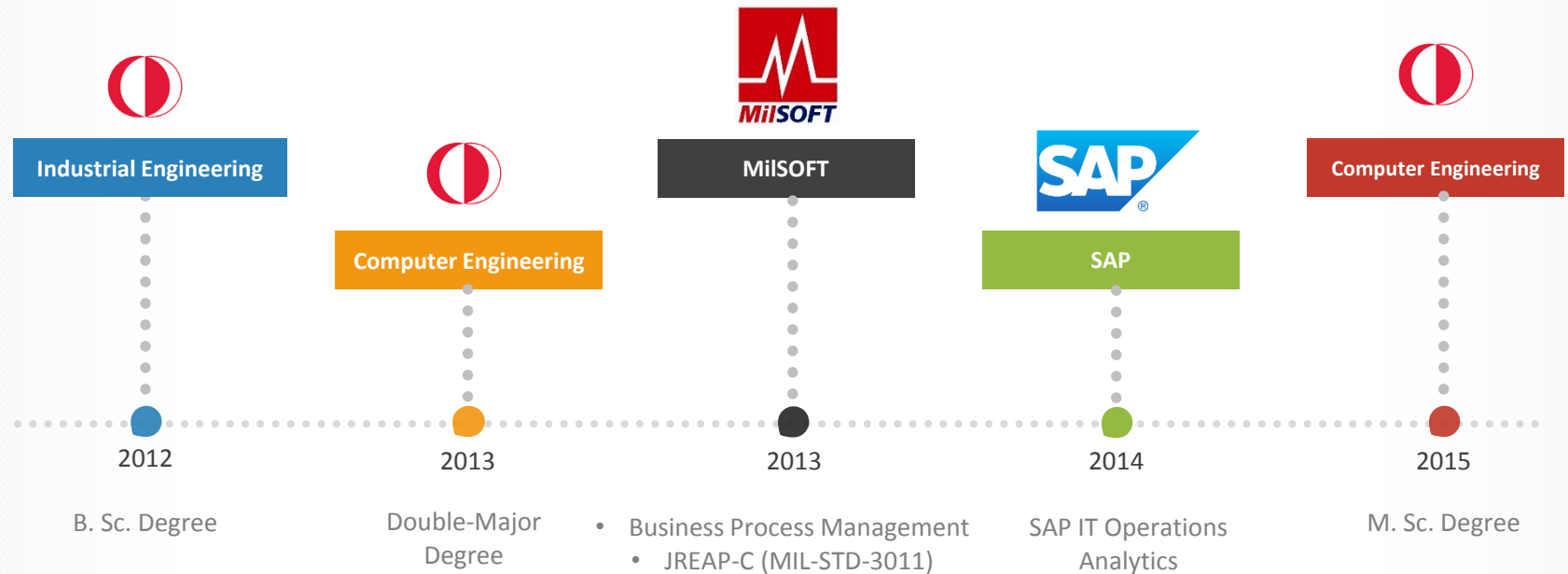
Recommendation Generation for Performance Improvement by using Cross-Organizational Process Mining

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Onur Yilmaz



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Introduction

Process Mining



Relatively young and developing research area and main idea is to

- discover,
- monitor and;
- improve processes by extracting information from event logs. [1]



Events recorded and available



Competitive business life

Introduction

Cross- Organizational Process Mining



Cloud computing
and shared
infrastructures

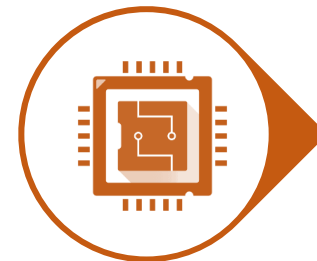


Event logs of
multiple
organizations [2]



Analyze the big
picture

Work together to execute
the same process



Learn from
each other

Execute the same task
on shared infrastructure [3]

Introduction

Focus of this Study



- A hybrid approach
 - Using different process mining subfields to create a new point of view
- Cross-organizational process mining
 - Processes are executed on several organizations,
 - Unsupervised learning using performances of organizations

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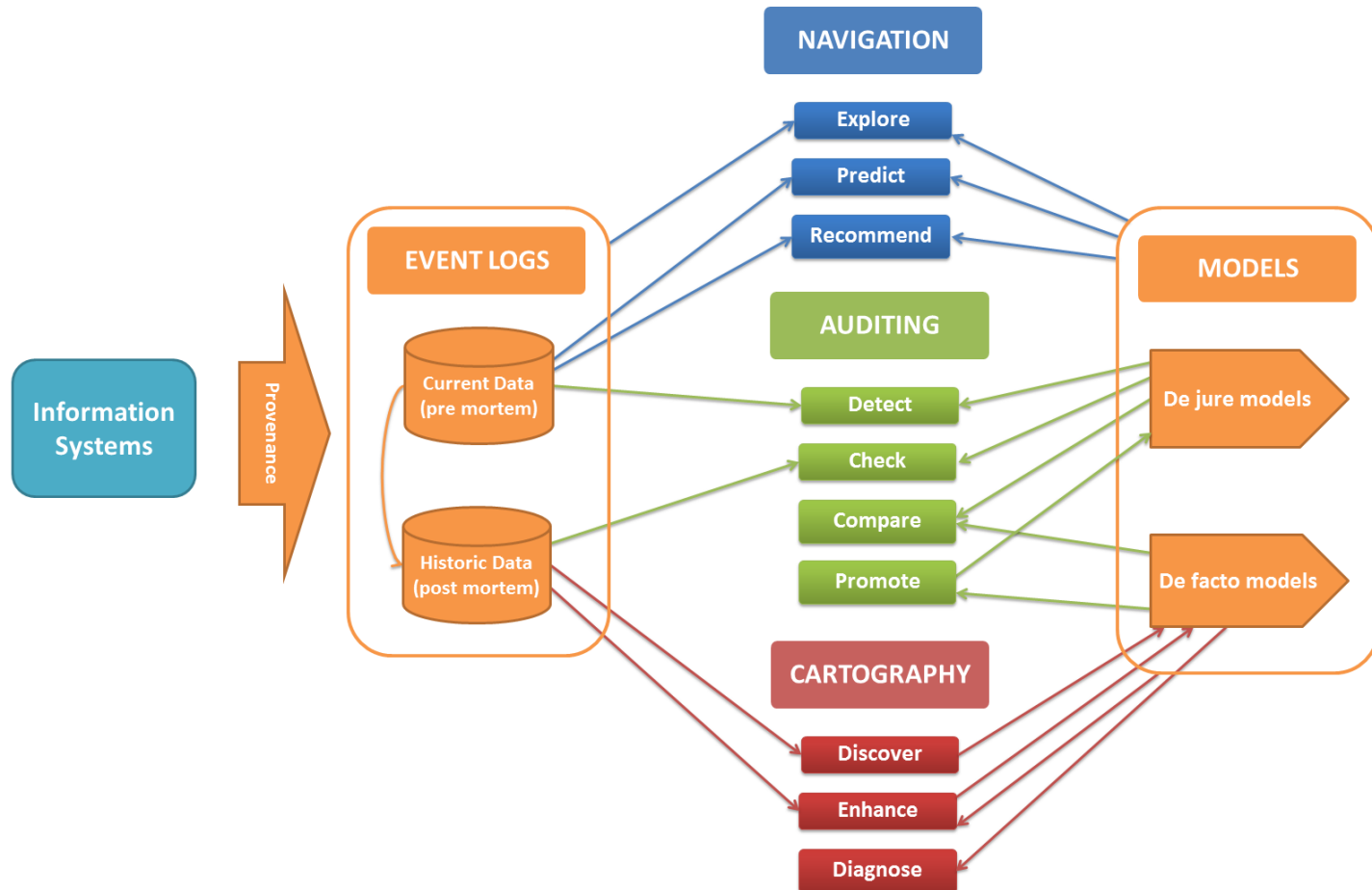
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Related Work

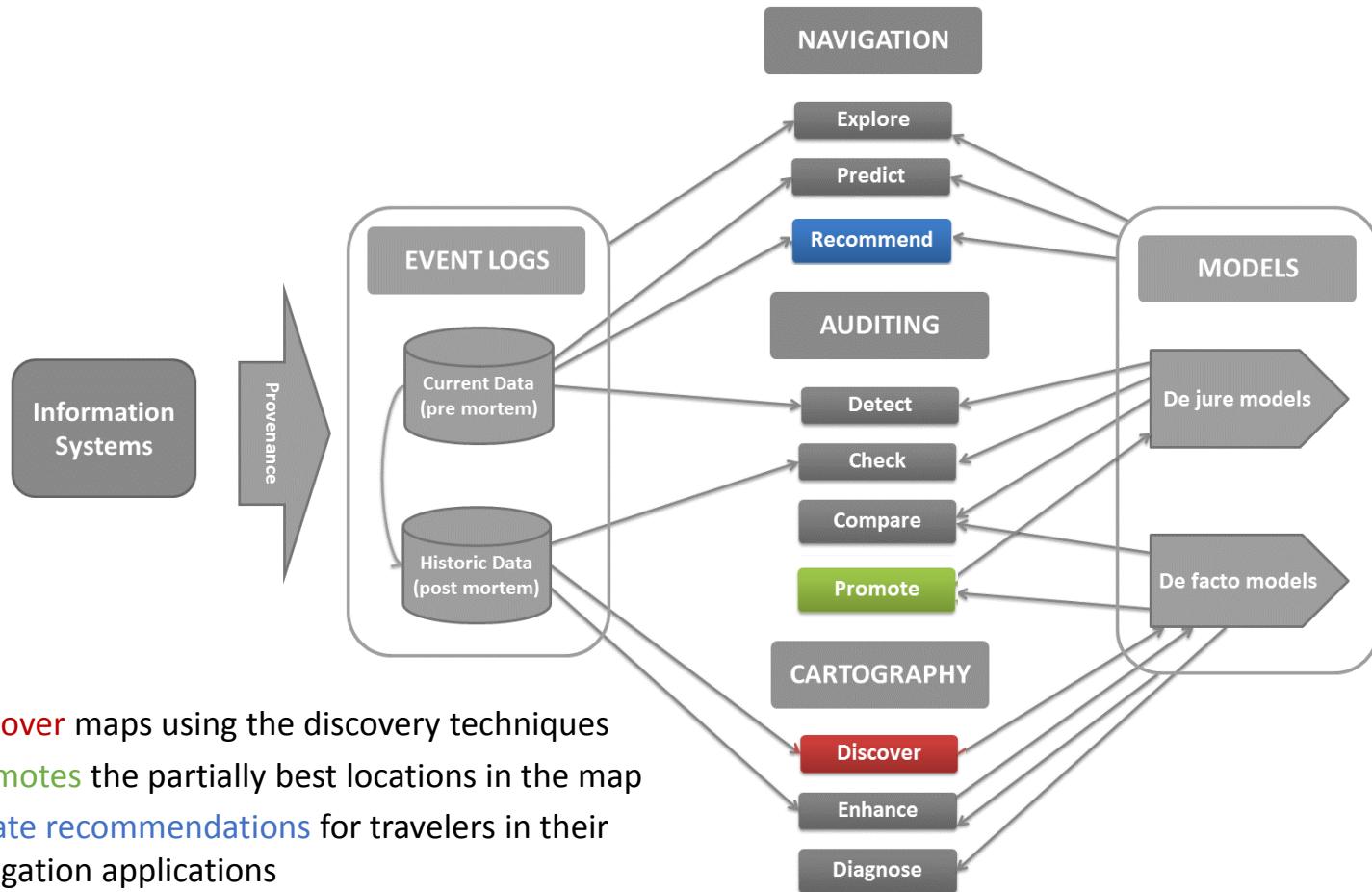
State of the Art in Process Mining



[4]

