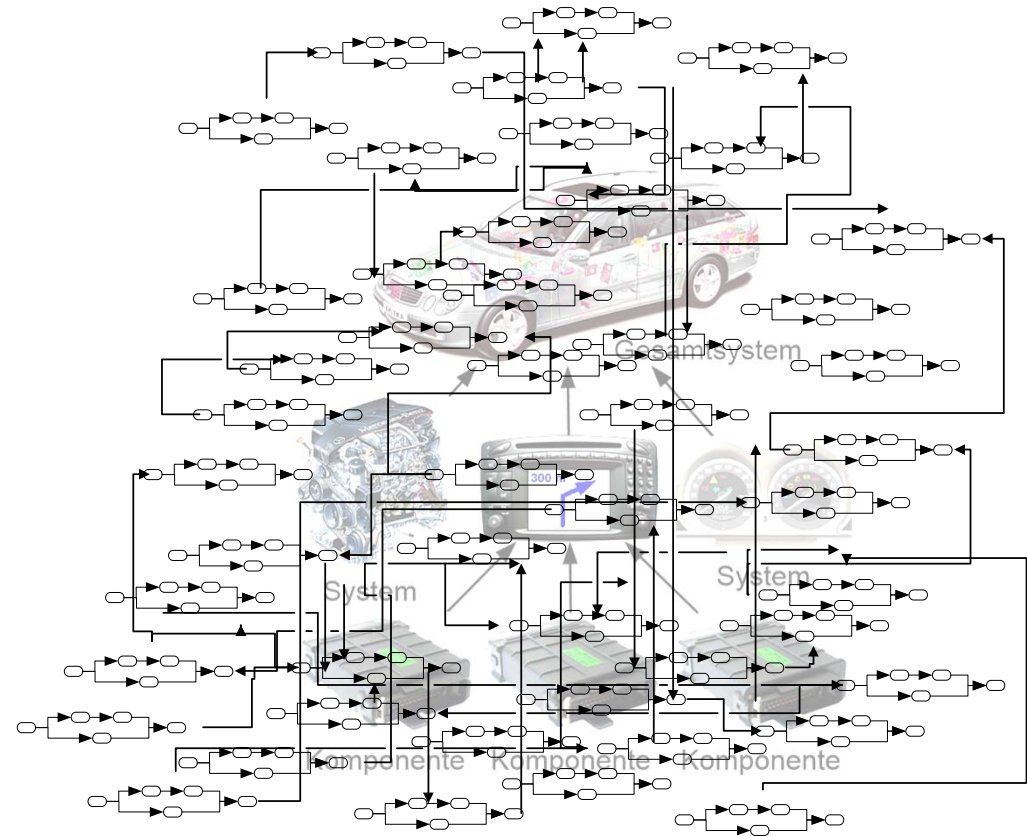


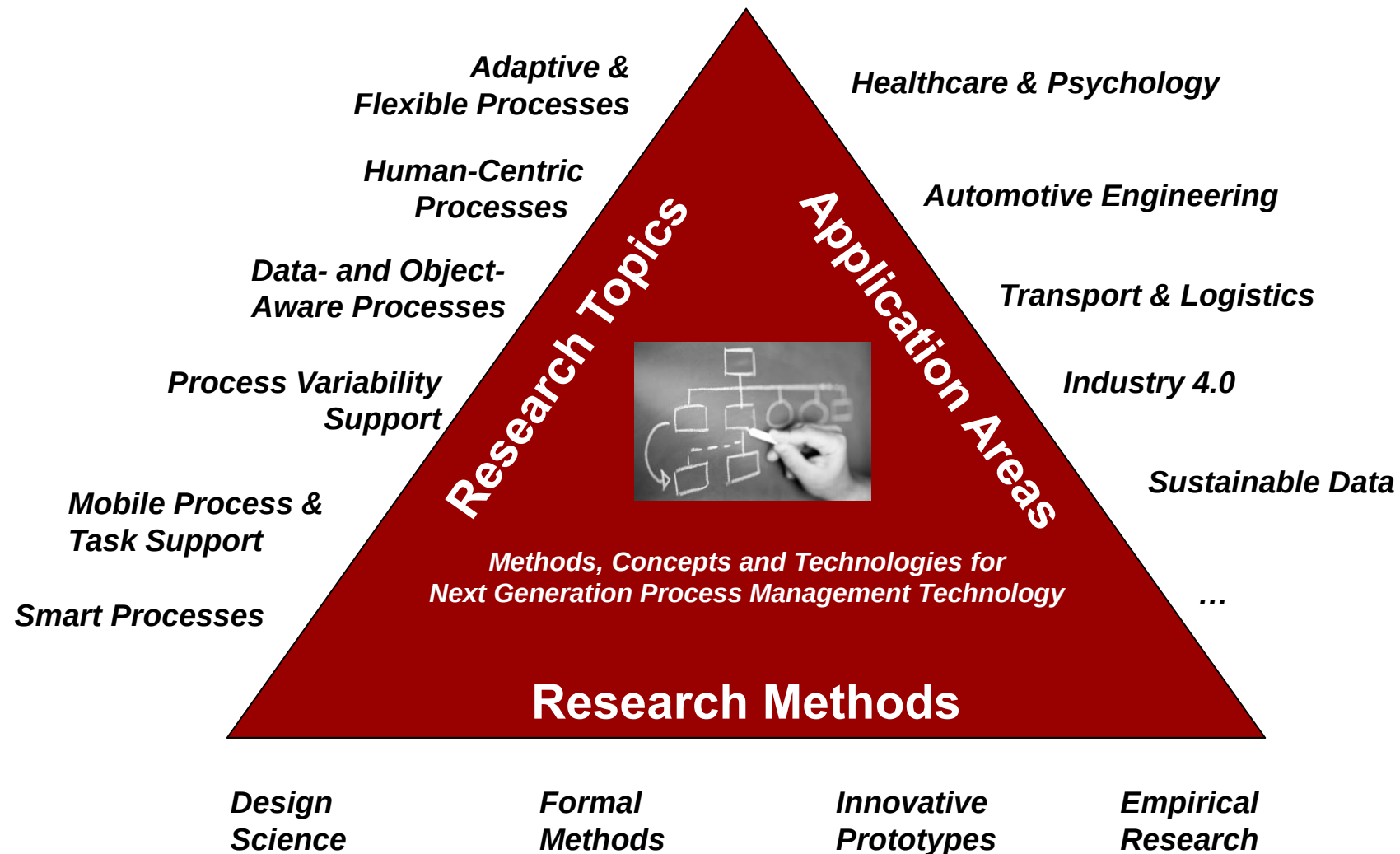


Data-centric Approaches to Business Process Management: Fundamental Concepts, Tool Support, Open Challenges

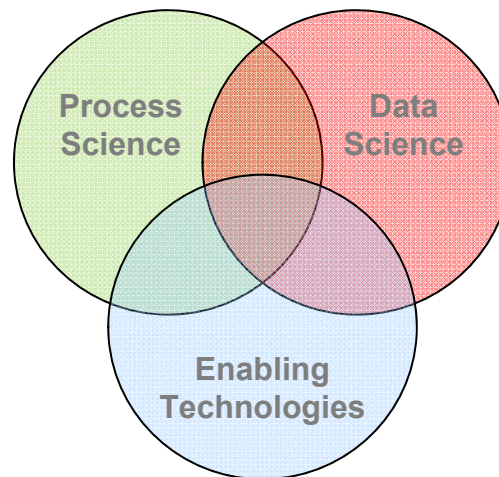
Manfred Reichert

www.uni-ulm.de/dbis

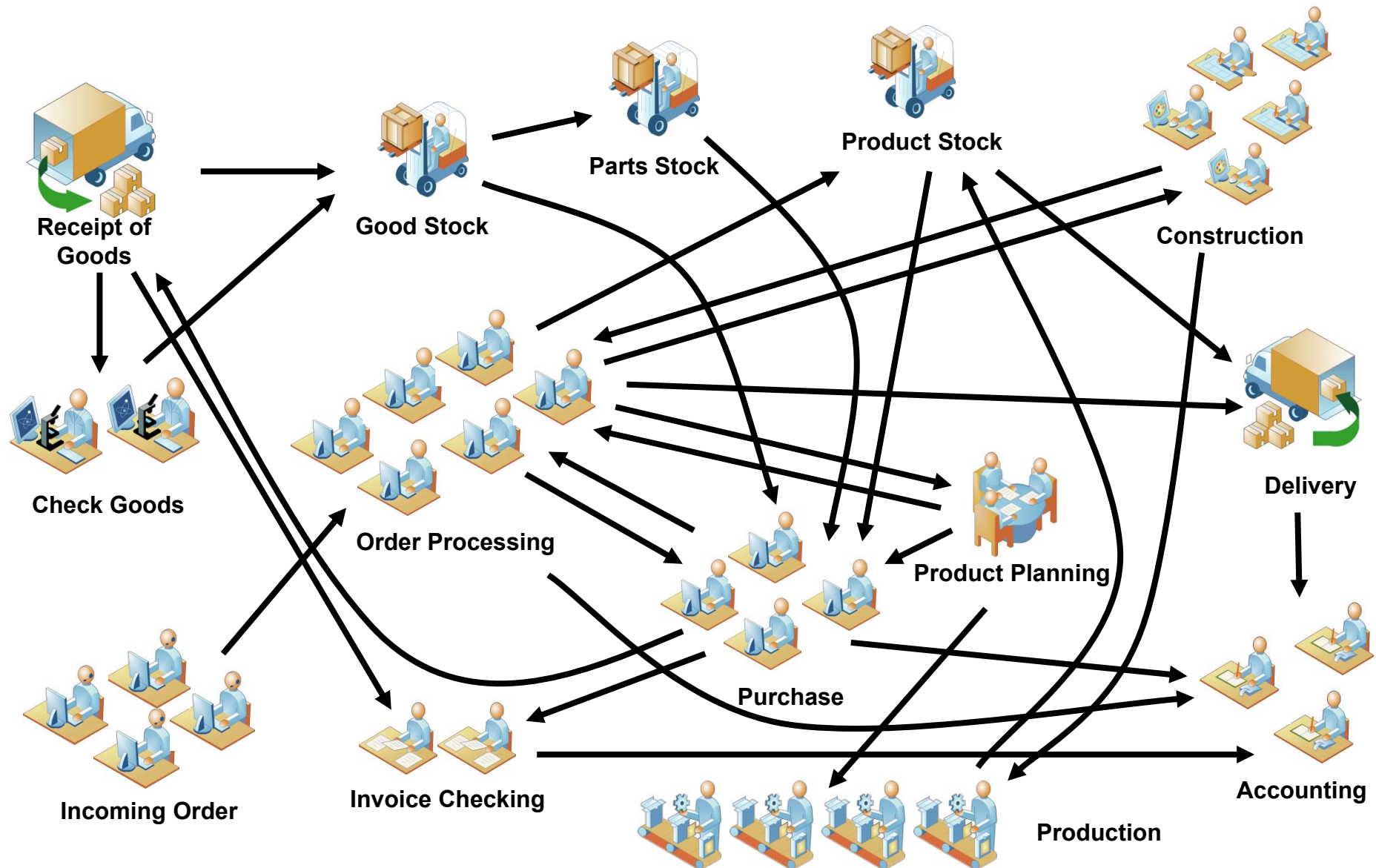
BPM Research at Ulm University



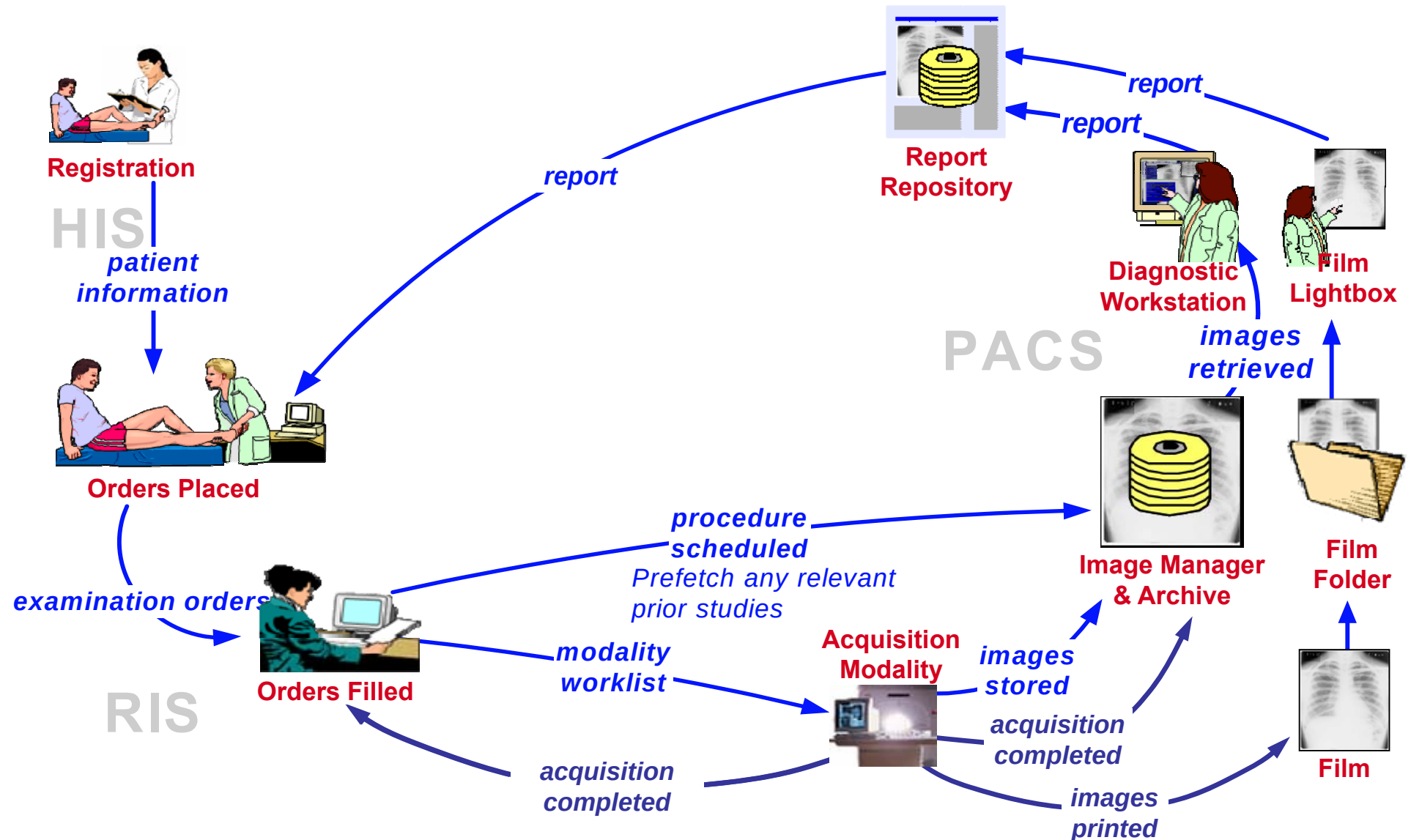
A Review of Previous BPM Research Projects



Scenario 1: Cross-Departmental Business Processes

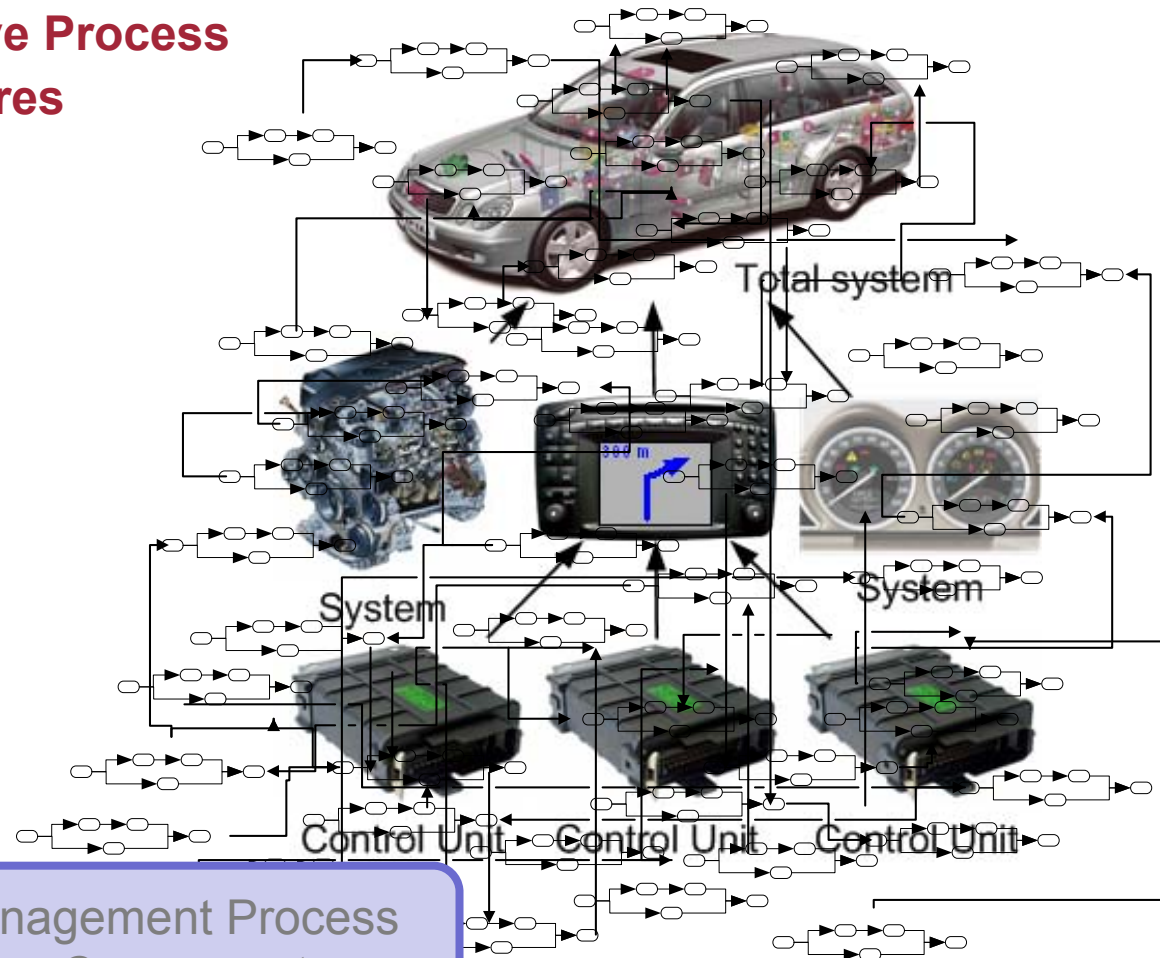


Scenario 2: Process-Centric Resource and Application Integration



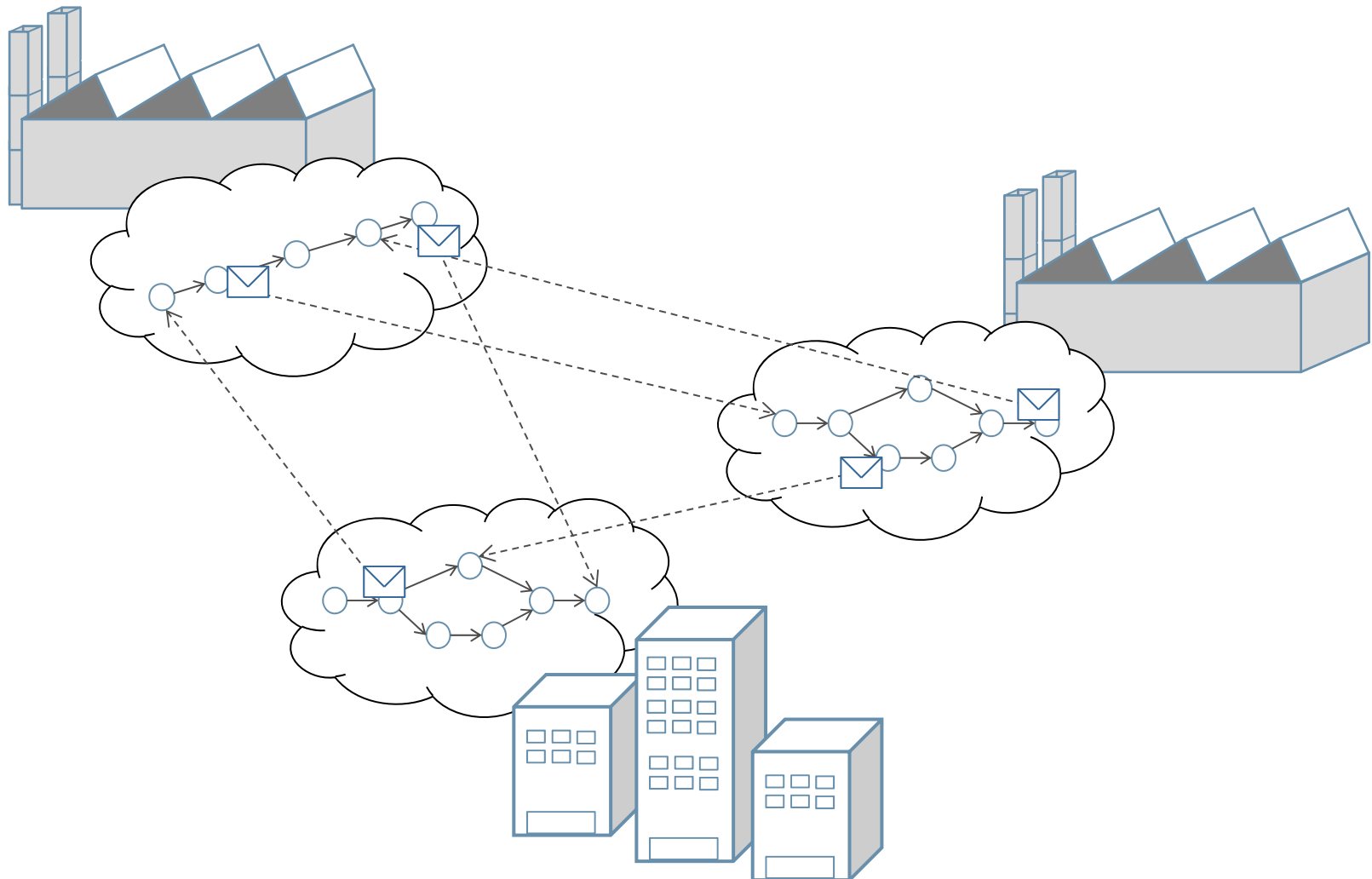
Scenario 3: Large Collective Process Structures

Large Collective Process Structures

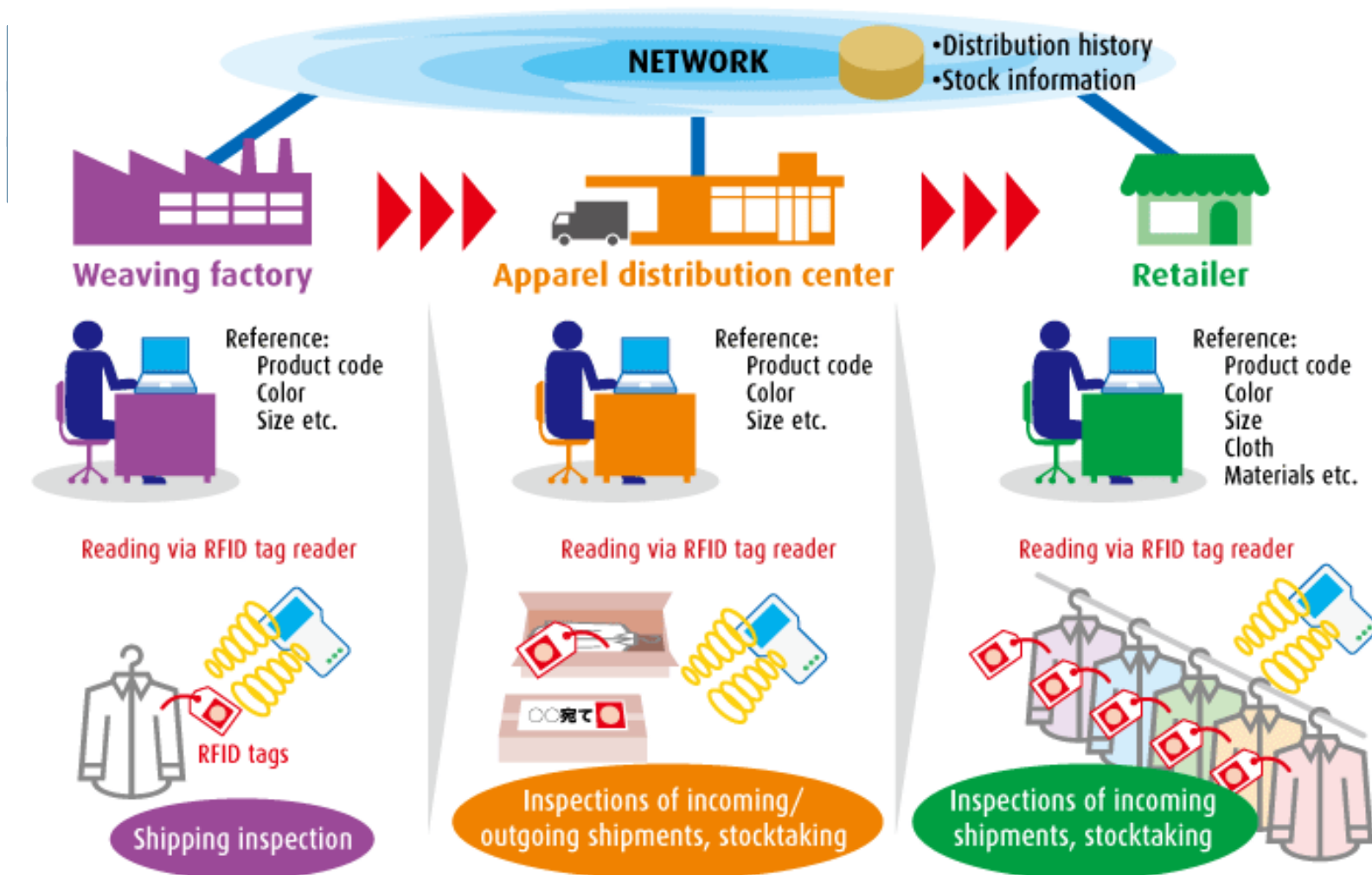


Release Management Process
for E/E Car Components

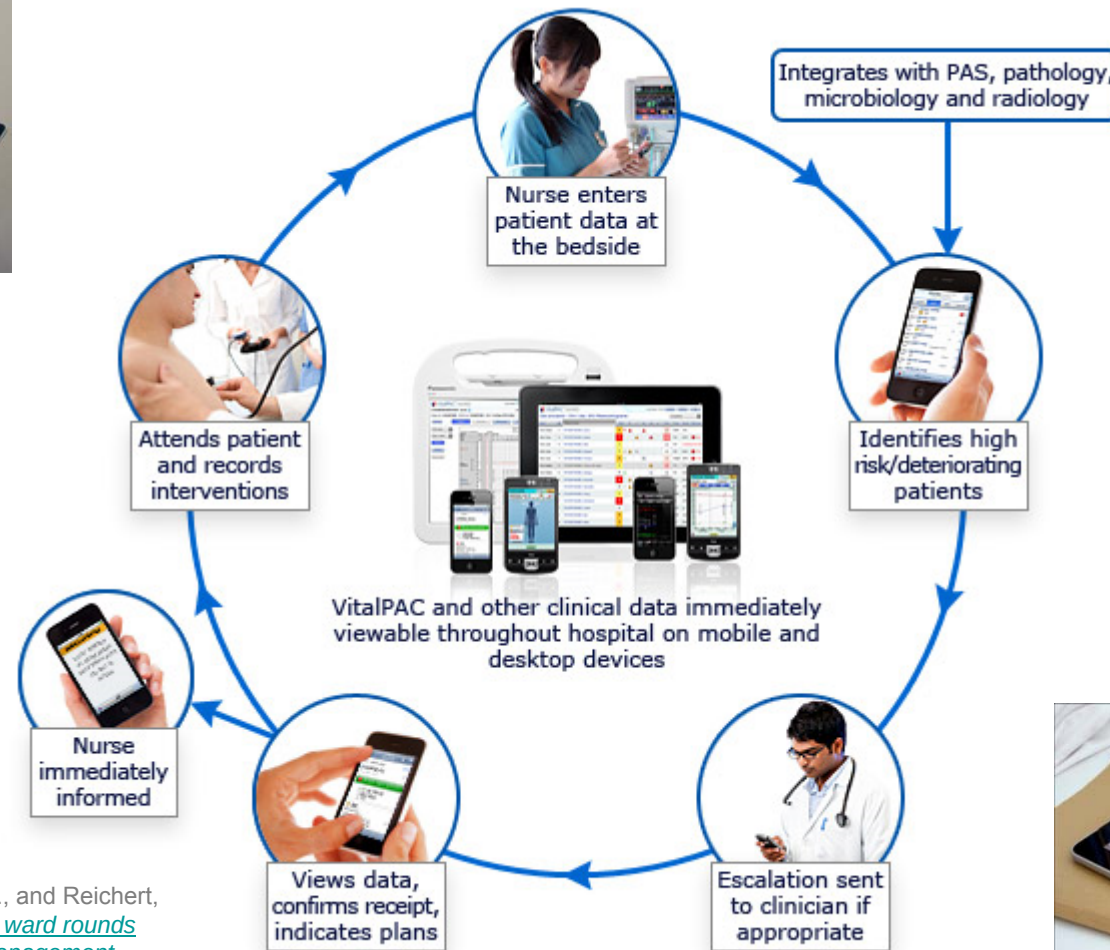
Scenario 4: Cross-Organizational Processes with Real-World Assets



