Business Process Simulation Revisited

Keynote 6th International Workshop on Enterprise & Organizational Modeling and Simulation (EOMAS 2010), June 7-8, 2010, Hammamet, Tunisia

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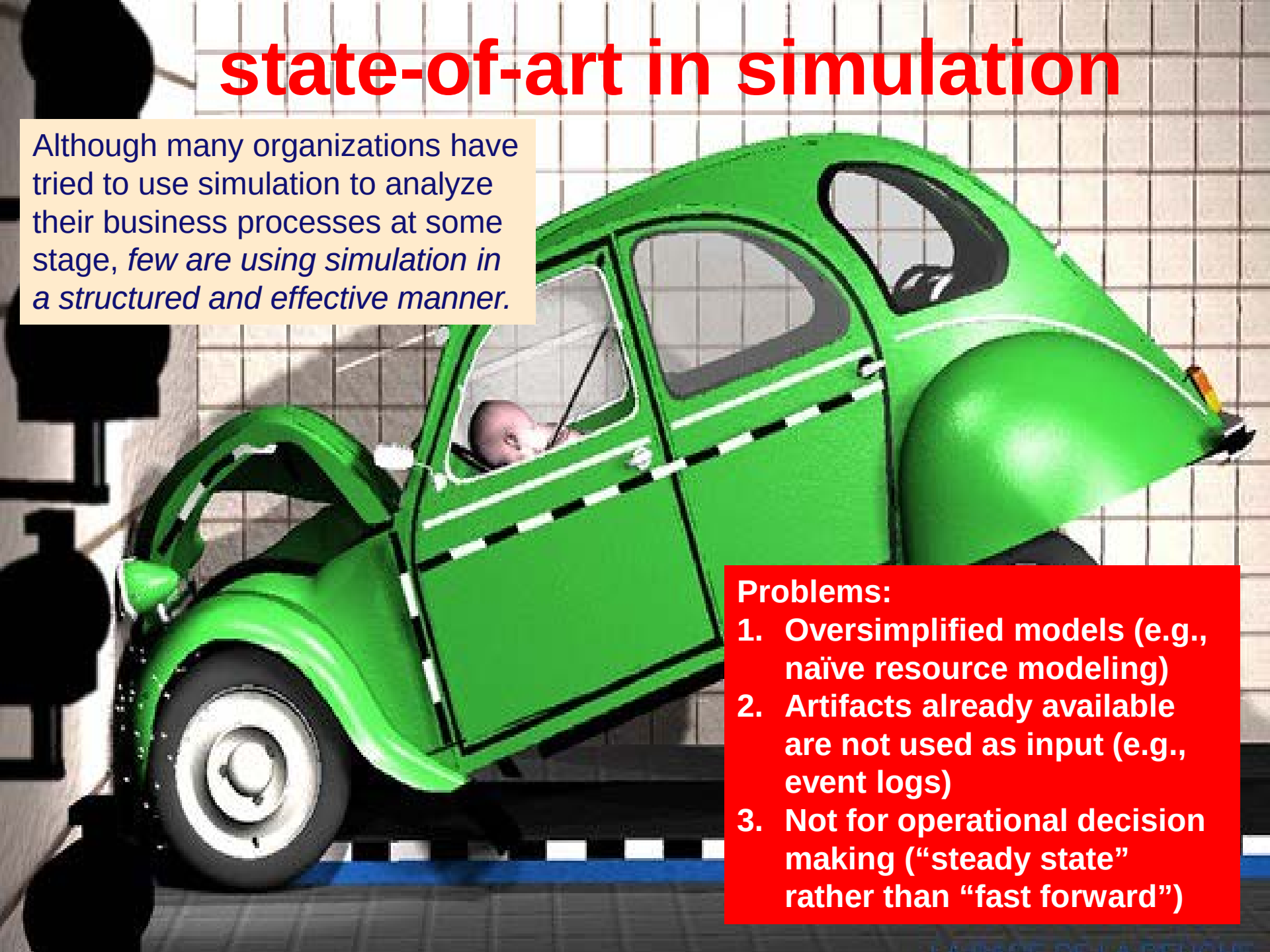
Where innovation starts

state-of-art in simulation

Although many organizations have tried to use simulation to analyze their business processes at some stage, *few are using simulation in a structured and effective manner.*



Problems:

1. **Oversimplified models (e.g., naïve resource modeling)**
2. **Artifacts already available are not used as input (e.g., event logs)**
3. **Not for operational decision making (“steady state” rather than “fast forward”)**

Acknowledgements 1/2

- **W.M.P. van der Aalst, J. Nakatumba, A. Rozinat, and N. Russell.** Business Process Simulation: How to get it right? In *Handbook on Business Process Management, International Handbooks on Information* Systems, pages 317-342. Springer-Verlag 2010. [1]
- **W.M.P. van der Aalst, M. Pesic, and M. Song.** Beyond Process Mining: From the Past to Present and Future. In *CAiSE'10, volume 6051 of Lecture Notes in Computer Science, pages 38-52. Springer-Verlag, 2010.* [2,3]
- **B.F. van Dongen, R.A. Crooy, and W.M.P. van der Aalst.** Cycle Time Prediction: When Will This Case Finally Be Finished? In *CoopIS 2008, volume 5331 of Lecture Notes in Computer Science, pages 319-336. Springer-Verlag, 2008.* [3]
- **J. Nakatumba and W.M.P. van der Aalst.** Analyzing Resource Behavior Using Process Mining. In S. Rinderle-Ma, S. Sadiq, and F. Leymann, editors, *BPM 2009-BPI'09, volume 43 of Lecture Notes in Business Information Processing, pages* 69-80. Springer-Verlag, 2010. [2]
- **H.A. Reijers and W.M.P. van der Aalst.** Short-Term Simulation: Bridging the Gap between Operational Control and Strategic Decision Making. In *IASTED International Conference on Modelling and Simulation, pages 417-421,1999.* [2,3]

Acknowledgements 2/2

- A. Rozinat, R.S. Mans, M. Song, and W.M.P. van der Aalst. Discovering Simulation Models. *Information Systems, 34(3):305-327, 2009.* [2]
- A. Rozinat, M. Wynn, W.M.P. van der Aalst, A.H.M. ter Hofstede, and C. Fidge. Workflow Simulation for Operational Decision Support. *Data and Knowledge Engineering, 68(9):834-850, 2009.* [2,3]
- N. Russell, W.M.P.van der Aalst, A.H.M. ter Hofstede, and D. Edmond. Workflow Resource Patterns: Identification, Representation and Tool Support. In *CAiSE'05 volume 3520 of Lecture Notes in Computer Science, pages 216-232. Springer-Verlag, 2005.* [1]
- M. Wynn, A. Rozinat, W.M.P. van der Aalst, A.H.M. ter Hofstede, and C. Fidge. Chapter 17: Process Mining and Simulation. In *Modern Business Process Automation: YAWL and its Support Environment, pages 437-457. Springer-Verlag,* 2010. [2,3]

Problem 1:
Oversimplified models (e.g., resource modeling)

Everything should be made as simple as possible, but not one bit simpler.
Albert Einstein (1879-1955)

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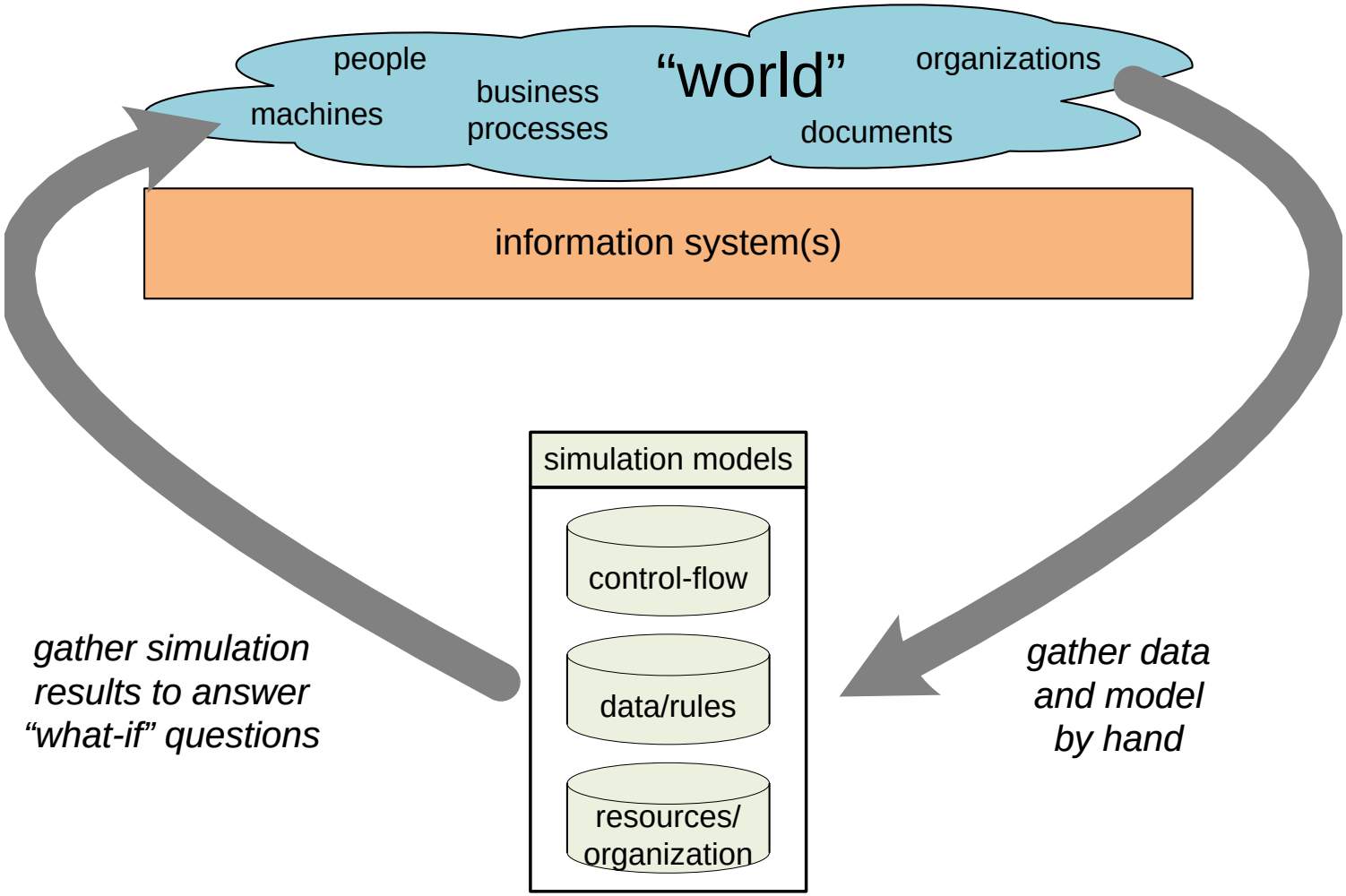
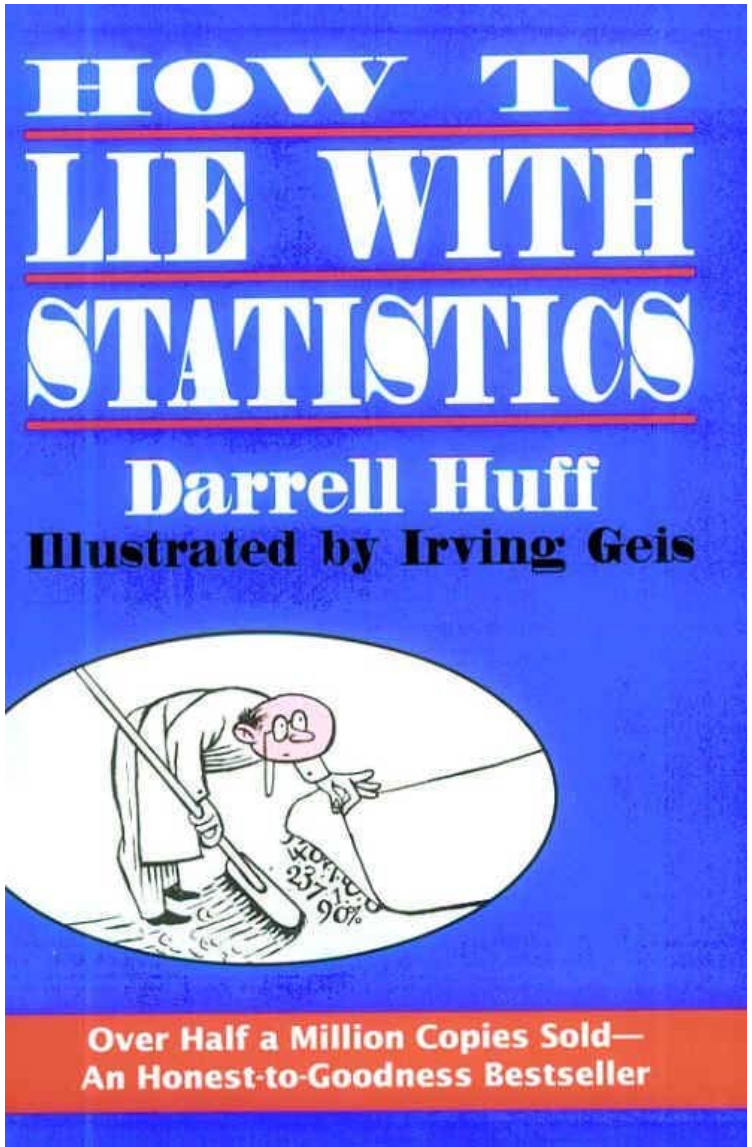
Where innovation starts

Business Process Simulation
(classical view)

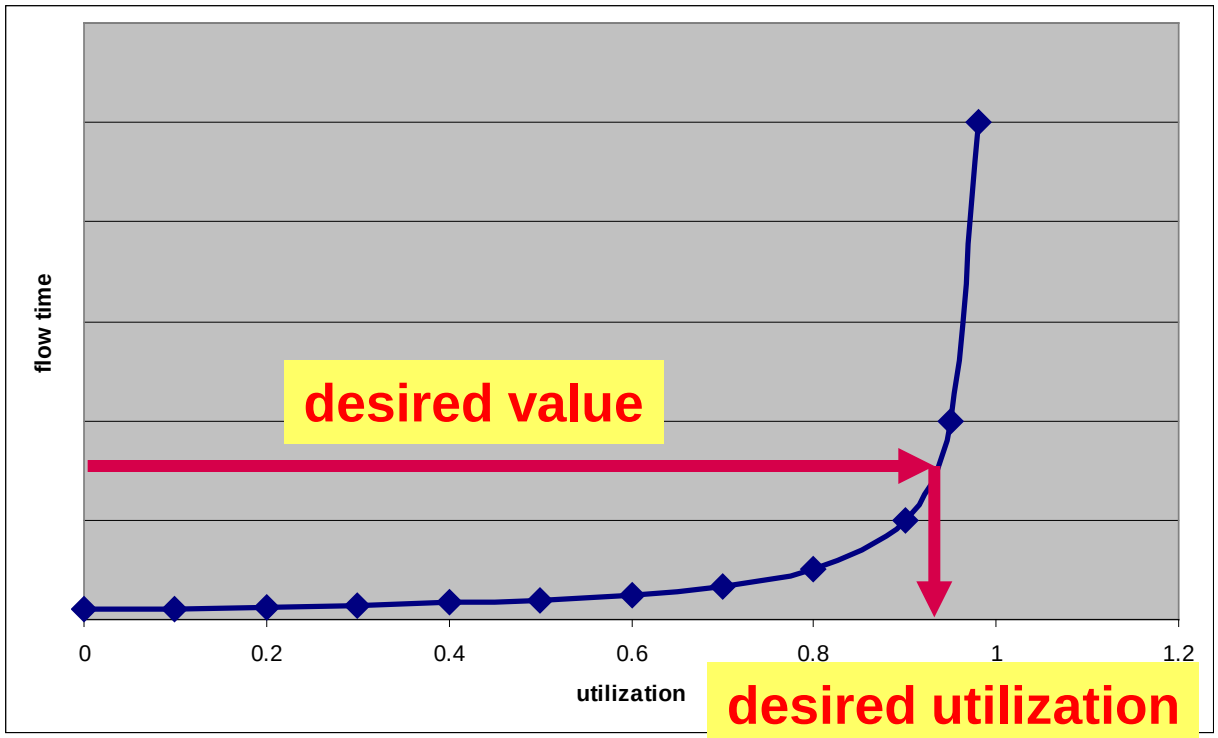


How to Lie With Statistics?