Related Work

State of the Art in Process Mining



- **Discover** maps using the discovery techniques
- **Promotes** the partially best locations in the map
- **Create recommendations** for travelers in their navigation applications

Related Work

Contributions of This Study



- Cross-organizational process mining approach for process performance improvement
- Generic, noise-capable process mining method for mining process models of different organizations
- Clustering of organizations based on their performance indicators
 - Unlike the clustering methods based on process structures in the literature [9]

Related Work

Contributions of This Study



- Mismatch analysis for spotting differences between processes of organizations
 - Formulation and implementation of patterns and analyzers
- Recommendation generation to show how organizations can learn from other organizations which perform better
- Open-source, extensible and configurable set of plugins in ProM framework



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Event Log

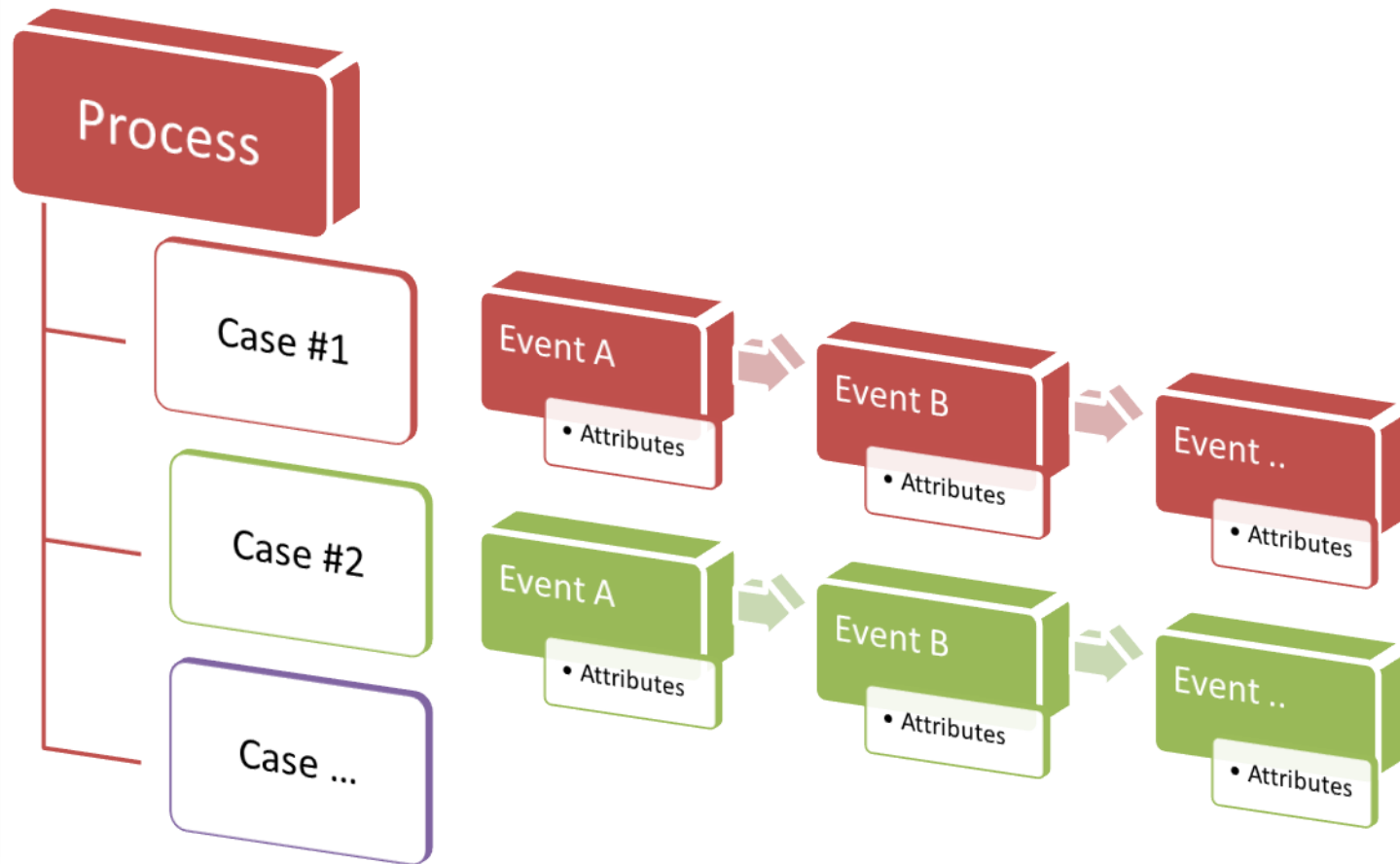
- Outputs of the software systems like Enterprise Resource Planning (ERP) or Business Process Management (BPM)



Event Log				
Attributes				
	Event	Date	Time	Transition
Case #1	Register Application	16.04.2013	14:37:27	Complete
	Check Credit	16.04.2013	14:41:19	Complete
	Check System	16.04.2013	14:47:35	Complete
	Calculate Capacity	16.04.2013	14:50:21	Complete
	Accept	16.04.2013	14:53:22	Complete
	Send decision e-mail	16.04.2013	14:55:11	Complete
Case #2	Register Application	16.04.2013	16:28:19	Complete
	Check Credit	16.04.2013	16:36:22	Complete

Background

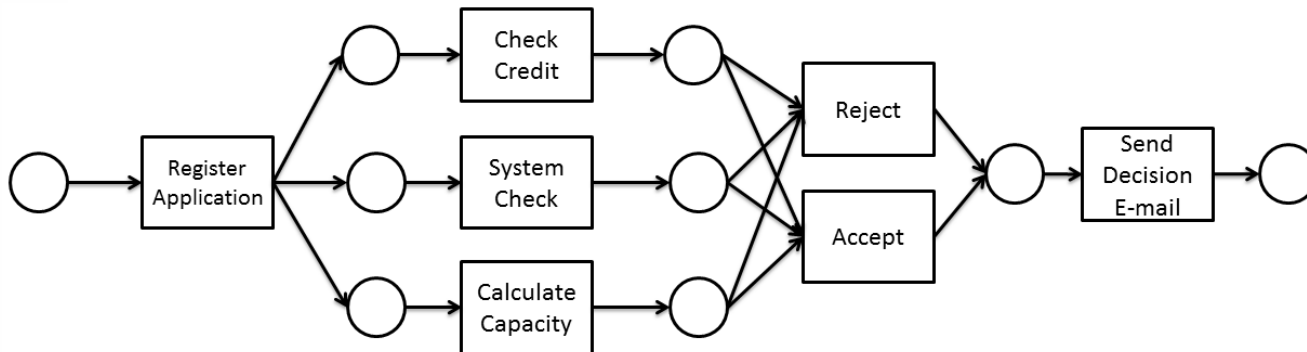
Event Log



Background

Process Modeling

- **Workflow Net**
 - Petri net with a start node, end node and connectedness

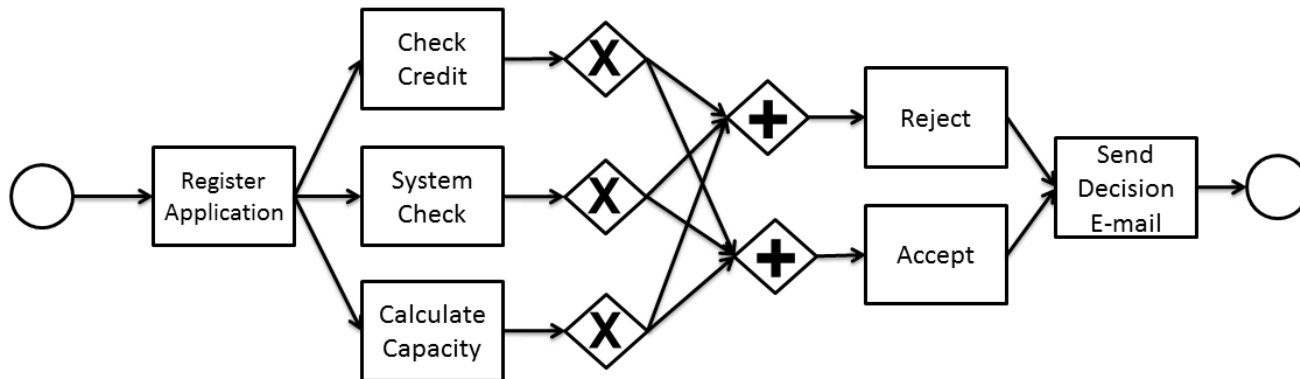


- Mathematical background

Background

Process Modeling

- Business Process Modelling Notation (BPMN)
 - Standardized and easy to understand by stakeholders



- Business oriented

Background

Process Discovery

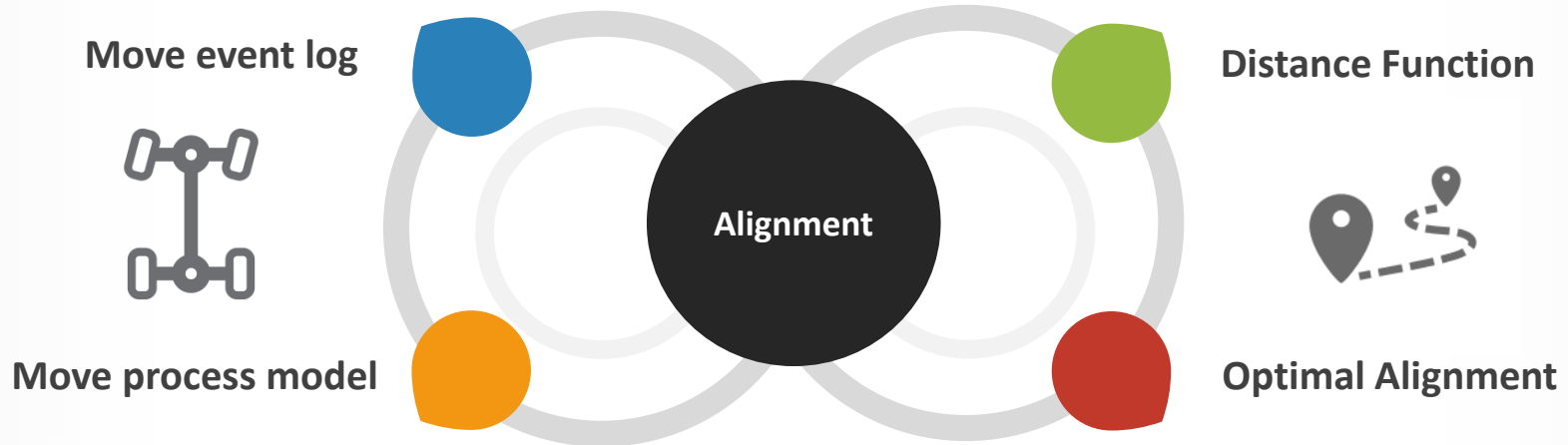


- One of the most challenging tasks is to construct a process model based on the behavior in the event logs
- Inductive Miner Infrequent (*IMi*) is used since it is simple, highly applicable and configurable to handle noise [20]
 - Block-structured Workflow Nets
 - Rediscoverability