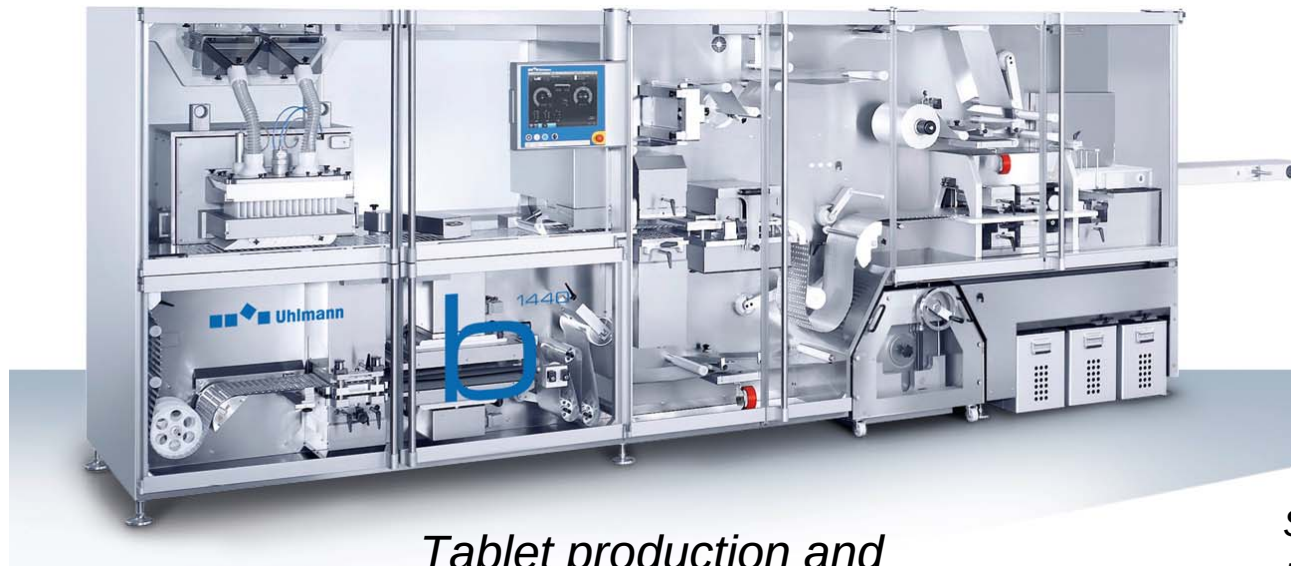
Scenario 4: Cross-Organizational Processes with Real-World Assets



Scenario 5: Mobile Processes



Scenario 6: Processes in a Cyber-Physical World



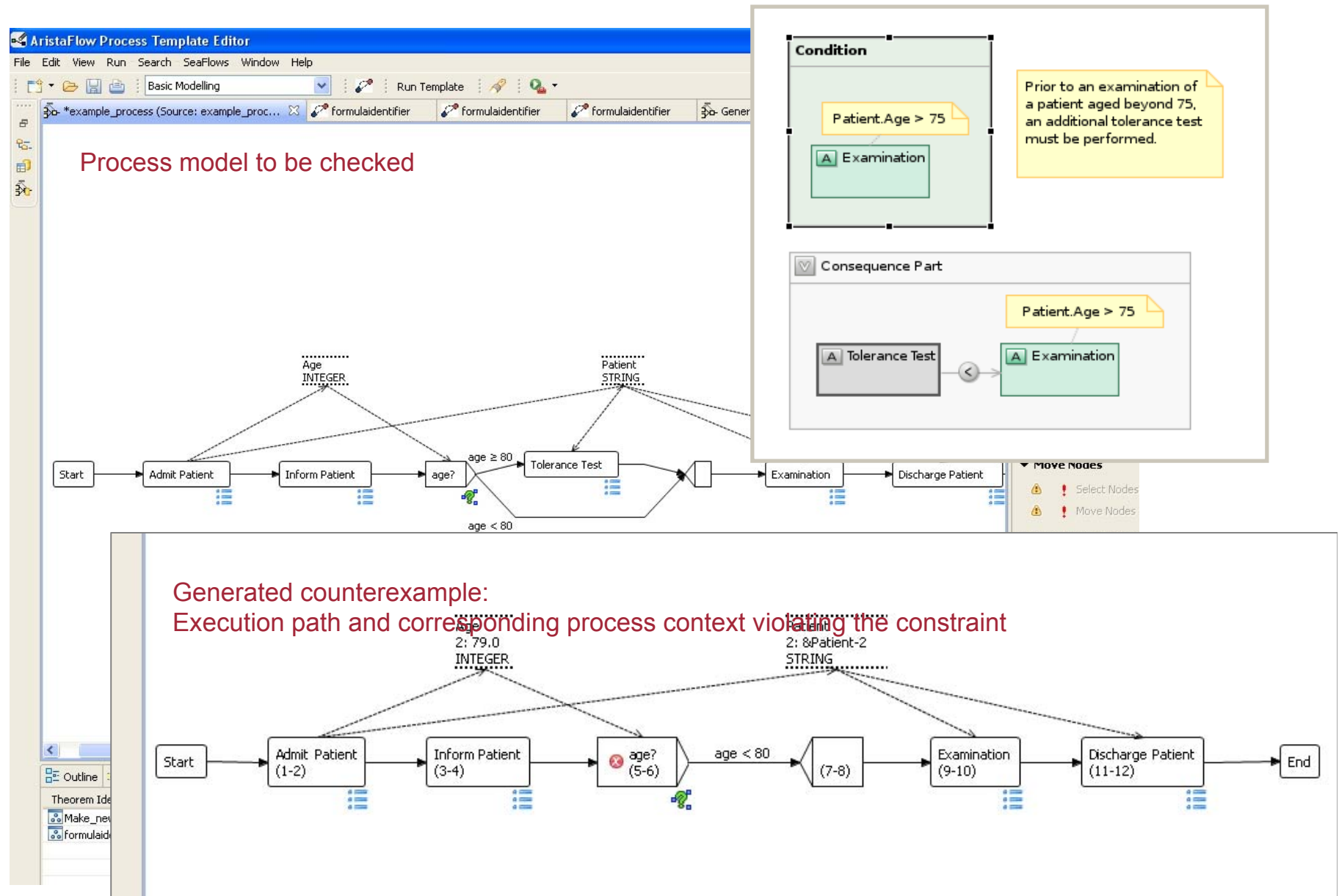
*Tablet production and
line with packing machines*

*Specific machines,
Integrated in one line:*

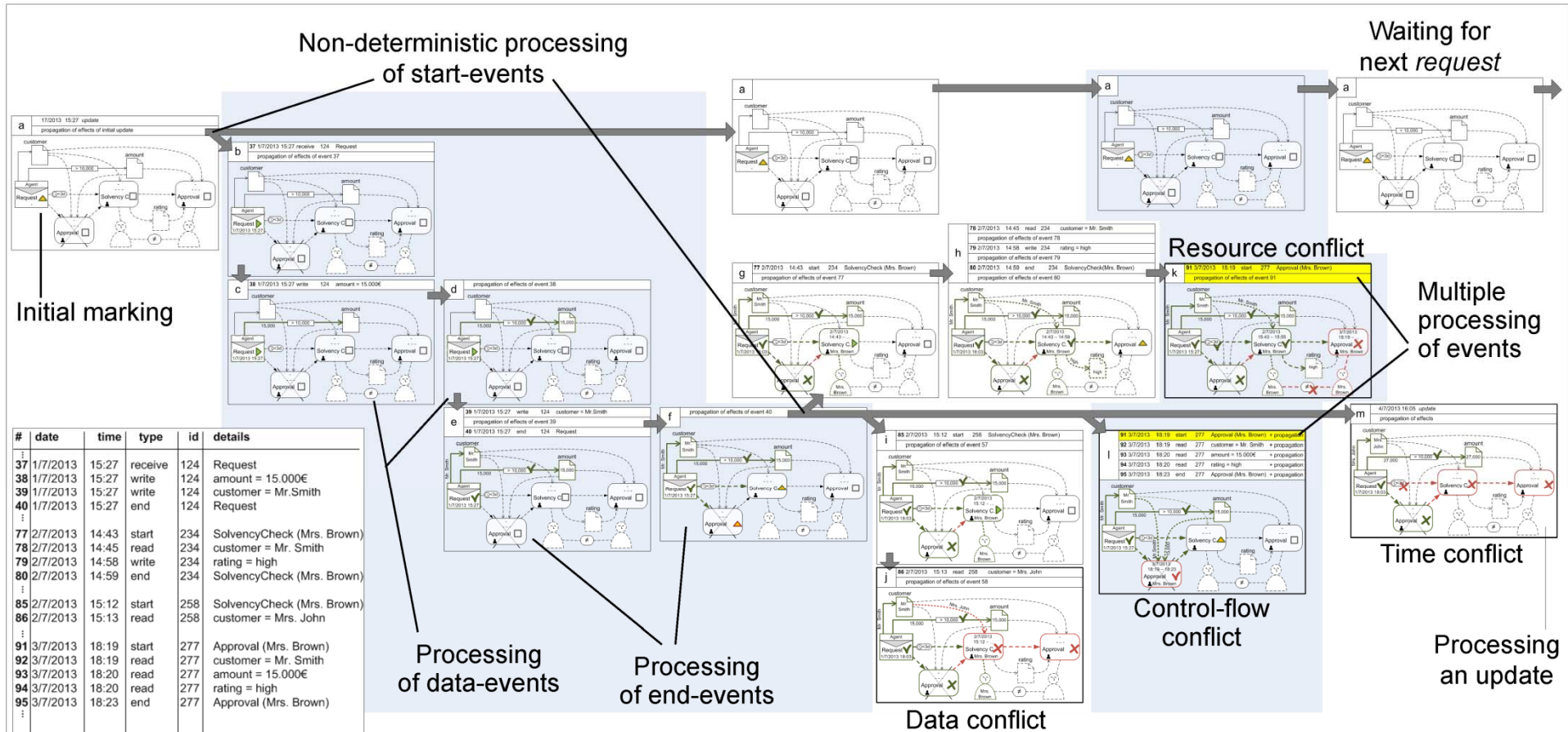
- *Blister packing*
- *Box packing*
- *Patient information leaflet*
- *Carton packaging*
- ...



SeaFlows: Process Compliance



C³Pro: Multi-Perspective Compliance Monitoring

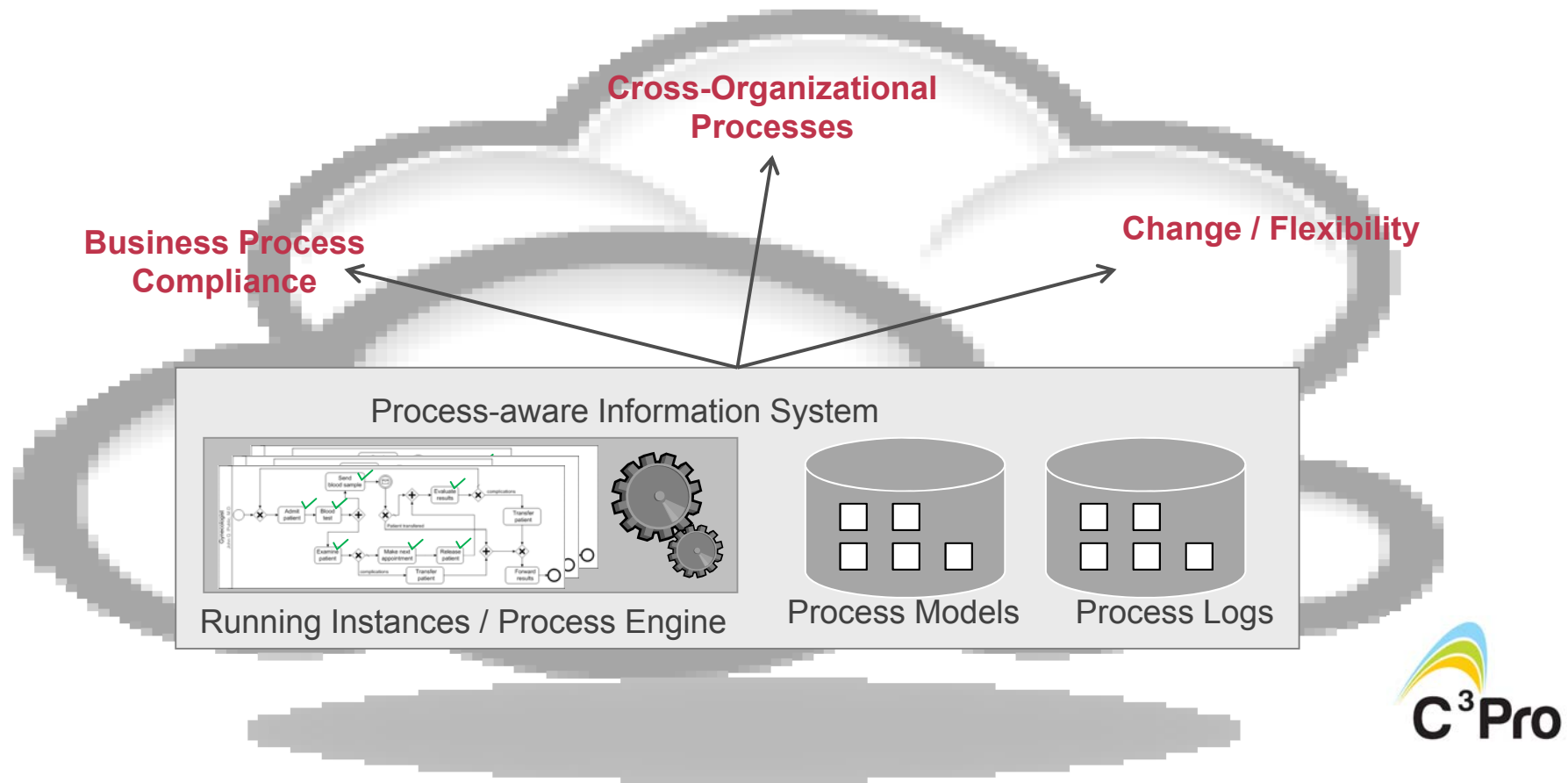


D. Knuplesch, M. Reichert, A. Kumar (2015): Visually Monitoring Multiple Perspectives of Business Process Compliance. BPM 2015: 263-279

Knuplesch, David and Reichert, Manfred (2017) *A Visual Language for Modeling Business Process Compliance Rules*. Software & Systems Modeling, Springer, Vol. 16, pp. 715-736

Knuplesch, David and Reichert, Manfred and Kumar, Akhil (2017) *A framework for visually monitoring business process compliance*. Information Systems, Elsevier, Vol. 64, pp. 381-409

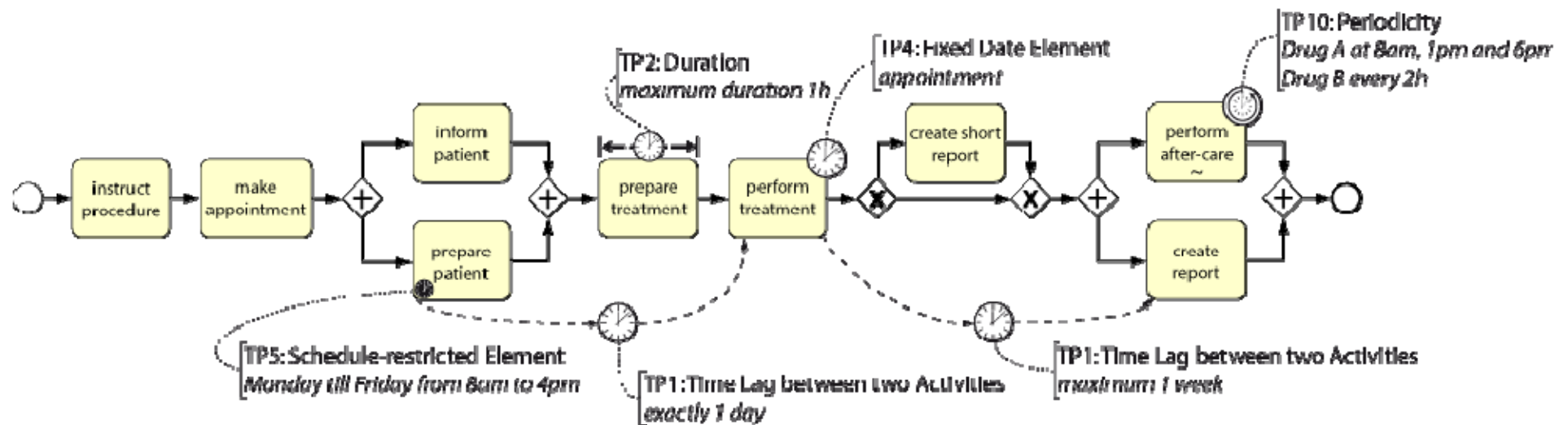
C³Pro: Compliance in Cross-Organizational Processes



Fdhila, C. Indiono, S. Rinderle-Ma, M. Reichert: Dealing with change in process choreographies: Design and implementation of propagation algorithms. Information Systems 49: 1-24 (2015)

D. Knuplesch, W. Fdhila, M. Reichert, S. Rinderle-Ma (2015) Detecting the Effects of Changes on the Compliance of Cross-organizational Business. ER 2015

ATAPIS: Time-Aware Processes

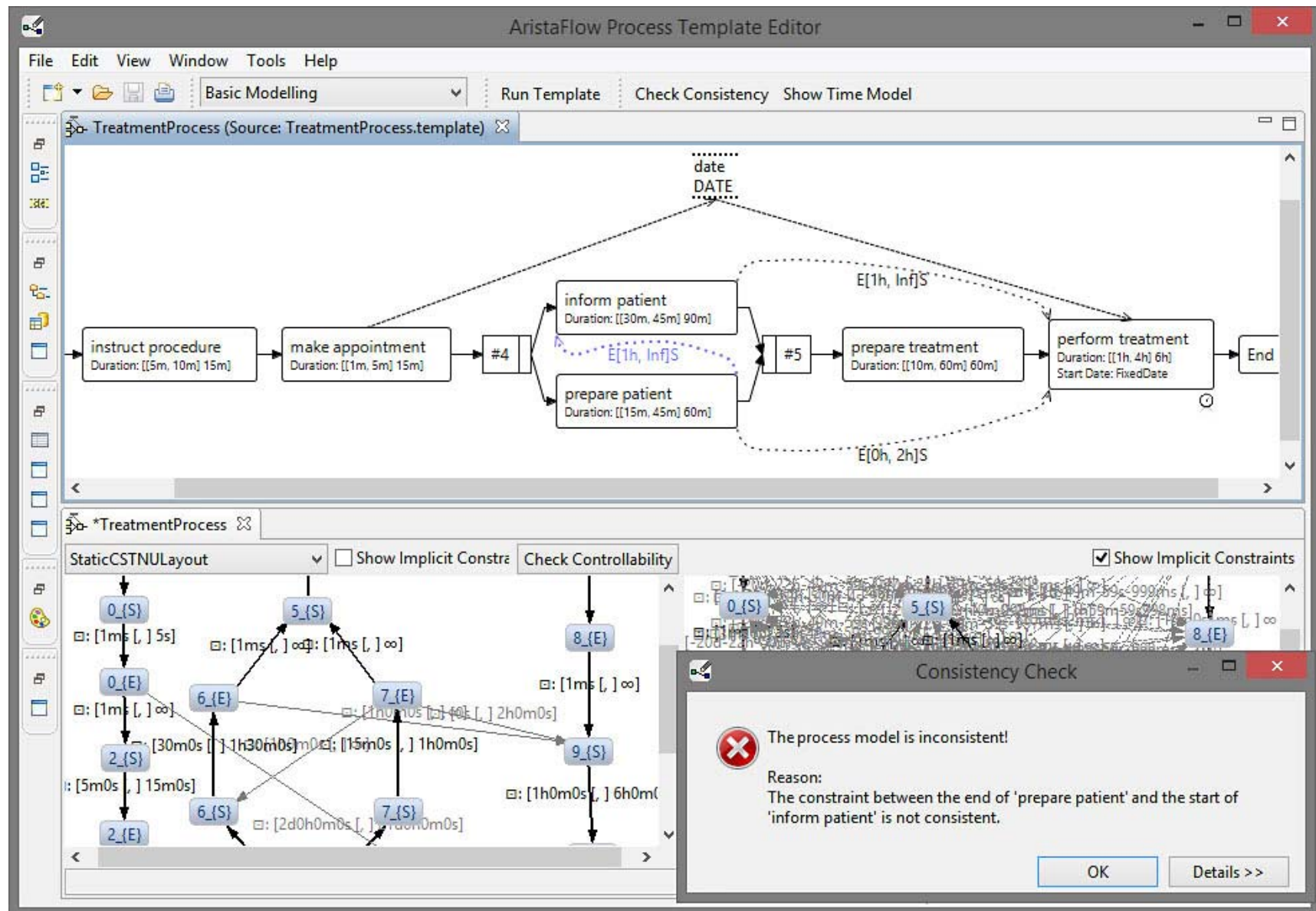


Lanz A., Weber B., Reichert, M. (2014): Time-Patterns for Process-Aware Information Systems. Requirements Engineering, 19(2): 113-141

Lanz A., Reichert M., Weber B. (2016): Process Time Patterns – A Formal Foundation. Information Systems, 57:38-68

Lanz A., Reichert M. (2014) Dealing with Changes of Time-Aware Processes. BPM 2014, pp. 217-233