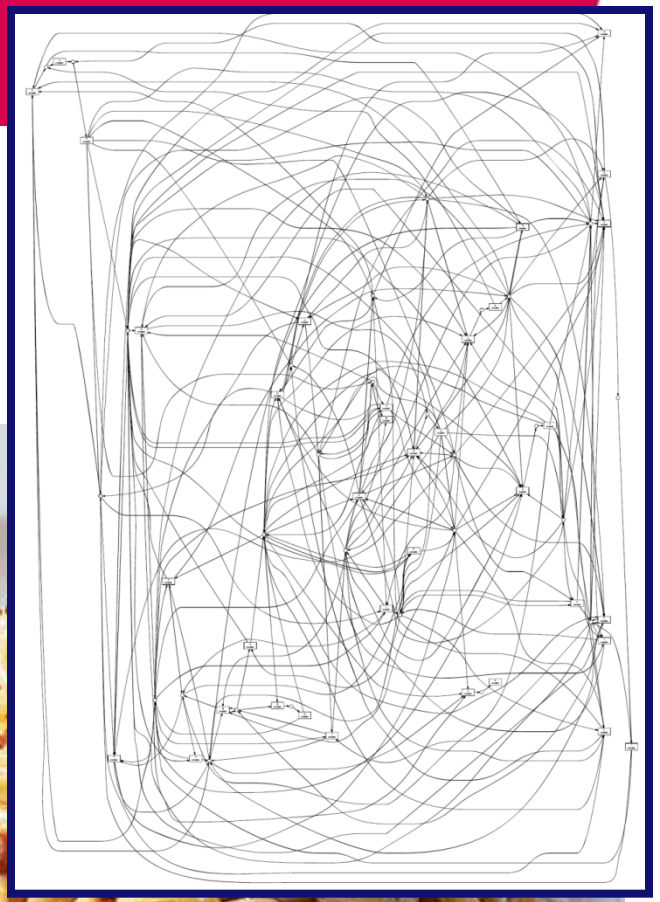


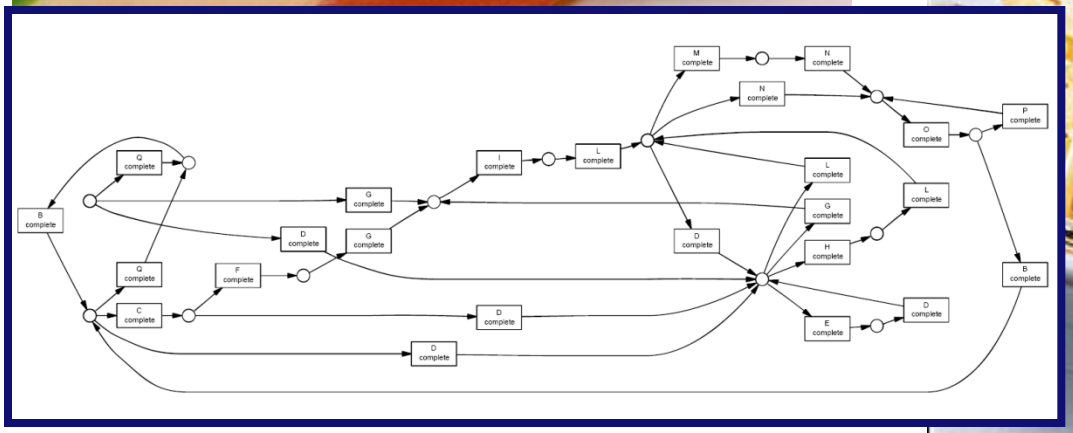
How to Lie With Simulation?

- M/M/1 queue: arrival rate λ, service rate μ, utilization ρ = λ/μ.
- Flow time = 1/(μ-λ), # in system = ρ/(1- ρ)



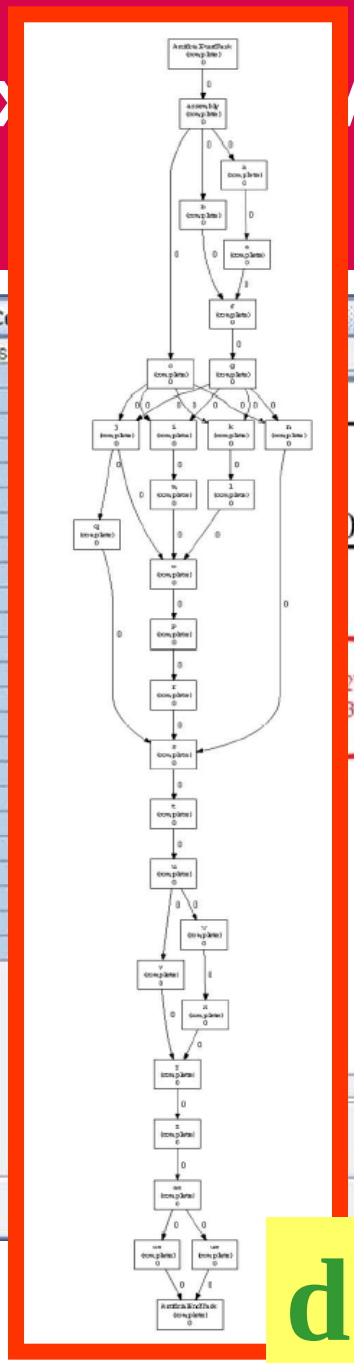
Processes cover the entire spectrum of Italian cuisine …





and are different from what people

Ex ASML test p



design

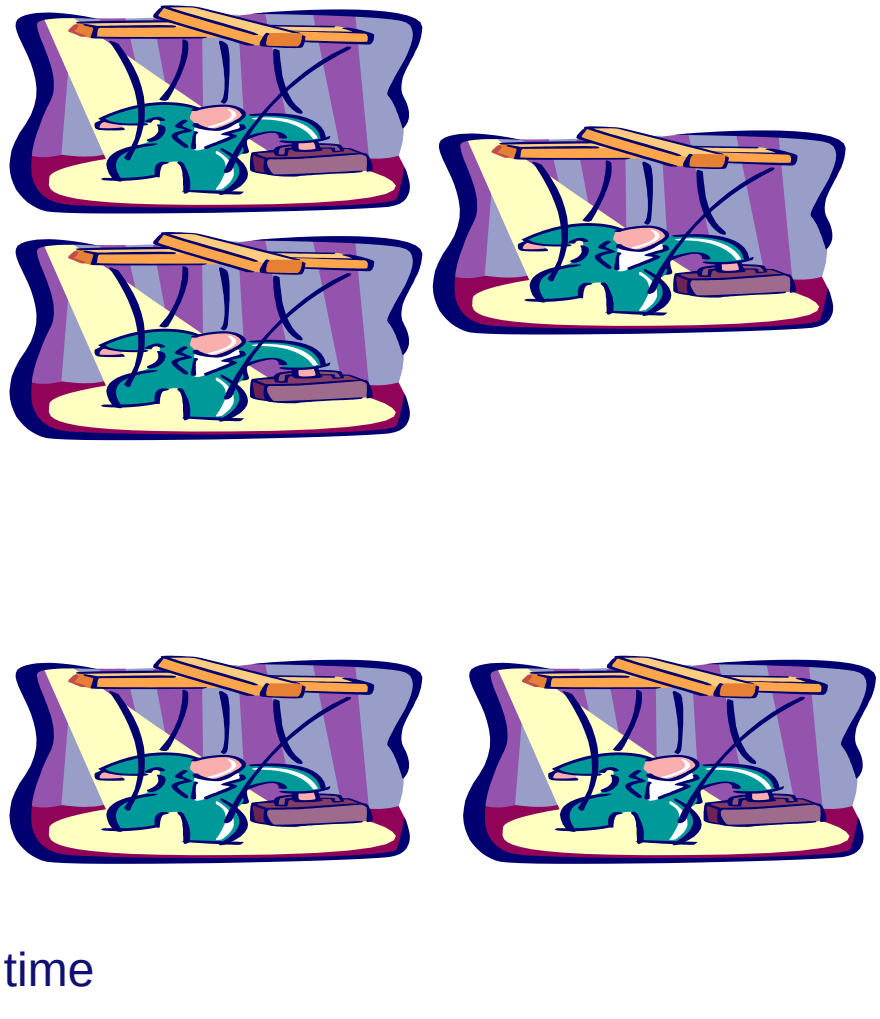
reality

Problems when modeling human resources

- **People do not work at a constant speed, cf. Yerkes-Dodson Law of Arousal, coffee breaks, weather, etc.**
- **People are involved in multiple processes. Hence, different processes/tasks compete for attention and availability is "fluid".**
- **People tend to work part-time and in batches. Different working patterns: every Friday, when the pile is too large, …**
- **Priorities are difficult to model. Competing processes/resources have undefined precedence rules.**
- **Processes may change depending on context. Things are skipped or done in a sloppy manner when …**

Yerkes-Dodson Law of Arousal

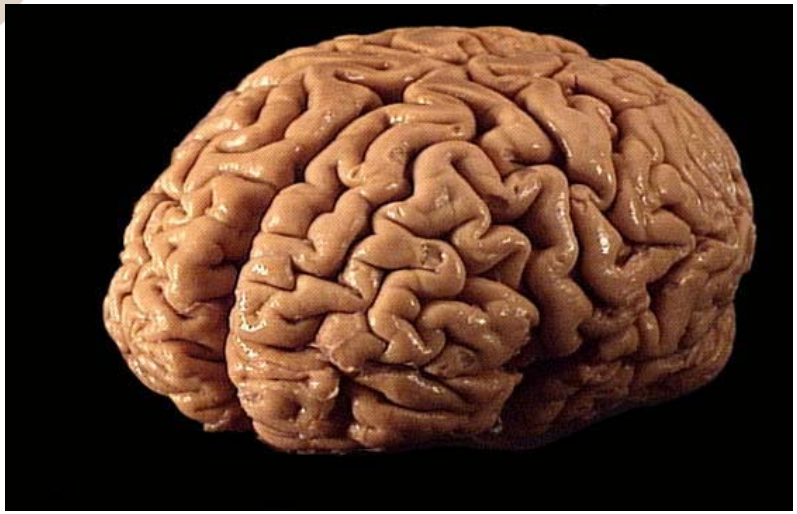
5*0.2 ≠ 1



Classical simulation assumptions

- A resource is:
  - eager to start working,
  - dedicated to a single process,
  - works at a constant speed,
  - does not work in batches,
  - does not have coffee breaks,
  - etc.
- Do you know this person?

Avoid modeling the world in a detailed manner

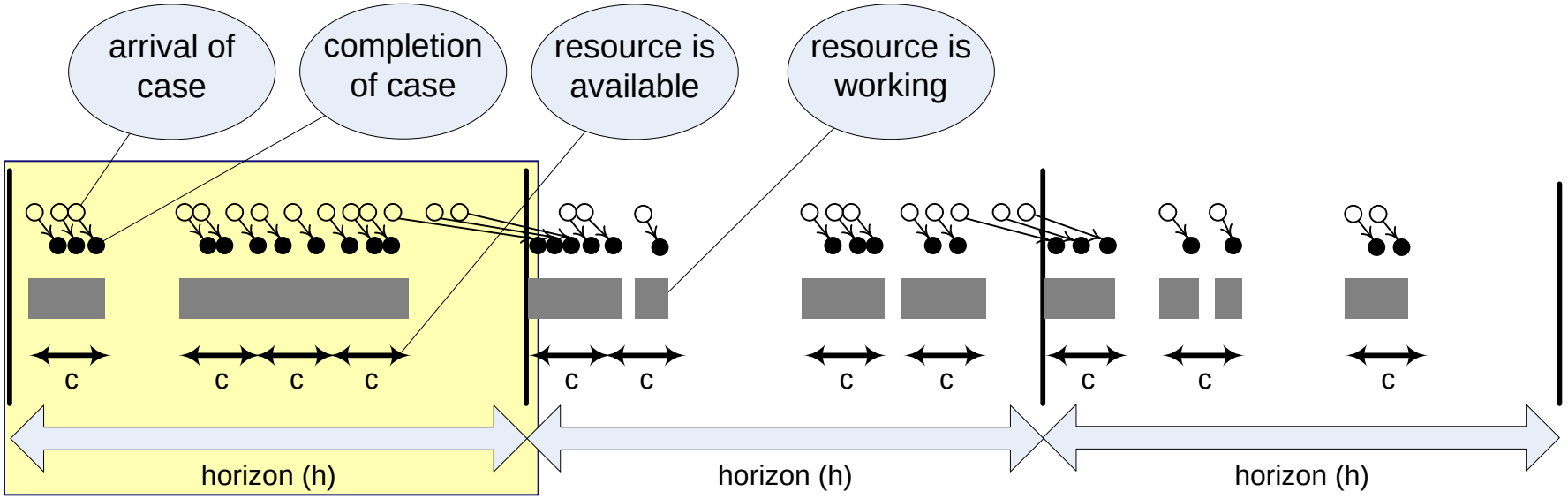


Goal: Characterize resource availability with just a few parameters

Chunks

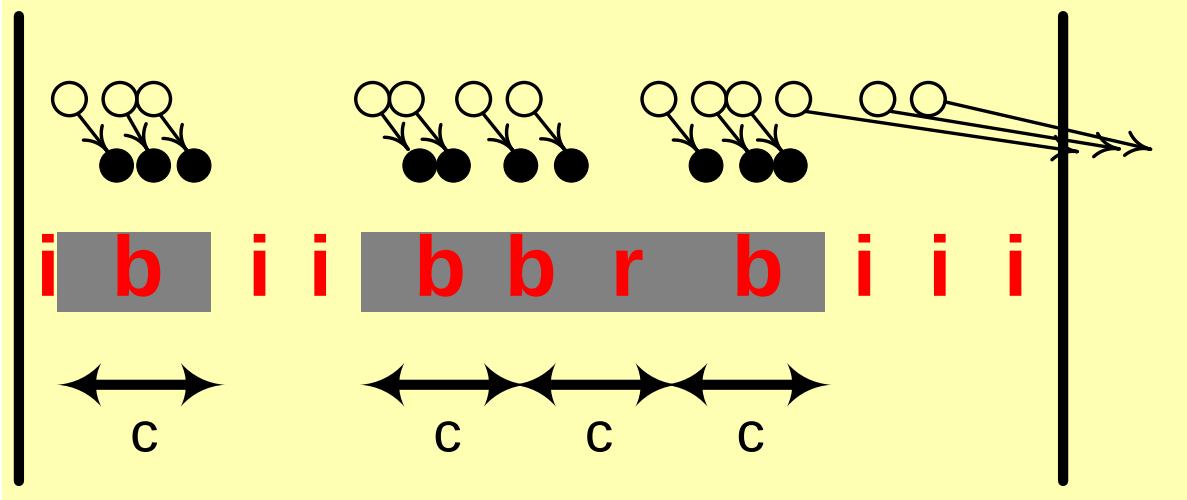
W.M.P. van der Aalst, J. Nakatumba, A. Rozinat, and N. Russell. Business Process Simulation: How to get it right? In *Handbook on Business Process Management, International Handbooks on Informa*tion Systems, pages 317-342. Springer-Verlag 2010.