Background

Process Performance Analysis

- Discover relationships between event logs and process models for conformance and performance analysis [21]



Background

Mismatch Patterns in Process Models



- Patterns for frequent mismatches between the similar process models by Dijkman [14]



Authorization



Activity

- Skipped Activity
- Refined Activity



Control Flow

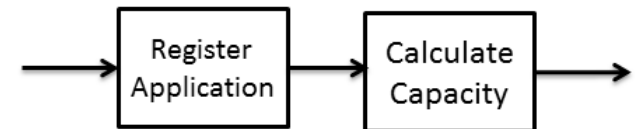
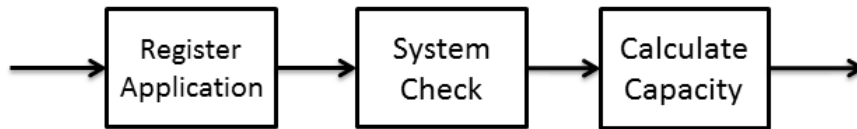
- Activities at Different Moments in Processes
- Different Conditions for Occurrence
- Different Dependencies
- Additional Dependencies

Background

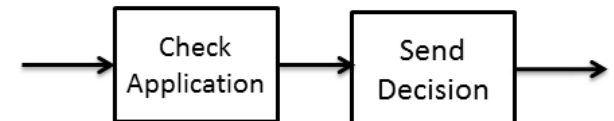
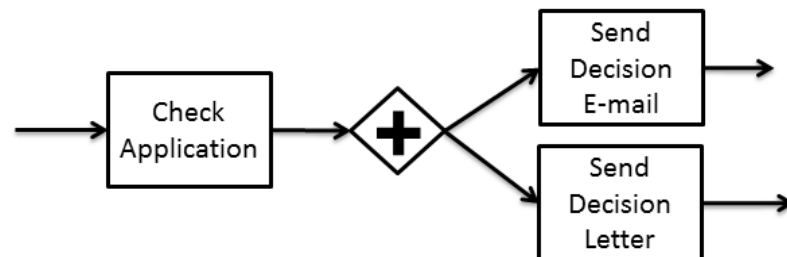
Mismatch Patterns in Process Models

Activity Mismatch Patterns [14]

- Skipped Activity



- Refined Activity

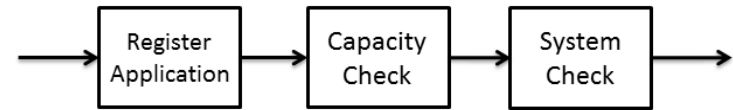
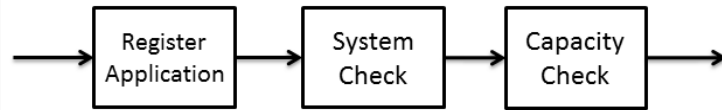


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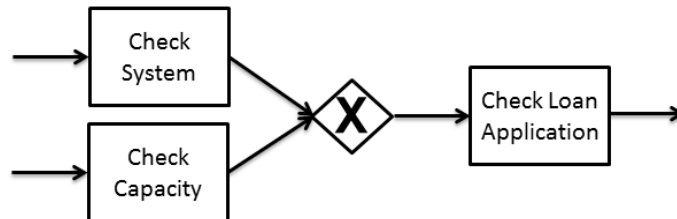
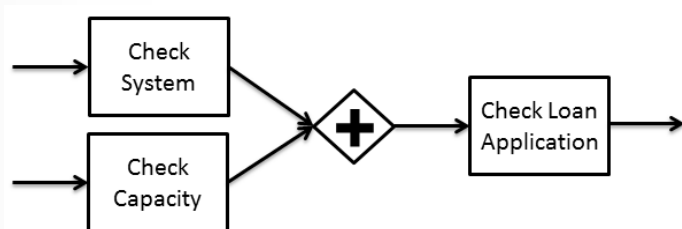
Mismatch Patterns in Process Models

Control Flow Mismatch Patterns [14]

- Activities at Different Moments in Processes



- Different Conditions for Occurrence

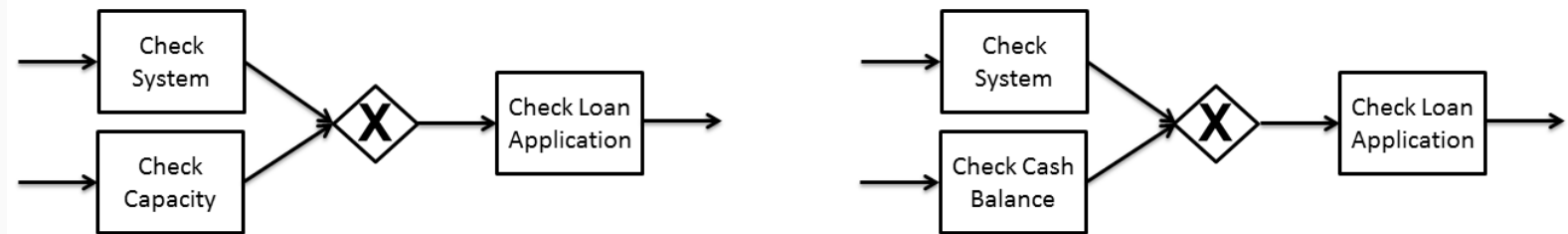


Background

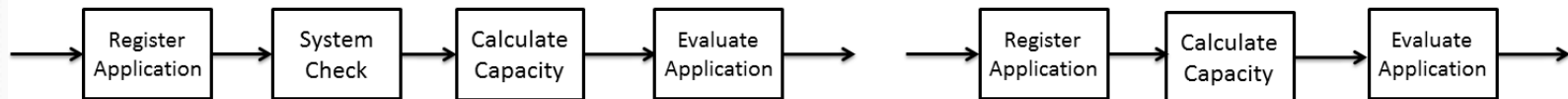
Mismatch Patterns in Process Models

Control Flow Mismatch Patterns [14]

- Different Dependencies



- Additional Dependencies



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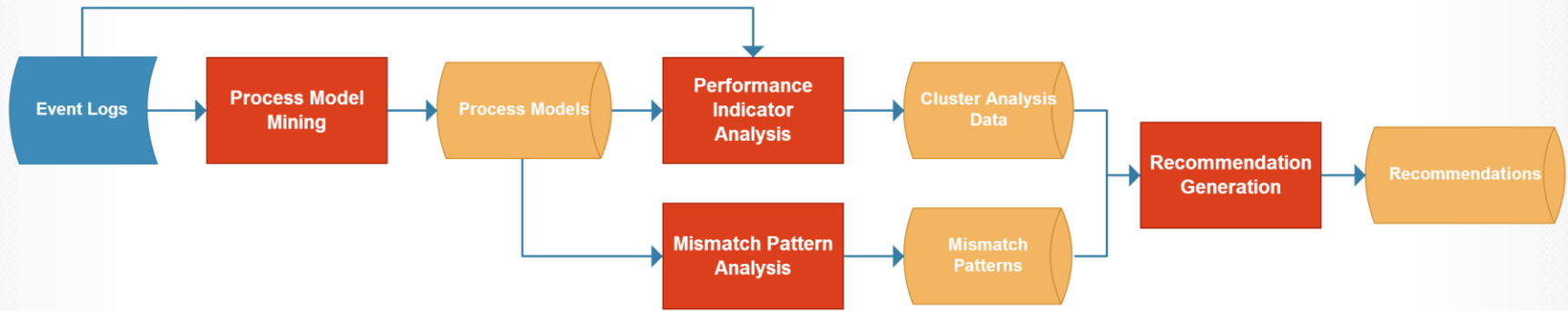
Methodology

Approach Overview



Methodology

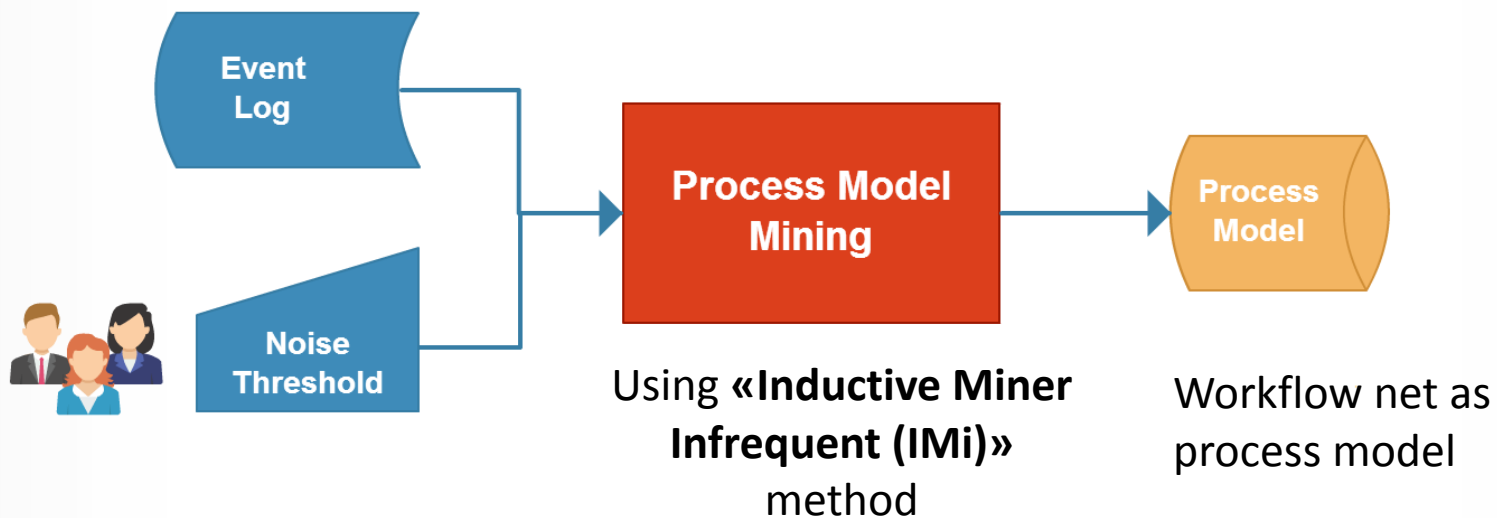
Approach Overview



Methodology

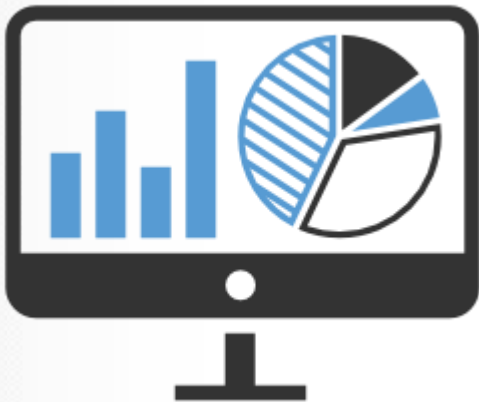
Process Model Mining

Applied for each organization:

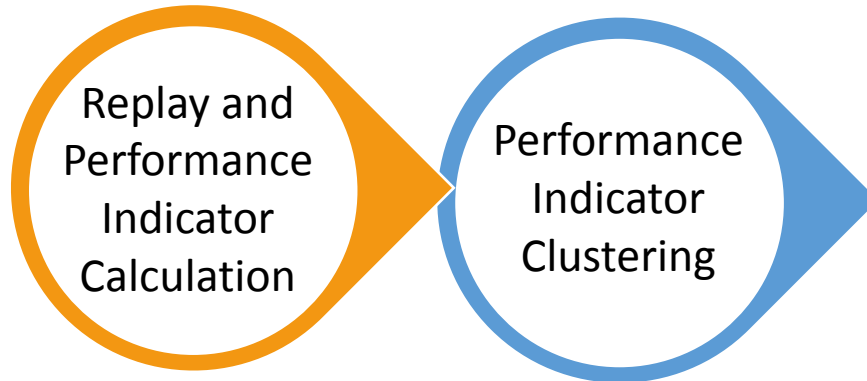


Methodology

Performance Indicator Analysis



- Two steps:



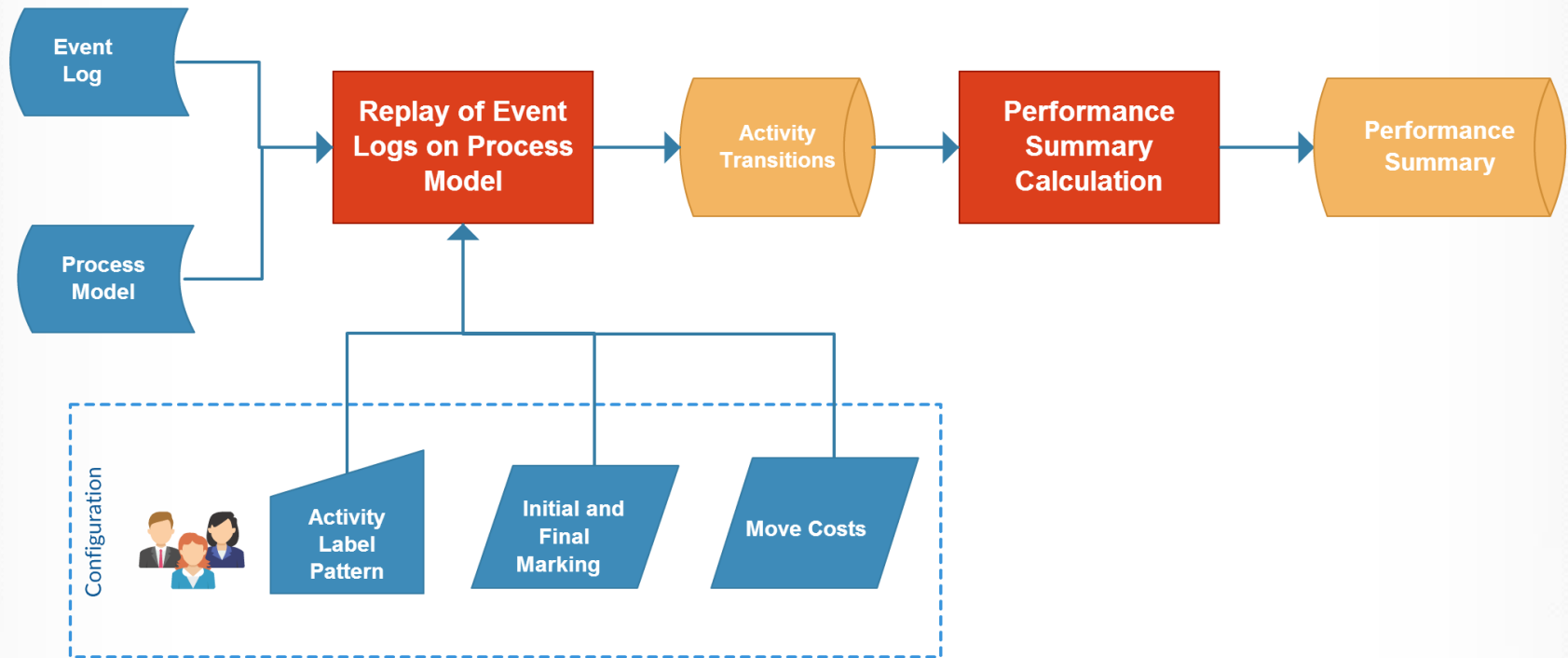
- Performance Indicators:
 - Average Time Between Activities
 - Standard Deviation of Time Between Activities



Methodology

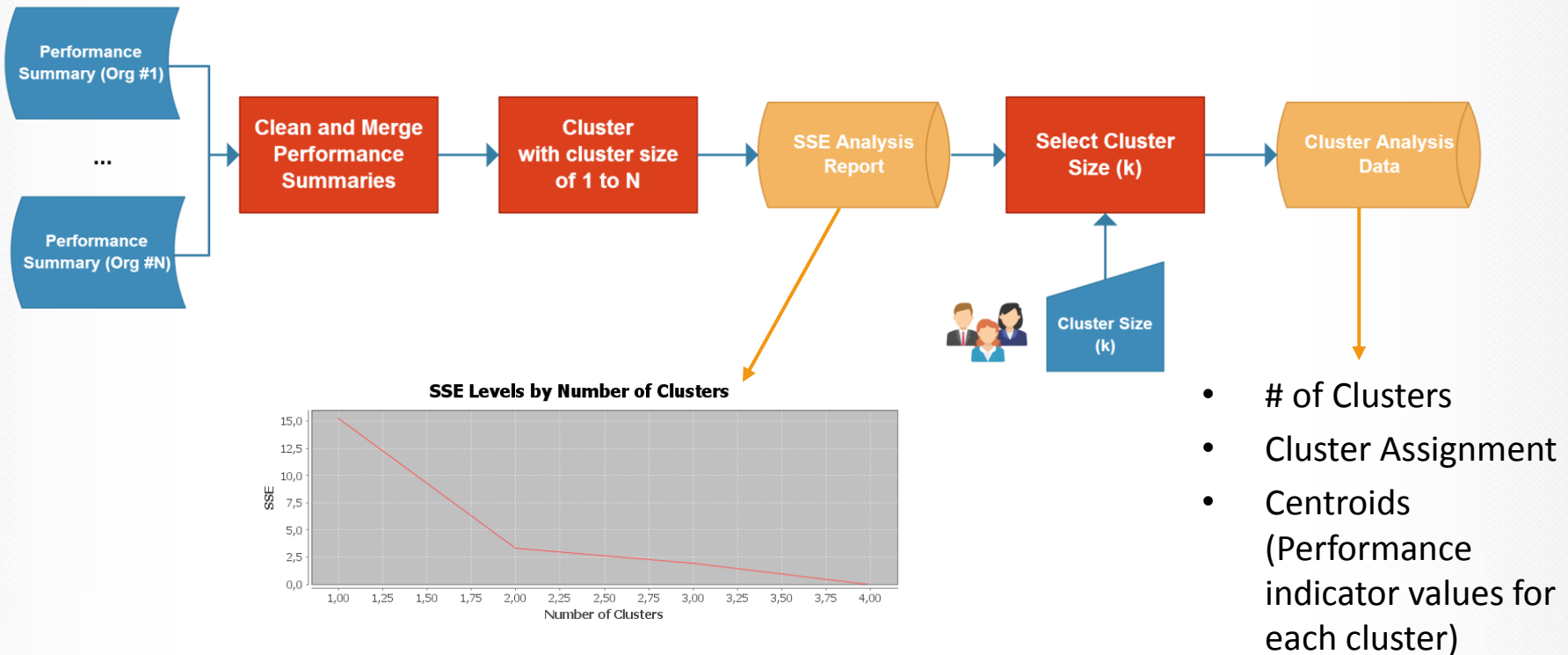
Performance Indicator Analysis - Replay and Performance Indicator Calculation

Applied for each organization:



Methodology

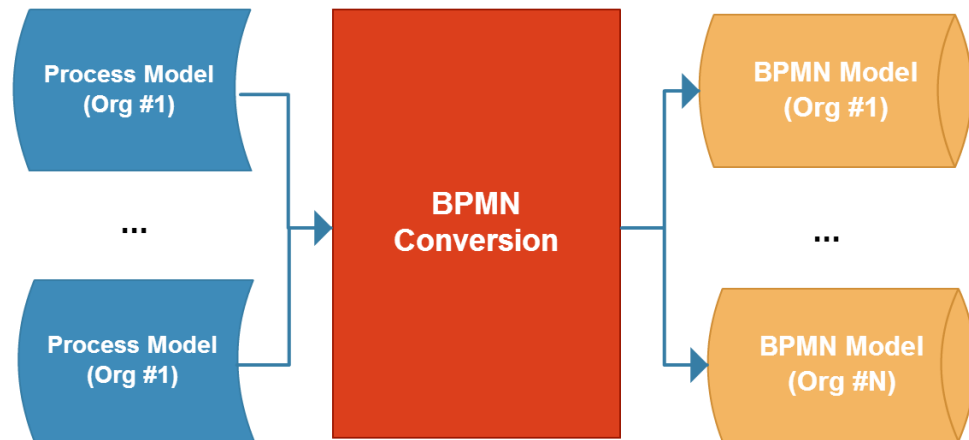
Performance Indicator Analysis – Performance Indicator Clustering



Methodology

Mismatch Pattern Analysis

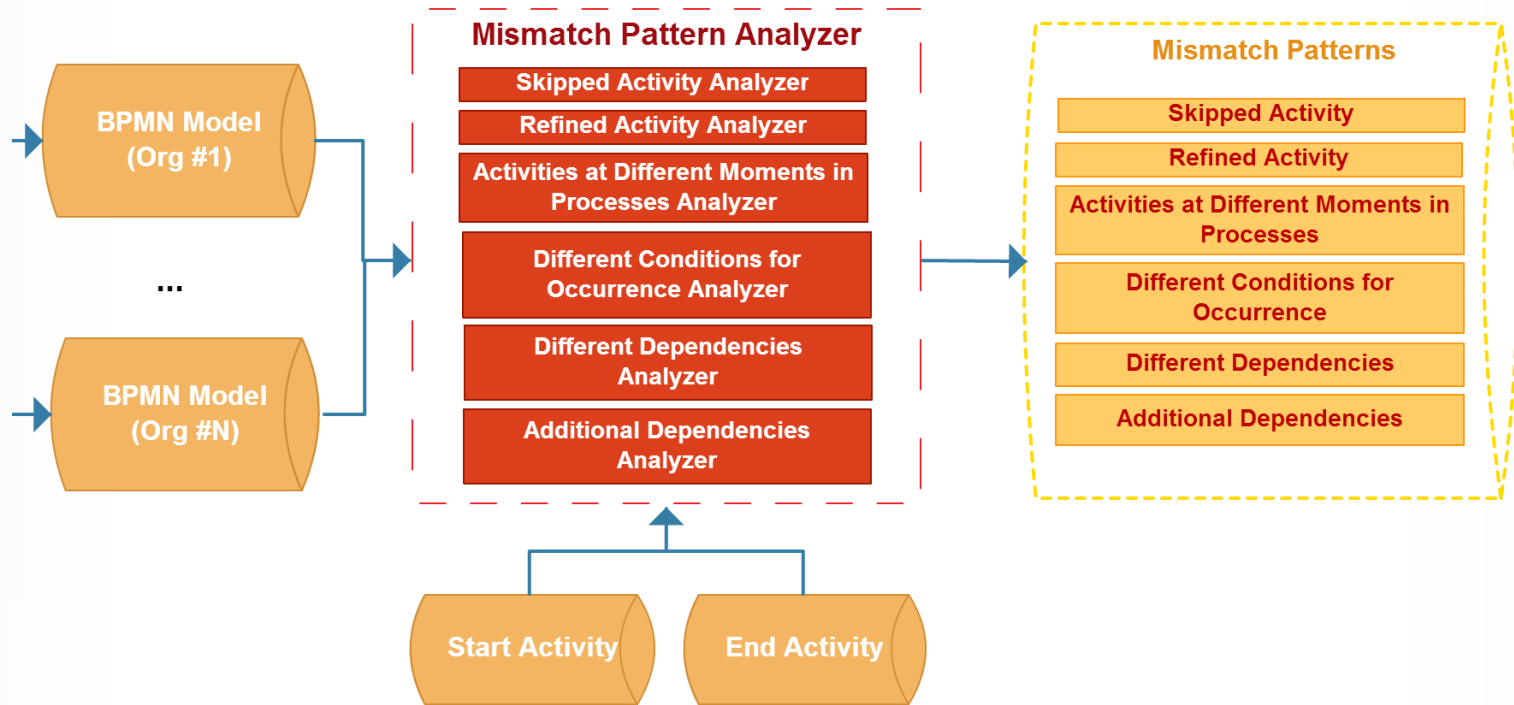
- Spot the differences between process models of different organizations as mismatch patterns
- BPMN used since notation is more appropriate to formulate mismatch patterns