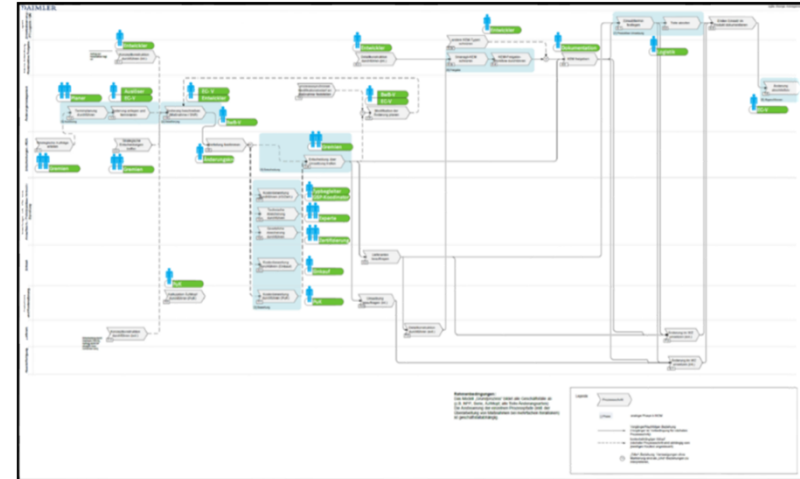
ATAPIS:Time-Aware Processes



ENPROSO: Aligning Business and Executable Process Models

Business Level

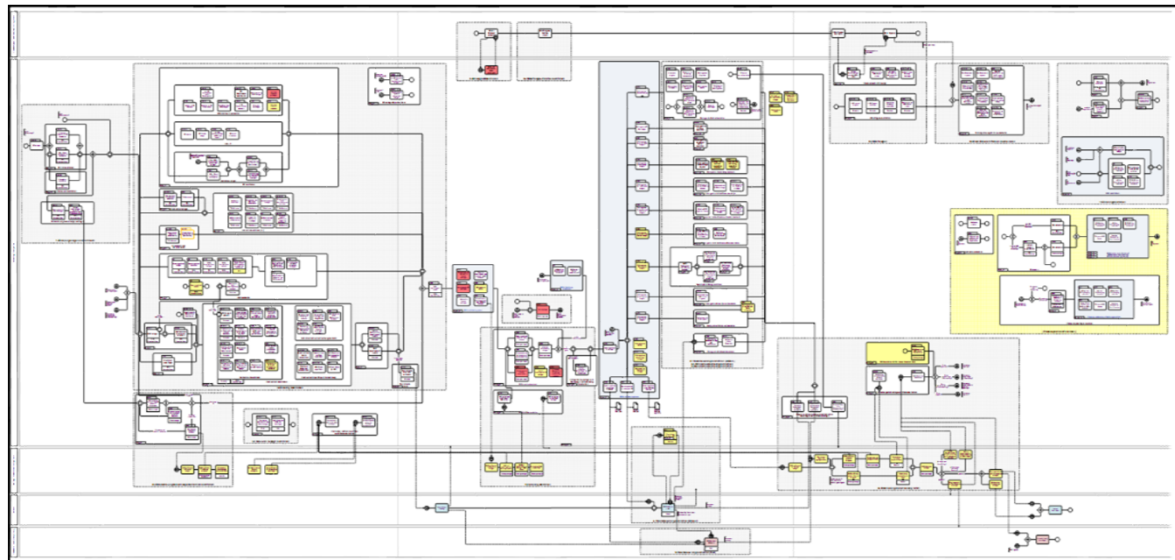
Model created by
domain expert



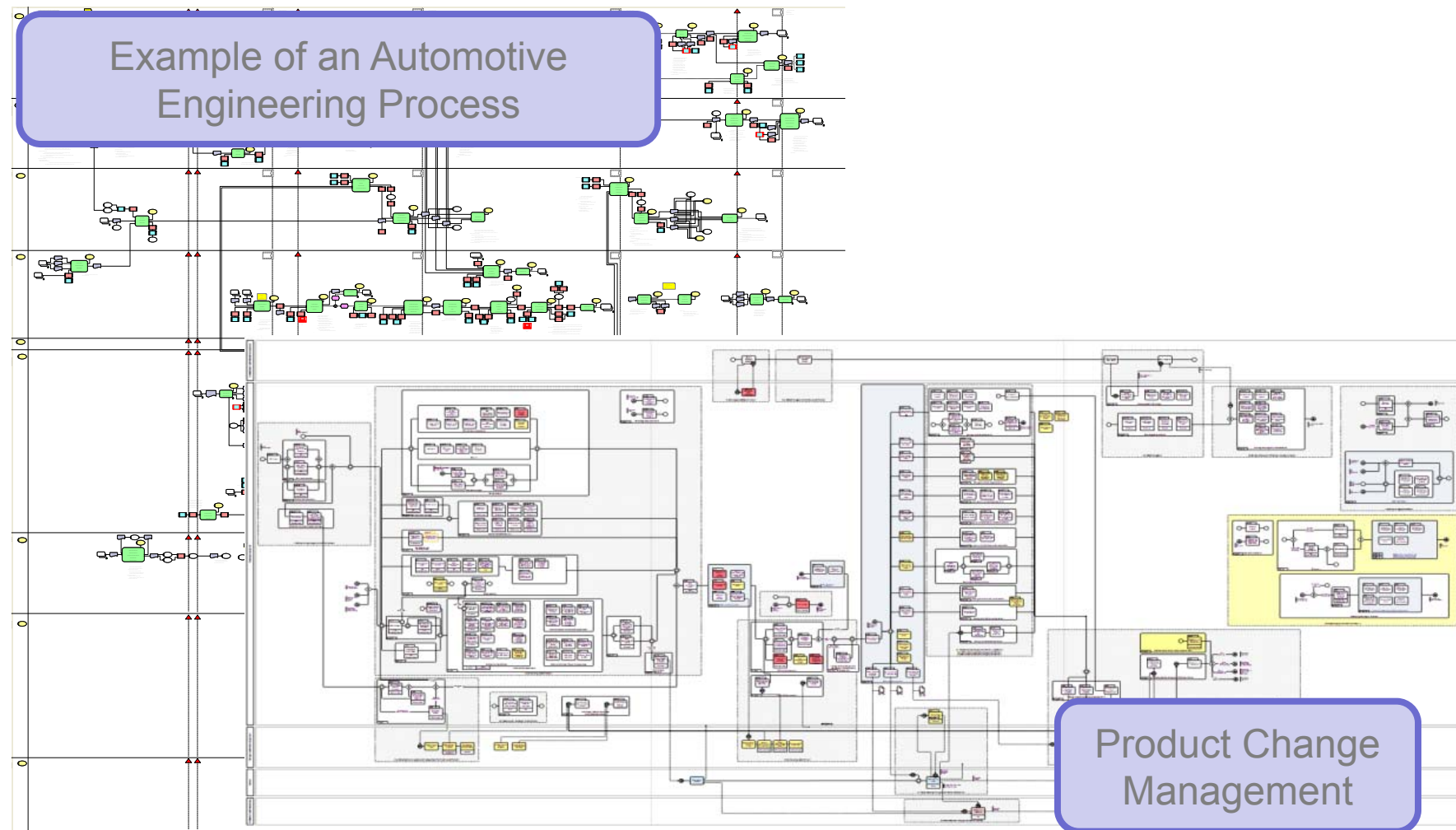
Model created by
IT expert



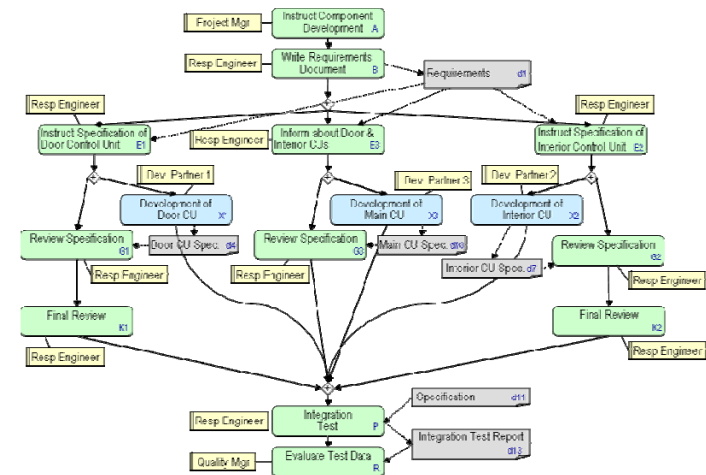
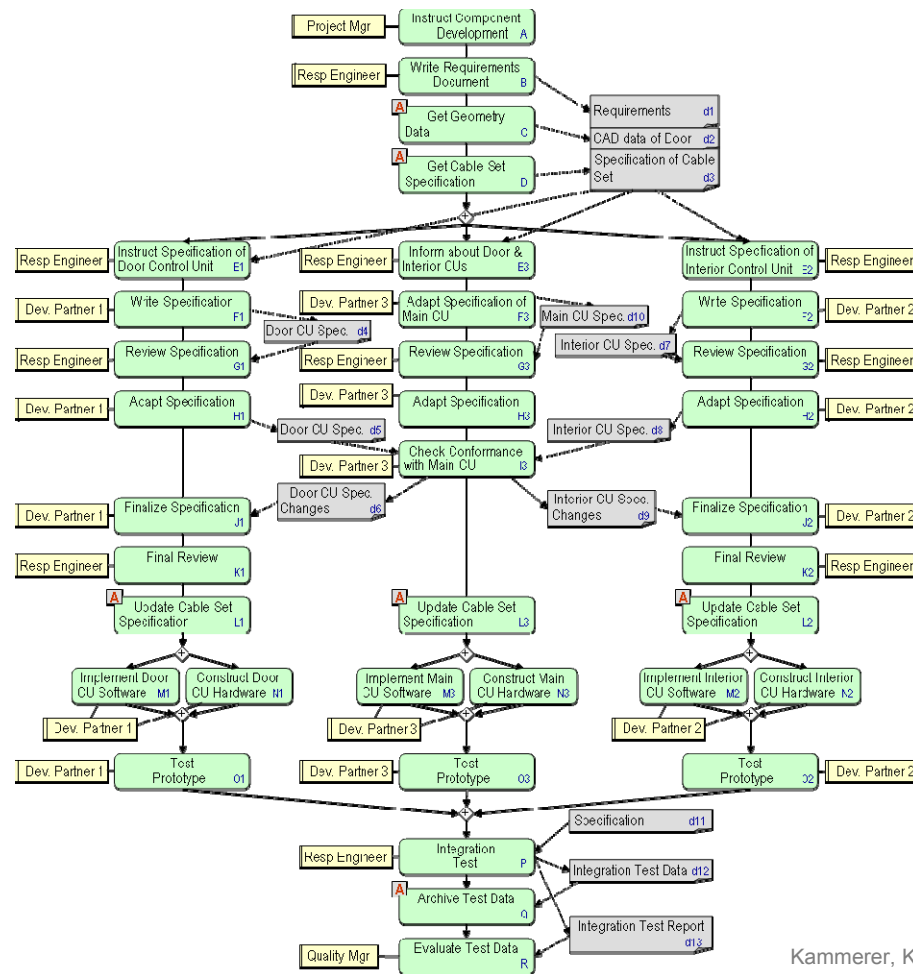
IT Level



ProView: Process Model Abstractions



ProView: Process Model Abstractions



Kammerer, Klaus and Kolb, Jens and Ronis, Sebastian and Reichert, Manfred (2015) [Collaborative Process Modeling with Tablets and Touch Tables: A Controlled Experiment](#). In: IEEE 9th Int'l Conf on Research Challenges in Information Science (RCIS 2015), pp. 31-41.

Kolb, Jens and Reichert, Manfred (2013) [A Flexible Approach for Abstracting and Personalizing Large Business Process Models](#). Applied Computing Review, 13(1): 6-17, ACM SIGAPP.

ProView: Process Model Abstractions



Kammerer, Klaus and Kolb, Jens and Ronis, Sebastian and Reichert, Manfred (2015) [Collaborative Process Modeling with Tablets and Touch Tables: A Controlled Experiment](#). In: IEEE 9th Int'l Conf on Research Challenges in Information Science (RCIS 2015), pp. 31-41.

Kolb, Jens and Reichert, Manfred (2013) [A Flexible Approach for Abstracting and Personalizing Large Business Process Models](#). Applied Computing Review, 13(1): 6-17, ACM SIGAPP.

ADEPT / AristaFlow: BPM Suite & Process Flexibility

Reichert, Manfred and Dadam, Peter (1998) *ADEPTflex-Supporting Dynamic Changes of Workflows Without Losing Control*. Journal of Intelligent Information Systems, Special Issue on Workflow Management Systems, 10(2): 93-129

Rinderle, Stefanie and Reichert, Manfred and Dadam, Peter (2004) *Flexible Support of Team Processes by Adaptive Workflow Systems*. Distributed and Parallel Databases, 16(1): 91-116, Springer

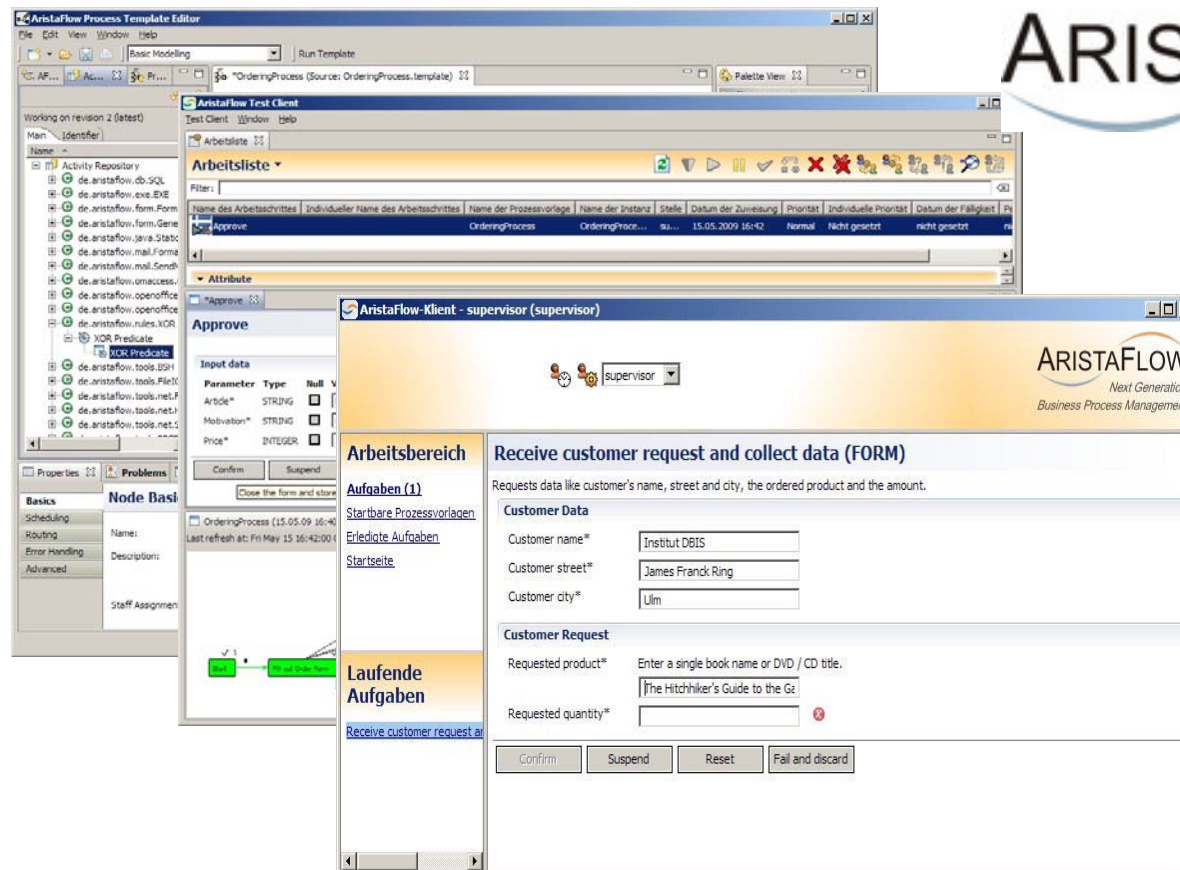
Rinderle, Stefanie and Reichert, Manfred and Dadam, Peter (2004) *Correctness Criteria for Dynamic Changes in Workflow Systems: A Survey*. Data & Knowledge Engineering, 50(1): 9-34



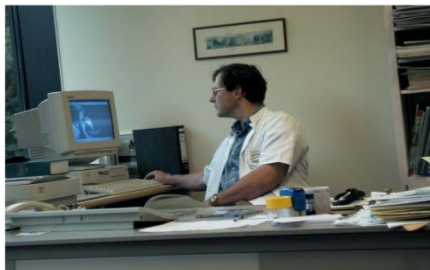
Guidance: Guidelines (on a road) show people where to go, but do not prevent deviations if they are necessary.

Enforcement: Guardrails (on a road) prevent deviation, but also prevent anything not predicted.

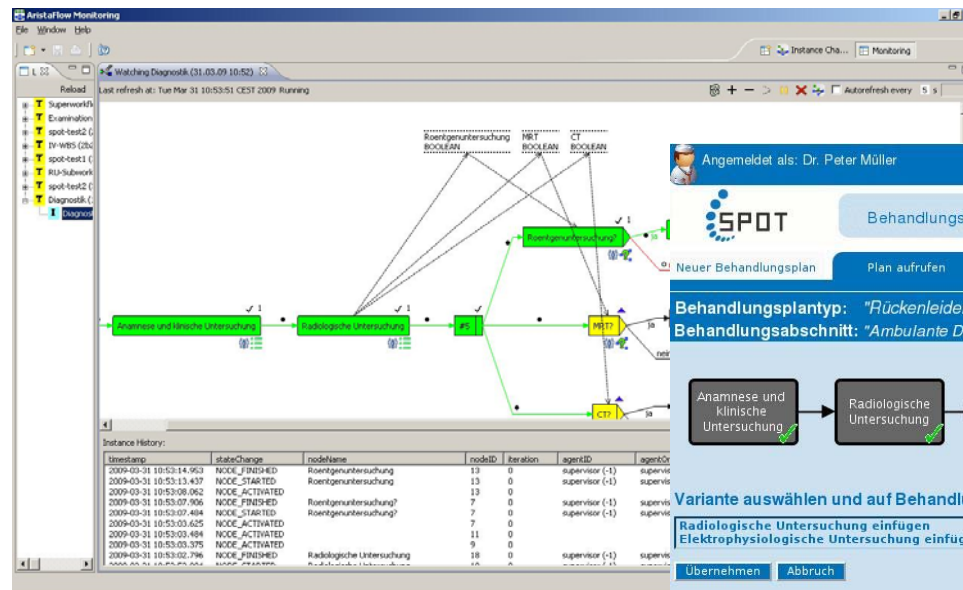
AristaFlow: BPM Suite & Process Flexibility



AristaFlow: BPM Suite & Process Flexibility

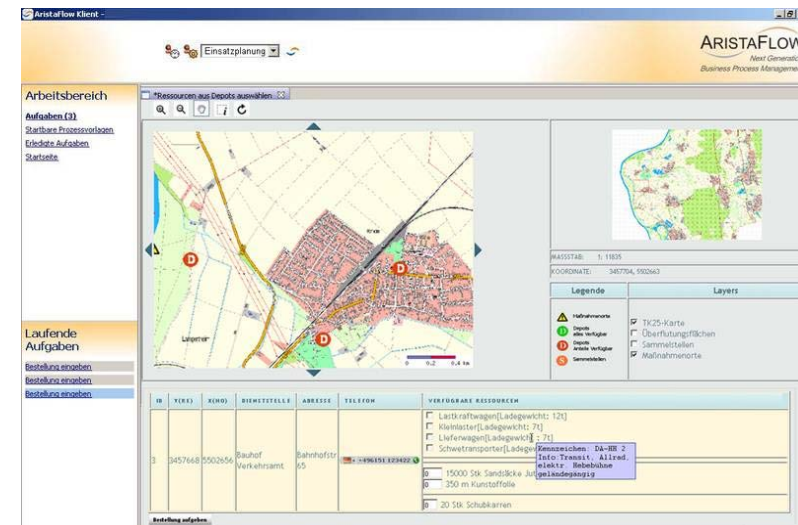
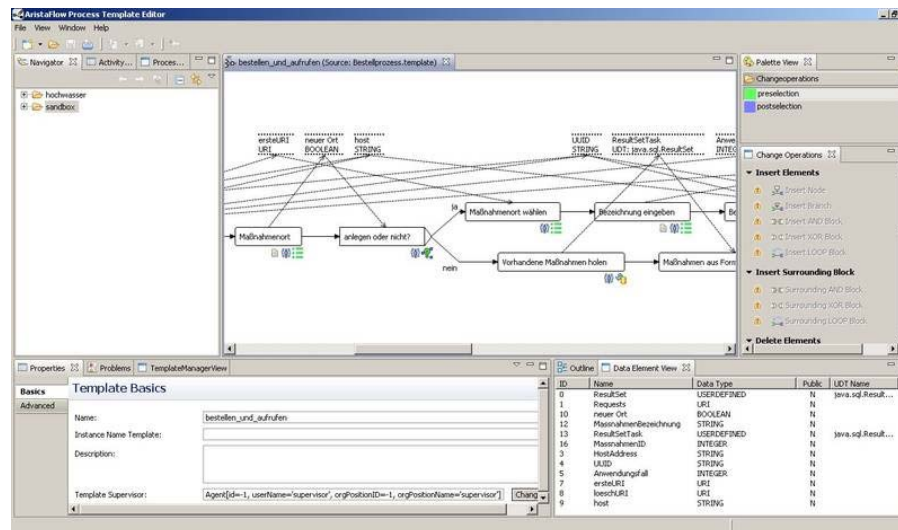


**Clinical Pathway
Support with the
AristaFlow BPM Suite**



AristaFlow: BPM Suite & Process Flexibility

Process-aware, Cooperative Emergency Management for Water Infrastructures



www.process-flexibility.com

The image shows two men standing next to a presentation board. The man on the left is wearing a purple shirt and the man on the right is wearing a dark blue shirt. They are both giving a thumbs up. The presentation board is titled "Managing a complex world..." and "Adaptive Process Management with ADEPT2". It lists the Institute of Databases and Information Systems, Prof. Dr. Peter Dadam, and Prof. Dr. Manfred Reichert. The board also features a diagram of the ADEPT2 Core-Architecture and a list of components including the Worklist Client, Process Editor, Organisational Model Editor, and Process Test Environment.

Managing a complex world...

Adaptive Process Management with ADEPT2

Institute of Databases and Information Systems, Prof. Dr. Peter Dadam, Prof. Dr. Manfred Reichert

ADEPT2 Core-Architecture

- layered architecture
- strong separation of duties
- loosely coupled services enable easy exchange of the implementation and allows for exchangeable communication techniques
- plug-in interfaces for extensions
- SQL abstraction layer for independent database persistence

Worklist Client

- advanced workload management
- balanced workload distribution
- manual and automatic prioritisation of work items
- delegation and escalation
- personalised worklist representation

Process Editor

- graphical editor for modeling template performing ad-hoc deviations of process
- fully syntactic
- ...

Organisational Model Editor

- comprehensive model for mapping complex organisational structures
- adding of arbitrary attributes to organisational entity-types (e.g. enterprise-specific data)
- vendor independent implementation of storage layer enables the use of any database

Process Test Environment

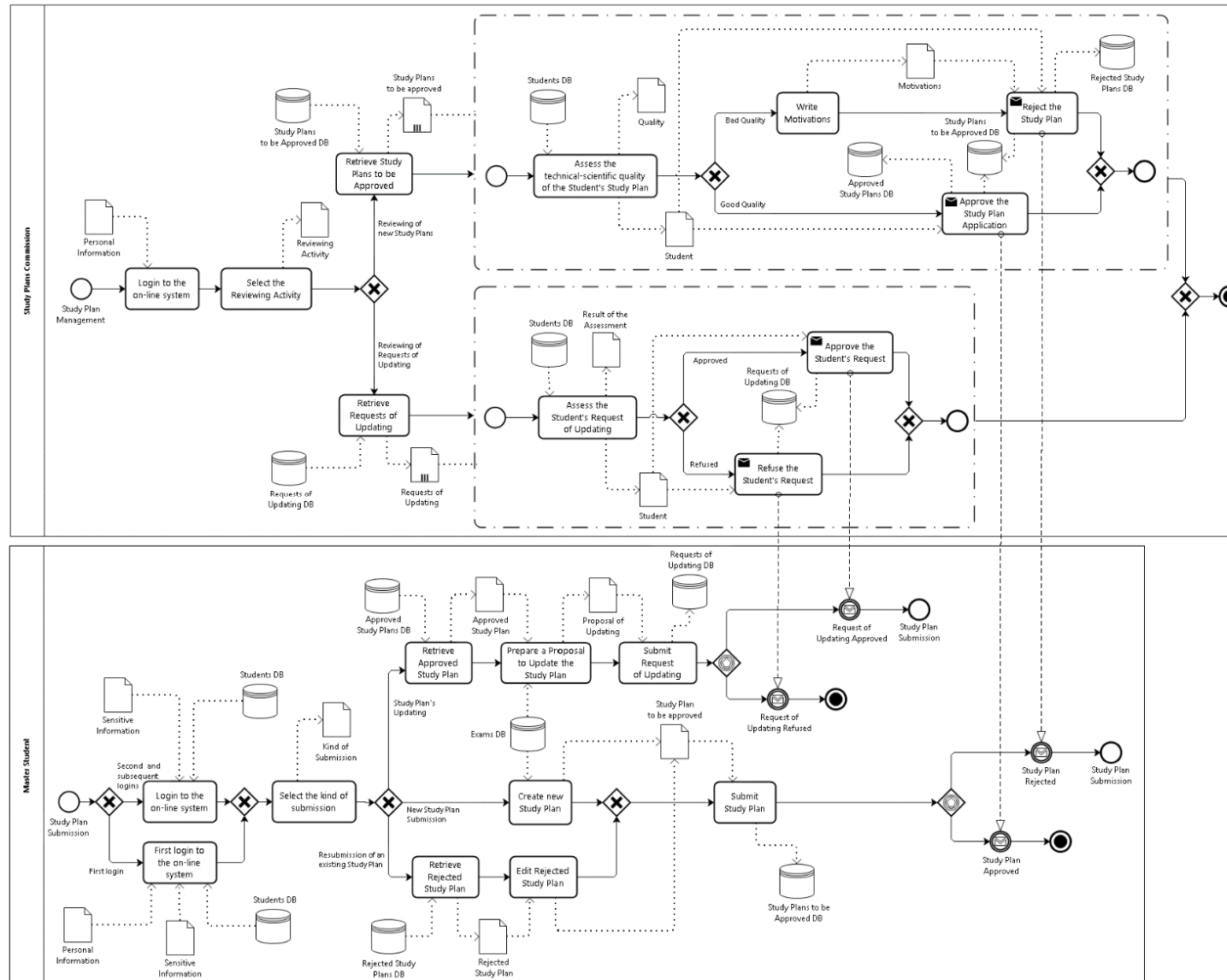
- fully-fledged test environment for process execution
- various execution modes ranging from pure simulation to production mode
- calls to arbitrary components including WebServices, JAVA, OpenOffice
- handling of manual and automatic process activities
- integration of software components with graphical user interfaces

Contact Us

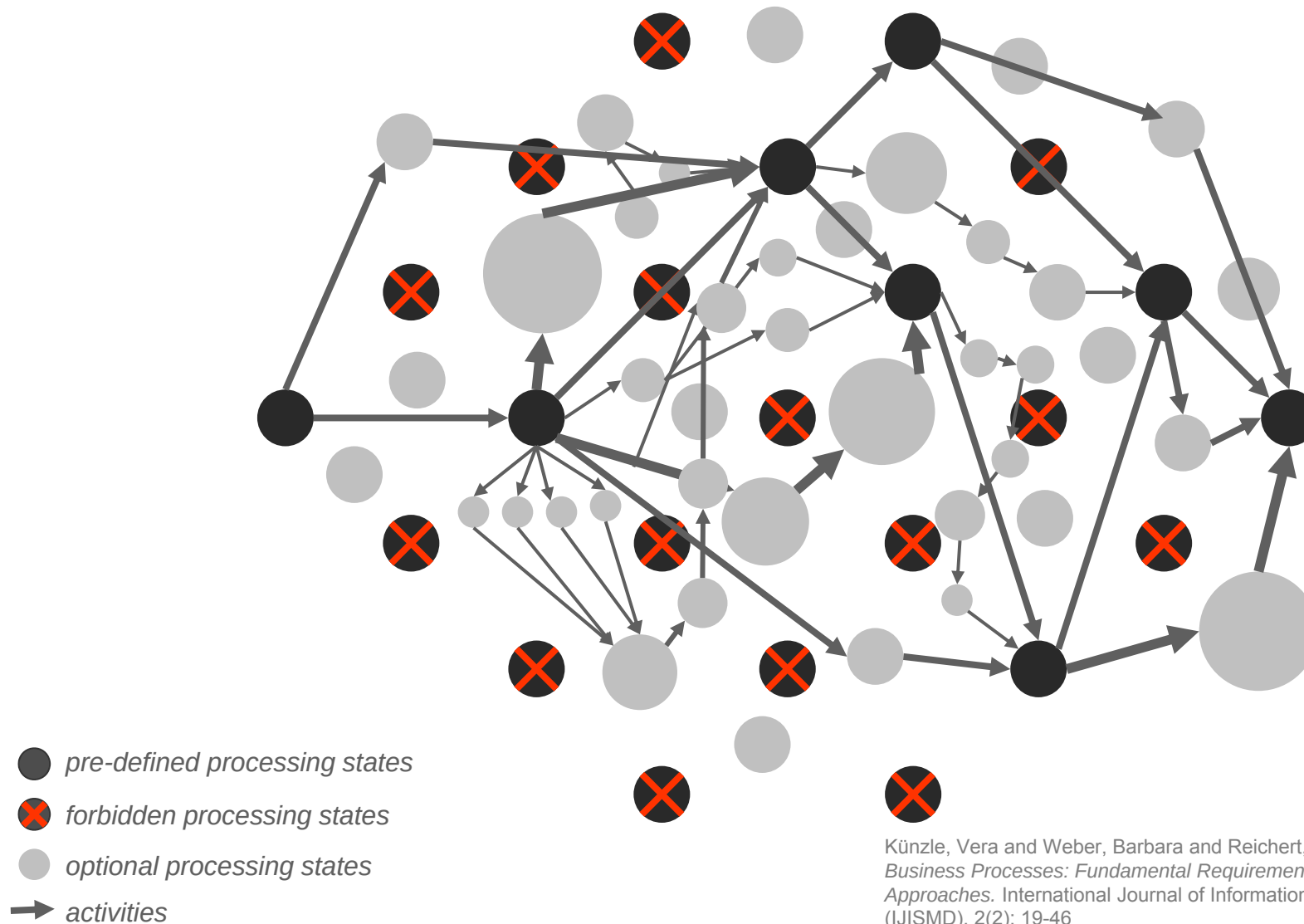
Prof. Dr. Peter Dadam, Prof. Dr. Manfred Reichert
Institute of Databases and Information Systems, James-Frank-Ring, 89081 Ulm
Email: {Peter.Dadam, Manfred.Reichert}@uni-ulm.de

Limitations of the Activity-Centric Modeling Paradigm

Limitations of the Activity-Centric Modeling Paradigm

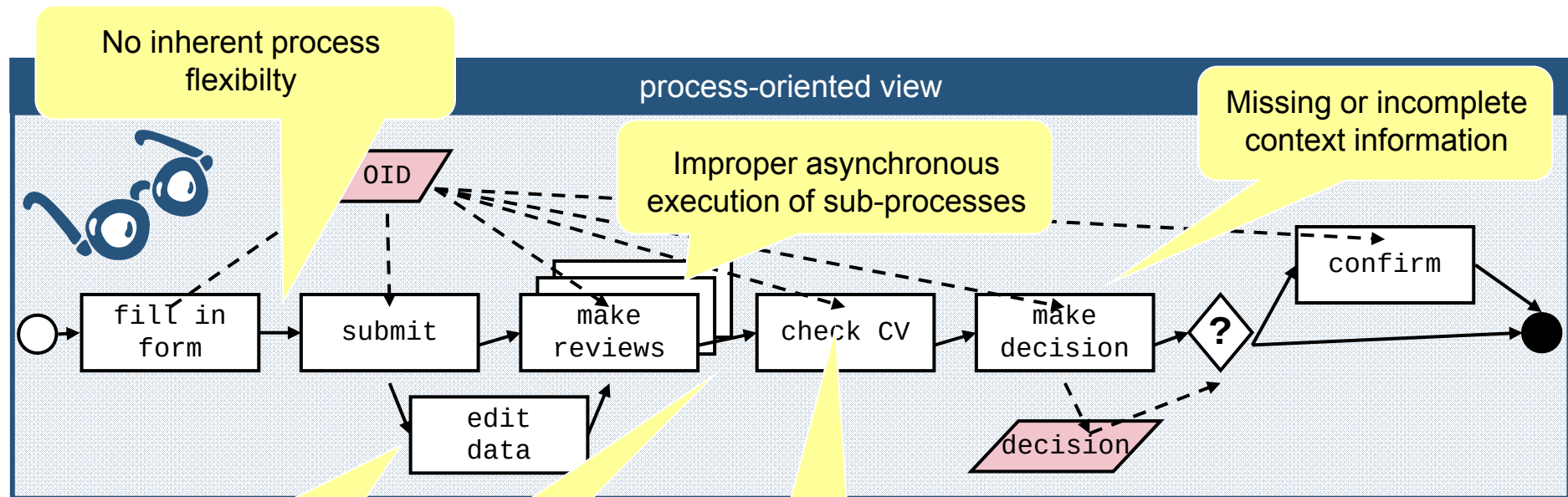


Limitations of the Activity-Centric Modeling Paradigm



Künzle, Vera and Weber, Barbara and Reichert, Manfred (2011) *Object-aware Business Processes: Fundamental Requirements and their Support in Existing Approaches*. International Journal of Information System Modeling and Design (IJISMD), 2(2): 19-46