Chunks: Basic Idea

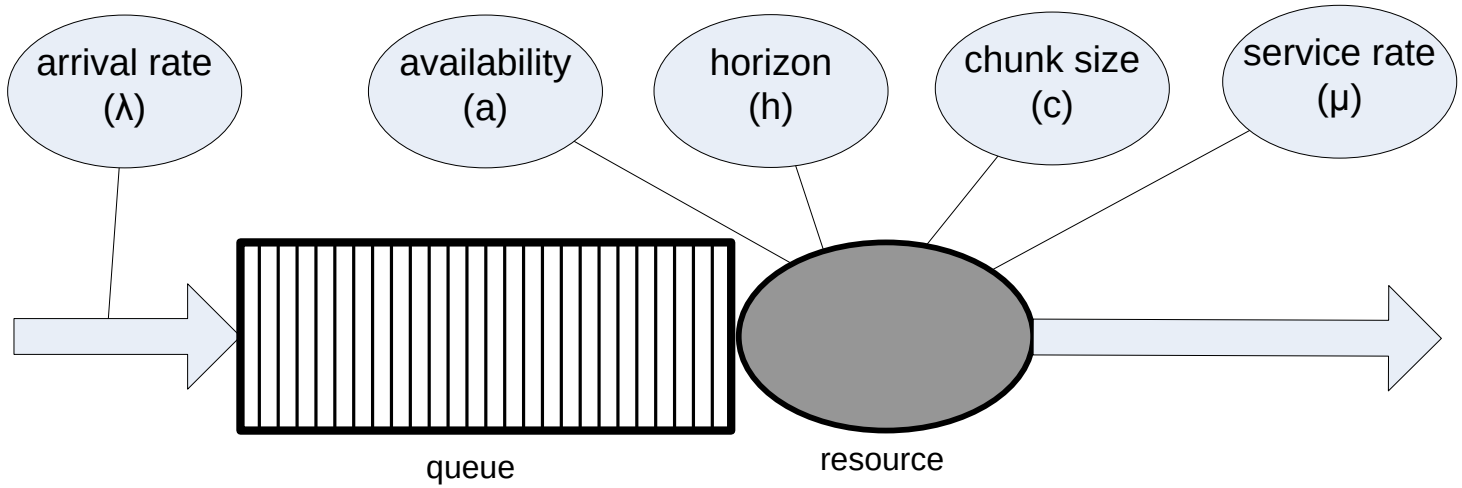


resource:

- **inactive**
- **ready**
- **busy**

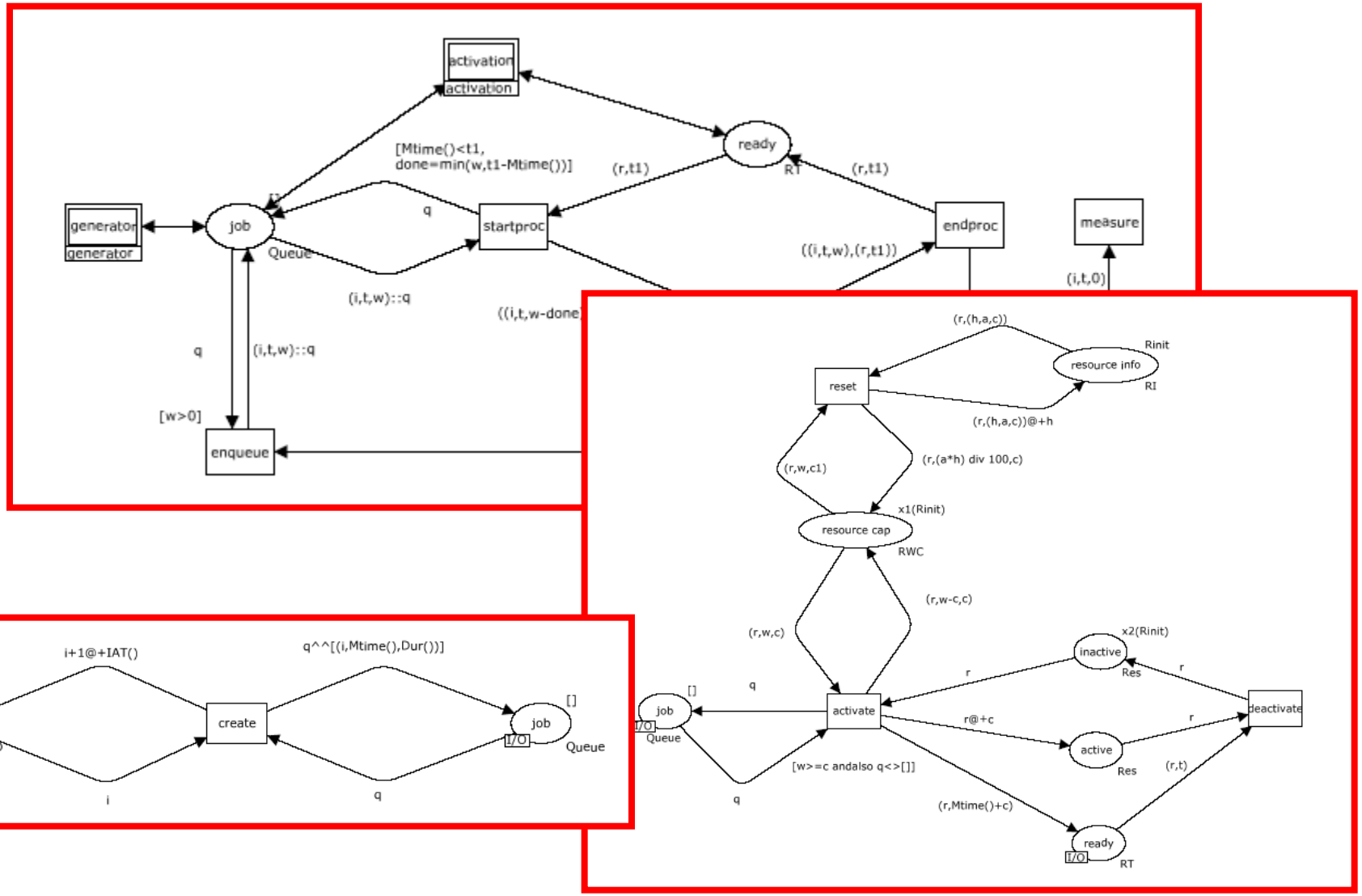


Parameters



- **ρ = λ/μ ≤ a, i.e., utilization is less than availability**
- **c ≤ h, i.e., chunk size cannot be larger than the horizon**
- **(a*h) mod c = 0 in experiments to avoid unusable availability**

CPN model


activation
activation
[Mtime()<t1,
done=min(w,t1-Mtime())]
ready
RT
(r,t1)
(r,t1)
generator
generator
job
Queue
q
startproc
endproc
measure
((i,t,w),(r,t1))
(i,t,0)
(i,t,w)::q
((i,t,w-done)
q
(i,t,w)::q
[w>0]
enqueue
(r,(h,a,c))
Rinit
resource info
RI
reset
(r,(h,a,c))@+h
(r,w,c1)
(r,(a*h) div 100,c)
x1(Rinit)
resource cap
RWC
(r,w-c,c)
(r,w,c)
x2(Rinit)
inactive
Res
r
r
[]
q
job
I/O
Queue
activate
r@+c
deactivate
active
Res
r
[w>=c andalso q<>[]]
(r,t)
q
(r,Mtime()+c)
ready
I/O
RT
i+1@+IAT()
q^^[(i,Mtime(),Dur())]
1
counter
CID
create
[]
job
I/O
Queue
i
q

Effect of availability (a)

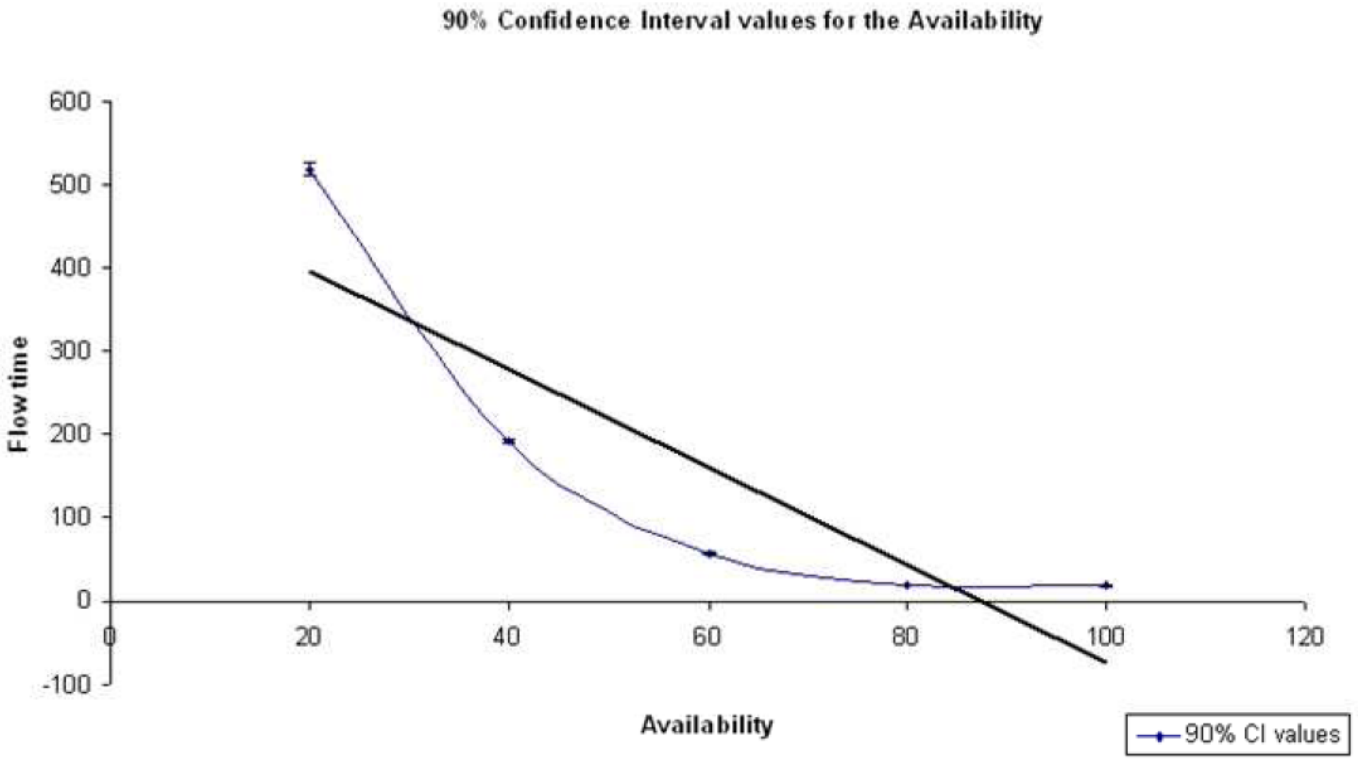


Fig. 9. Graph showing availability against flow time ($\lambda = \frac{1}{100}$, $\mu = \frac{1}{15}$, $\rho = 0.15$, $c = 200$, and $h = 1000$). The flow time reduces as the availability increases. (The straight line shows the trend using linear regression.)

Effect of chunk size (c)

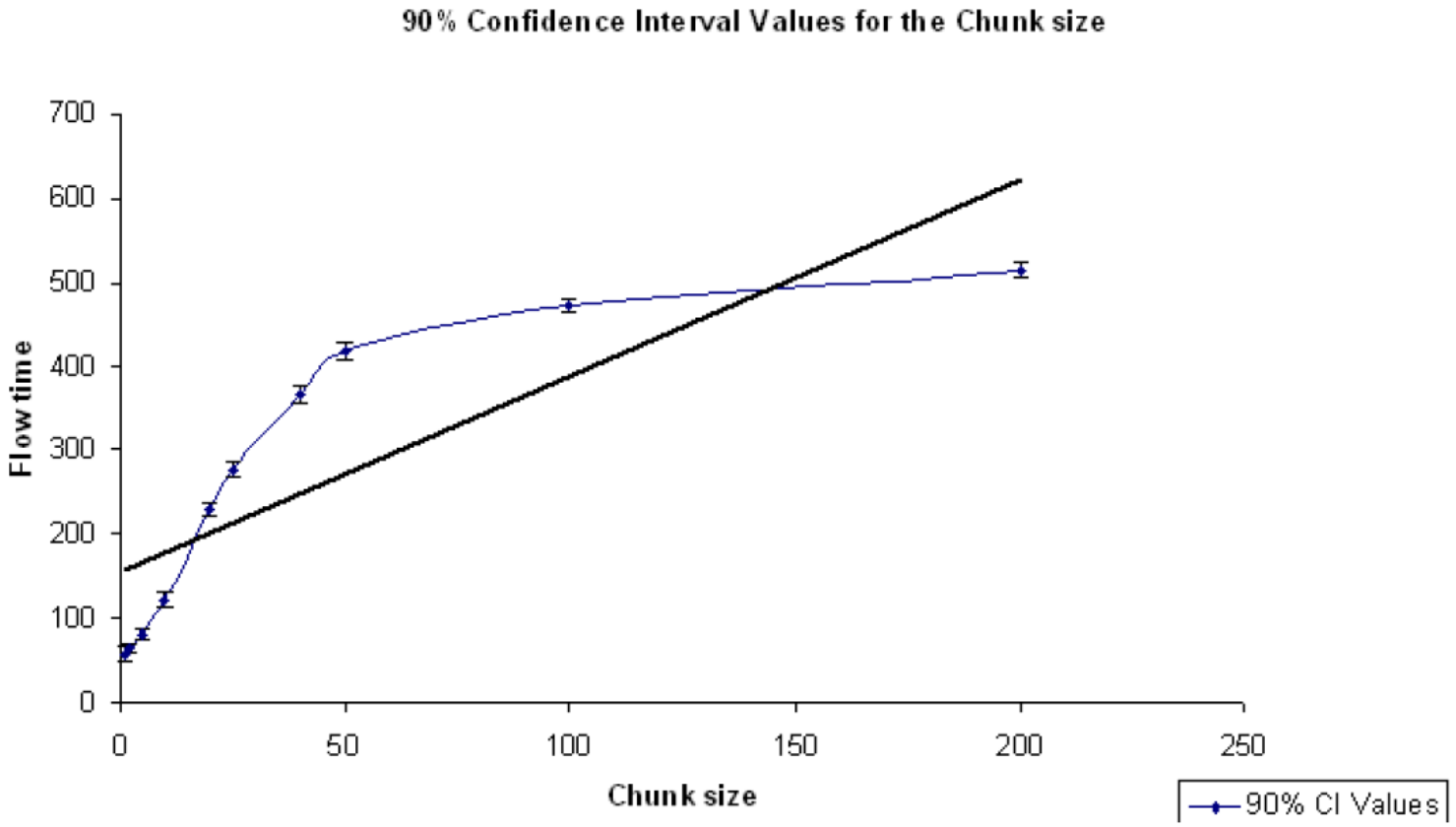


Fig. 10. Graph showing chunk size against flow time ($\lambda = \frac{1}{100}$, $\mu = \frac{1}{15}$, $\rho = 0.15$, $a = 0.2$, and $h = 1000$). The flow time increases as the chunk size increases.