Methodology

Mismatch Pattern Analysis

- Mismatch patterns and analyzers are developed



Methodology

Recommendation Generation

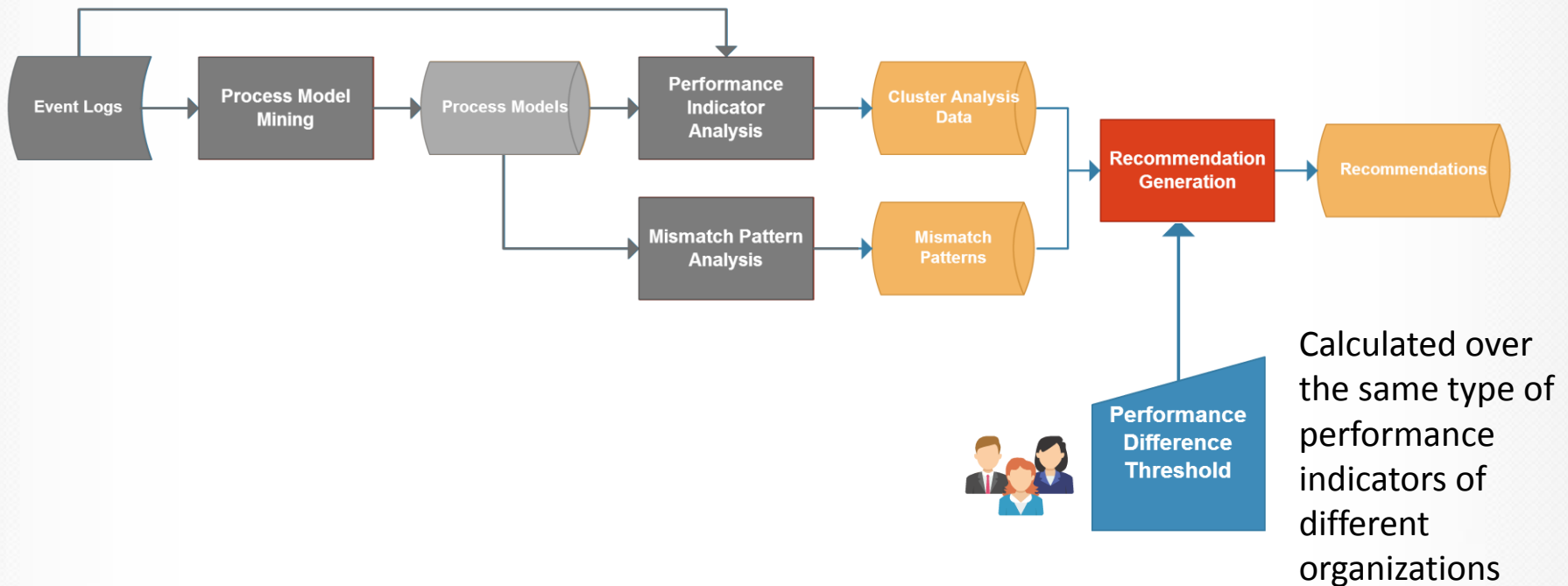


- Providing a set of mismatch patterns for each organization to enhance their processes.
 - Mismatch patterns between organizations, which are **performing better** in terms of their performance indicator values.

Recommendation = (Organization, A_{start} , A_{end} , Mismatch Patterns)

Methodology

Recommendation Generation



Methodology

Recommendation Generation

RecommendationGeneration

input: **O** organization, **C** Cluster Analysis Data, **P** performance difference threshold

output: **Recommendations** a set of recommendations

Recommendations \leftarrow {}

i \leftarrow Cluster of organization **O**

for each centroid for cluster **i**

Get other cluster **j** with the centroids of A_{start} and A_{end} ; and value difference larger than **P**

for each organization **O'** in the cluster **j**

MismatchPatterns \leftarrow Mismatch Pattern Analysis(**O**, **O'**, A_{start} , A_{end})

Recommendations \leftarrow Recommendation(**O**, A_{start} , A_{end} , **MismatchPatterns**)

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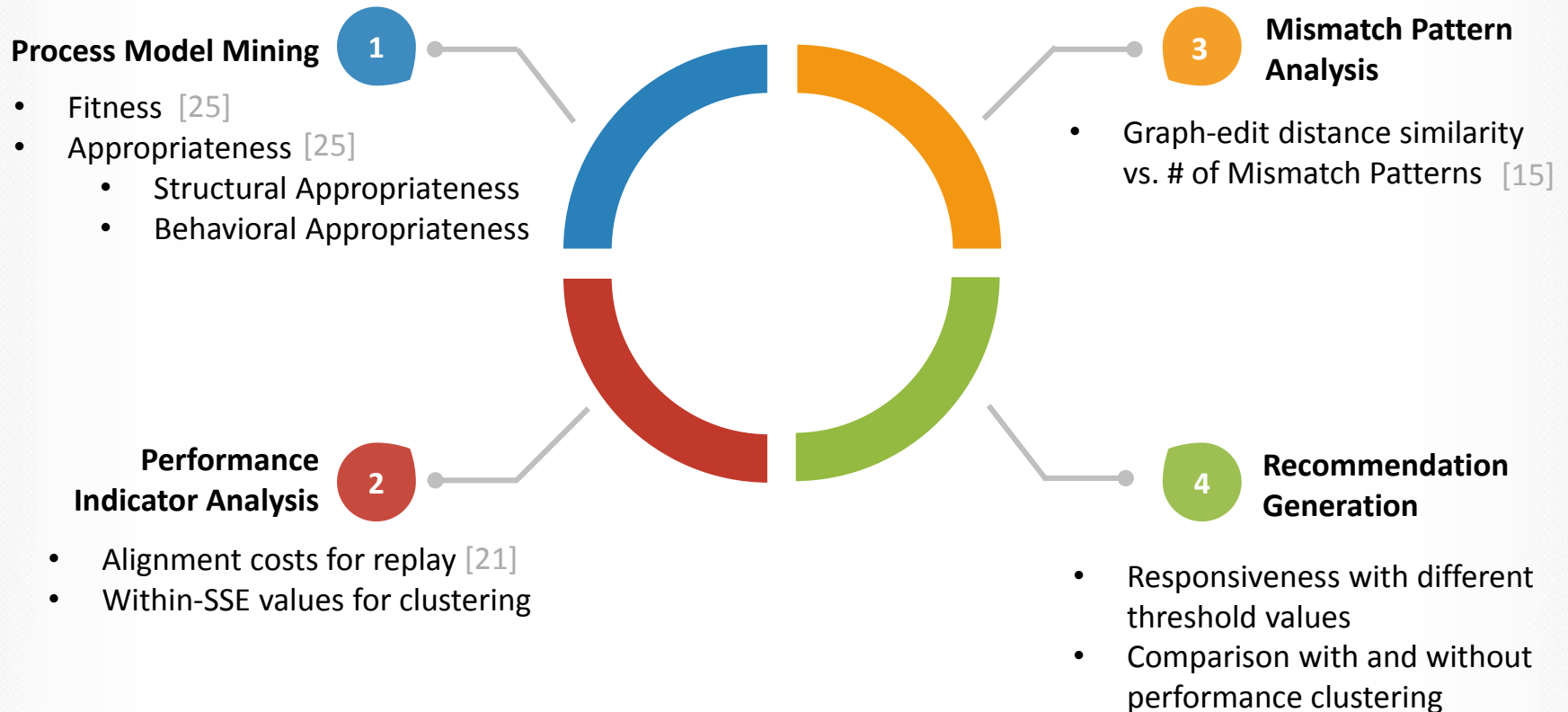
Conclusion & Future Work

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Demonstration

Results & Discussions

Evaluation Metrics



Results & Discussions

Dataset Selection



- **Loan Application Process** [26]
 - Synthetically generated
 - 4 variants of a simple loan application in a financial institute
- **Environmental Permit Application Process** [27]
 - Real-life event log from "Configurable Services for Local Governments (CoSeLoG)" project [13]
 - «Environmental Permit Application Process» of 5 municipalities in Netherlands

Results & Discussions

Loan Application Process

	Cases	Events	Percentage
Variant #1	100	590	24 %
Variant #2	70	420	17 %
Variant #3	200	800	33 %
Variant #4	105	630	26 %