Limitations of the Activity-Centric Modeling Paradigm



No optional activities

Access on data only during the activity execution

Isolated execution of process instance



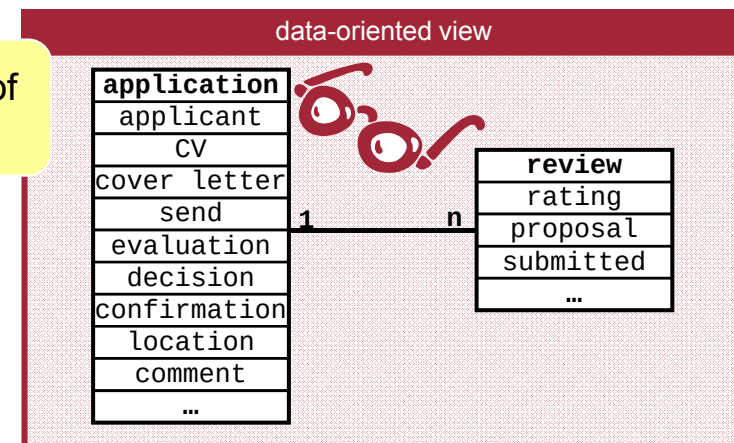
generic functions



comprehensive lifecycle support

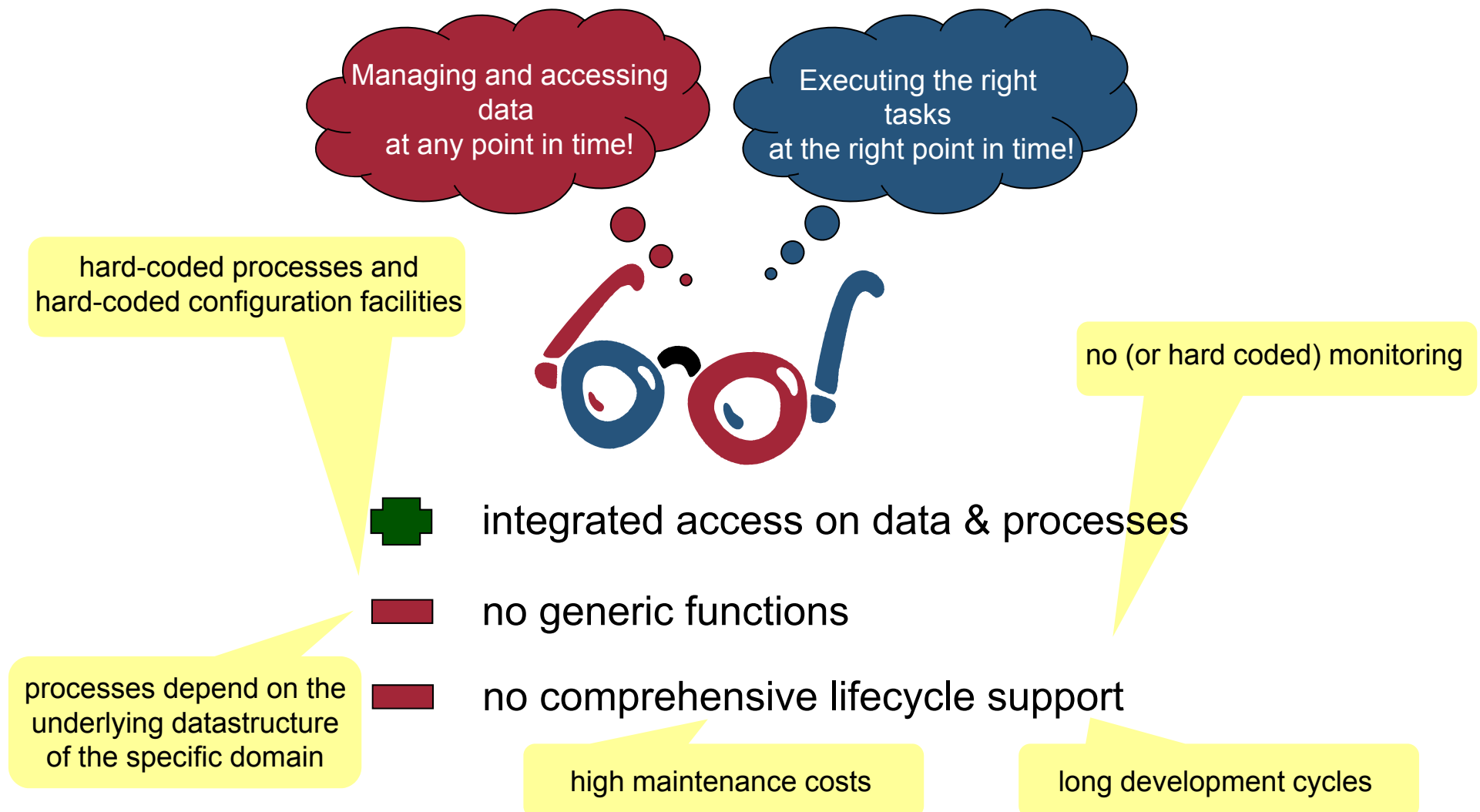


missing data-oriented view



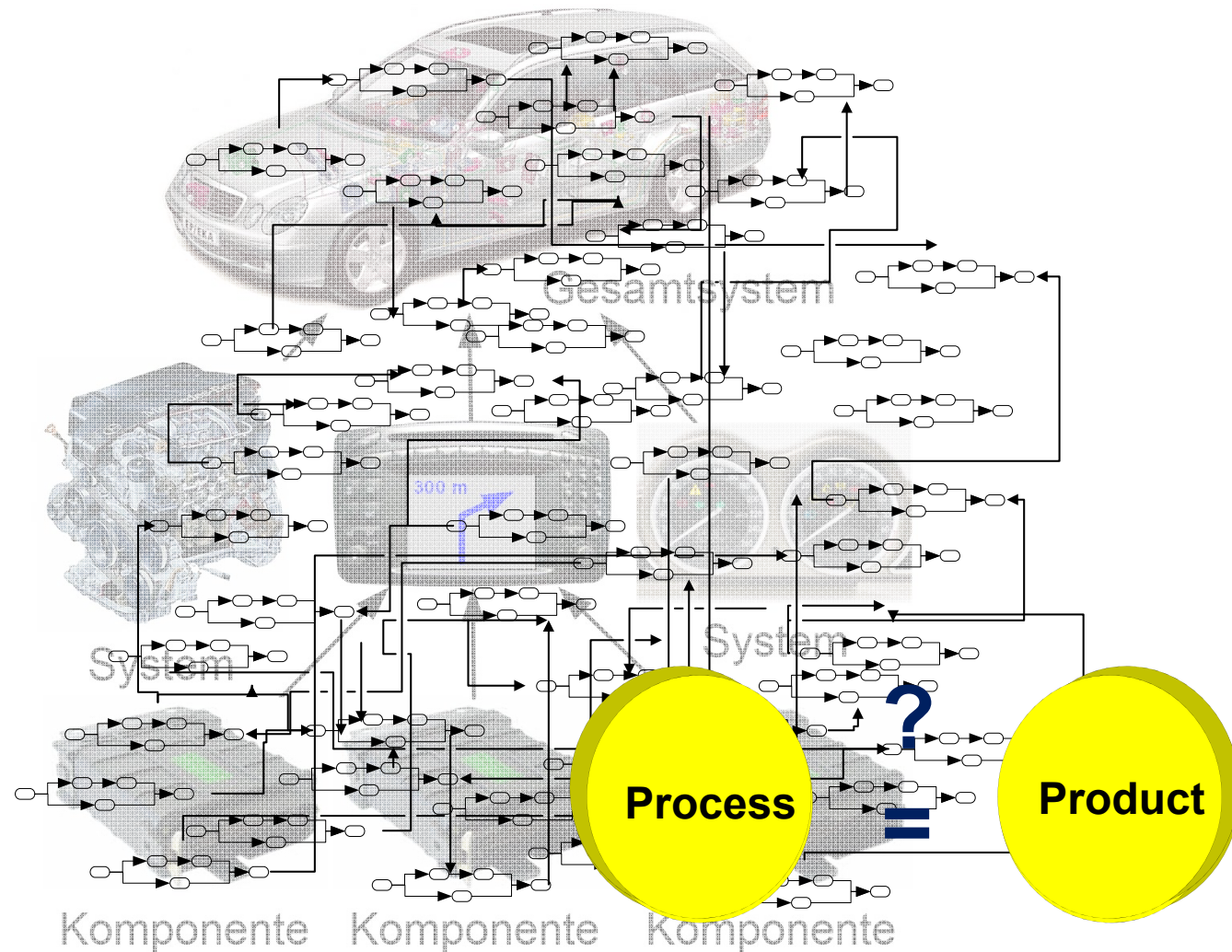
Limitations of the Activity-Centric Modeling Paradigm

Contemporary ERP and Application Software



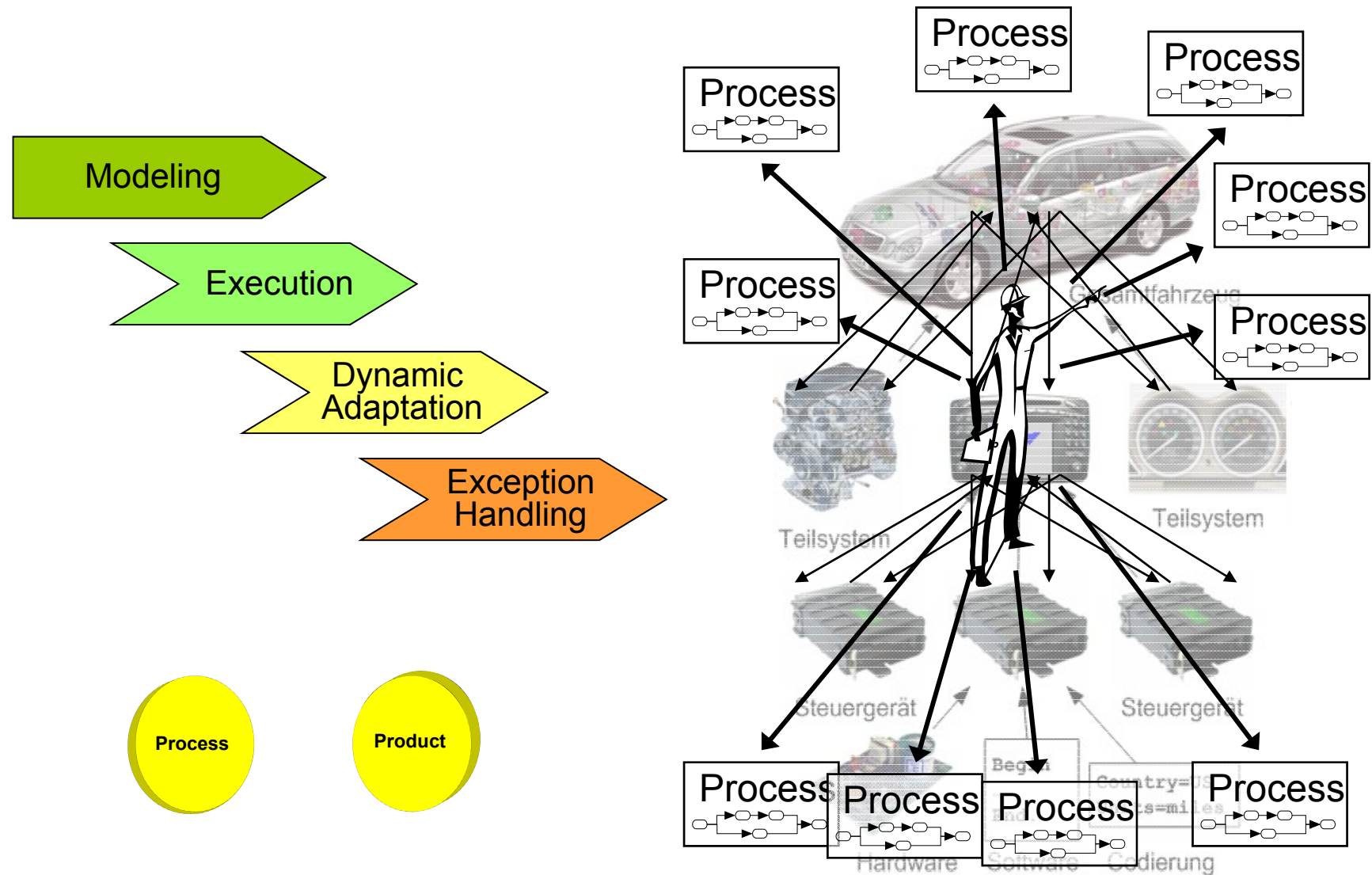
Data-Driven Process Structure: The Corepro Approach

Data-Driven Process Structure: The Corepro Approach

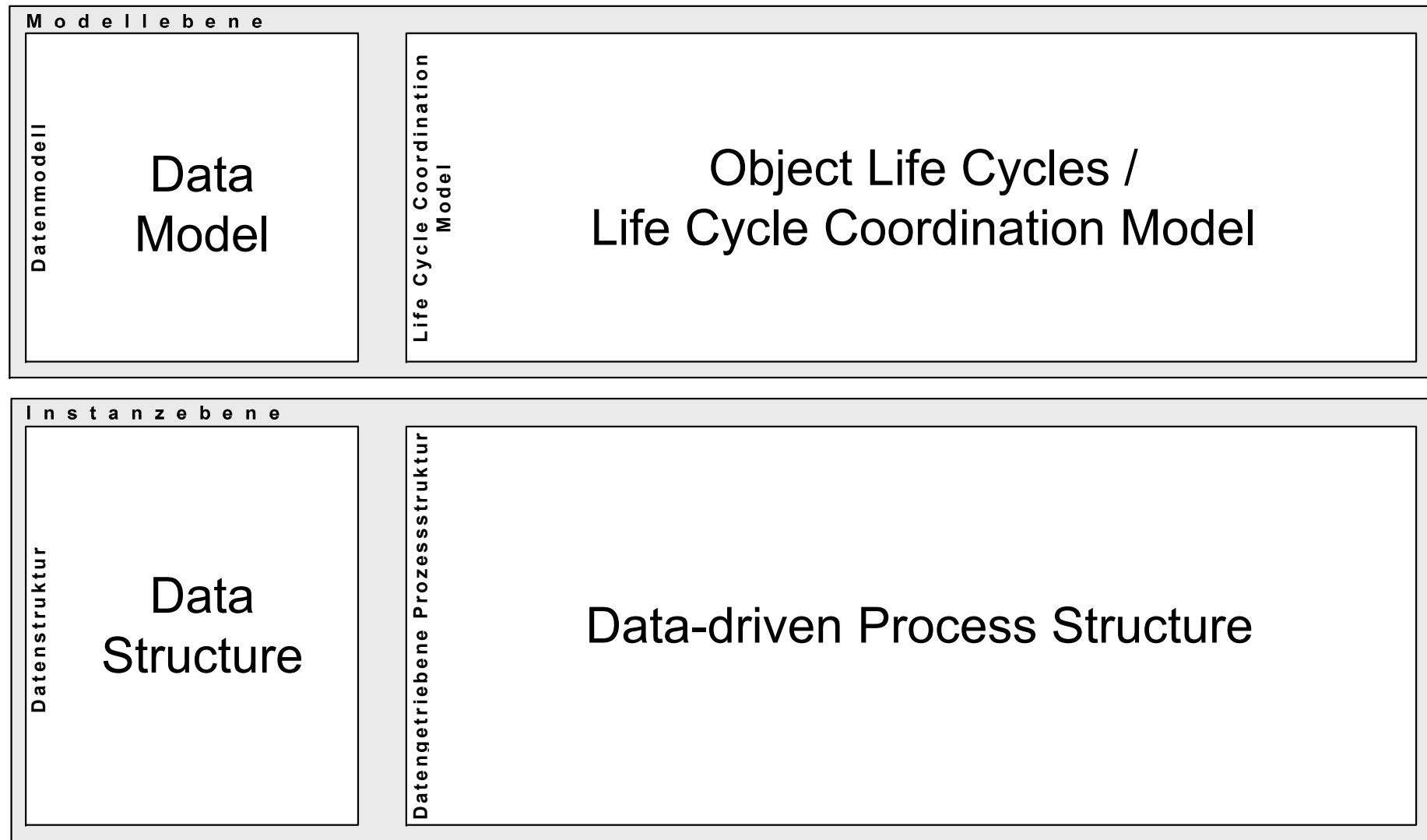


D. Müller, M. Reichert, J. Herbst: A New Paradigm for the Enactment and Dynamic Adaptation of Data-Driven Process Structures. CAiSE 2008: 48-63

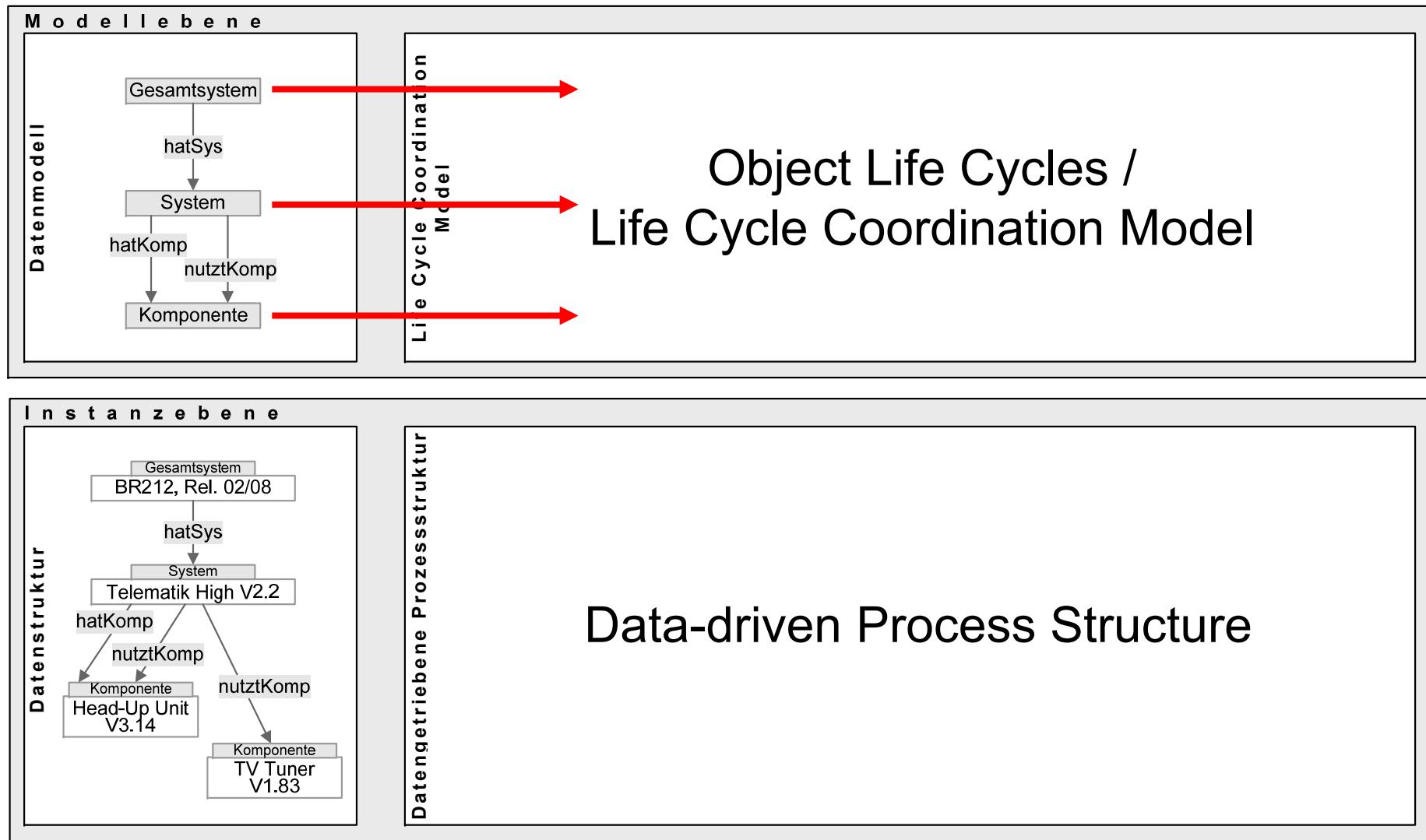
Data-Driven Process Structure: The Corepro Approach



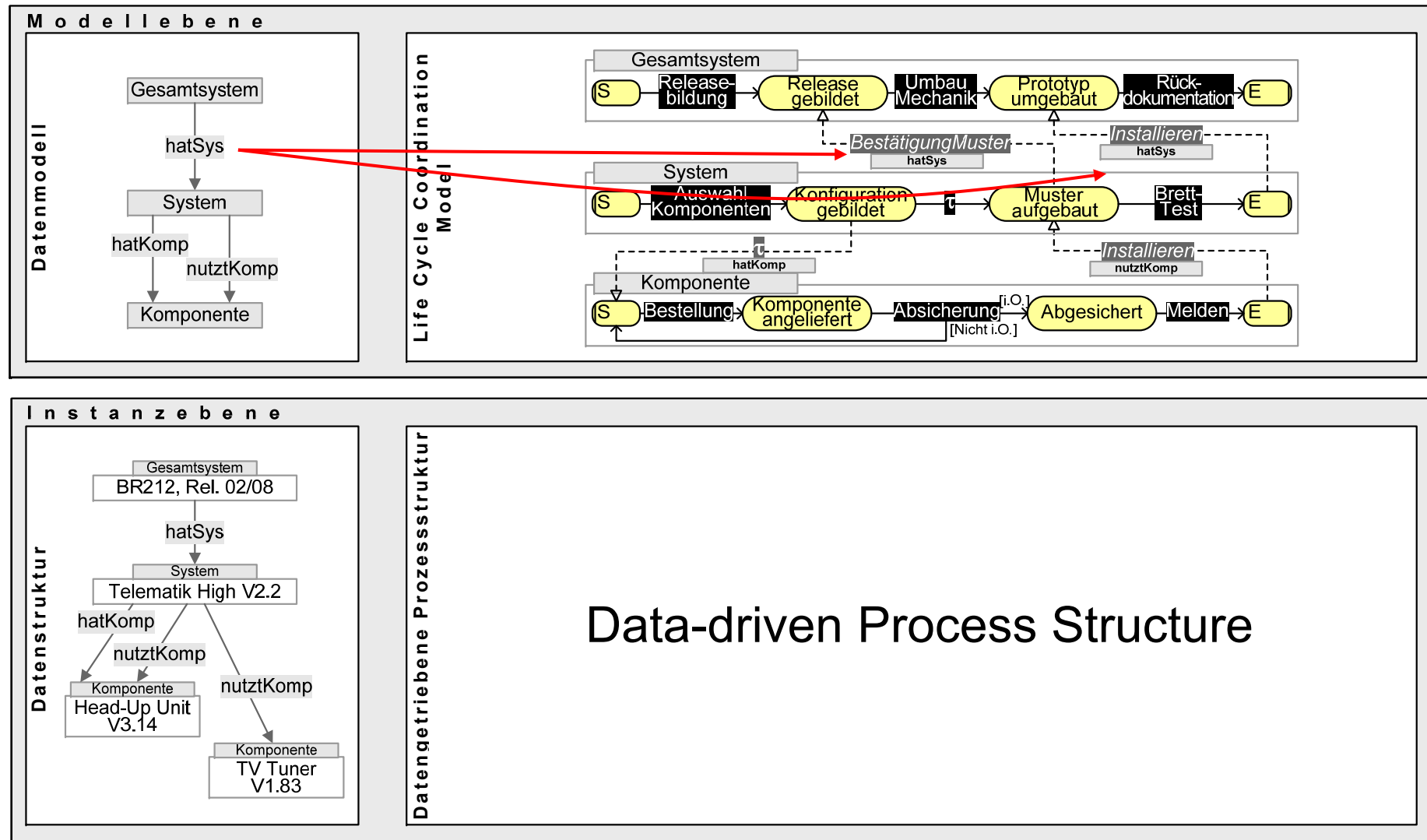
Data-Driven Process Structure: The Corepro Approach



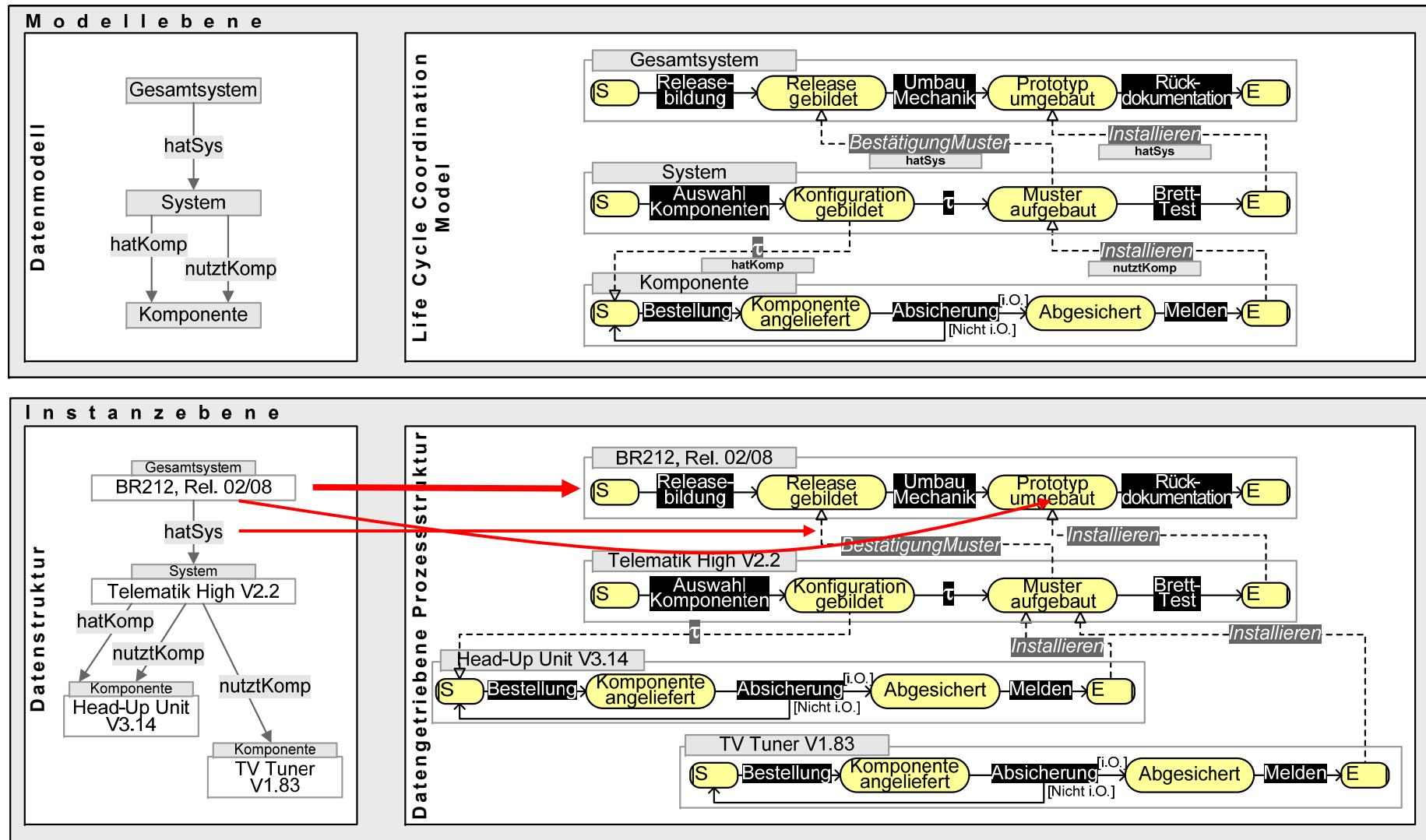
Data-Driven Process Structure: The Corepro Approach