Effect of horizon (h)

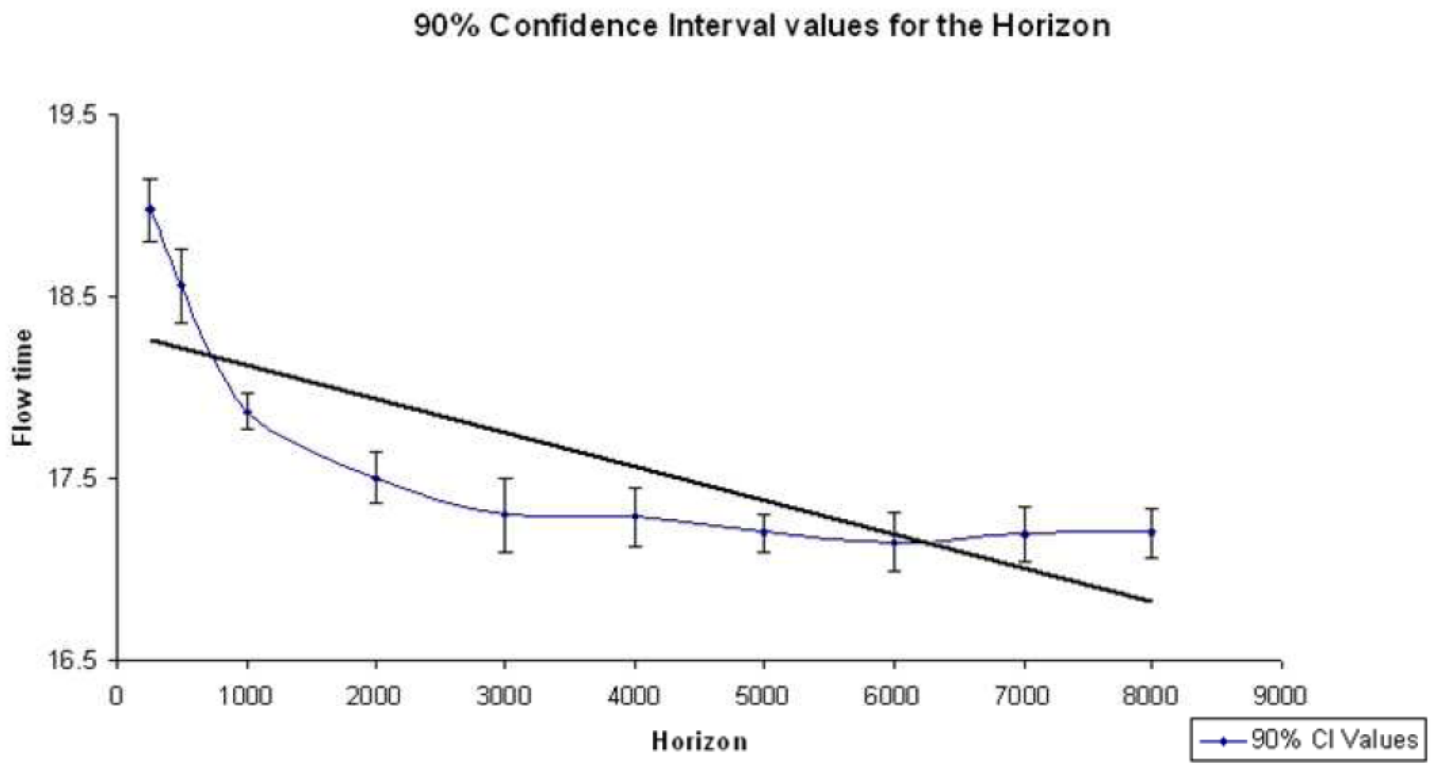


Fig. 11. Graph showing the horizon against the flow times ($\lambda = \frac{1}{100}$, $\mu = \frac{1}{15}$, $\rho = 0.15$, $c = 200$, and $a = 0.8$). The flow time decreases as the horizon increases.

Effect of utilization (ρ)

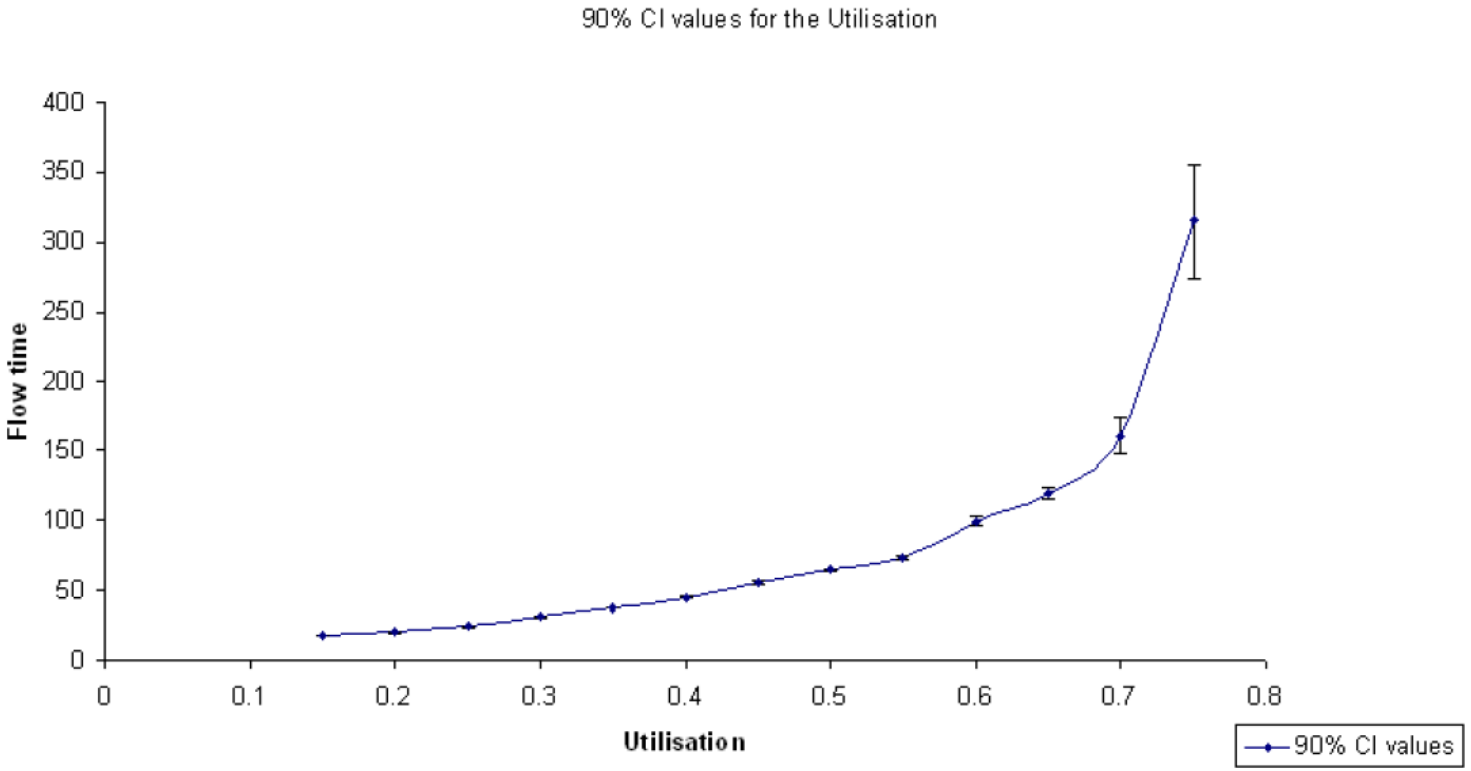
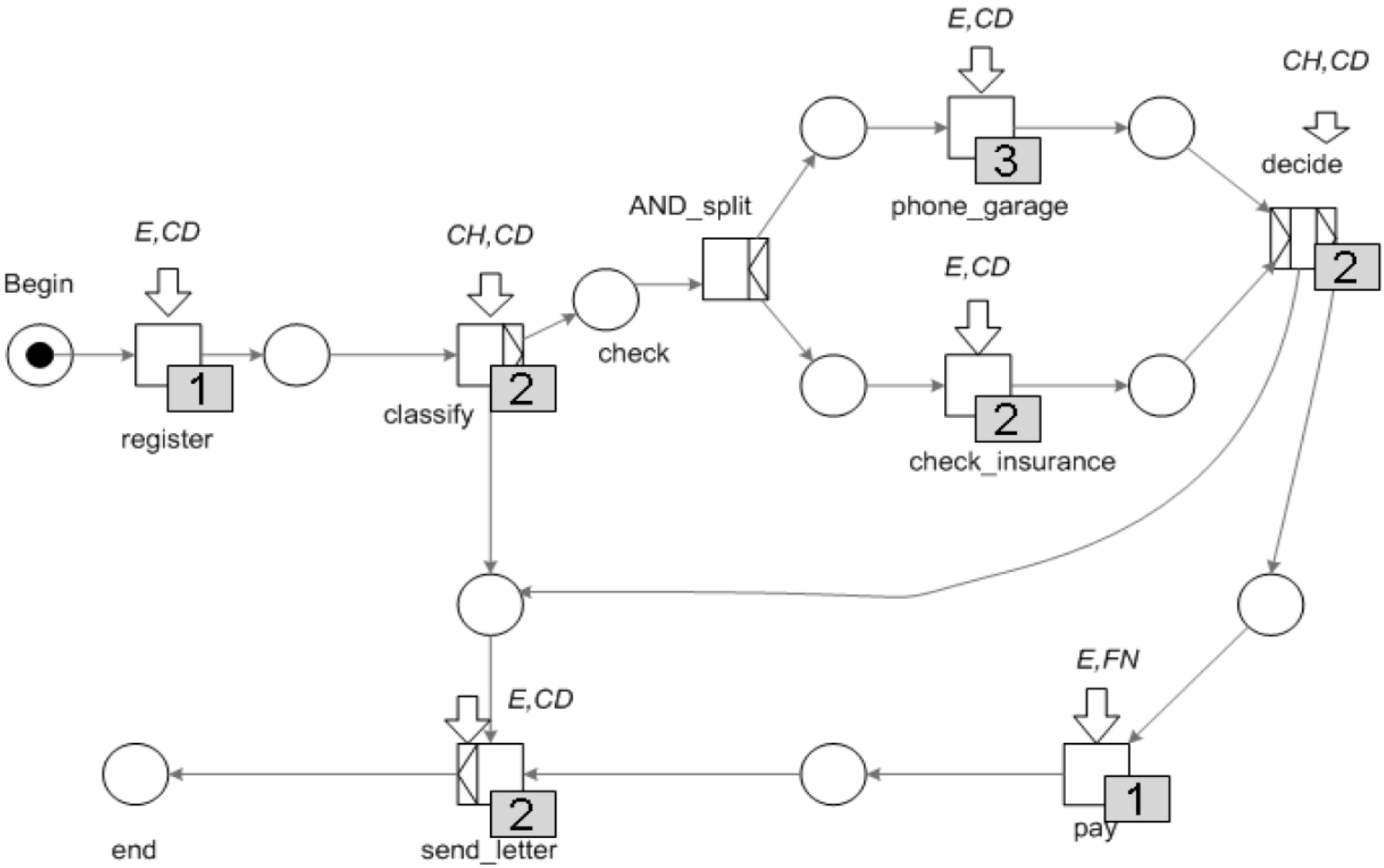
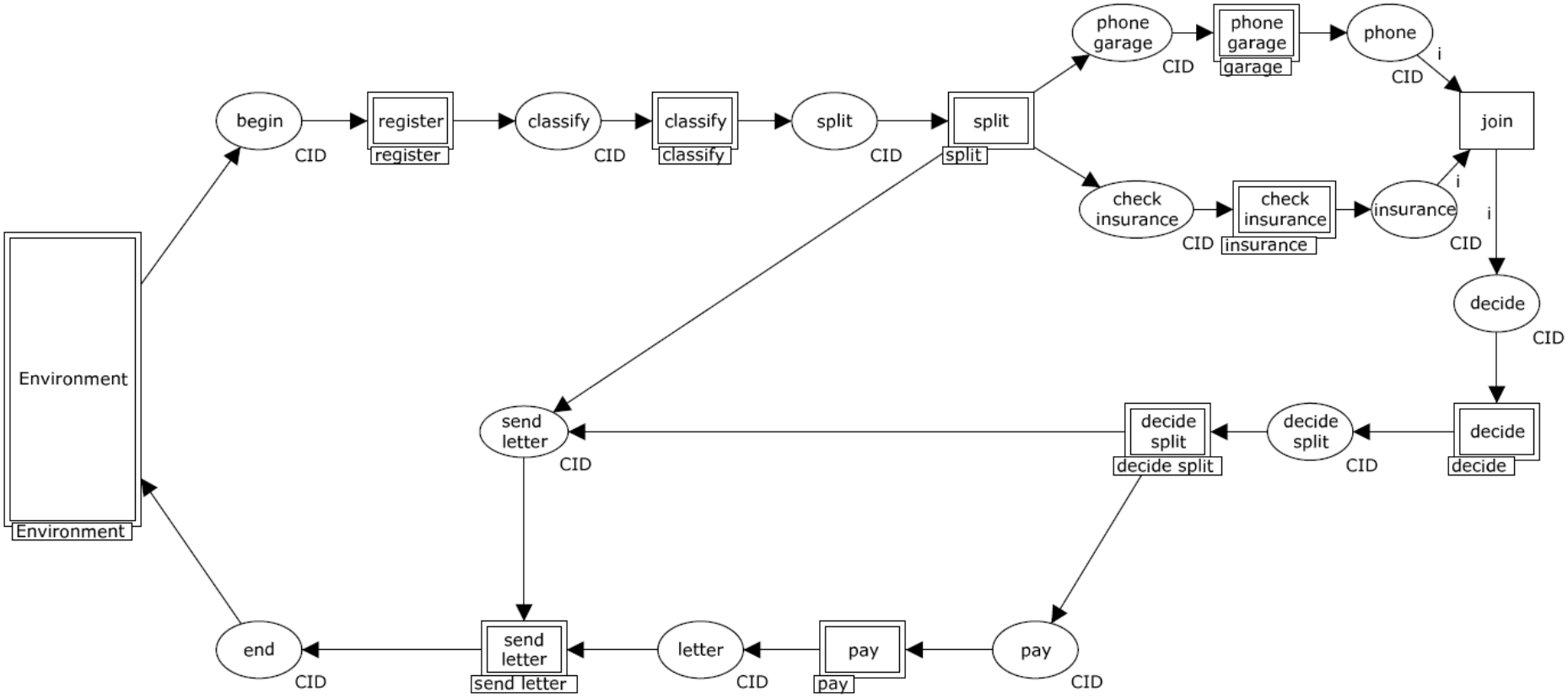


Fig. 12. Graph showing utilization against flow time ($\mu = \frac{1}{15}$, $c = 200$, $a = 0.8$, and $h = 1000$). The flow time increases as utilization increases.