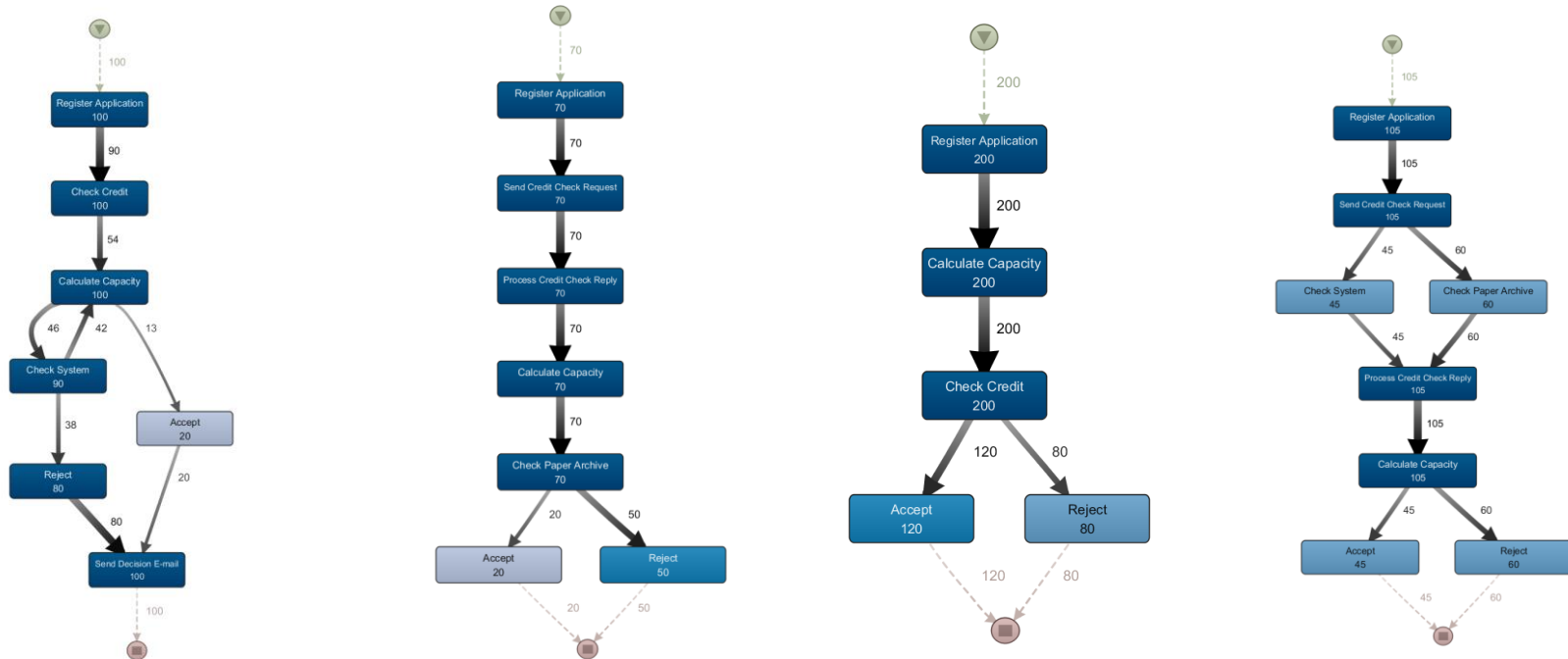
Cases
475

Events
2440

- These variants are used as organizational logs

Results & Discussions

Loan Application Process – Process Model Mining

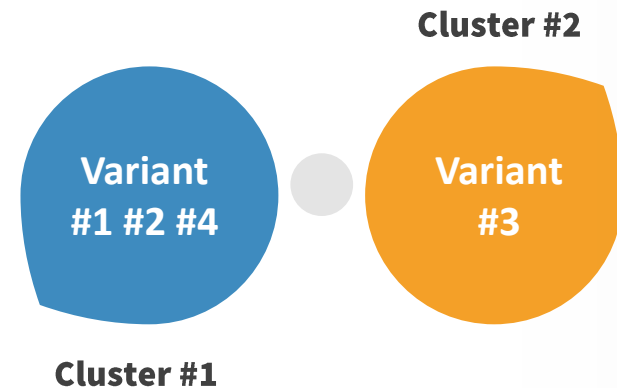
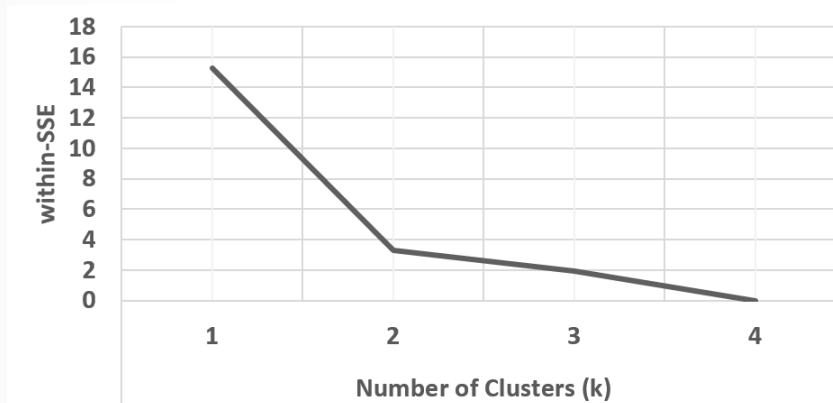


Variant #1	Variant #2	Variant #3	Variant #4
100 % (Fitness)	100 % (Fitness)	100 % (Fitness)	100 % (Fitness)
84.2 % (Avg. App.)	100 % (Avg. App.)	100 % (Avg. App.)	99.1 % (Avg. App.)

Results & Discussions

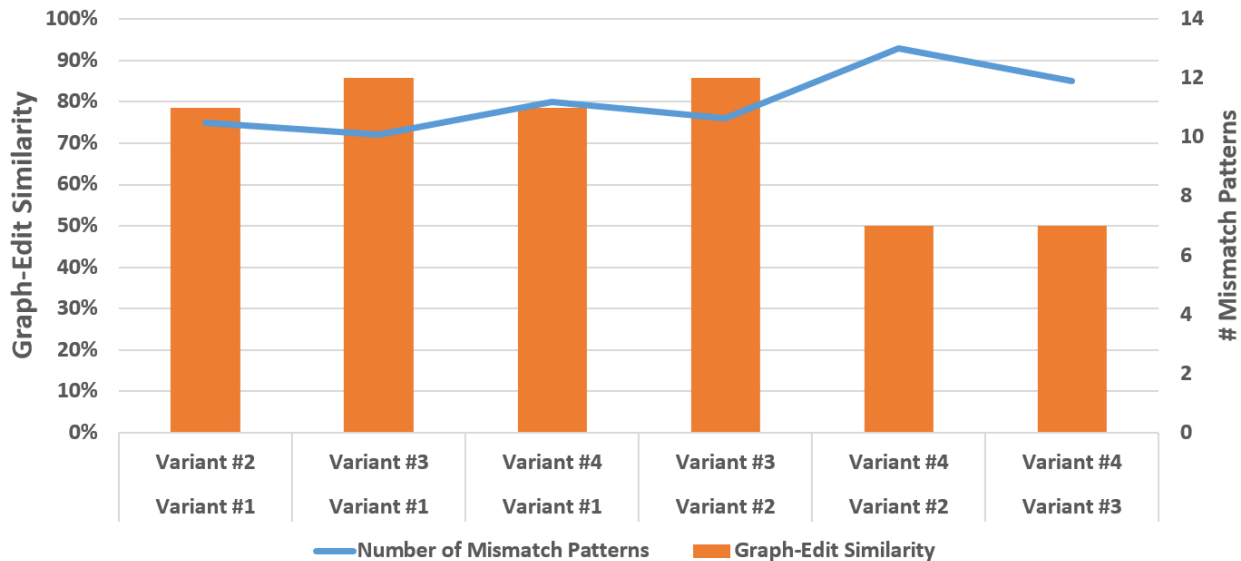
Loan Application Process – Performance Indicator Analysis

- **Clustering:**



Results & Discussions

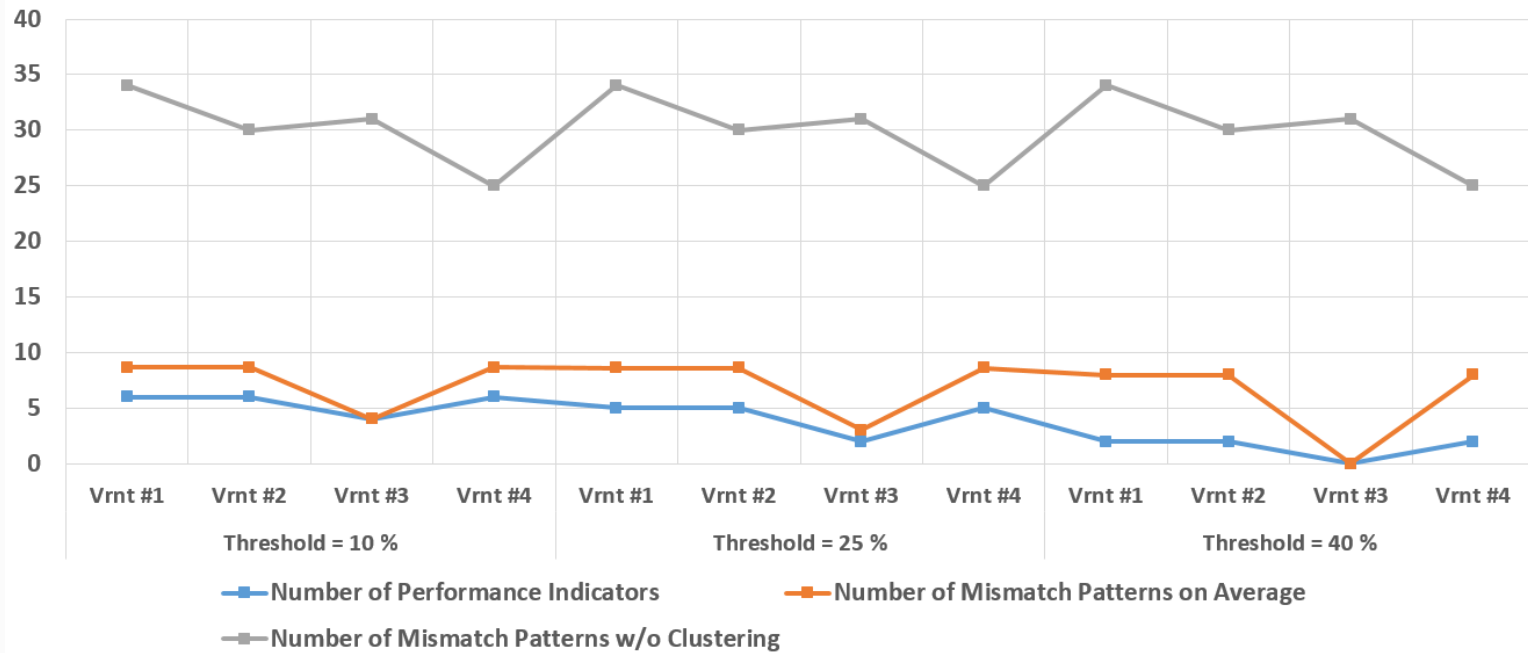
Loan Application Process – Mismatch Pattern Analysis



Correlation between graph-edit similarity and number of mismatch patterns

Results & Discussions

Loan Application Process – Recommendation Generation



- Responsiveness and degree of helping the user to focus on the performance improvement

Results & Discussions

Environmental Permit Application Process

	Cases	Events	Percentage
Municipality #1	54	131	6.1 %
Municipality #2	302	586	27.3 %
Municipality #3	37	73	3.4 %
Municipality #4	340	507	23.7 %
Municipality #5	481	845	39.4 %

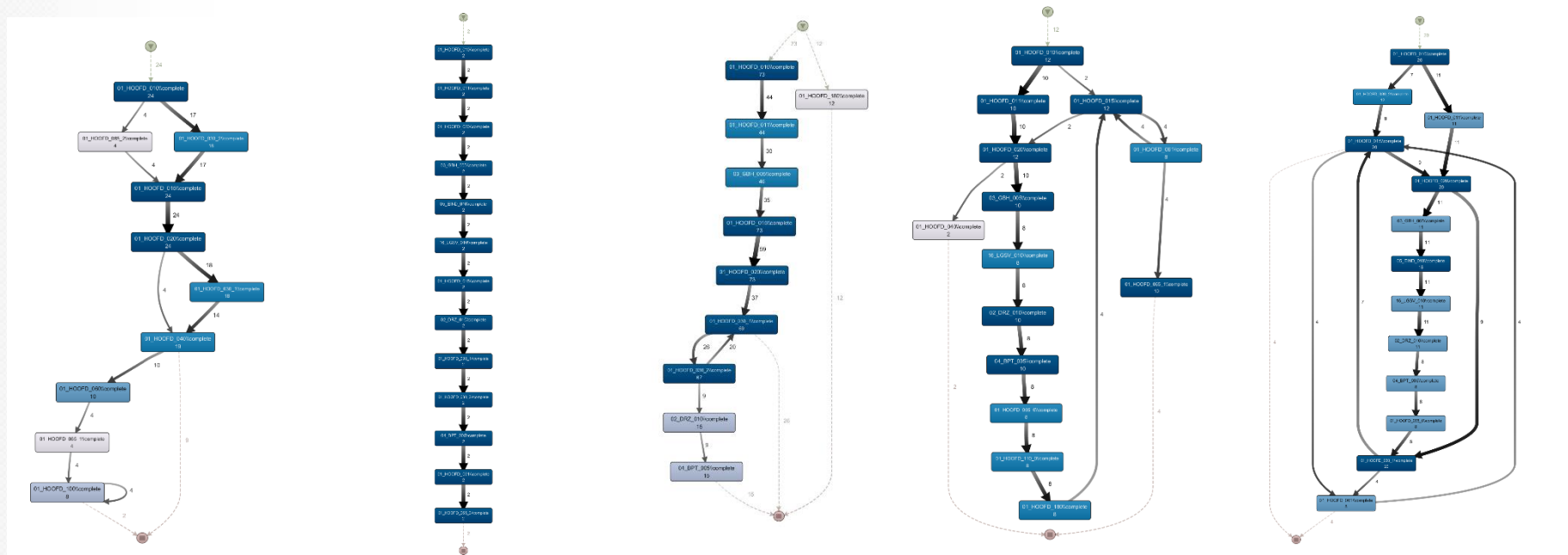
Cases 1214 Events 2142

- Preprocessing is undertaken on the raw dataset [28]
- These municipalities are used as organizational logs