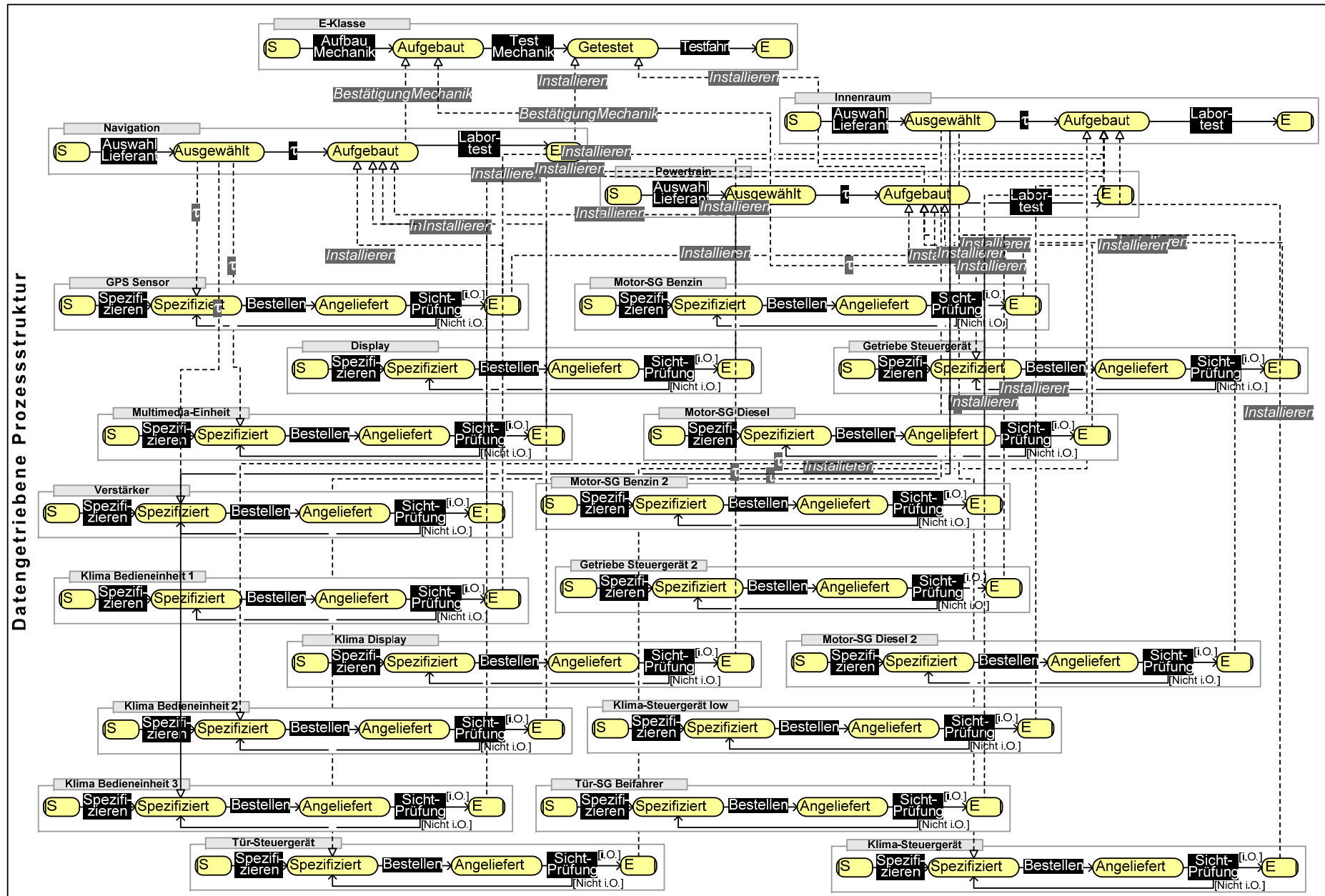


Data-Driven Process Structure: The Corepro Approach



Data-Driven Process Structure: The Corepro Approach





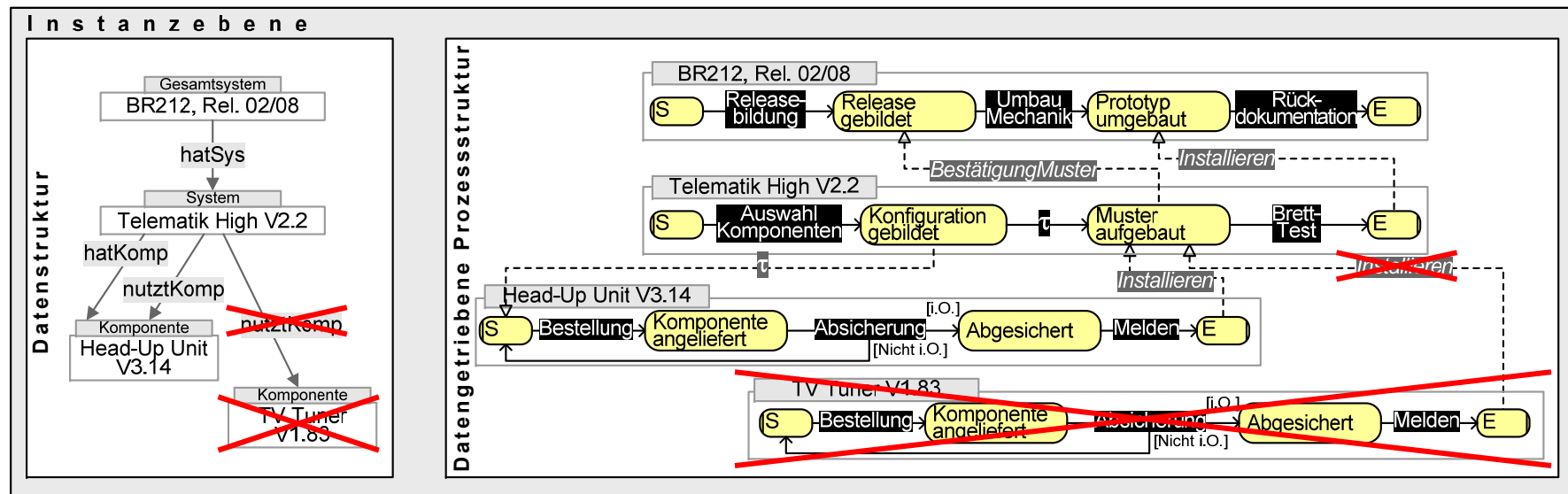
Data-Driven Process Changes in Corepro

Change Operation (Data Structure)

- 1) `removeRelation(Telematik High V2.2, TV Tuner V1.83, nutztKomp);`
- 2) `removeObject(TV Tuner V1.83);`

Change Operation (Process Structure)

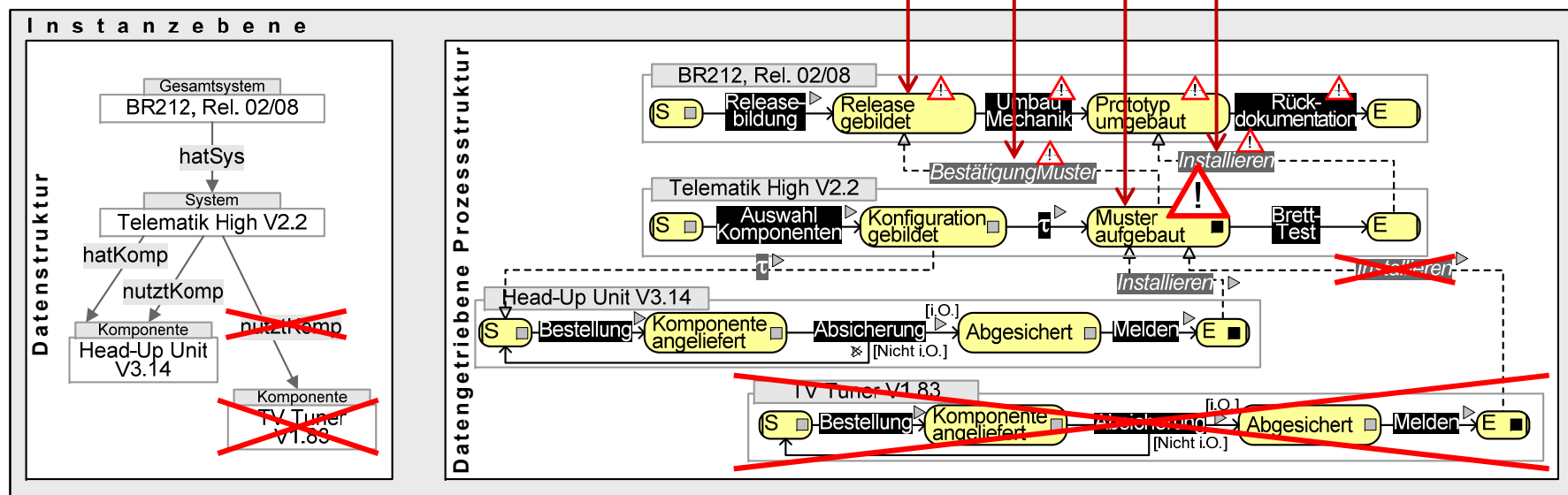
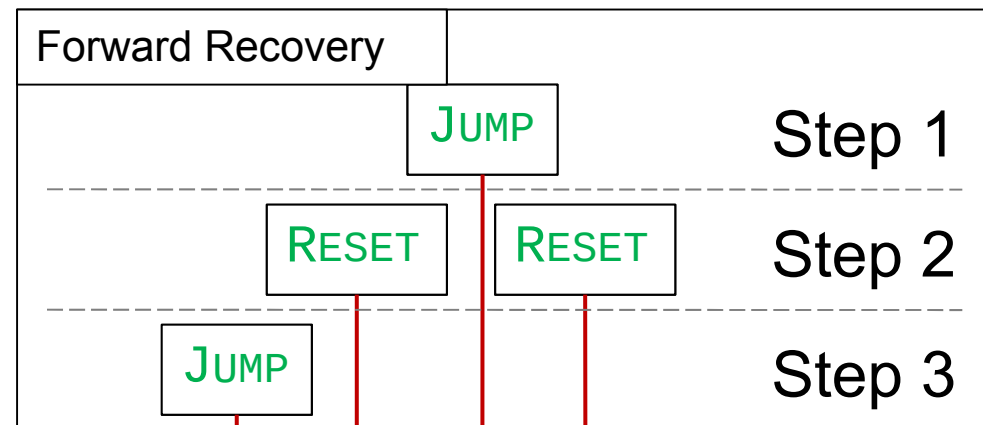
- 1) `removeExtTrans(Telematik High V2.2 . Muster Aufgebaut, Installieren, TV Tuner V1.83 . E);`
- 2) `removeOLC(Tuner V1.83);`



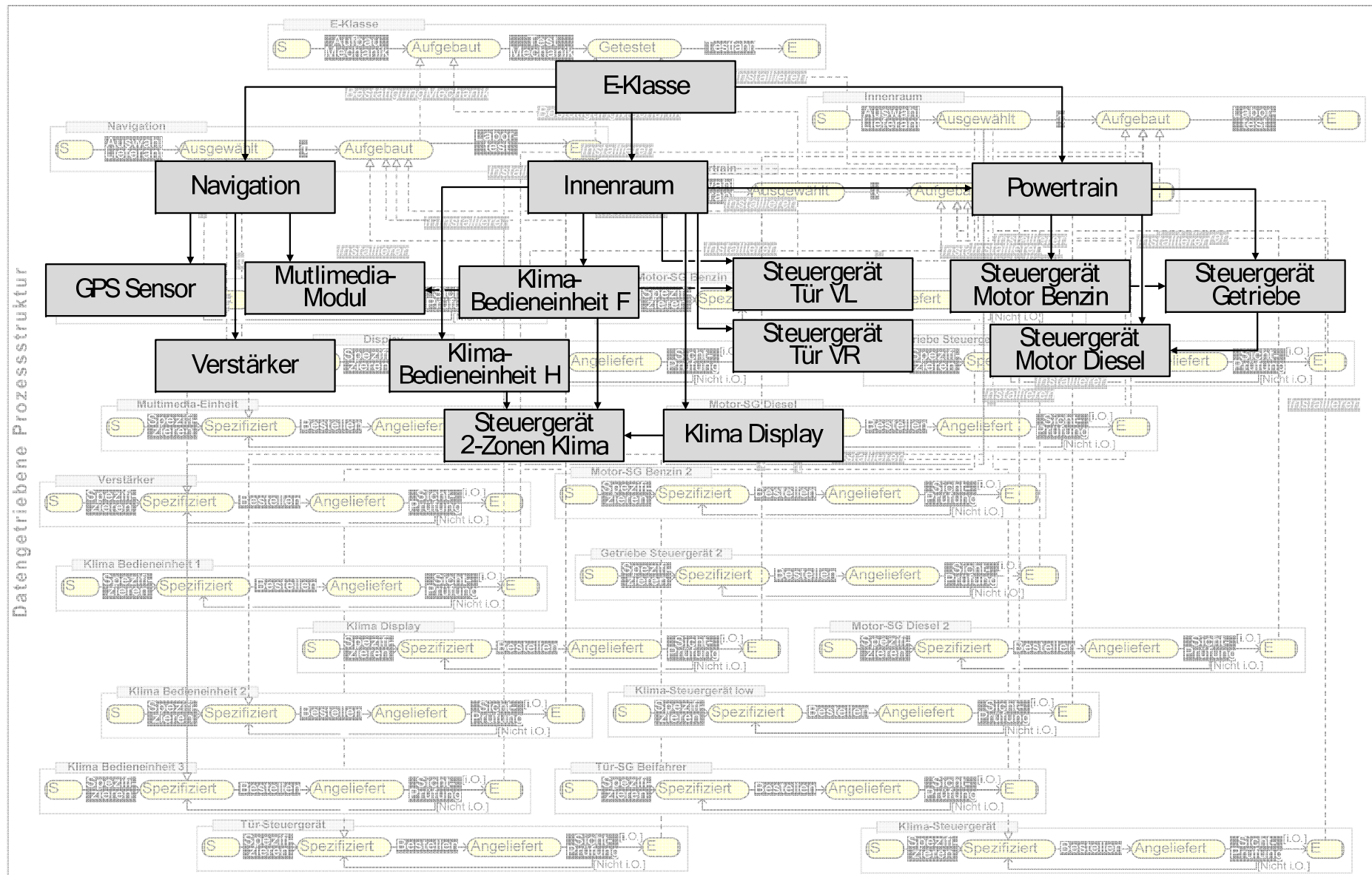
Executing a Process Structure in Corepro

Müller, D., Reichert, M., and Herbst, J. (2008) *A New Paradigm for the Enactment and Dynamic Adaptation of Data-driven Process Structures*. In: 20th Int'l Conf. on Advanced Information Systems Engineering (CAiSE'08), Montpellier, France, LNCS 5074, Springer, pp. 48-63

Müller, D., Reichert, M., and Herbst, J. (2007) *Data-driven Modeling and Coordination of Large Process Structures*. In: 15th Int'l Conf. on Cooperative Information Systems (CoopIS'07), Vilamoura, Portugal, LNCS 4803, Springer, pp. 131-149



Corepro: Case Study

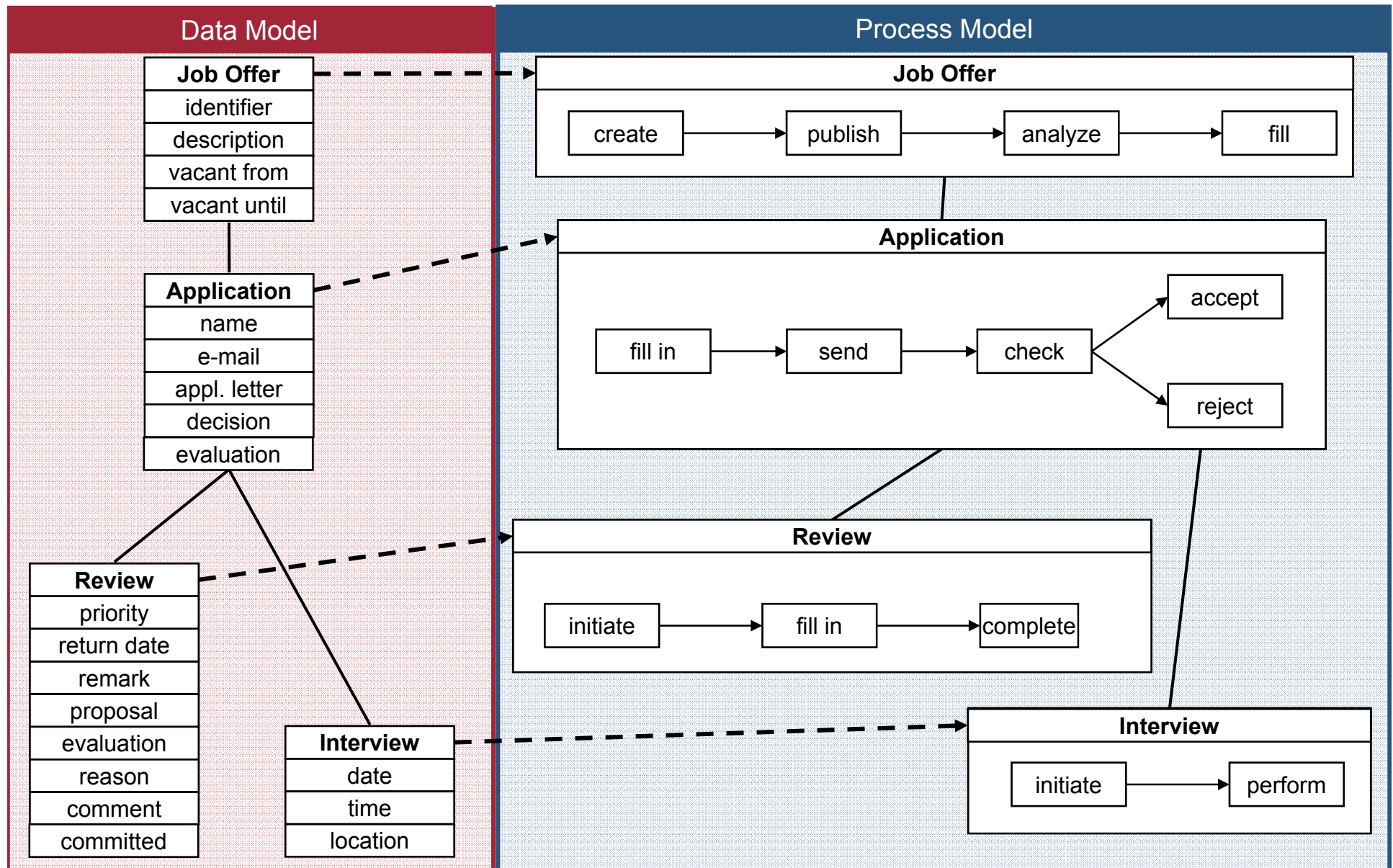


Object-Aware Processes: Characteristic Features

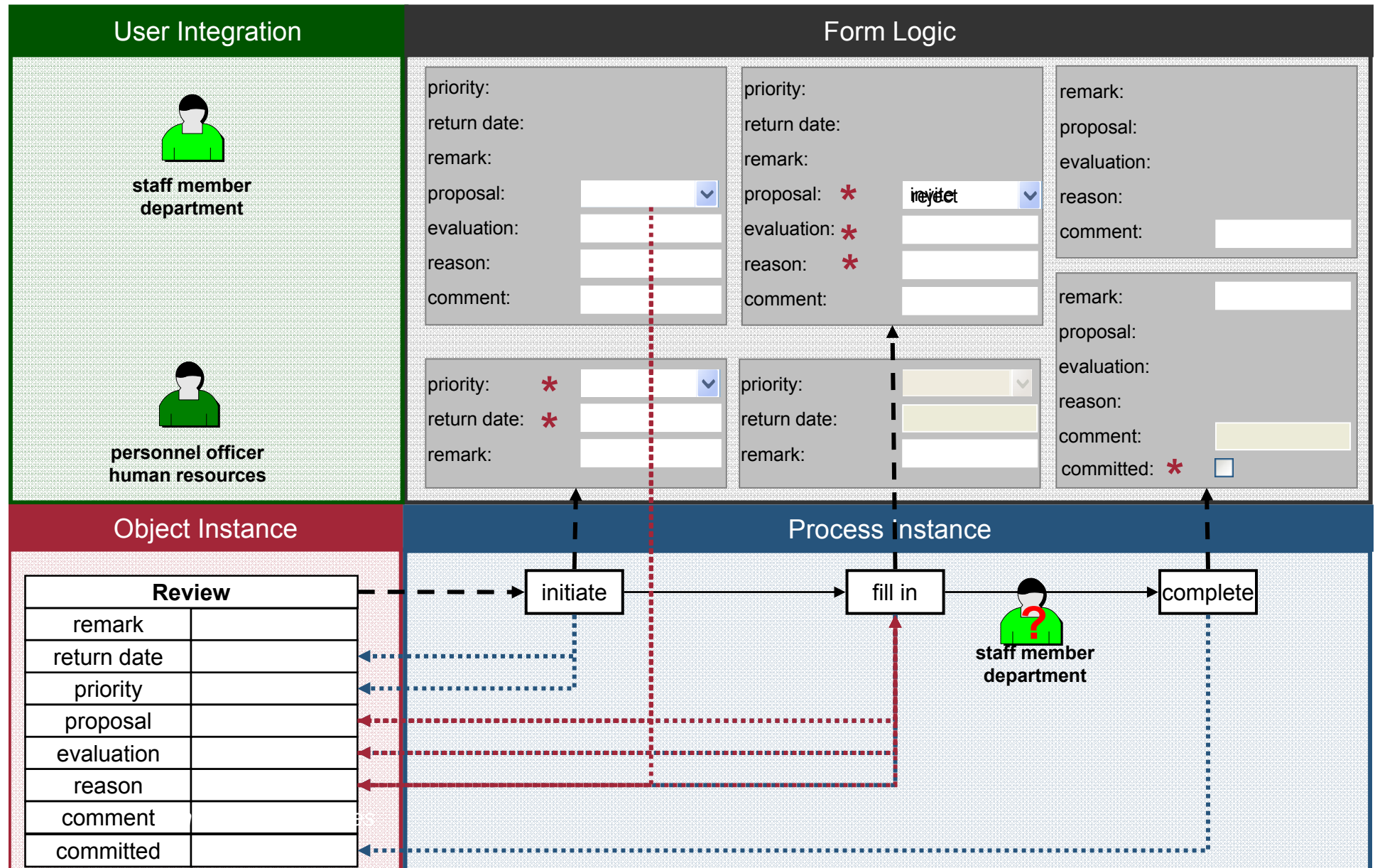
Künzle, Vera and Weber, Barbara and Reichert, Manfred (2011) *Object-aware Business Processes: Fundamental Requirements and their Support in Existing Approaches*. International Journal of Information System Modeling and Design, 2(2): 19-46

Künzle, Vera and Reichert, Manfred (2012) *Striving for Object-aware Process Support: How Existing Approaches Fit Together*. In: 1st Int'l Symposium on Data-driven Process Discovery and Analysis (SIMPDA'11), Campione d'Italia, Italy, June 29 - July 1, 2011, LNBIP 116, Springer, pp. 169-188

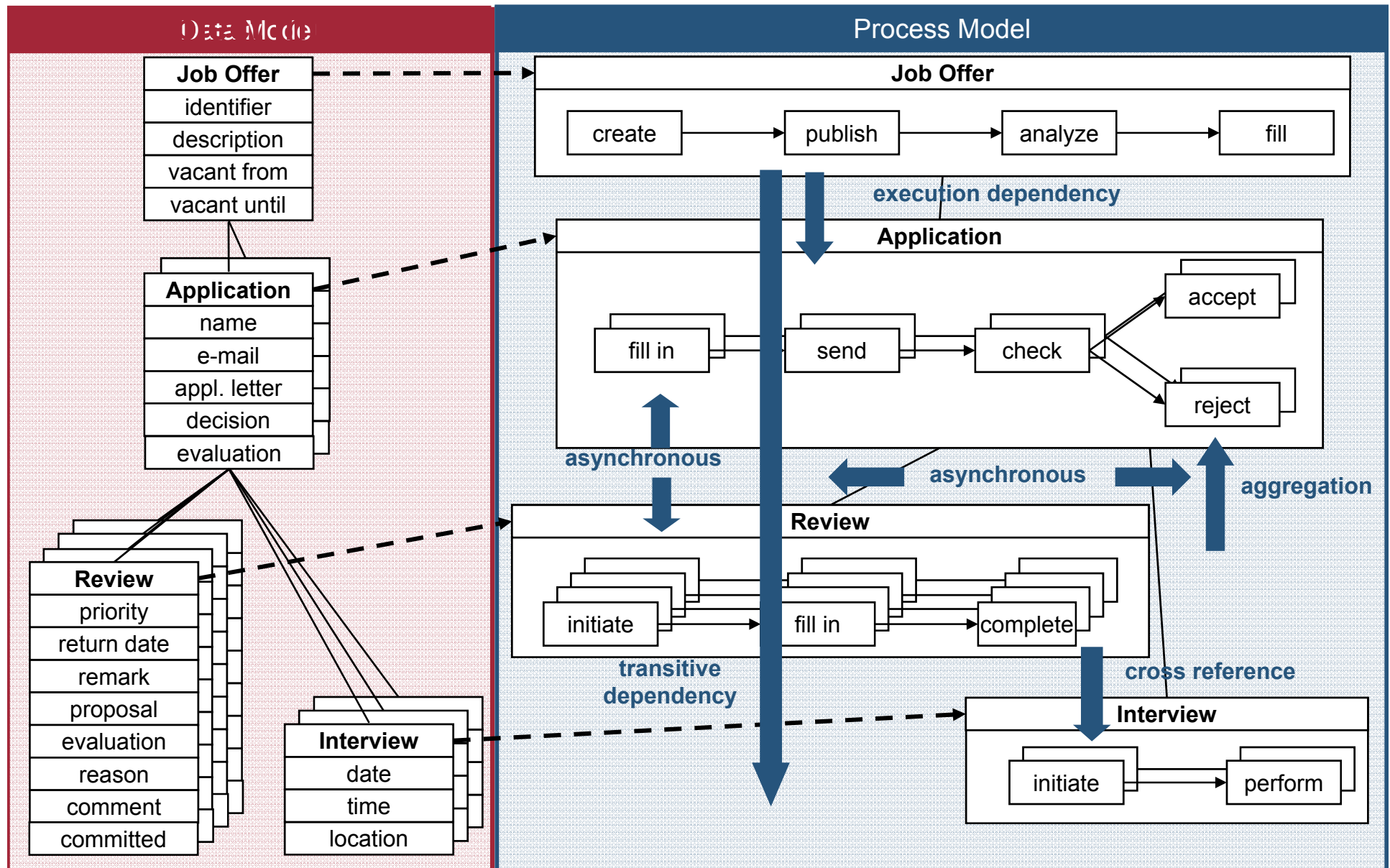
Object-Aware Processes: Characteristic Features