Experiment: Note multiple resources and potential accumulation of effects

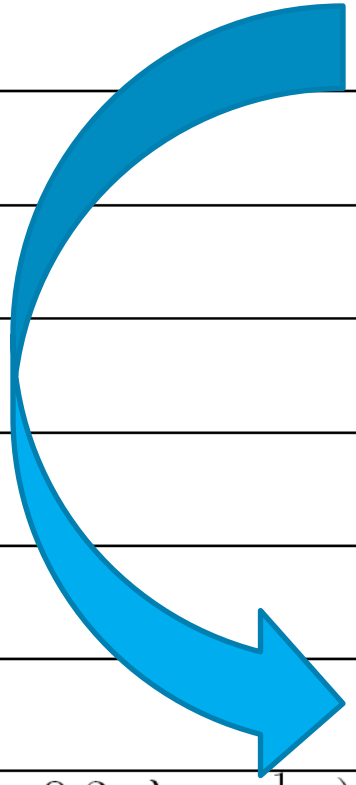


CPN model


Environment
Environment
begin
CID
register
register
classify
CID
classify
classify
split
CID
split
split
phone garage
CID
phone garage
garage
phone
CID
i
join
check insurance
CID
check insurance
insurance
insurance
CID
i
i
decide
CID
decide
decide
decide split
CID
decide split
decide split
send letter
CID
send letter
send letter
end
CID
letter
CID
pay
pay
pay
CID

Some findings

		Parameters	Flow Time
a)		Base Case Scenario ($c = 5$, $h = 2000$, $\lambda = \frac{1}{50}$ and $a = 0.4$, see Appendix B for all other parameters)	757.6 ±65.0
b)	i)	Divide the horizon by 20 ($h = 100$)	1218.9 ±72.3
	ii)	Divide the horizon by 40 ($h = 50$)	1247.8 ±51.8
c)	i)	Multiply the chunk size by 5 ($c = 25$)	1158.7 ±47.2
	ii)	Multiply the chunk size by 20 ($c = 100$)	1698 ±139
	iii)	Multiply the chunk size by 80 ($c = 400$)	1950 ±83.7
	iv)	Multiply the chunk size by 160 ($c = 800$)	2025 ±99
d)	i)	Decrease availability and arrival rate by 2 ($a = 0.2$, $\lambda = \frac{1}{100}$)	1634 ±105
	ii)	Decrease availability and arrival rate by 4 ($a = 0.1$, $\lambda = \frac{1}{200}$)	3420.32 ±252



"Chunks" Conclusion

- It is important not to assume that people are always available and eager to work when cases arrive.
- Assumptions heavily impact flow time, e.g., the bigger the chunk size, the longer the flow times of cases.
- The "chunk model" is rather simple, however, the typical assumptions made in today's simulation tools (i.e. $a = 1$, $c = 0$, and $h = \infty$), may result in flow times of minutes or hours while with more realistic settings for a, c, and h the flow time may go up to weeks or months and actually coincide with the actual flow times observed.

Problem 2:
Artifacts already available are not used as input (e.g., event logs)

Learning is not compulsory …

neither is survival.

William Edwards Deming (1900-1993)

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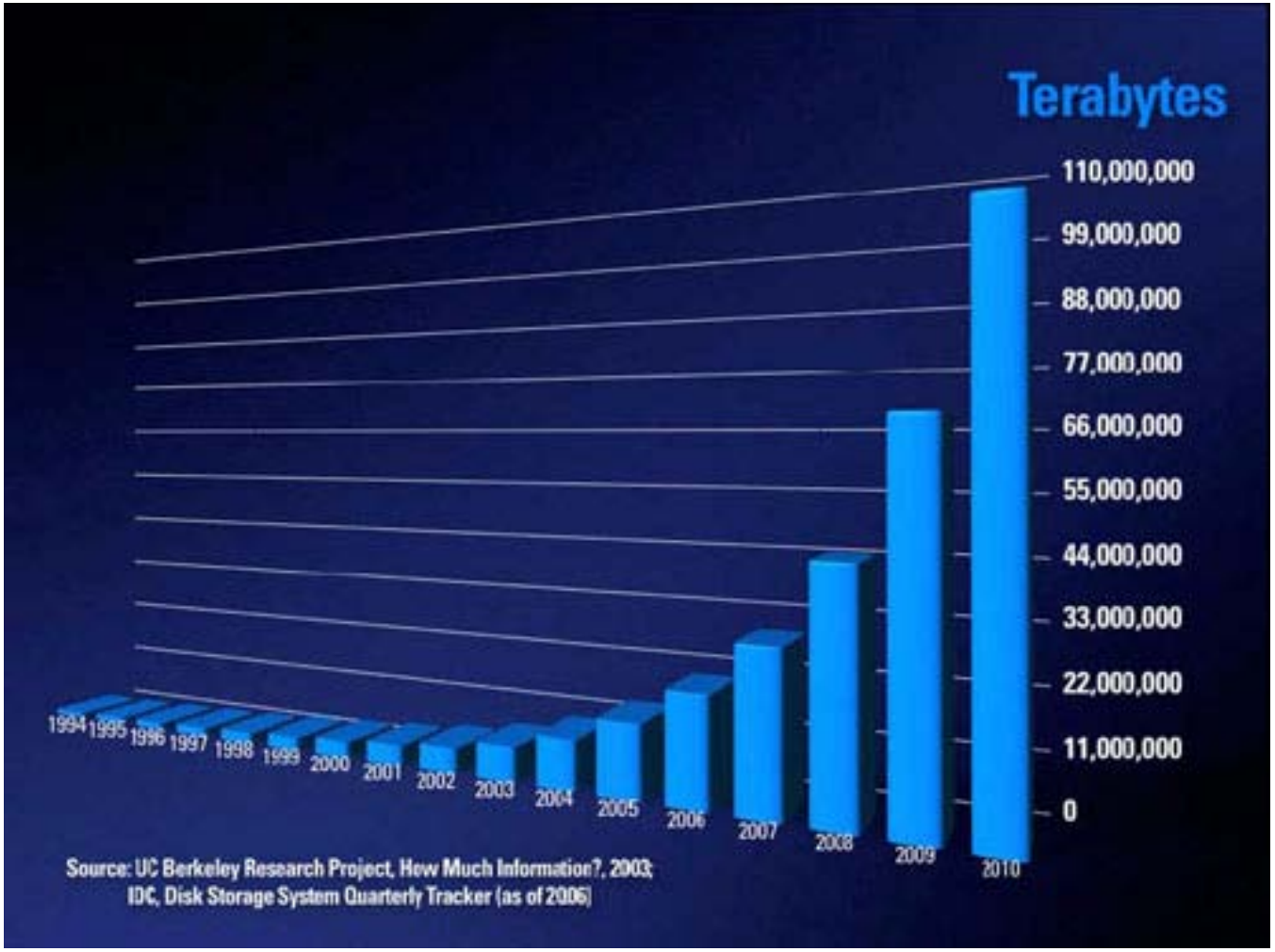
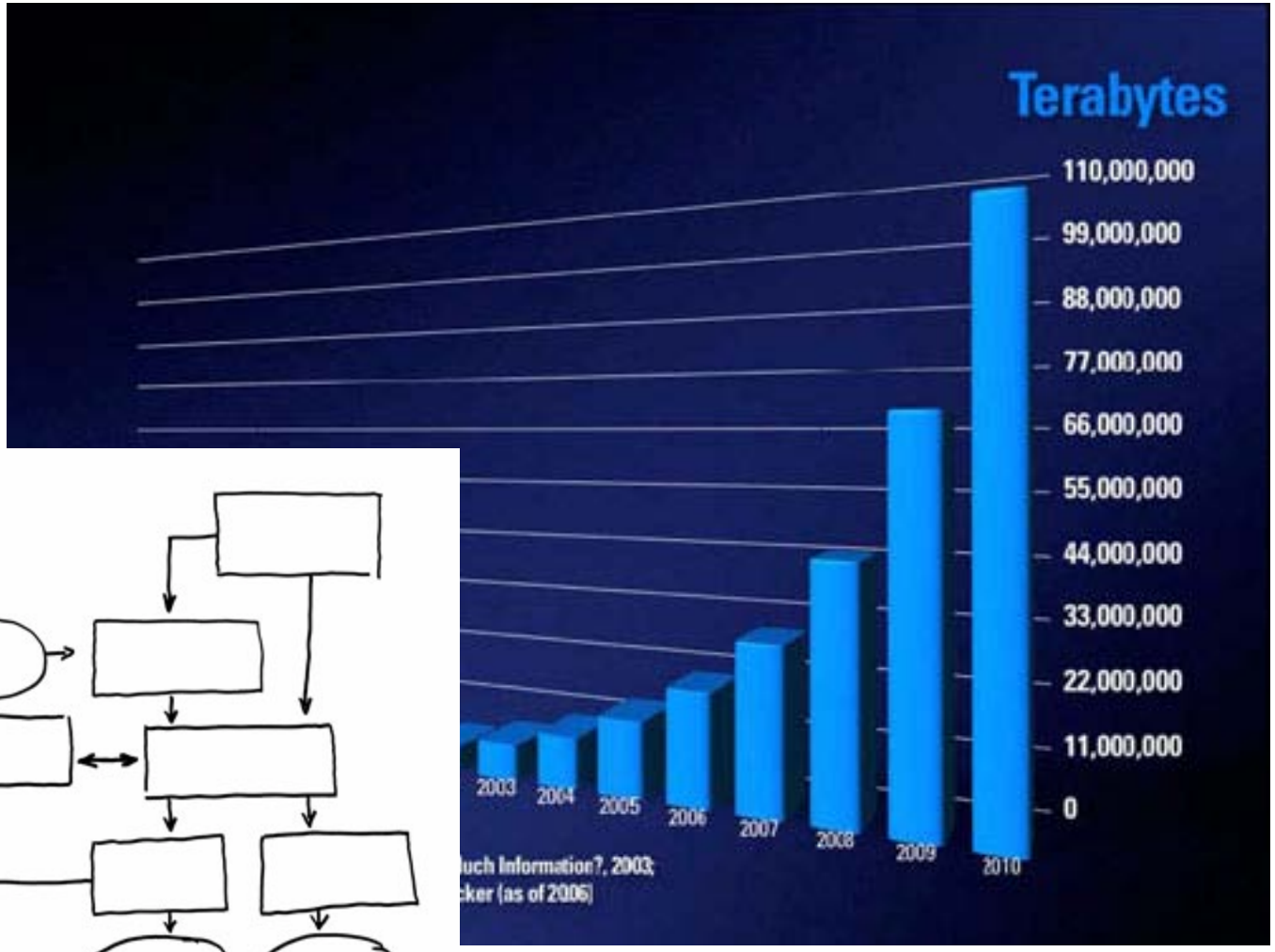
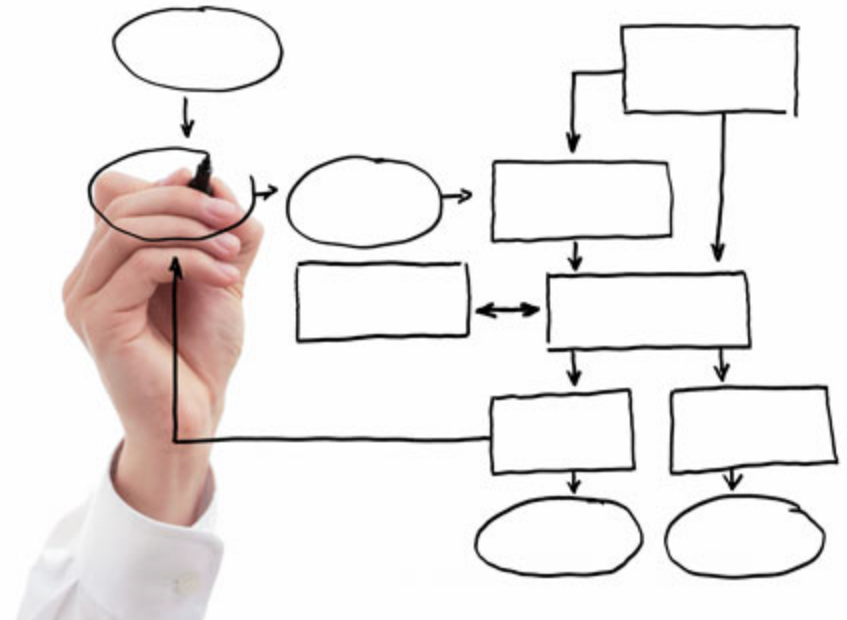
Where innovation starts