Results & Discussions

Environmental Permit Application Process – Process Model Mining

- 10 to 20 times simplified process models

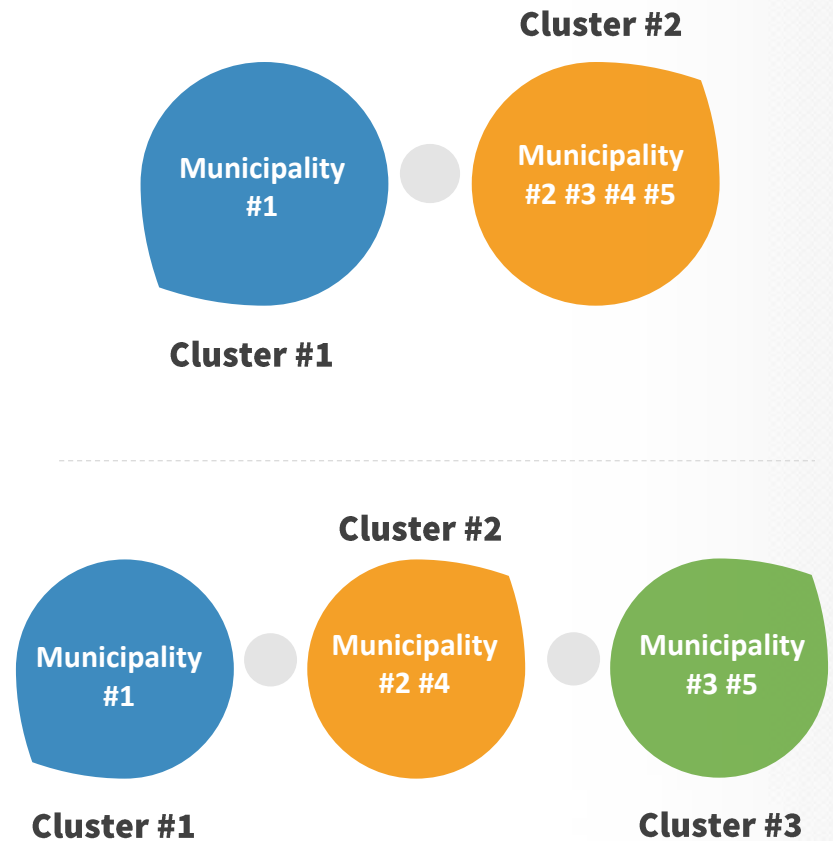
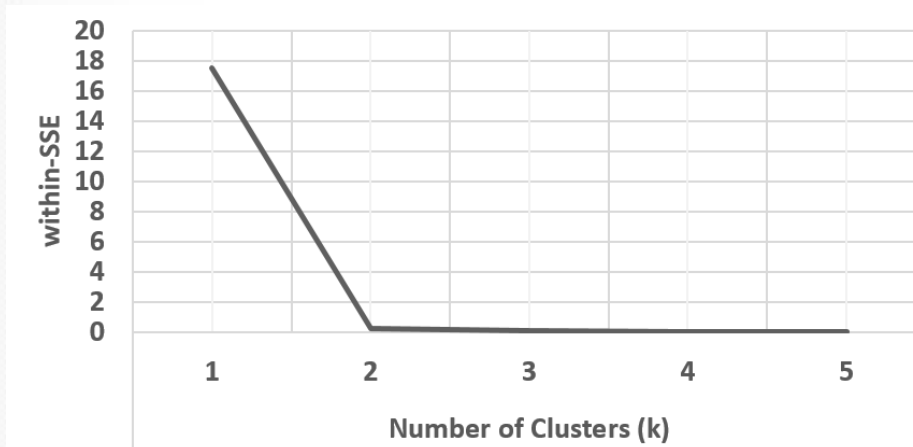


Municipality #1	Municipality #2	Municipality #3	Municipality #4	Municipality #5
86 % (Fitness)	100 % (Fitness)	92.3 % (Fitness)	96.8 % (Fitness)	94.5 % (Fitness)
76 % (Avg. App.)	100 % (Avg. App.)	69.1 % (Avg. App.)	64.9 % (Avg. App.)	49.3 % (Avg. App.)

Results & Discussions

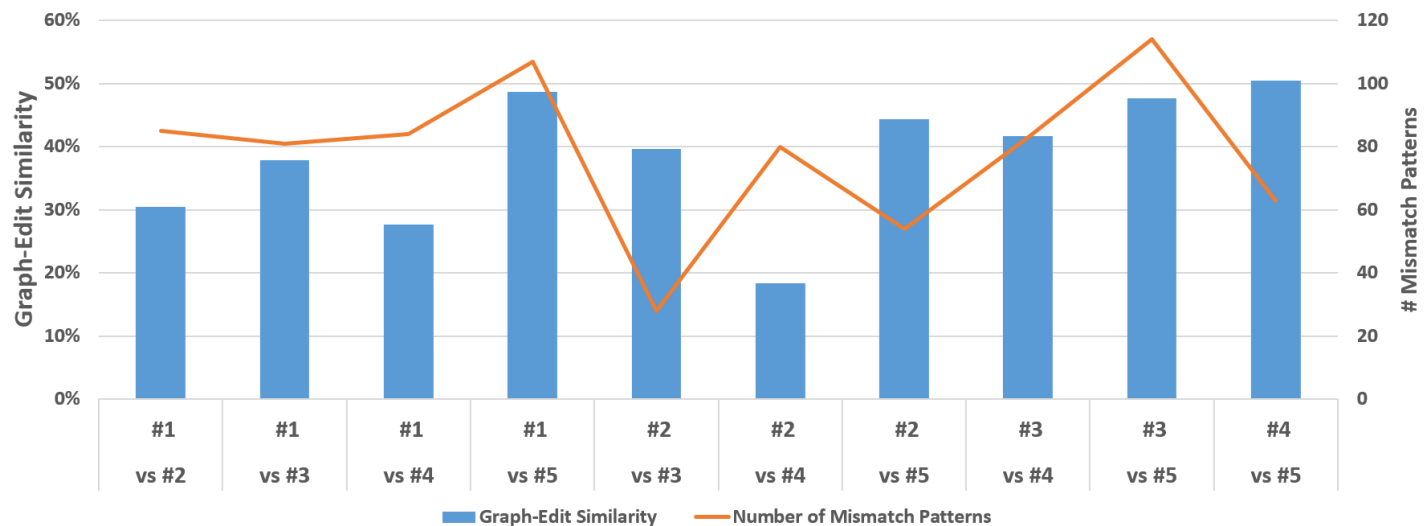
Environmental Permit Application Process – Performance Indicator Analysis

- Clustering:**



Results & Discussions

Environmental Permit Application Process – Mismatch Pattern Analysis

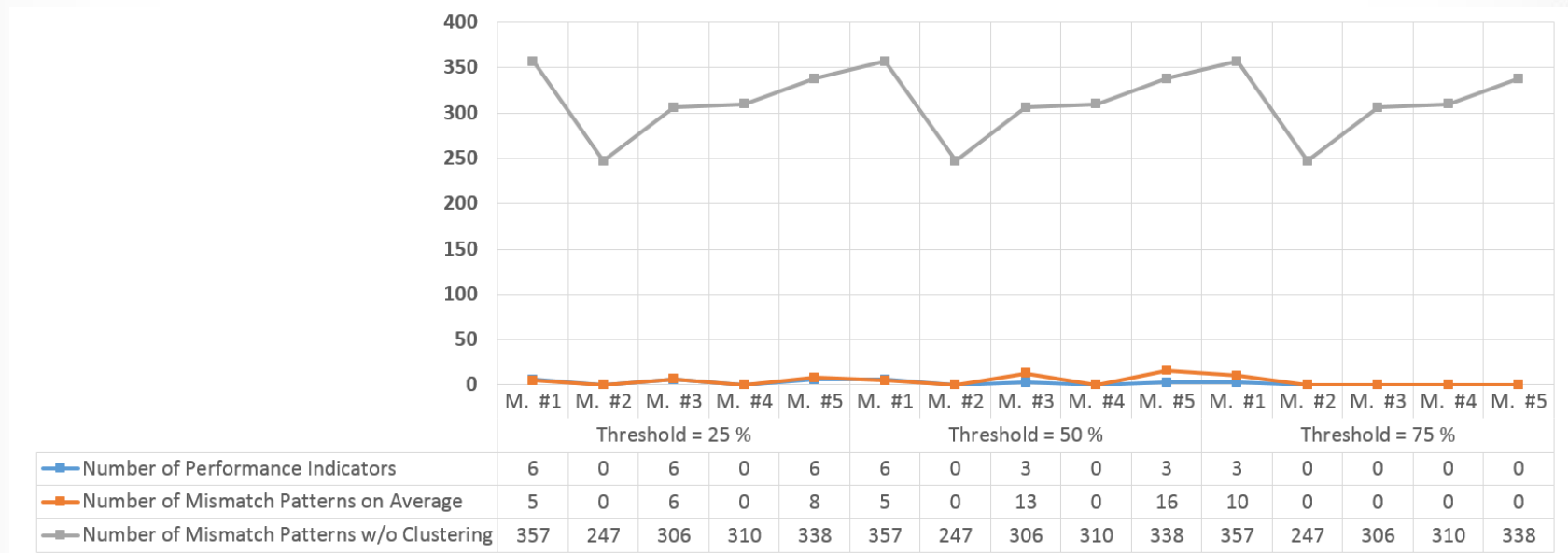


- Correlation between graph-edit similarity and number of mismatch patterns except Municipality #4 and #5

Results & Discussions

Environmental Permit Application Process – Recommendation Generation

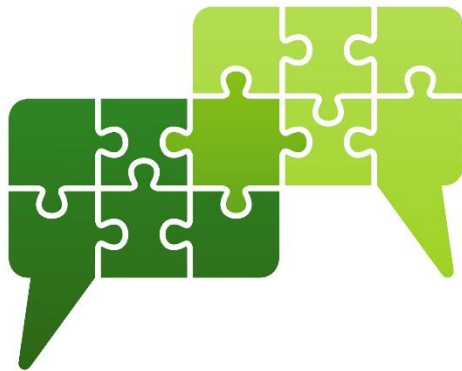
(with 3 clusters)



- Learning opportunities increases as number of cluster increases
- Number of mismatch patterns to check significantly decreases with performance clustering

Results & Discussions

Discussions



- Mismatch analysis stage:
 - Differences in accordance with similarity metrics
 - Information value of mismatch patterns are not equal
- Recommendation generation stage:
 - Performance clustering helps to focus on differences
 - 3 times less in Loan Application Process Dataset
 - 100 times less in Environmental Permit Application Process Dataset

Results & Discussions

Discussions



- Business value of generated recommendations:
 - Results may be
 - important or
 - infeasible and irrelevant for business environment
 - Some insights about results can be provided but business environment and case related assessment is important.