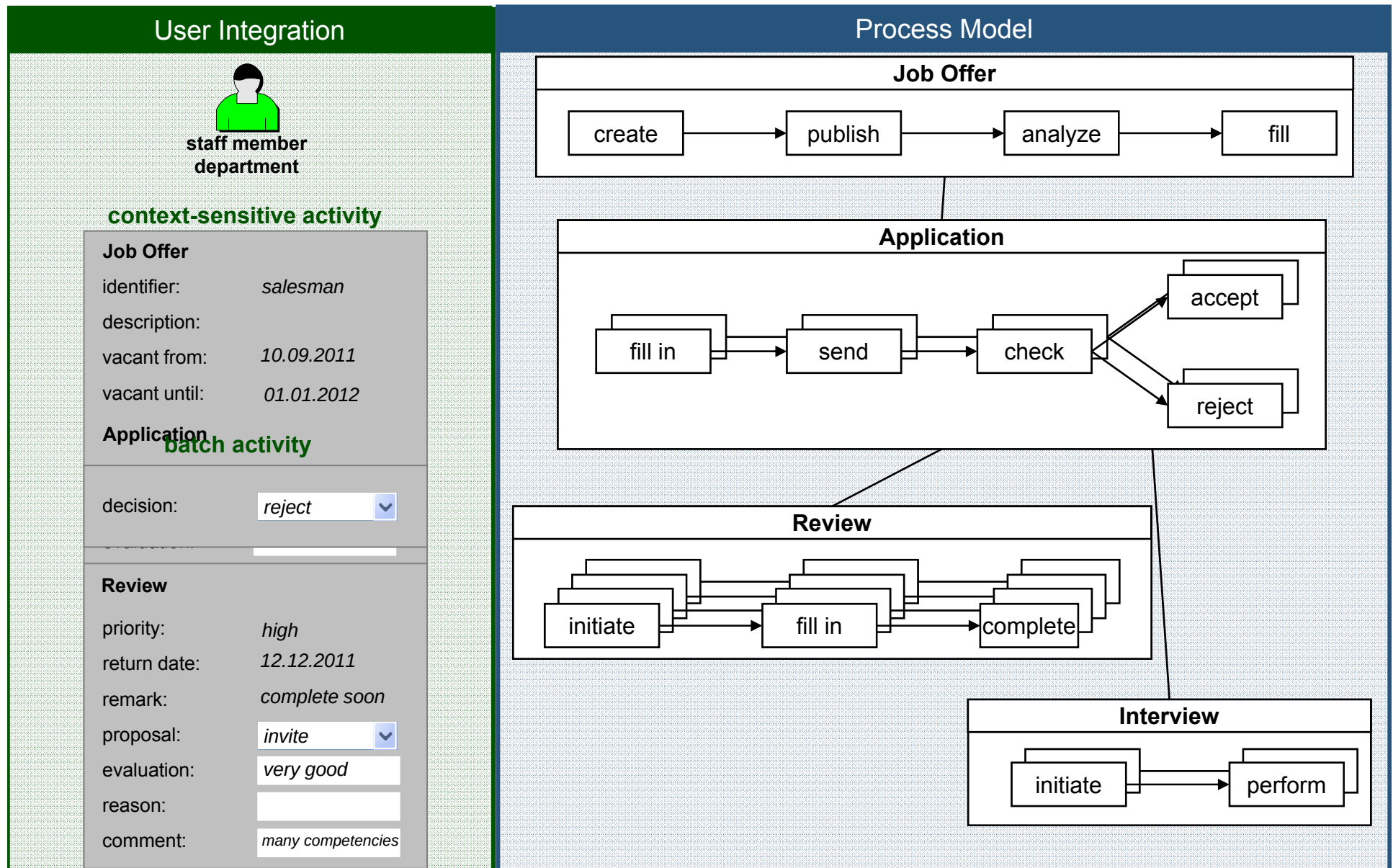
Object-Aware Processes: Characteristic Features



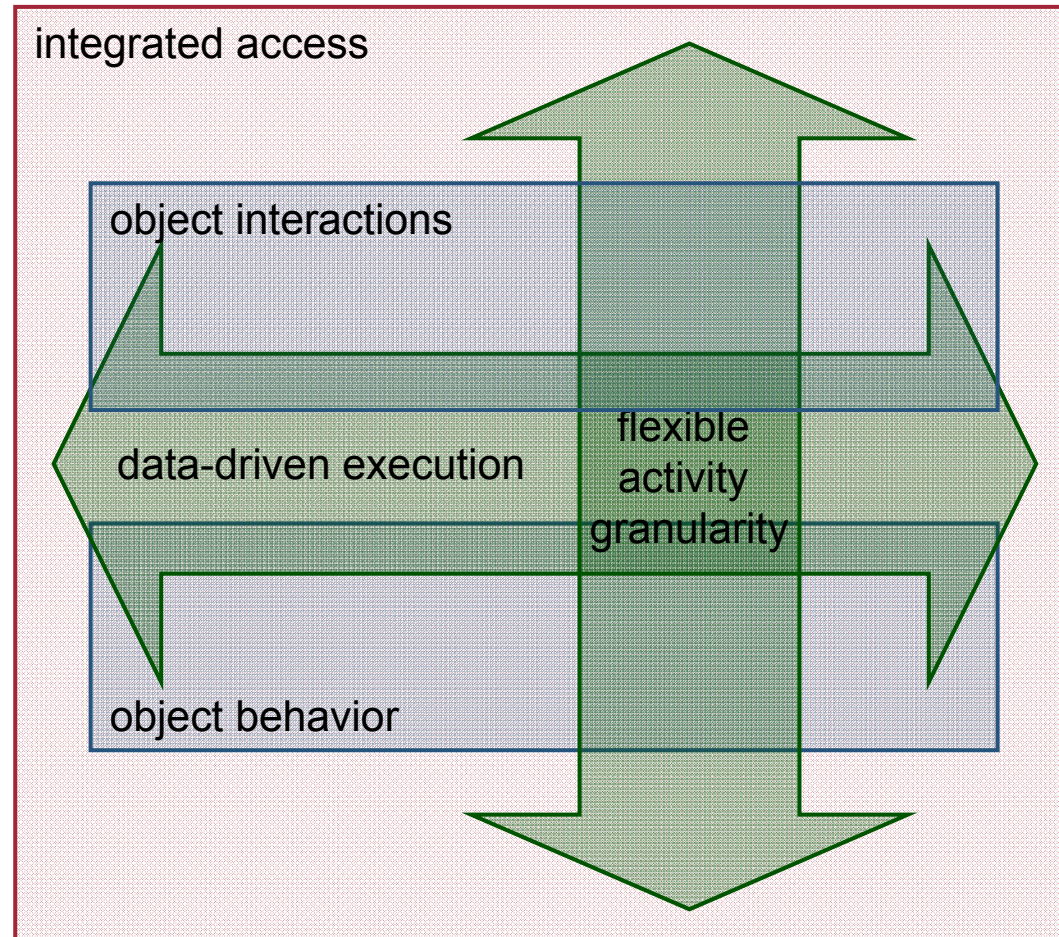
Object-Aware Processes: Characteristic Features

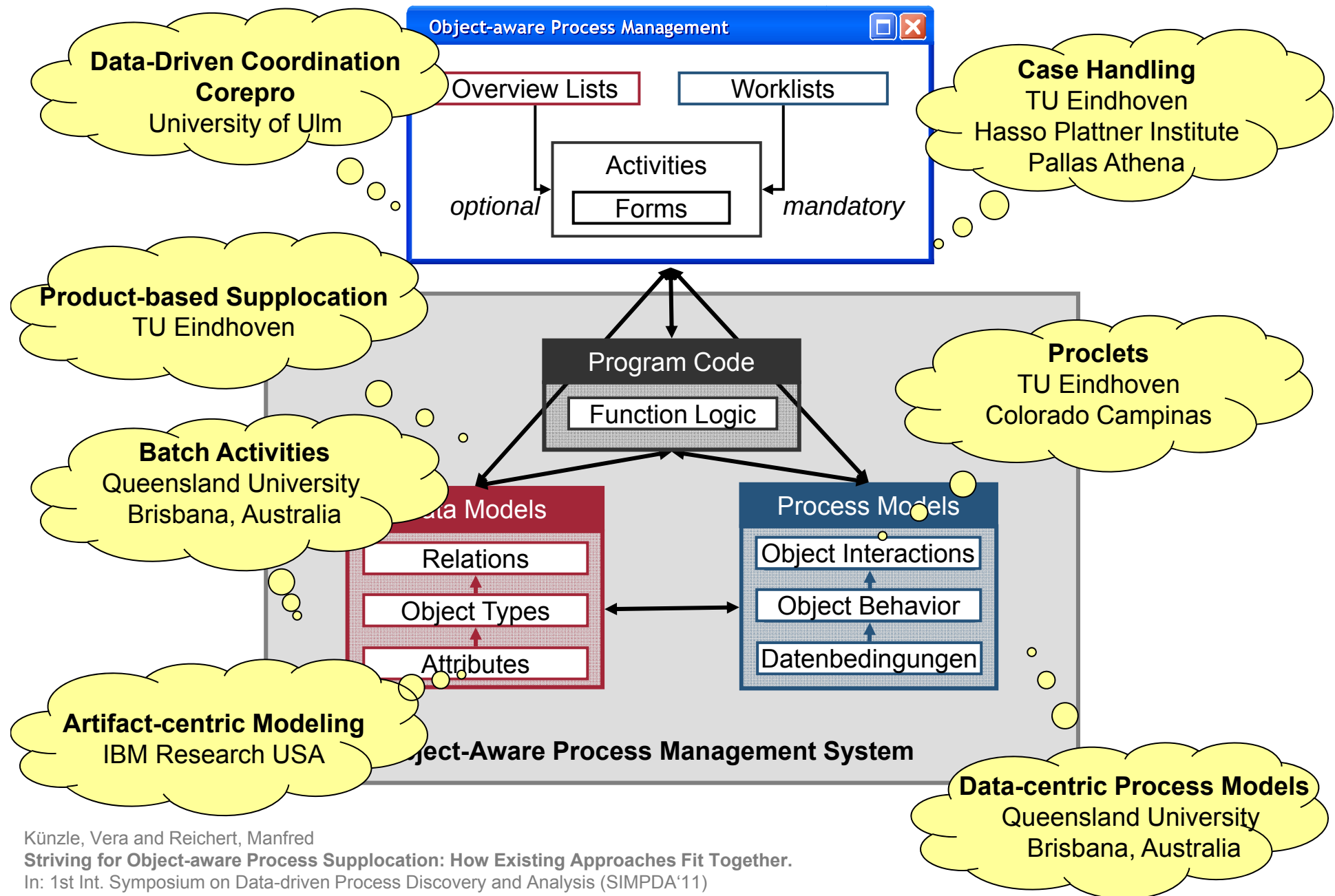


Object-Aware Processes: Characteristic Features



Object-Aware Processes: Characteristic Features





Künzle, Vera and Reichert, Manfred

Striving for Object-aware Process Supplocation: How Existing Approaches Fit Together.

In: 1st Int. Symposium on Data-driven Process Discovery and Analysis (SIMPDA'11)

Object-Aware Processes: Characteristic Features

Existing Approaches	object behavior	object interactions	data-driven execution	activity granularity	integrated access
Proclets ⁽¹⁾		X		(X)	
Case Handling ⁽²⁾	X		(X)		(X)
Business Artifacts ⁽³⁾	X	(X)	(X)		
Data-driven Coordination ⁽⁴⁾	(X)	X	(X)		
Data-centric Process Models ⁽⁵⁾		X			
Product-based Workflow Support ⁽⁶⁾	X		(X)		
Batch Activities ⁽⁷⁾				X	

(1) van der Aalst, W.M.P., Weske, M., Grünbauer, D.: Case Handling: A new Paradigm for Business Process Support. DKE 53(2) (2005) 129-162

(2) van der Aalst, W.M.P., Barthelmess, P., Ellis, C.A., Wainer, J.: Workow Modeling using Proclets. In: Proc. CoopIS'00. (2000) 198-209

(3) Bhattacharya, K., Hull, R., Su, J. In: A Data-Centric Design Methodology for Business Processes. IGI Global (2009) 503-531

(4) Müller, D., Reichert, M., Herbst, J.: Data-Driven Modeling and Coordination of Large Process Structures. In: Proc. CoopIS'07. LNCS 4803 (2007) 131-149

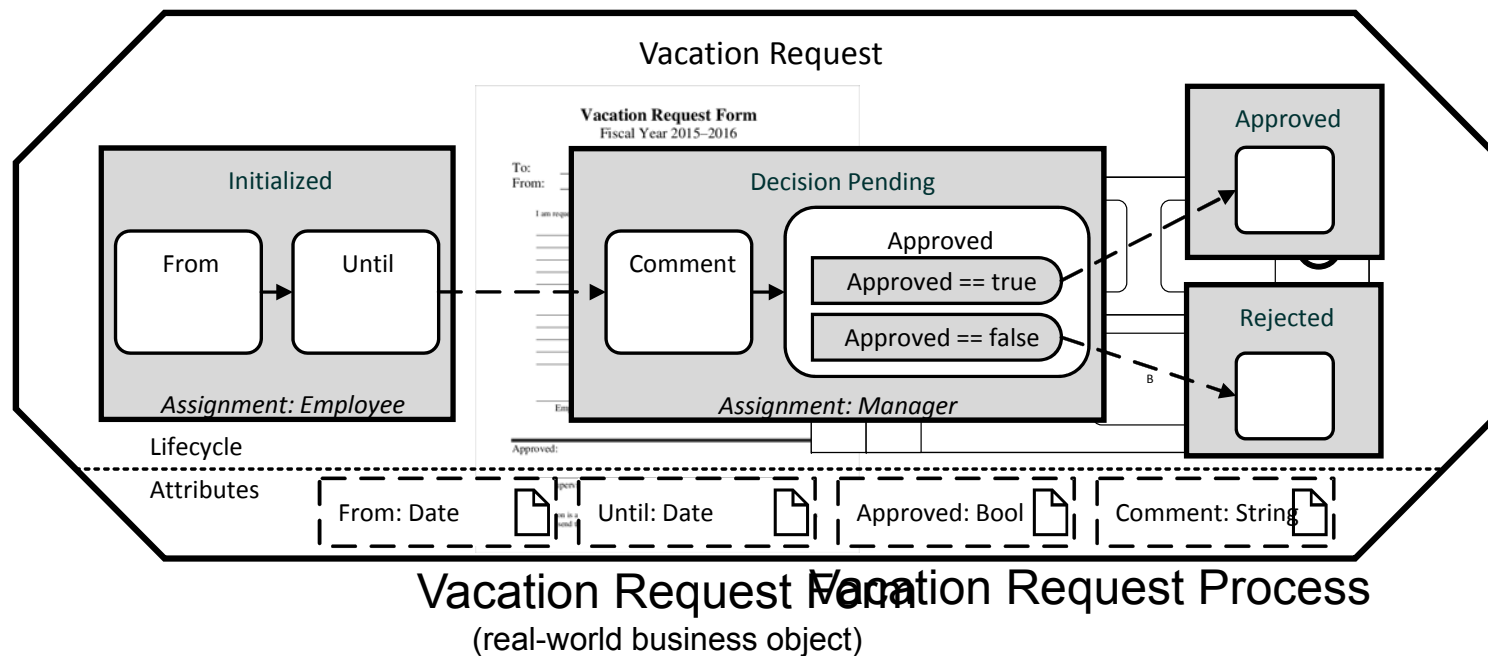
(5) Redding, G.M., Dumas, M., ter Hofstede, A.H.M., Iordachescu, A.: A flexible, object-centric approach for business process modelling. Service Oriented Computing and Applications (2009) 1-11

(6) Vanderfeesten, I., Reijers, H.A., van der Aalst, W.M.P.: Product-based Workow Support. Information Systems 36(2) (2011) 517-535

(7) Sadiq, S.W., Orlowska, M.E., Sadiq, W., Schulz, K.: When workows will not deliver: The case of contradicting work practice. In: Proc. BIS'05. (2005)

Object-Aware Processes: The PHILharmonicFlows Approach

Object-Aware Processes: PHILharmonicFlows



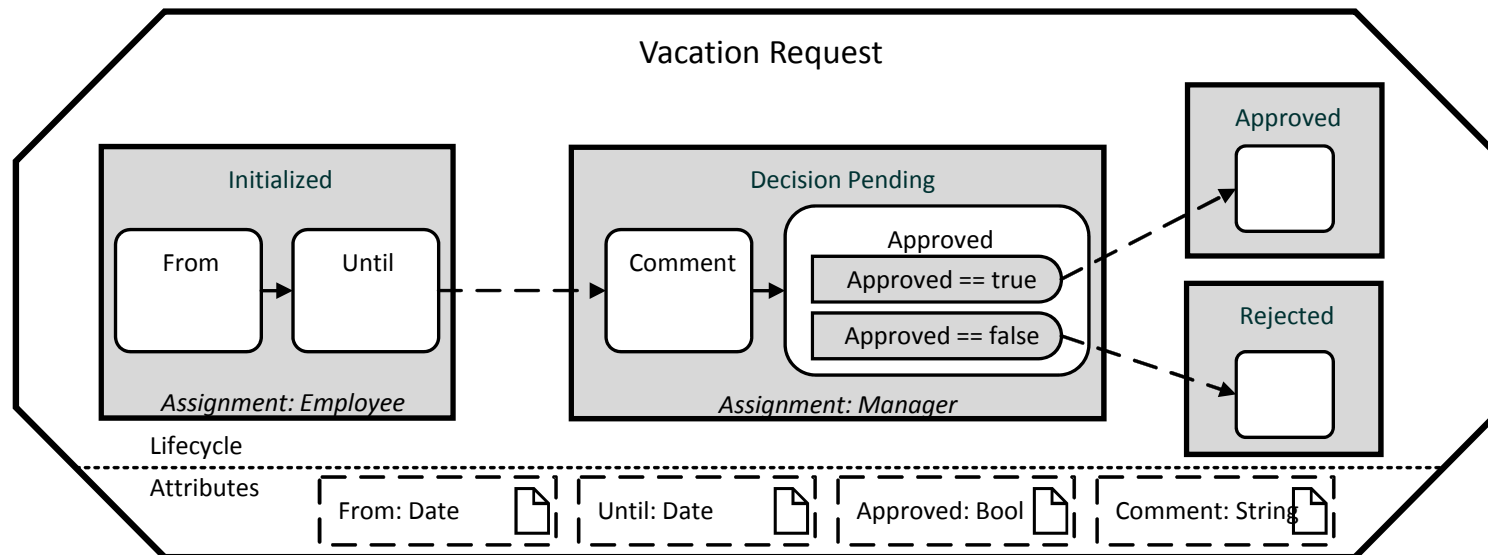
[1] Künzle, Vera and Reichert, Manfred

PHILharmonicFlows: towards a framework for object-aware process management
Journal of Software Maintenance and Evolution: Research and Practice

[2] Künzle, Vera

Object-Aware Process Management
PhD thesis, University of Ulm.

Object-Aware Processes: PHILharmonicFlows



Vacation Request – Init

From

Until

Submit

Vacation Request – Decision

From

Until

Approved

Comment

Submit

Object-Aware Processes: PHILharmonicFlows

PHILharmonicFlows

PHILharmonicFlows Login



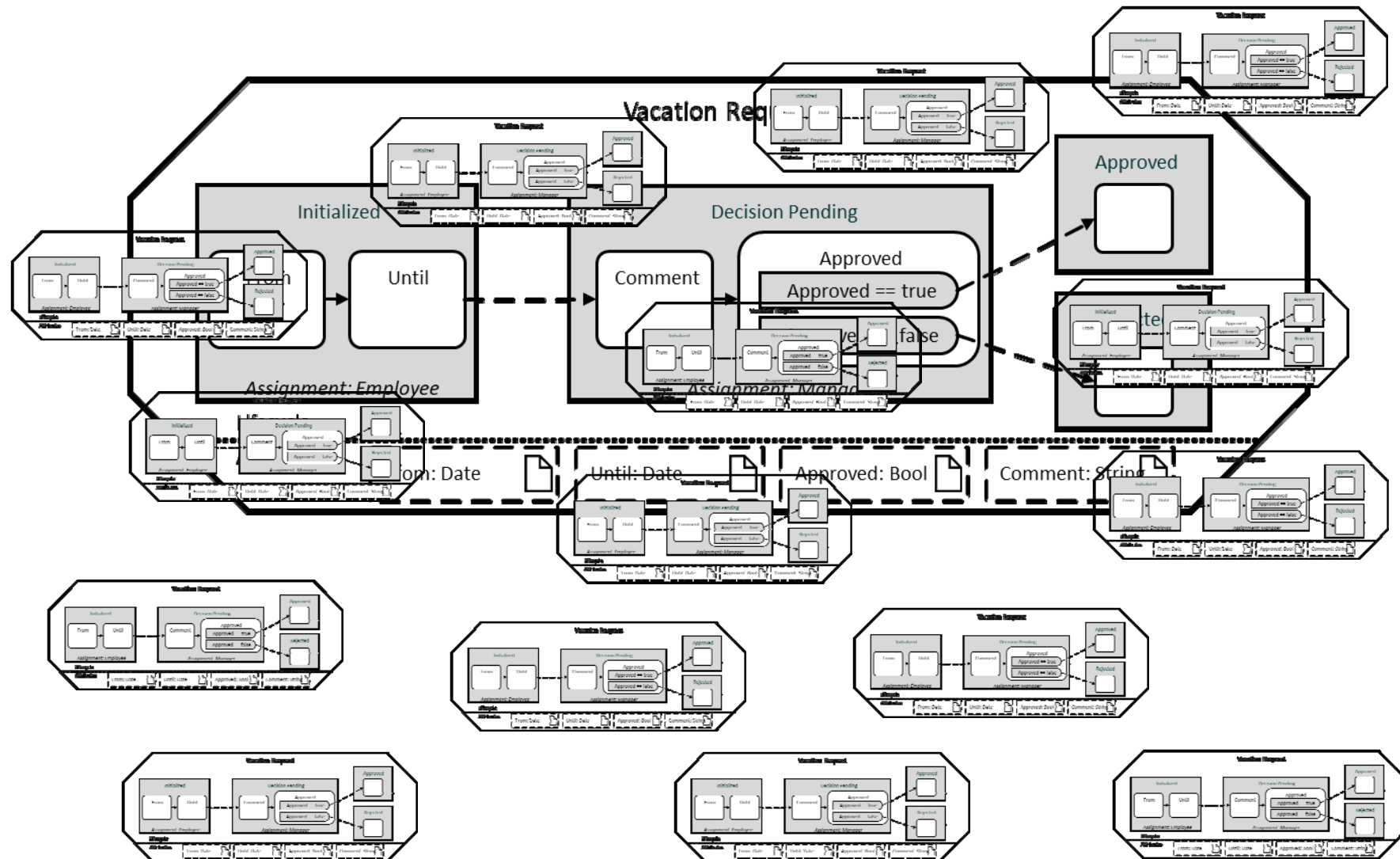
Project
Demo

Username

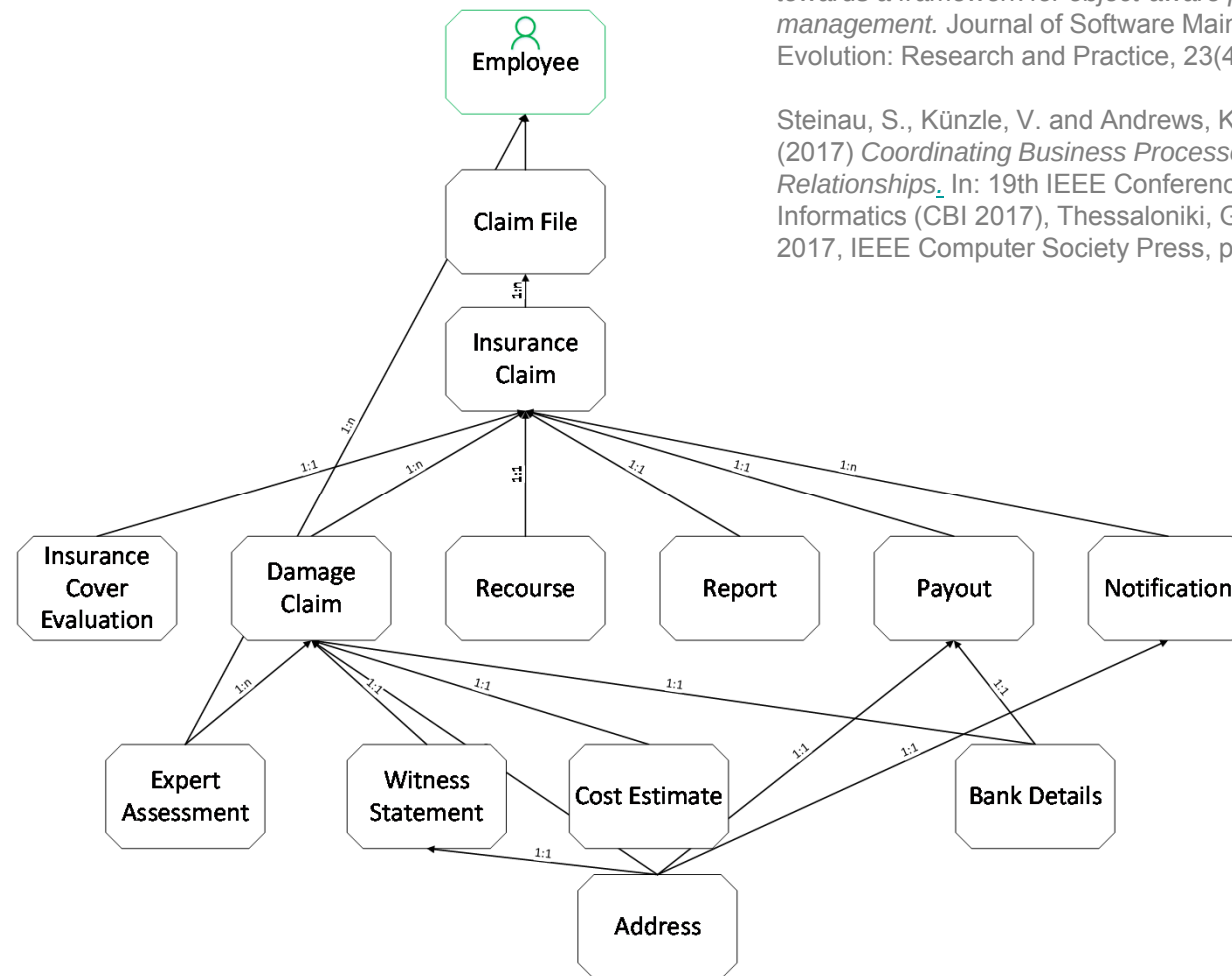
Password

Login

Object-Aware Processes: PHILharmonicFlows



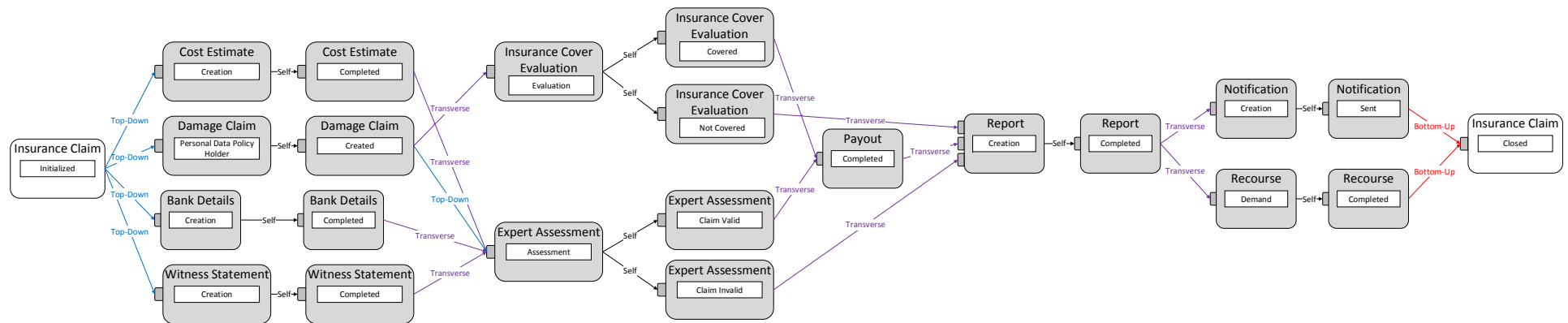
Object-Aware Processes: PHILharmonicFlows