Growth of data

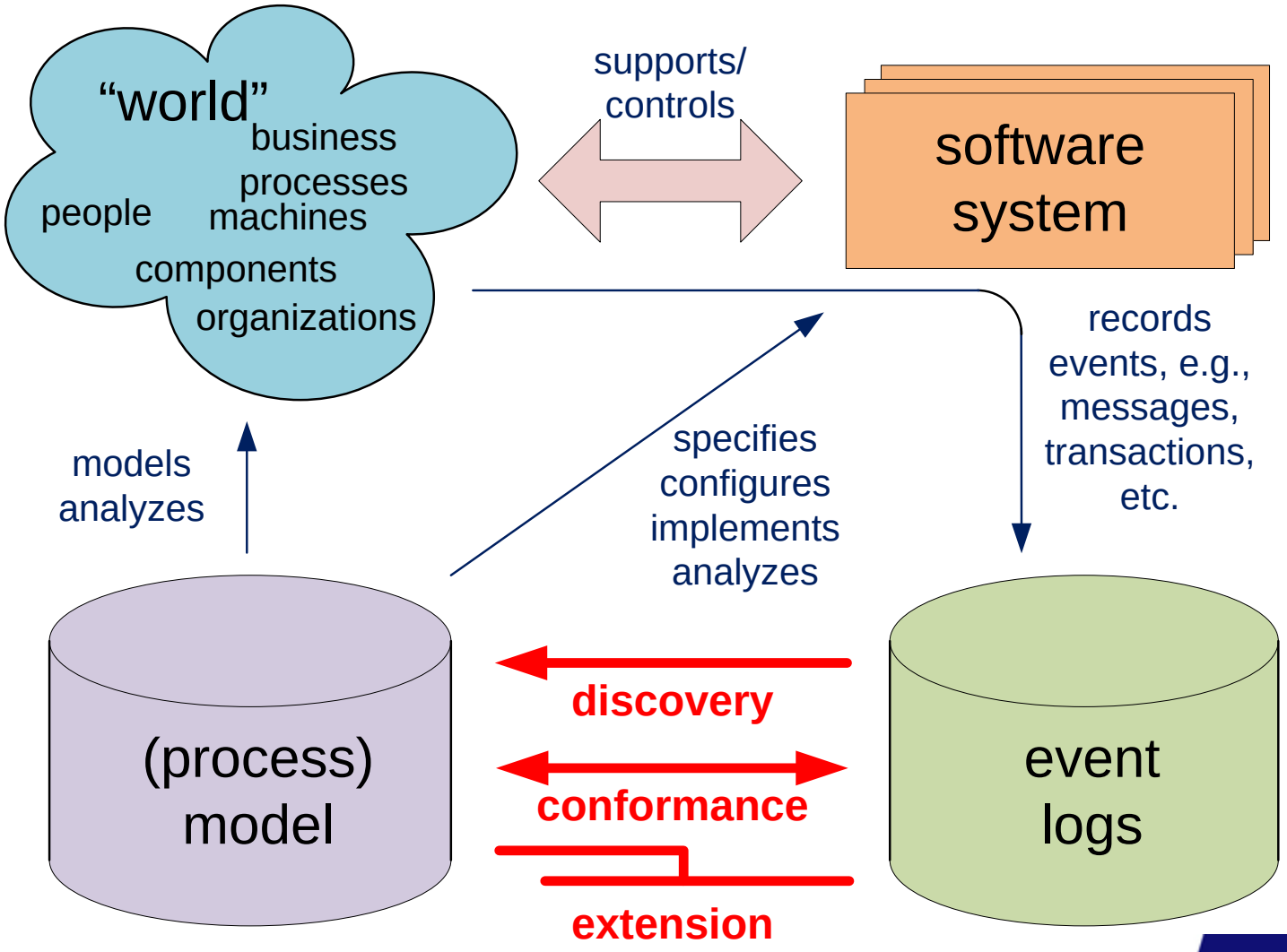


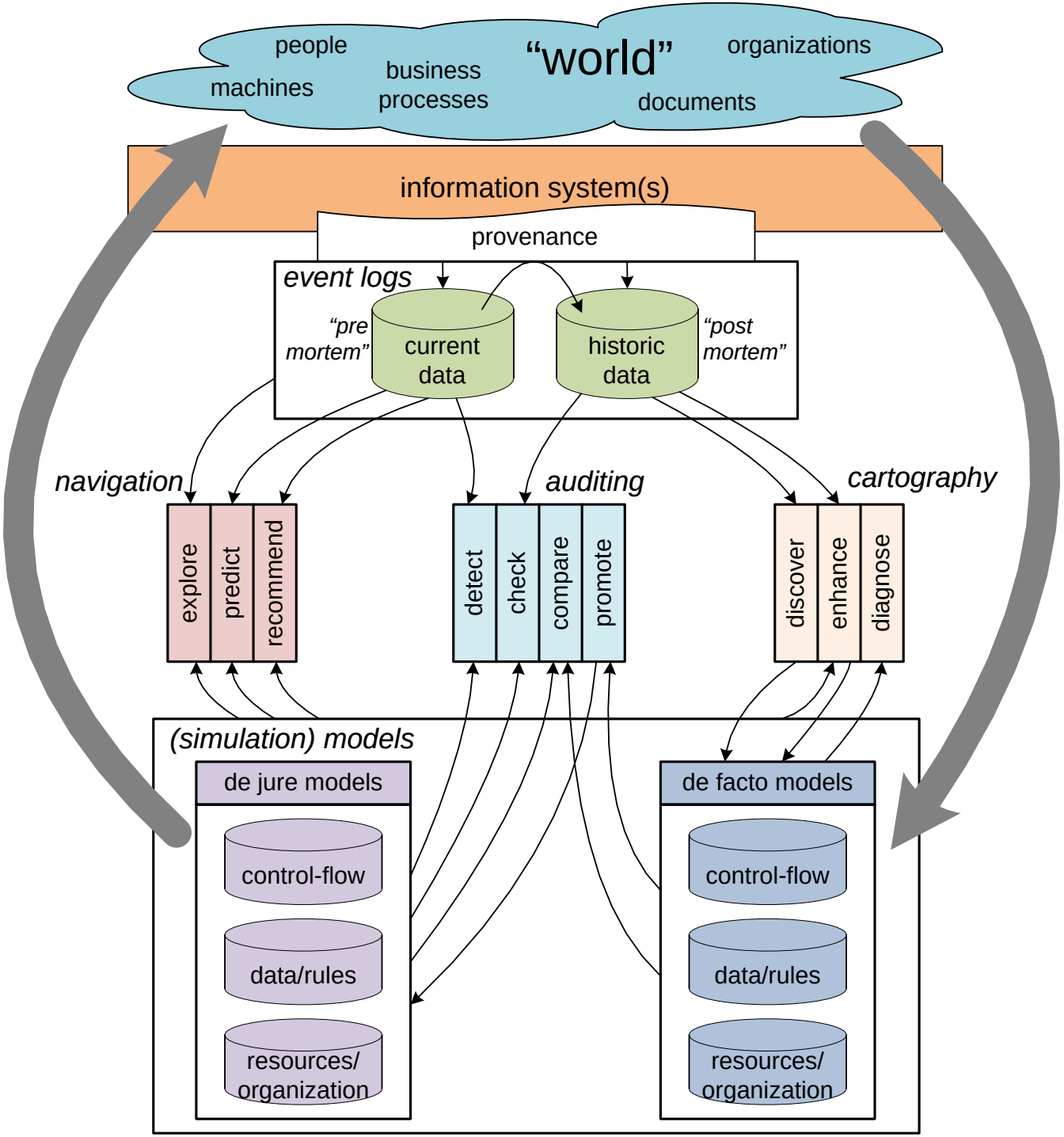
Growth of data, processes, and their models

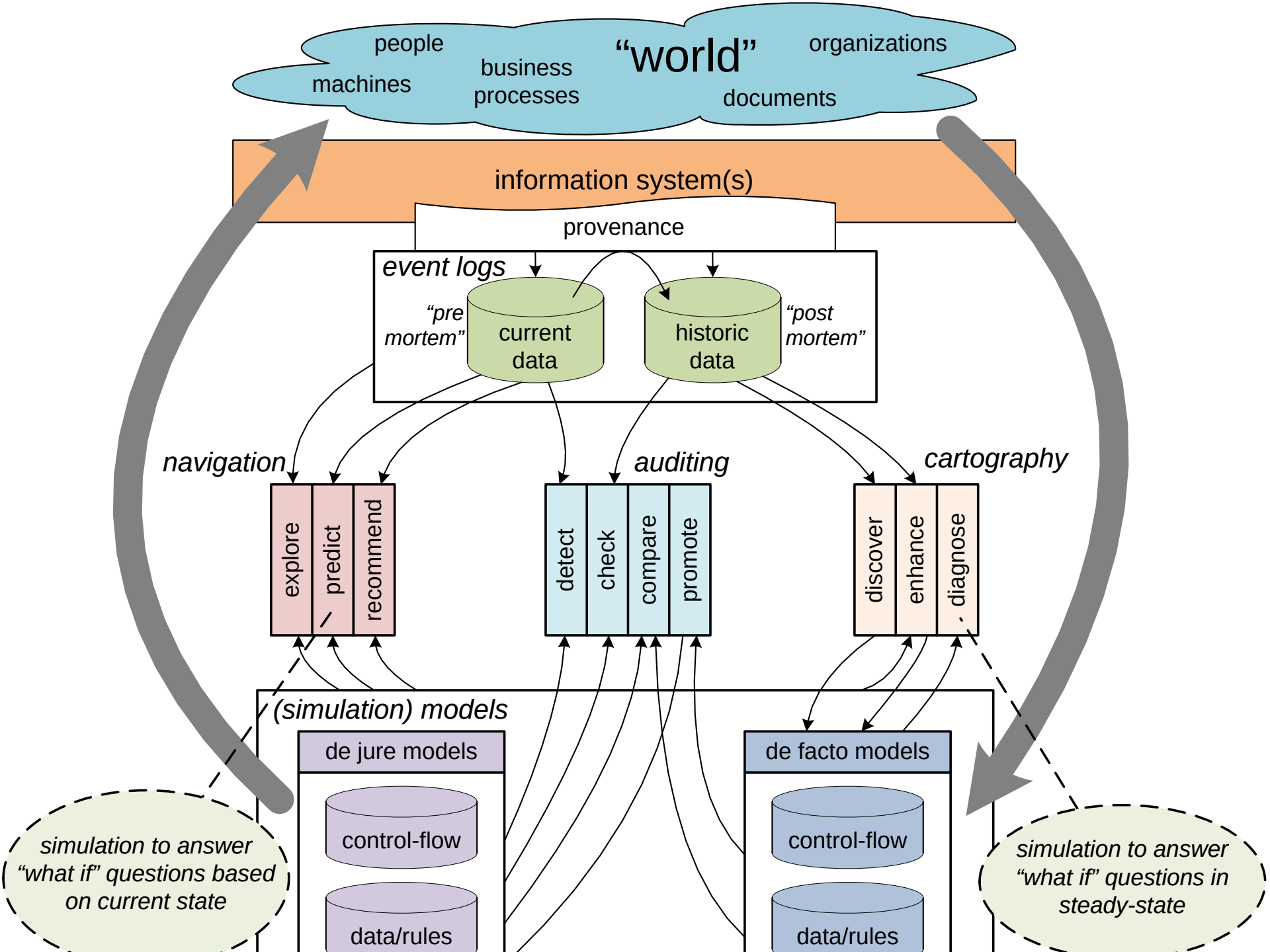




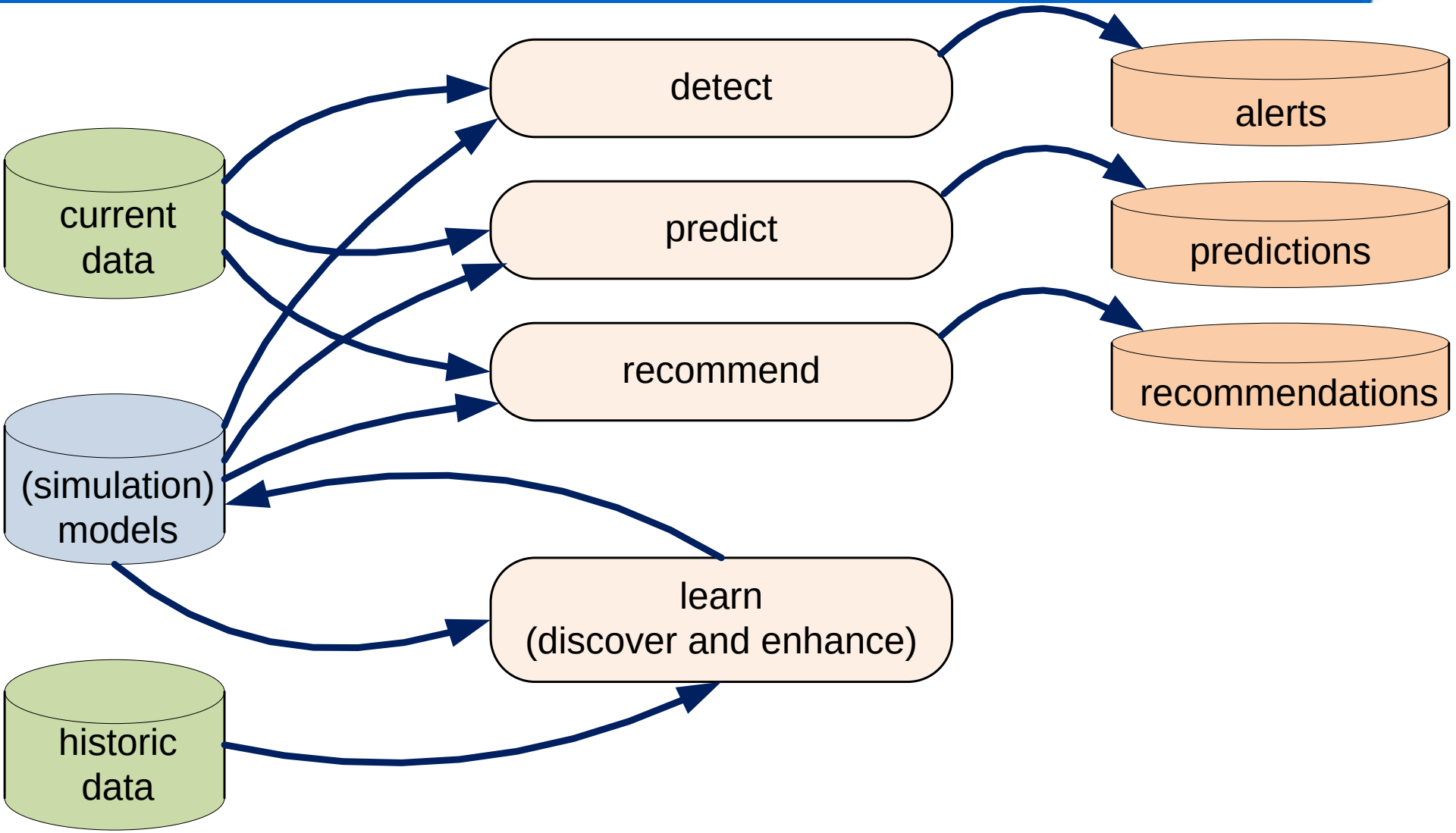
Process Mining: Linking events to models




people
machines
business processes
"world"
organizations
documents
information system(s)
provenance
event logs
"pre mortem"
current data
historic data
"post mortem"
navigation
explore
predict
recommend
auditing
detect
check
compare
promote
cartography
discover
enhance
diagnose
(simulation) models
de jure models
control-flow
data/rules
resources/ organization
de facto models
control-flow
data/rules
resources/ organization


people
machines
business processes
"world"
organizations
documents
information system(s)
provenance
event logs
"pre mortem"
current data
historic data
"post mortem"
navigation
explore
predict
recommend
auditing
detect
check
compare
promote
cartography
discover
enhance
diagnose
(simulation) models
de jure models
control-flow
data/rules
de facto models
control-flow
data/rules
simulation to answer "what if" questions based on current state
simulation to answer "what if" questions in steady-state