Results & Discussions

Discussions

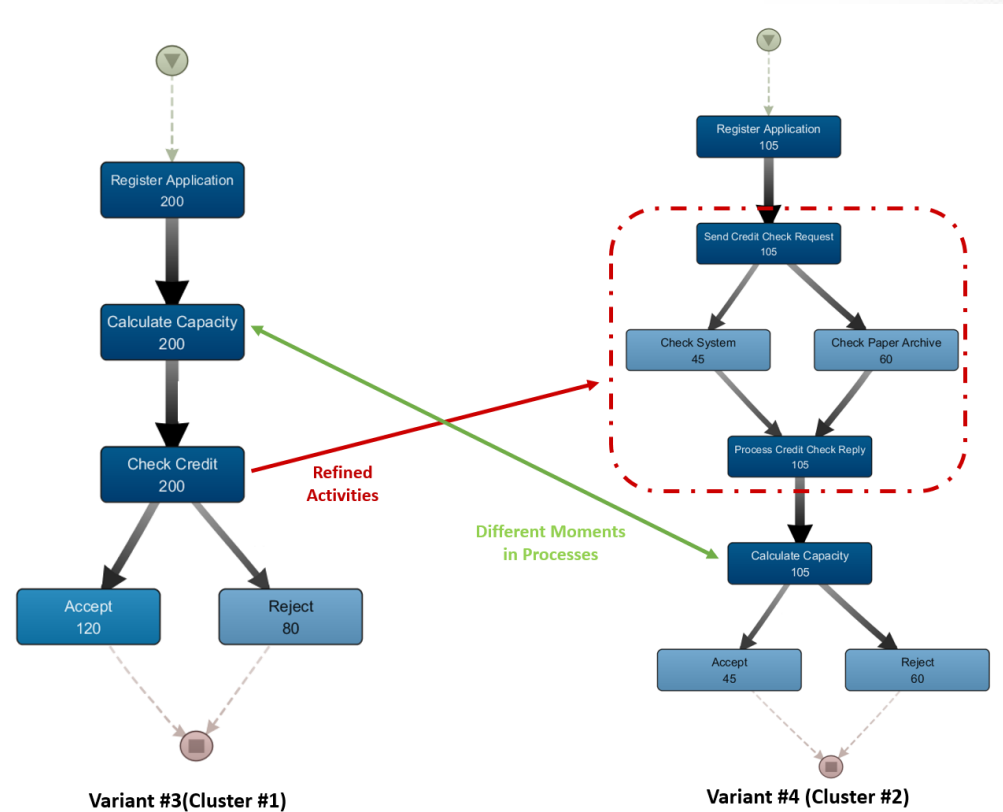
In **Loan Application Process**,

Variant #4 performs better

- 27 % on average time and
- 12 % on standard deviation time

between activities

Calculate Capacity → Accept



Process models between activities «Calculate Capacity» and «Accept»

Results & Discussions

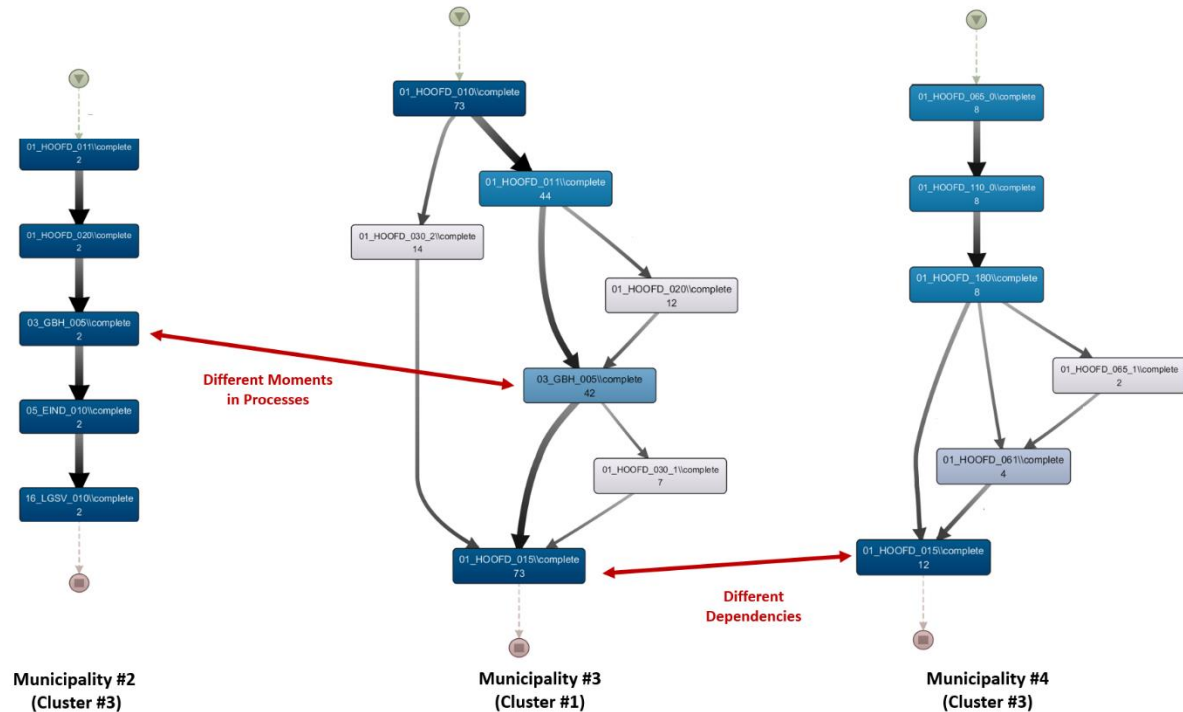
Discussions

In **Environmental Permit Application Process**, Municipality #3 performs worse

- 40 % on average time and
- 53 % on standard deviation time

between activities

01_HOOFD_010 →
01_HOOFD_015



Simplified process models between activities «01_HOOFD_010» and «01_HOOFD_015»

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Conclusion



- Cross-organizational process mining is applied
 - Unsupervised learning with predictor variables as performances of organizations
 - In an environment where processes are executed on several organizations
- Results show that it is possible to use cross-organizational process mining and mismatch patterns for performance improvement recommendations

Conclusion

- A four-stage solution is presented and their performances are explained



Conclusion

Future Work



- Process mining stage:
 - Different techniques can be used to mine complex process models
- Performance indicator stage:
 - New indicators based on business environment and needs

Conclusion

Future Work



- Mismatch pattern analysis:
 - New patterns can be introduced
- Recommendation generation:
 - Domain or BPM expertise to assess the quality of recommendations

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ProM Implementation

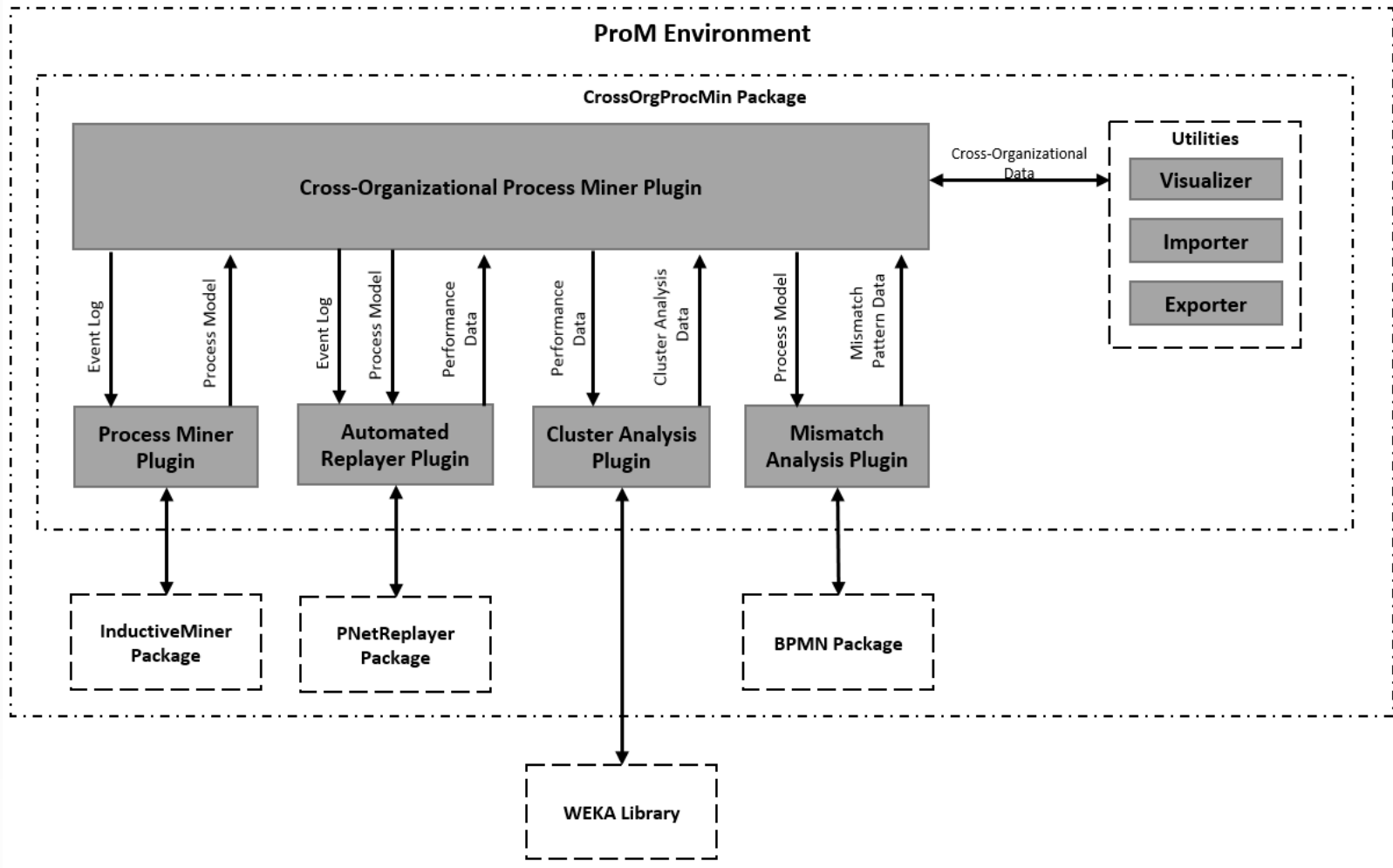


- ProM, extensible framework that supports a wide variety of process mining techniques in form of plugins [24]
- Widely accepted in industry and academia with an active community
- Developed set of plugins are packaged with the name of «**CrossOrgProcMin**» and published on Github.



onuryilmaz/cross-orc-proc-min

ProM Implementation



Demonstration



Also available on YouTube
<http://youtu.be/T92UrRfl3r0>

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Questions & Comments



Thank you for your
attention!



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