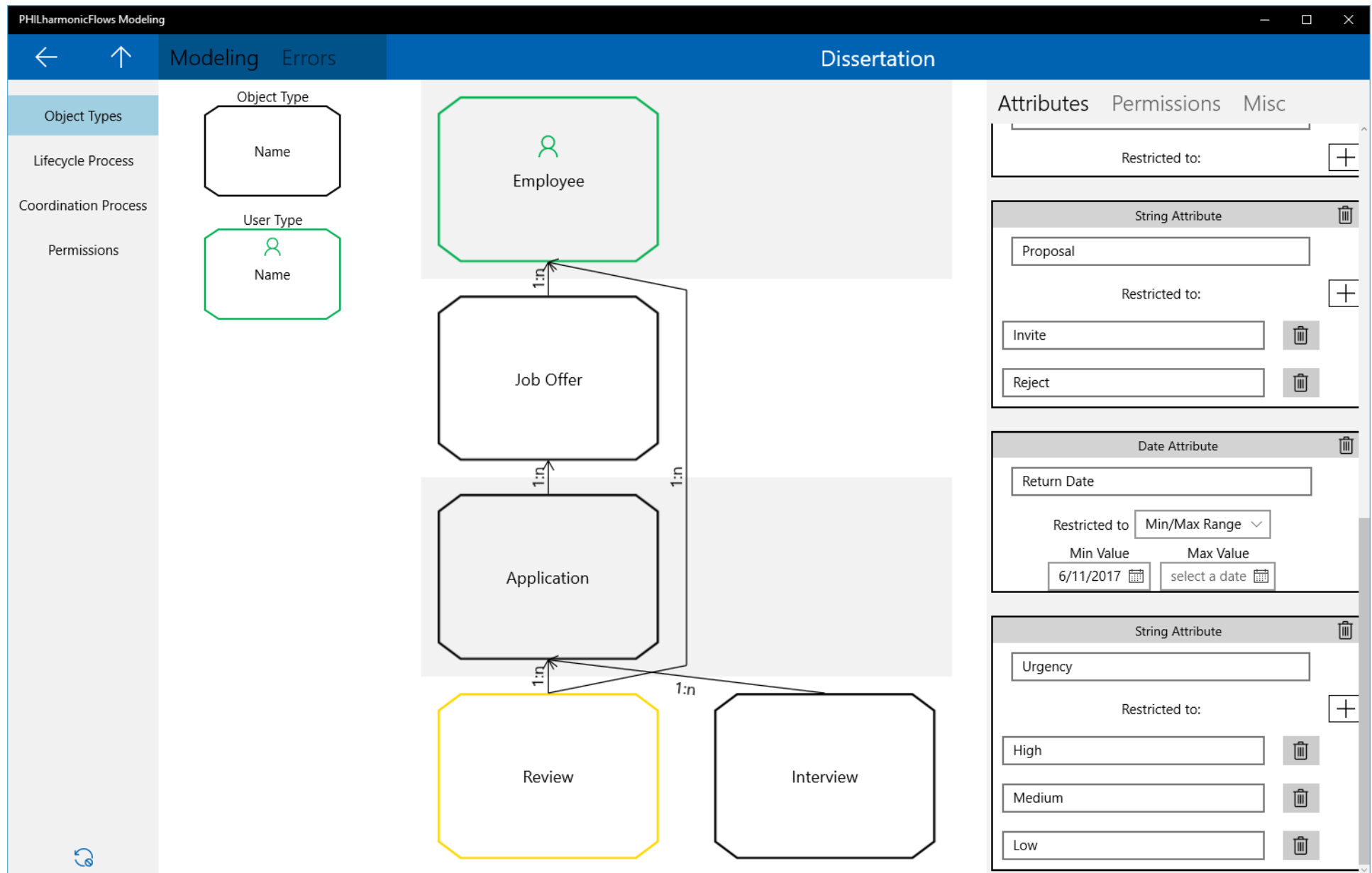


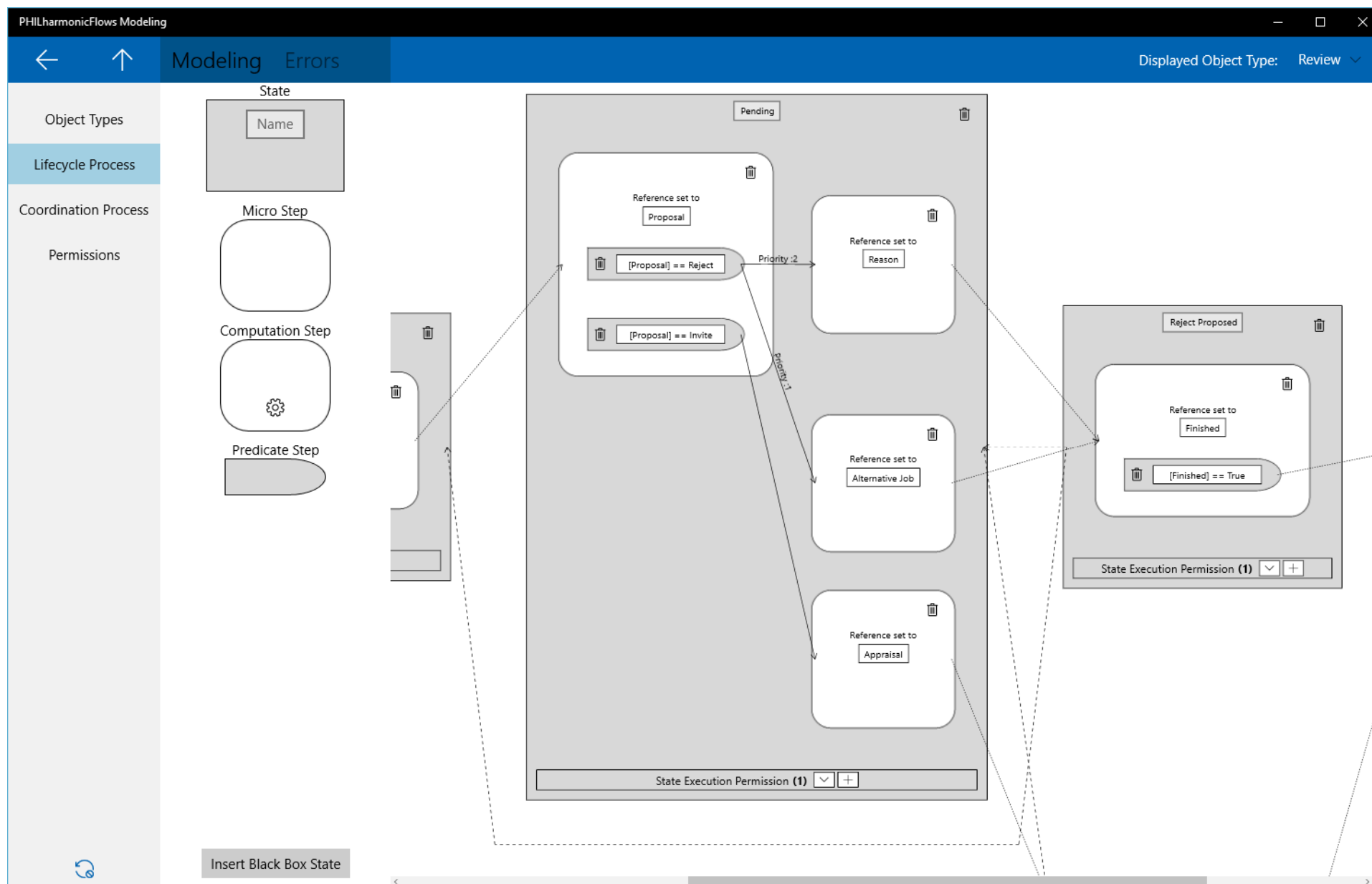
Künzle, V. and Reichert, M. (2011) *PHILharmonicFlows: towards a framework for object-aware process management*. Journal of Software Maintenance and Evolution: Research and Practice, 23(4): 205-244, Wiley

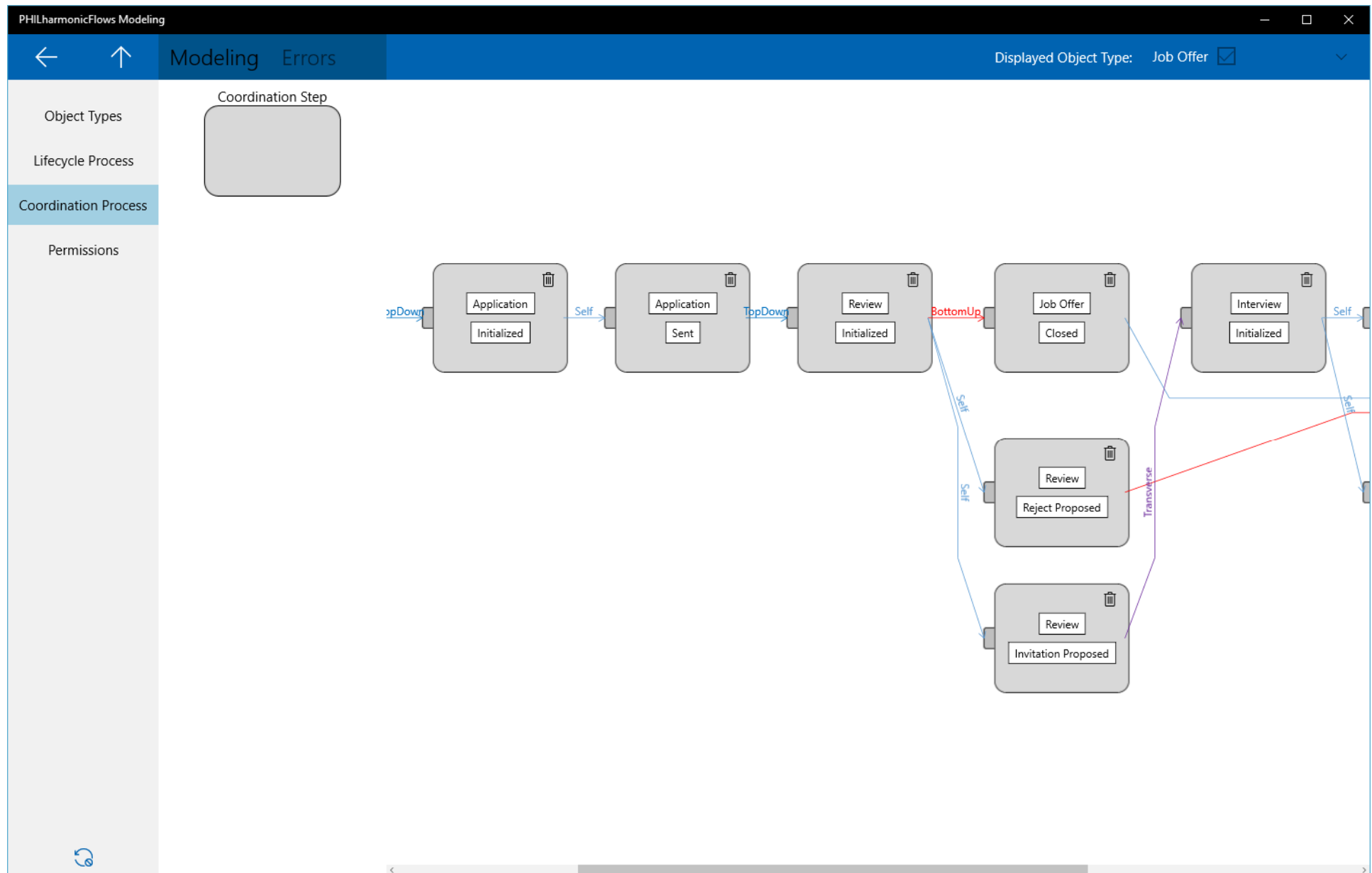
Steinau, S., Künzle, V. and Andrews, K., and Reichert, M. (2017) *Coordinating Business Processes Using Semantic Relationships*. In: 19th IEEE Conference on Business Informatics (CBI 2017), Thessaloniki, Greece, 24-26 July 2017, IEEE Computer Society Press, pp. 33-42

Object-Aware Processes: PHILharmonicFlows









PHILharmonicFlows Modeling							
Object Types	Permission Table:	Employee Context Role	Reviewer	Personnel Officer	Personnel Officer For Rejected Reviews	Personnel Officer For Accepted Reviews	
	Review	Instantiate		Delete			
Lifecycle Process	Initialized			Execute			
	Attributes						
	Urgency		Read	Write			
	Return Date		Read	Write			
Coordination Process	Proposal						
	Reason						
	Alternative Job						
	Remark		Read	Write			
Permissions	Comment		Write				
	Appraisal						
	Finished						
	Pending		Execute				
	Attributes						
	Urgency		Read	Read			
	Return Date		Read	Read			
	Proposal		Write				
	Reason		Write				
	Alternative Job		Write	Read			
	Remark		Read	Read			
	Comment		Write	Read			
	Appraisal		Write				
	Finished						
	Reject Proposed				Execute		
	Attributes						
	Urgency						
	Return Date						
	Proposal						
	Reason						
	Alternative Job						
	Remark						
	Comment						
	Appraisal				Write		
	Finished						
	Invitation Proposed					Execute	
	Attributes						
	Urgency						
	Return Date						

PHILharmonicFlows Runtime

← ↑ Dissertation Edit Delete Filter Execute

Administrator Worklist

4407658291381996482	Job Offer	Closed	6/11/2017 4:55:26 PM	✓
8288672291684580076	Review	Reject Proposed	6/11/2017 4:55:26 PM	✓
-3970306653706878424	Review	Reject Proposed	6/11/2017 4:55:26 PM	✓
8671489088404099594	Review	Reject Proposed	6/11/2017 4:55:26 PM	✓
-8419984937993741539	Review	Initialized	6/11/2017 4:49:28 PM	✓
7630257585817070920	Review	Pending	6/11/2017 4:55:26 PM	✓
4918915507557312524	Review	Initialized	6/11/2017 4:49:29 PM	✓
4790065286363751117	Review	Invitation Proposed	6/11/2017 4:55:26 PM	✓
-639893494739306410	Review	Pending	6/11/2017 4:55:26 PM	✓
-6180318946247778032	Review	Pending	6/11/2017 4:55:26 PM	✓
-4363376569576081433	Interview	Planned	6/11/2017 4:55:26 PM	✓
-8932175026097589114	Review	Pending	6/11/2017 4:55:26 PM	✓
-7285684711112844959	Interview	Conducted	6/11/2017 4:55:26 PM	✓
3590480695781055469	Interview	Conducted	6/11/2017 4:55:26 PM	✓
7388703511994963673	Interview	Conducted	6/11/2017 4:55:26 PM	✓
5497268771763492786	Interview	Conducted	6/11/2017 4:55:26 PM	✓
-3570444321314257539	Interview	Planned	6/11/2017 4:55:26 PM	✓
-9097192747705590155	Interview	Planned	6/11/2017 4:55:26 PM	✓

PHILharmonicFlows Runtime

← ↑ Link Edit Delete

Dissertation Filter

Objects

Administrator

Name
Application

State
Sent

Status
Running

Date Last Changed
6/11/2017 4:51:29 PM

Attribute Values

Review

Qualification
VFMRDL

AverageBreakTime
HHDXOW

Immediately Available?
True

Job Offer

Name
AQRV

Proficiencies
JDITP

Job Offer

Name	State	Status	Changed	Linked
Job Offer	Closed	Running	6/11/2017 4:50:01 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:01 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	True
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	False
Job Offer	Closed	Running	6/11/2017 4:50:02 PM	True

Review

Name	State	Status	Changed	Linked
Review	Initialized	Running	6/11/2017 4:49:28 PM	True
Review	Pending	Running	6/11/2017 4:50:02 PM	True
Review	Initialized	Running	6/11/2017 4:49:29 PM	True
Review	Invitation Proposed	Running	6/11/2017 4:50:03 PM	True
Review	Pending	Running	6/11/2017 4:50:02 PM	True
Review	Pending	Running	6/11/2017 4:50:01 PM	True
Review	Pending	Running	6/11/2017 4:51:31 PM	True

Interview

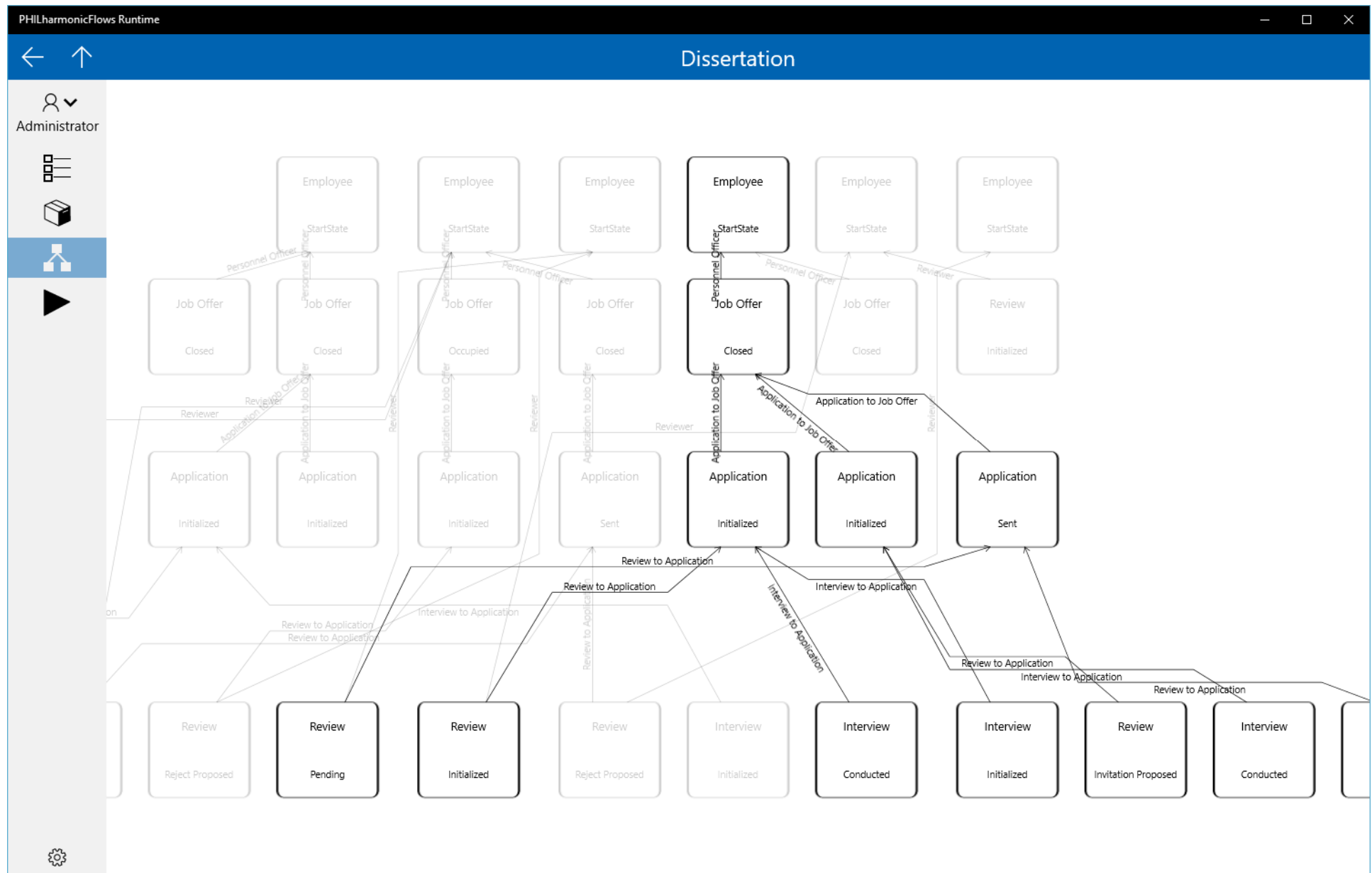
Name	State	Status	Changed	Linked
Interview	Planned	Running	6/11/2017 4:49:56 PM	False
Interview	Conducted	Running	6/11/2017 4:50:02 PM	True
Interview	Conducted	Running	6/11/2017 4:50:01 PM	True
Interview	Conducted	Running	6/11/2017 4:50:01 PM	False
Interview	Conducted	Running	6/11/2017 4:50:00 PM	True
Interview	Planned	Running	6/11/2017 4:49:58 PM	False
Interview	Planned	Running	6/11/2017 4:49:58 PM	False

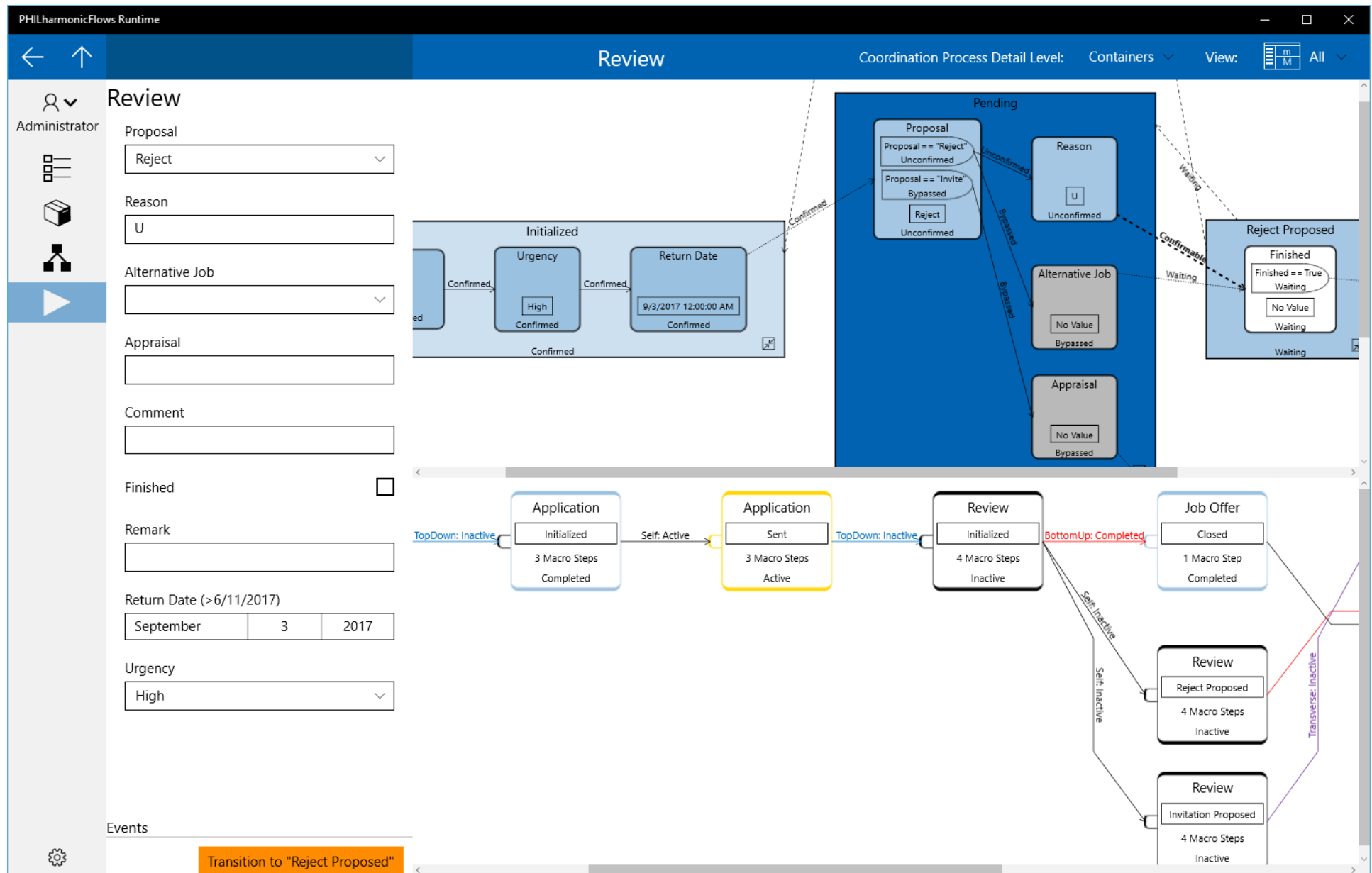
Application

Name	State	Status	Changed	Linked
Application	Initialized	Running	6/11/2017 4:50:02 PM	True
Application	Initialized	Running	6/11/2017 4:51:29 PM	True
Application	Sent	Running	6/11/2017 4:51:29 PM	True
Application	Initialized	Running	6/11/2017 4:51:32 PM	True
Application	Initialized	Running	6/11/2017 4:51:31 PM	True
Application	Sent	Running	6/11/2017 4:51:33 PM	True
Application	Initialized	Running	6/11/2017 4:51:33 PM	True

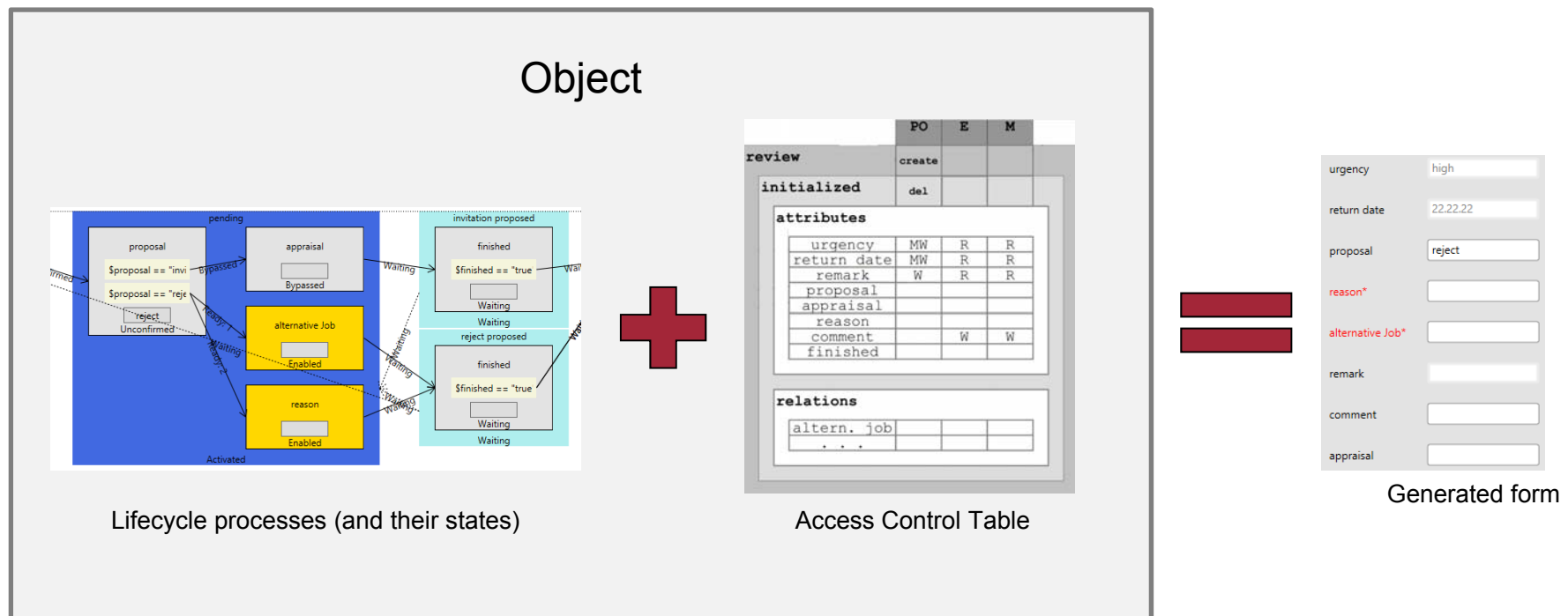
Employee

Name	State	Status	Changed	Linked
Employee			6/11/2017	





Object-Aware Processes: PHILharmonicFlows



Automated Creation of User Forms

Object-Aware Processes in the Large Scale

Object-Aware Processes in the Large Scale

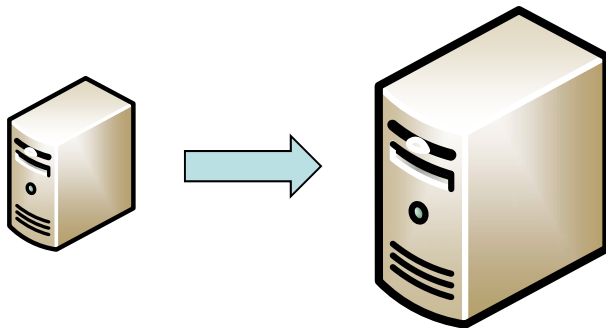
- Can object-aware process support tools scale up horizontally, i.e. over multiple servers? (→ *Hyperscale Process Management*)
- Which coordination patterns are required to cover all potential relations between objects? (→ *The Relational Process Structure*)
- How to integrate real-world objects and resources into the approach?
- How to utilize object-aware processes to fully implement object- and process-aware information systems? (→ *Development Frameworks*)
- How to support engineers in designing object-aware processes? Are there any comprehensibility issues? (→ *The Process of Modeling and Understanding Object-aware Processes*)

Towards Scalable Object-Aware Process Support

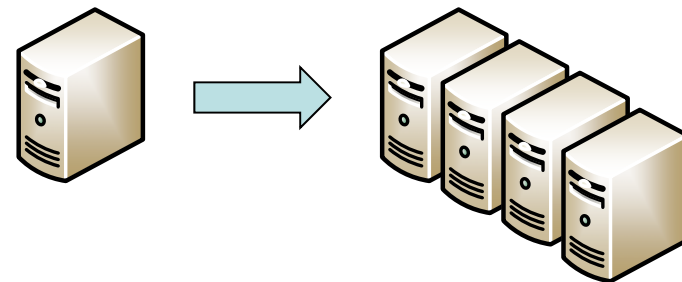
What is scalability?

“Scalability is the capability of a system to handle larger workloads when hardware resources are added.”