Using history, models, and current state information



Problem 3:
Not for operational decision making ("steady state" rather than "fast forward")

If you don't know where you are going, any road will get you there.
Lewis Carroll (1832-1898)

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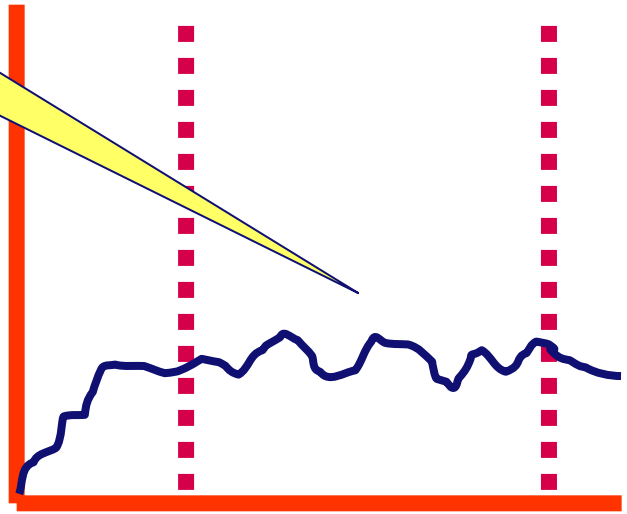
Where innovation starts

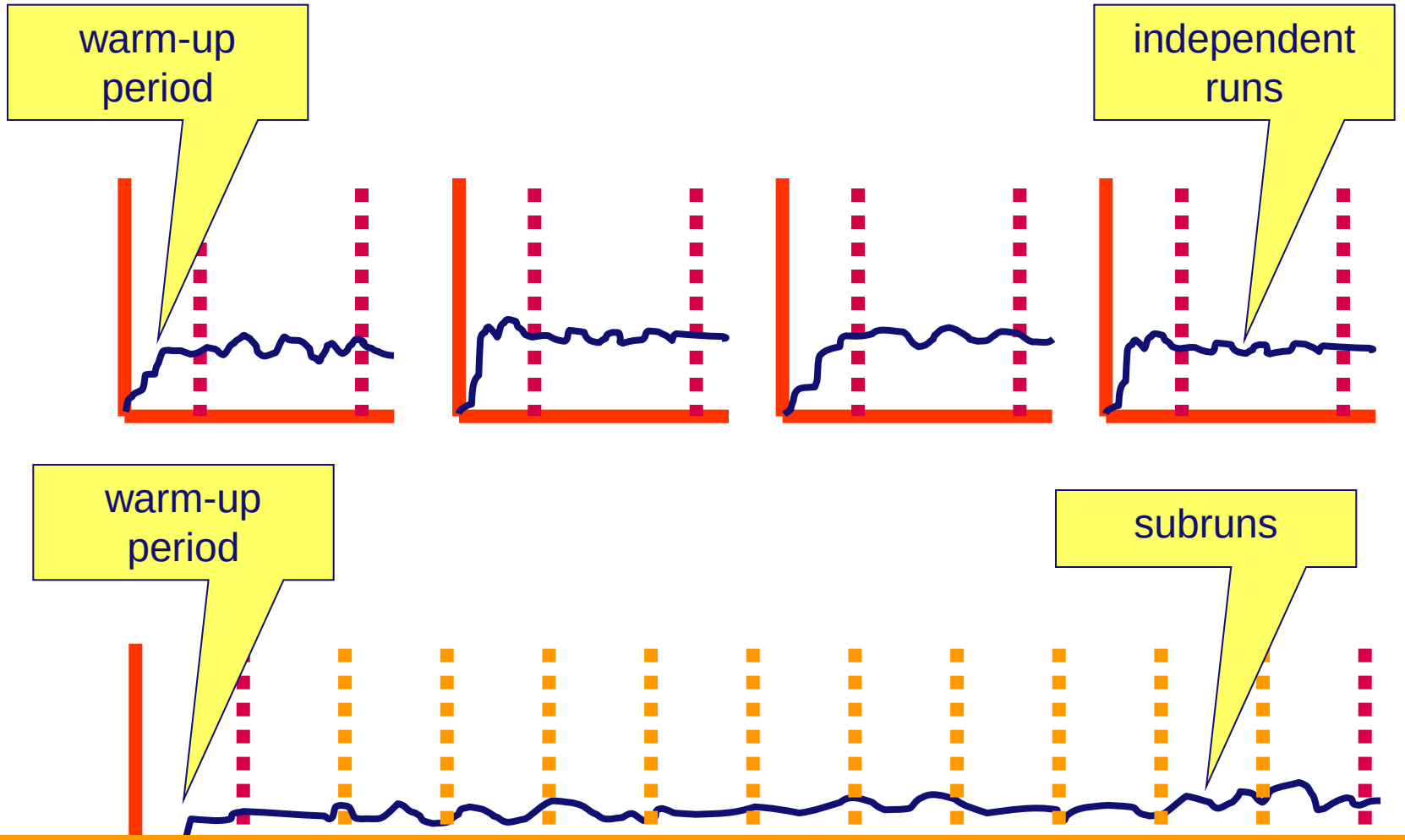
Focus Business Process Simulation

traditional steady state analysis focusing on long-term average behavior



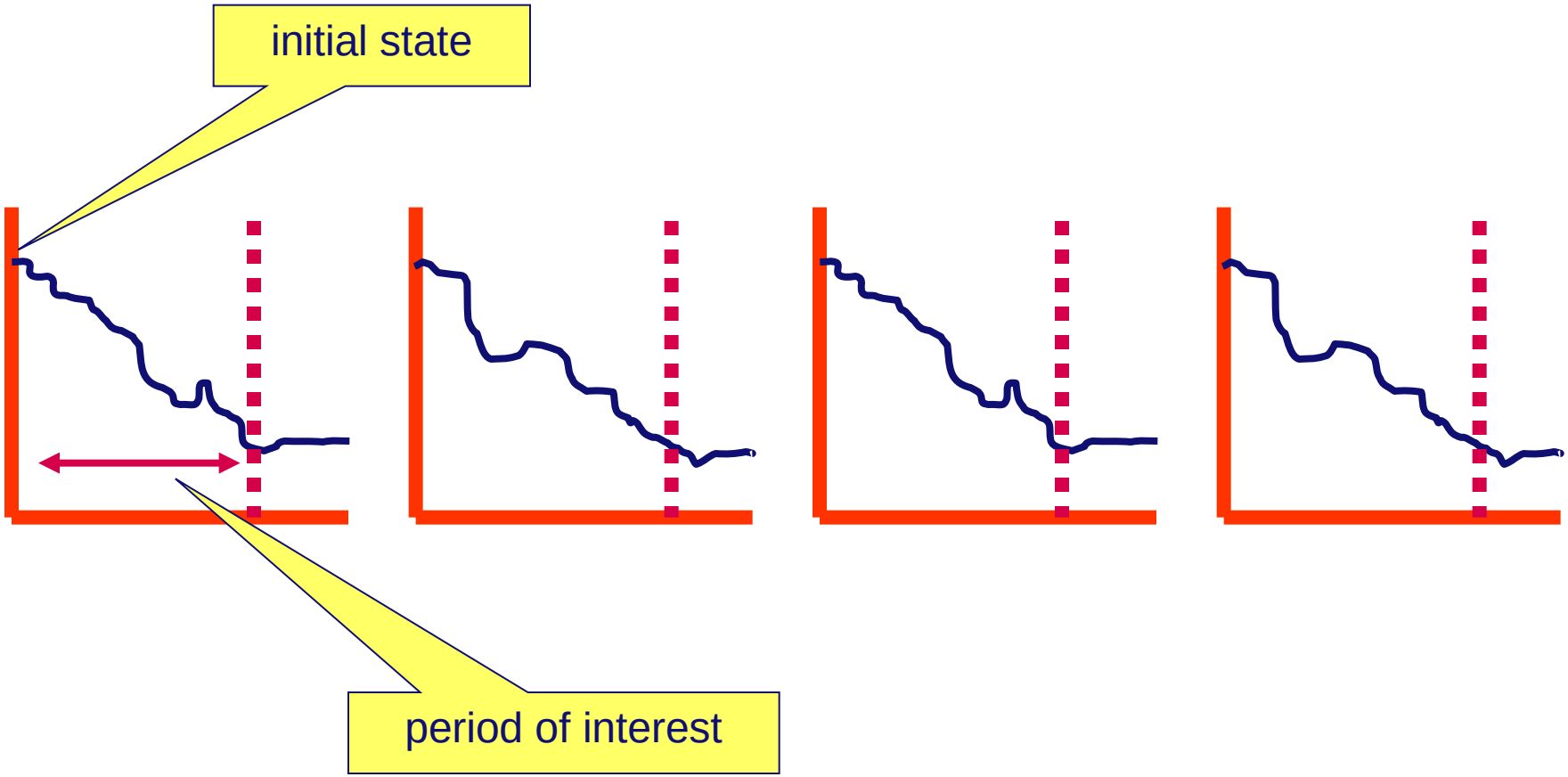
classical focus of simulation (tools)