Vertical Scalability:



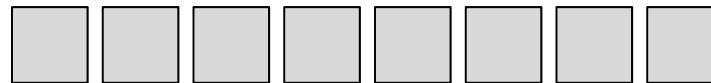
Horizontal Scalability:



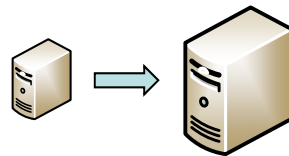
Towards Scalable Object-Aware Process Support

What is scalability?

Workload (8 Work Items, 1x Speed):



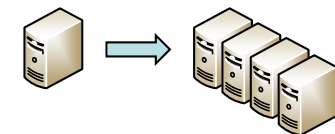
Vertical Scalability:



Workload (8 Work Items, 4x Speed):



Horizontal Scalability:



Workload A (2 Work Items, 1x Speed):



Workload B (2 Work Items, 1x Speed):



Workload C (2 Work Items, 1x Speed):

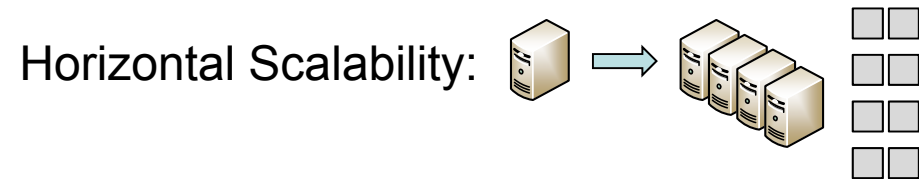
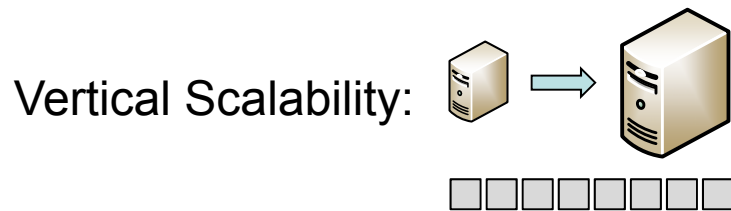


Workload D (2 Work Items, 1x Speed):



Towards Scalable Object-Aware Process Support

What is scalability?



- More Downtime
- More Costly



- Less downtime
- Less costly

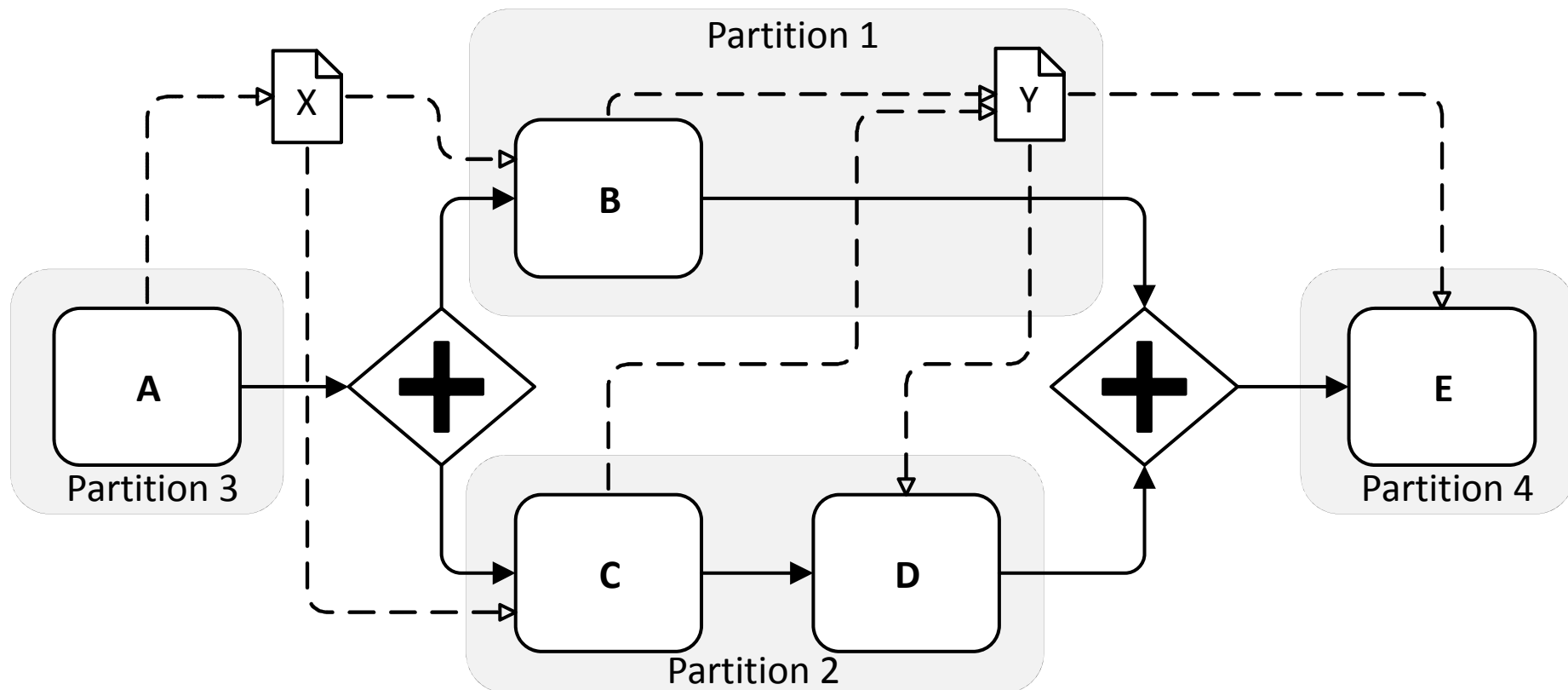


- Applicable to any workload
- Simple
- No communication

- Workload has to be executable in parallel
- Complex
- Requires communication

Towards Scalable Object-Aware Process Support

How scalable are activity-centric processes?



The degree of parallelism is determined by process model structure!



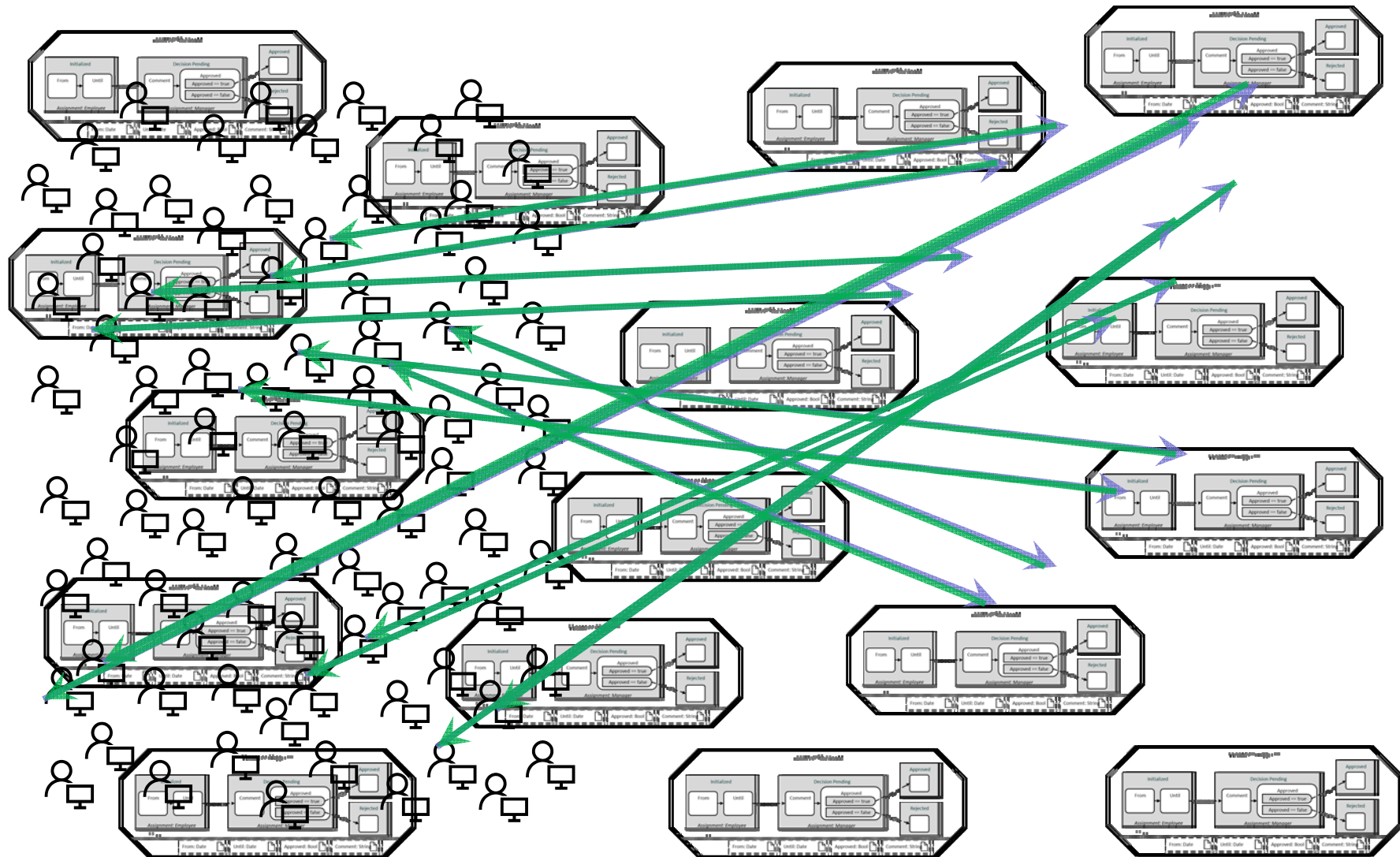
Horizontal scalability for a single process instance is limited!



The amount of clients that can interact with the process at the same time is limited!

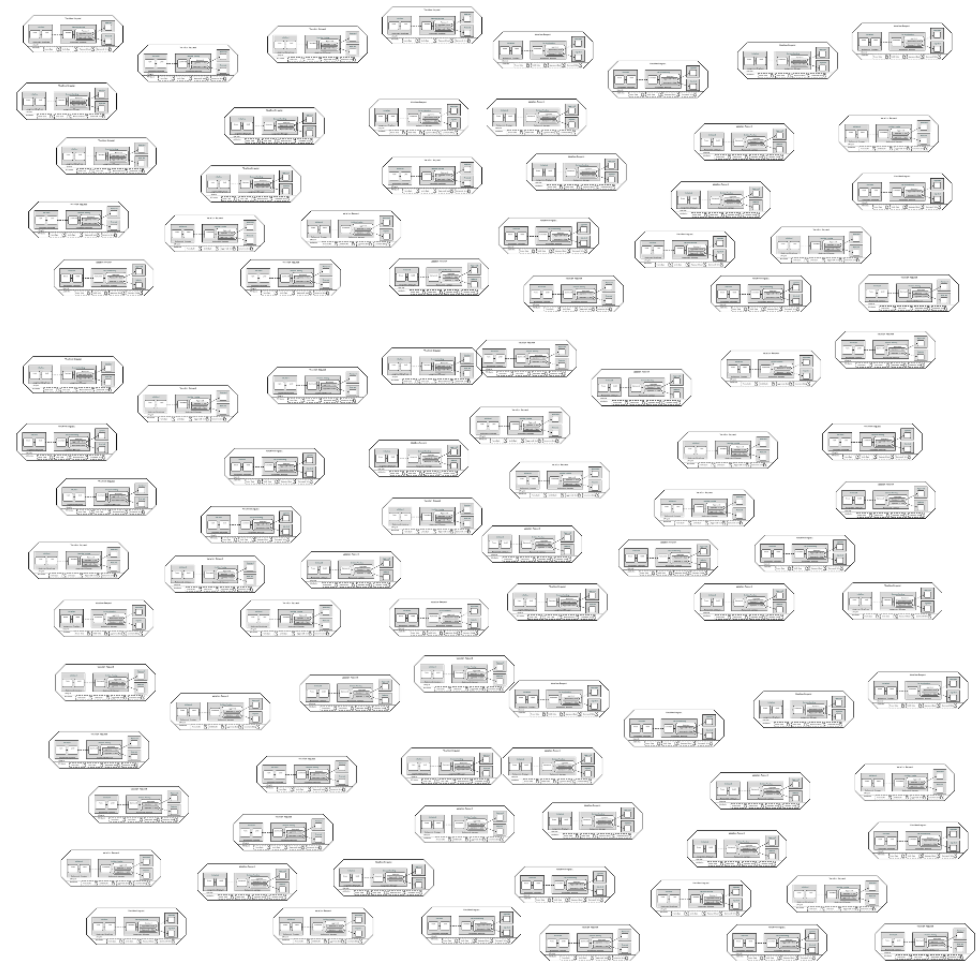
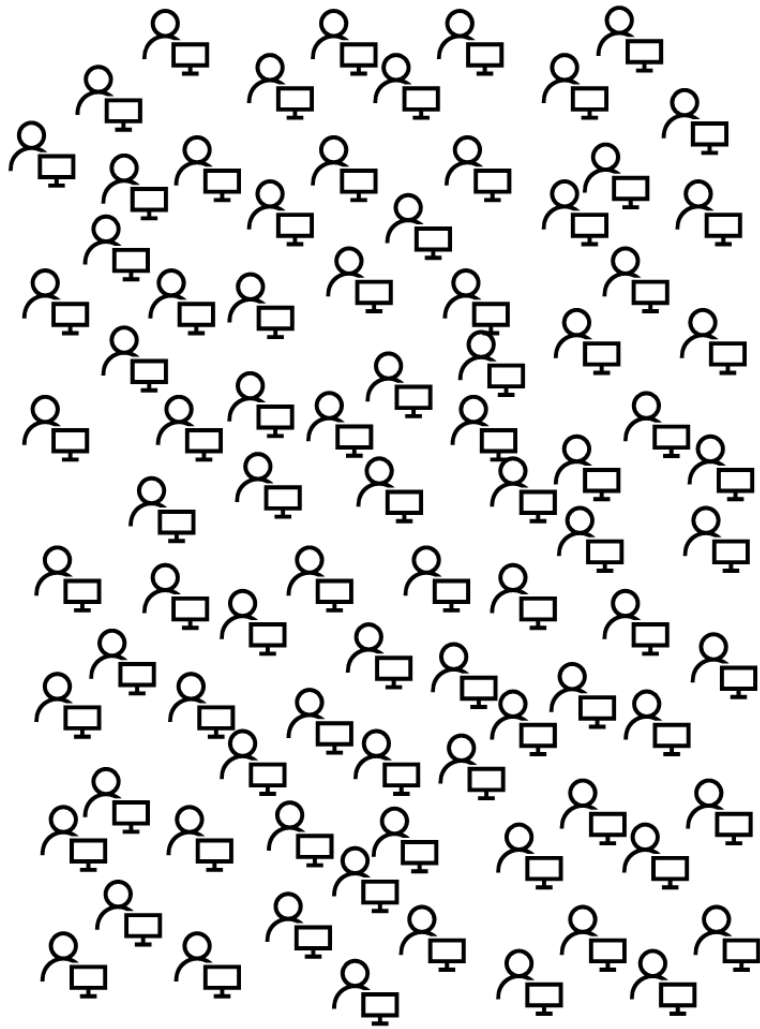
Towards Scalable Object-Aware Process Support

Are object-aware processes more scalable?



Towards Scalable Object-Aware Process Support

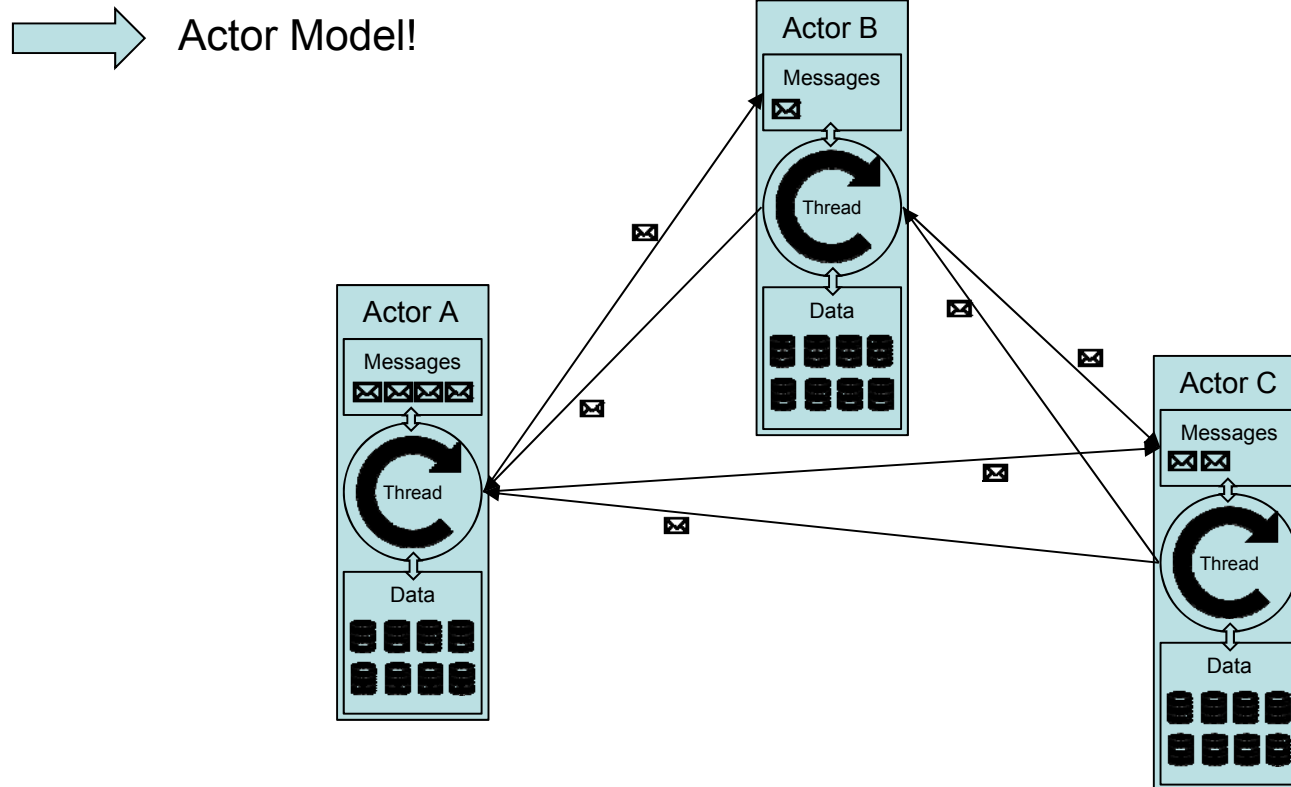
Are scalable object-aware processes technically feasible?



Microservices?

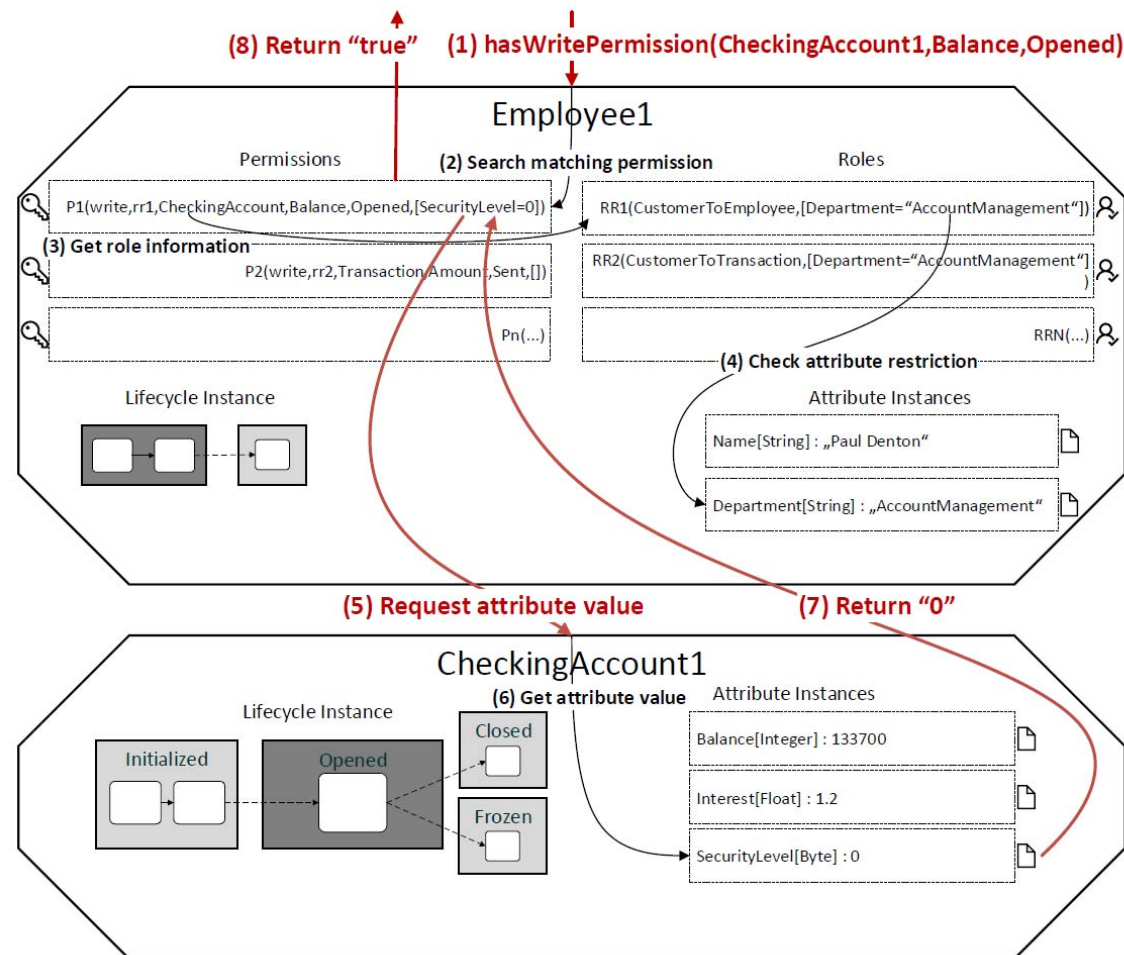
Towards Scalable Object-Aware Process Support

Are scalable object-aware processes technically feasible?

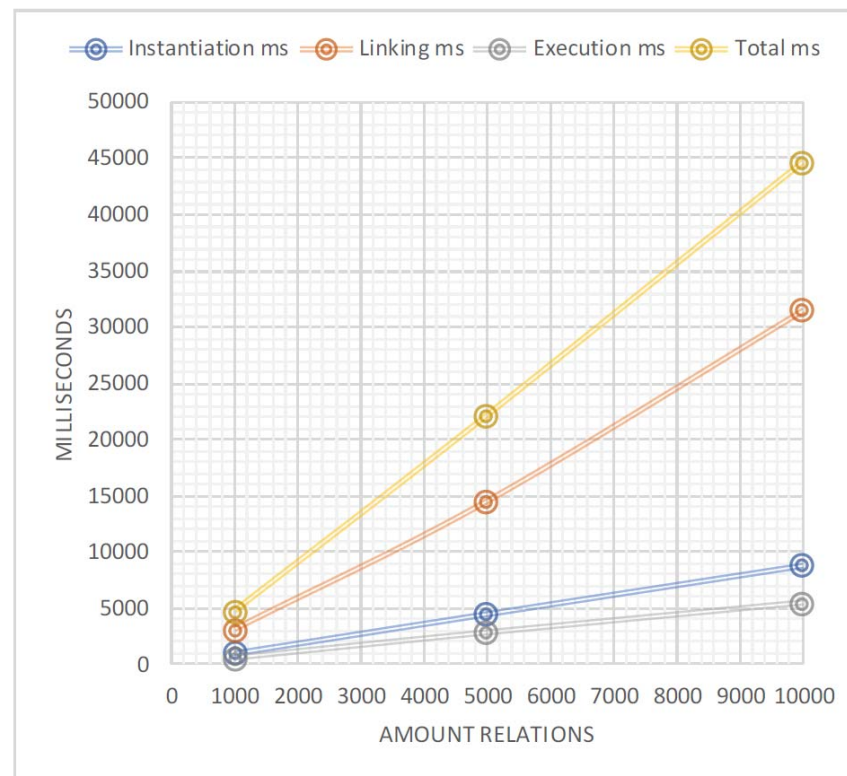


[3] Agha, Gul
*Actors: A Model of Concurrent
Computation in Distributed Systems*
PhD thesis, MIT.

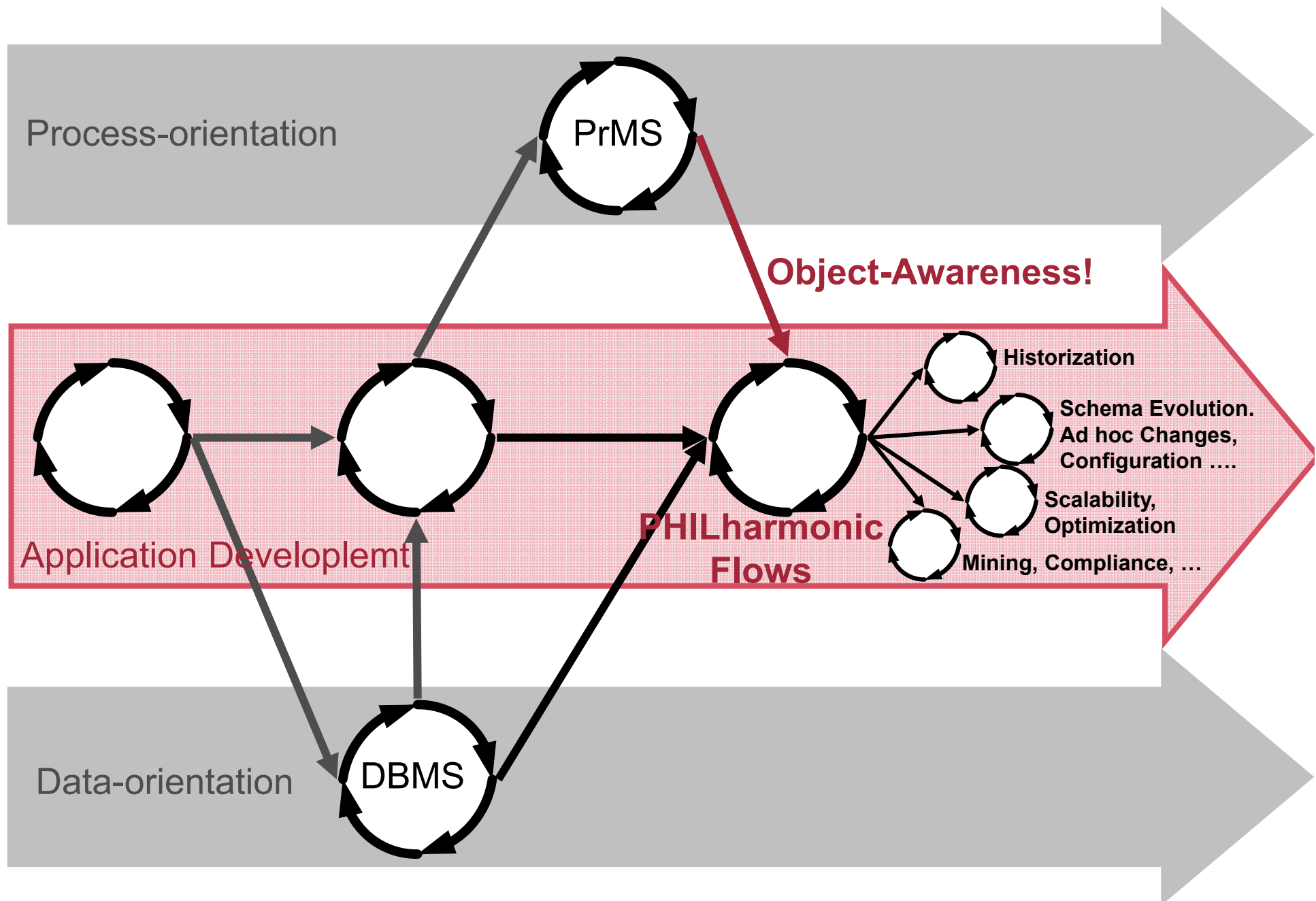
Towards Scalable Object-Aware Process Support First Results



Towards Scalable Object-Aware Process Support First Results



Outlook





Thank you!