Steady state analysis



(re-)design-time analysis, i.e., not for operational decision making

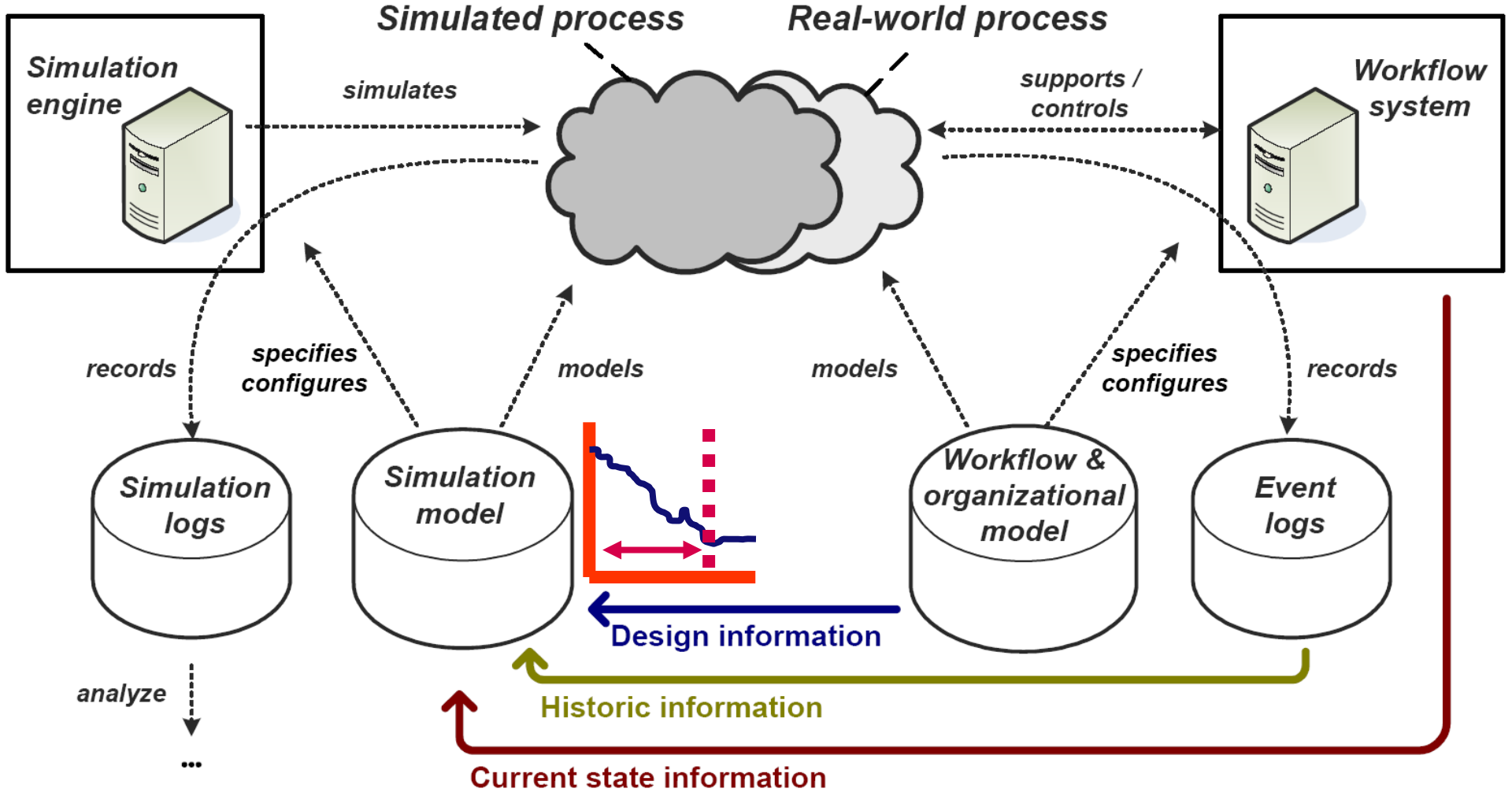
Transient analysis



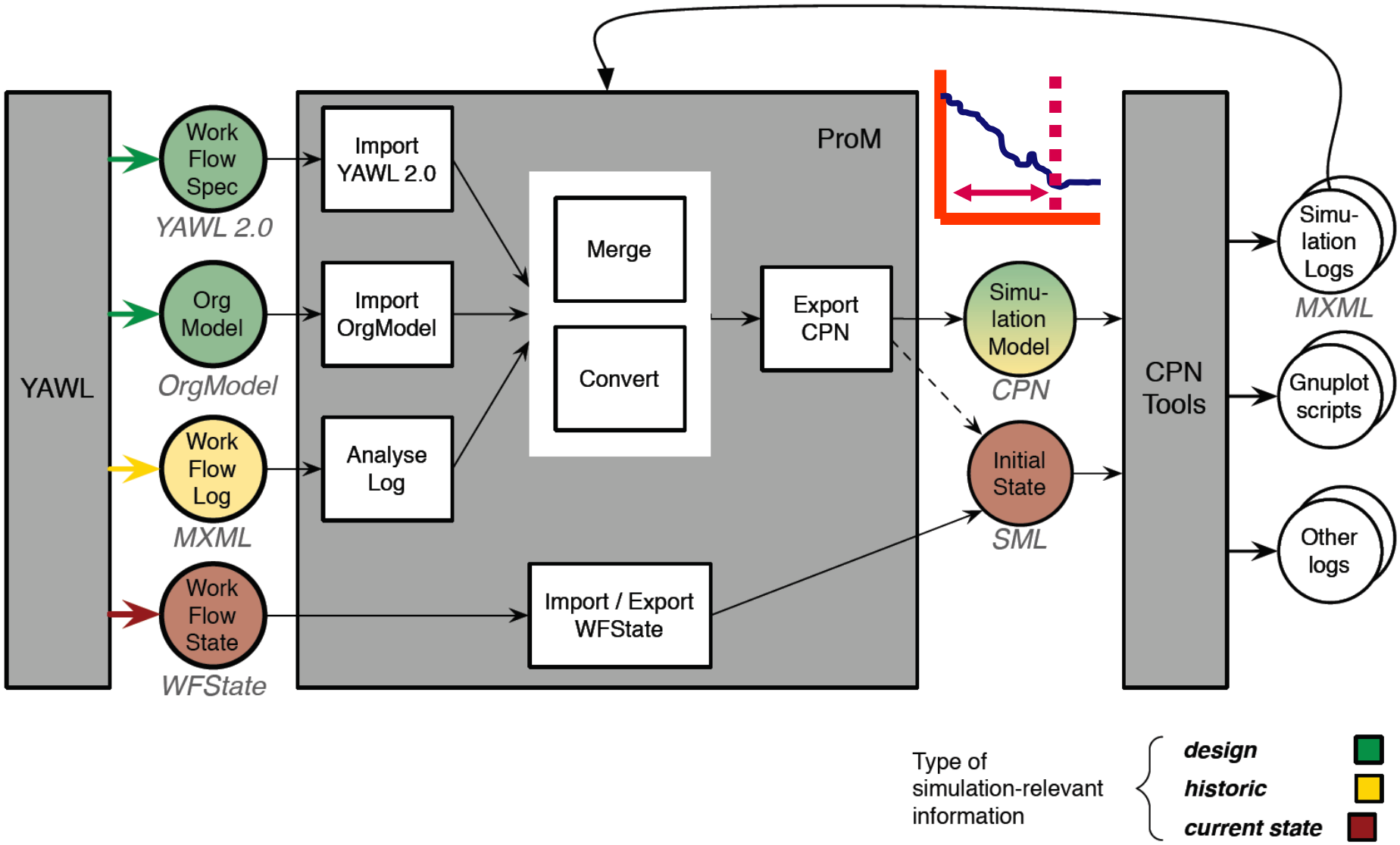
Steady-state may not exist and may not be relevant!

Example: Short-Term Simulation

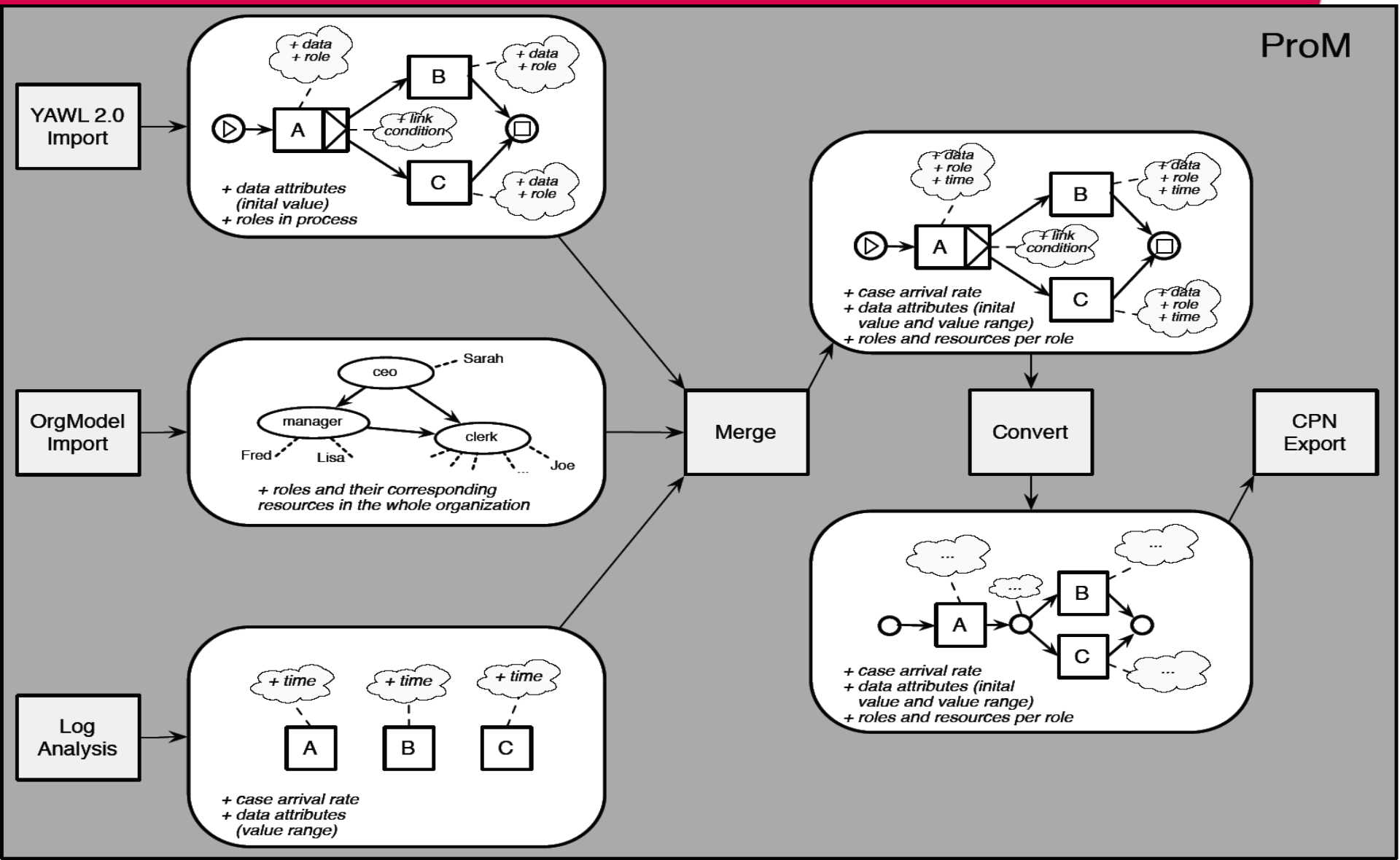
Overview: Short-Term Simulation



Implementation using YAWL, ProM, and CPN Tools

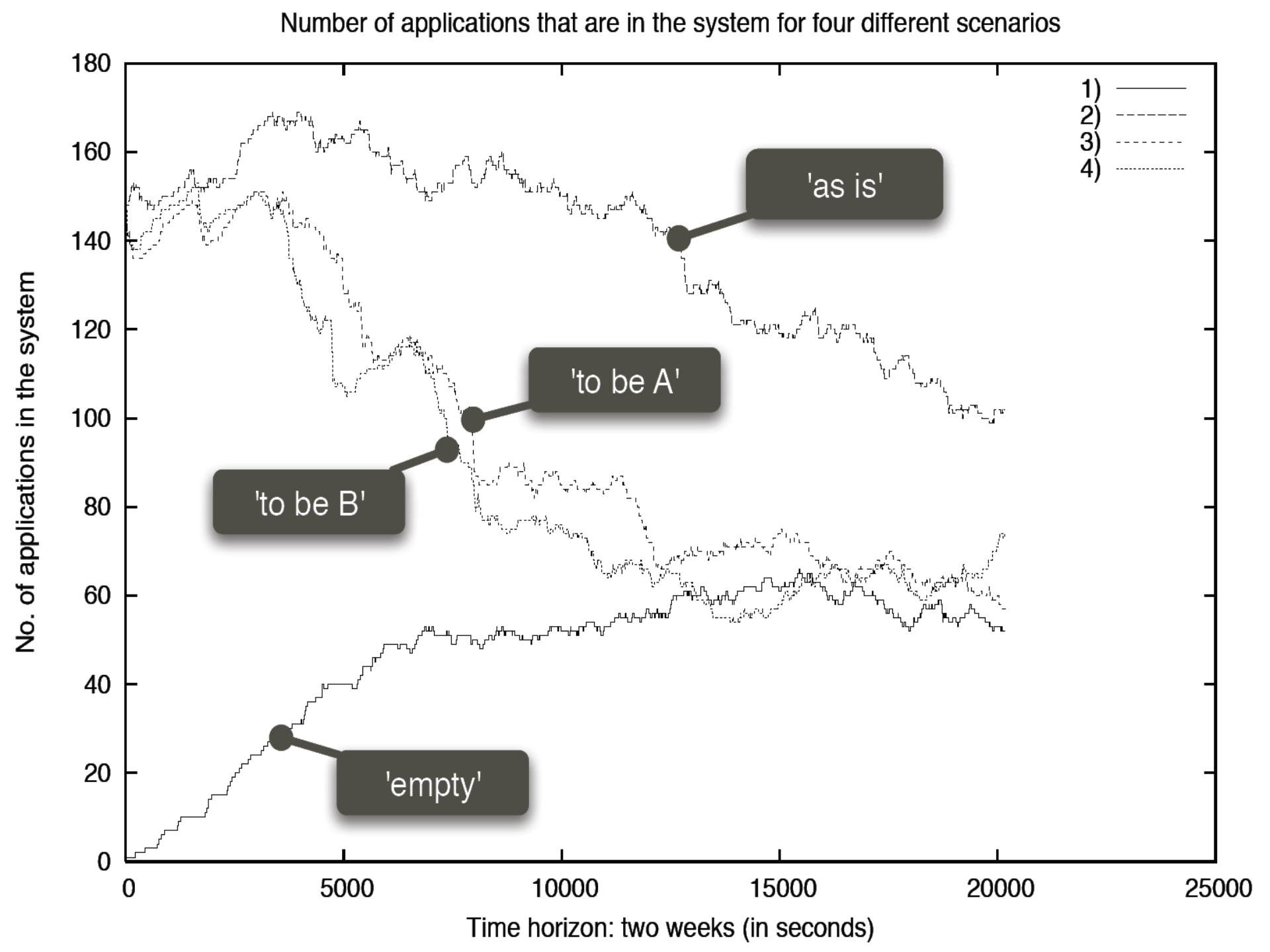


ProM: Merging and converting models covering different aspects

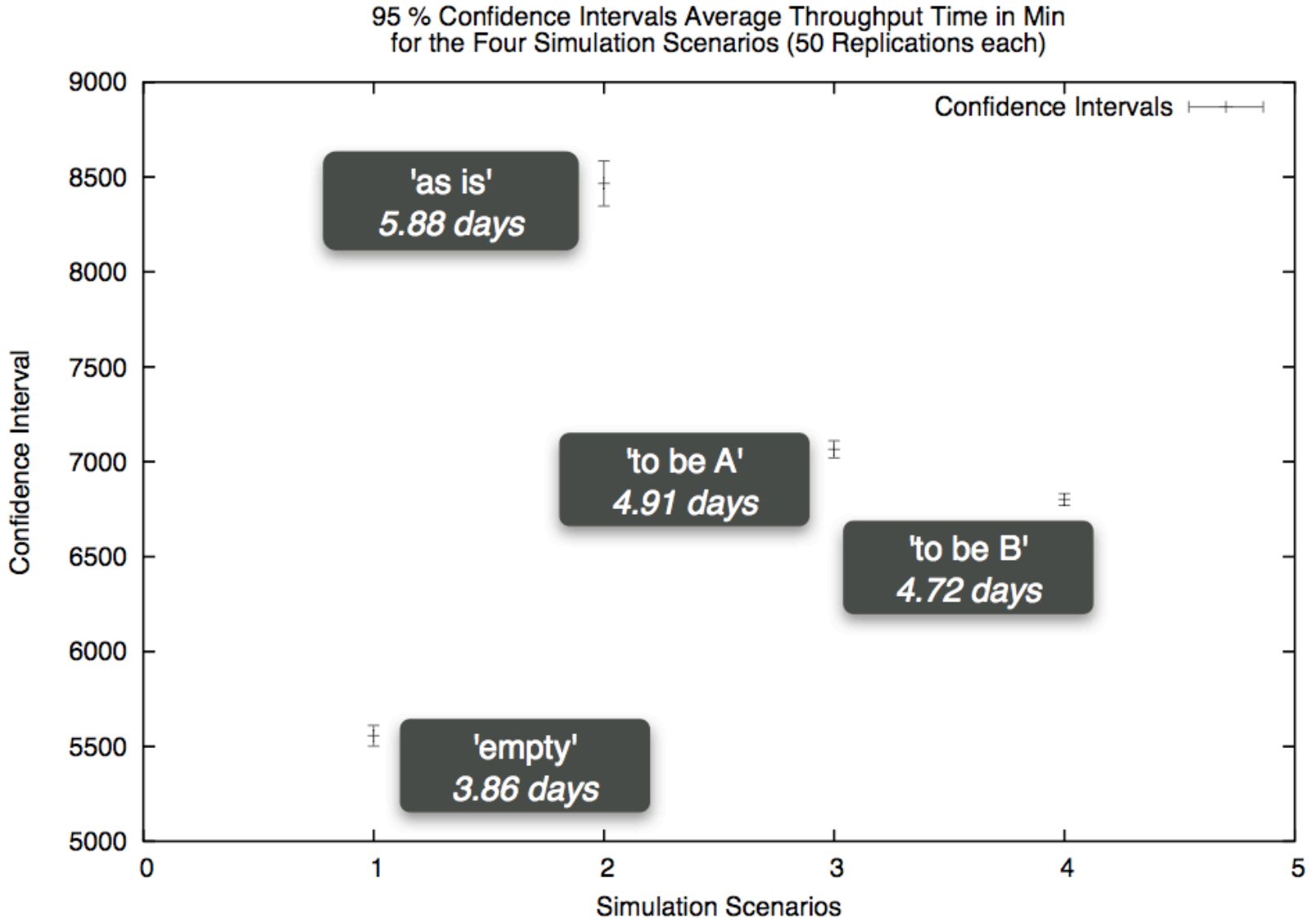


Example: Four different simulation scenarios

1. An empty initial state (‘empty’)
2. After loading the current state file with the 150 applications currently in the system (‘as is’)
3. After loading the current state file but adding four extra resources (‘to be A’)
4. After loading the current state file and adding eight extra resources (‘to be B’)


Number of applications that are in the system for four different scenarios
No. of applications in the system
Time horizon: two weeks (in seconds)
0
20
40
60
80
100
120
140
160
180
0
5000
10000
15000
20000
25000
1)
2)
3)
4)
'as is'
'to be A'
'to be B'
'empty'

Confidence intervals



Conclusion Short-Term Simulation

- **Transient analysis is essential for operational decision making!**
- **The initial state matters!**
- **Artifacts (design, historic, and current state information) from a workflow management systems like YAWL can be used!**
- **Interesting side effect of the YAWL, ProM, CPN Tools integration: the real and simulated process can be viewed in a unified manner using process mining!**

Conclusion

Technische Universiteit
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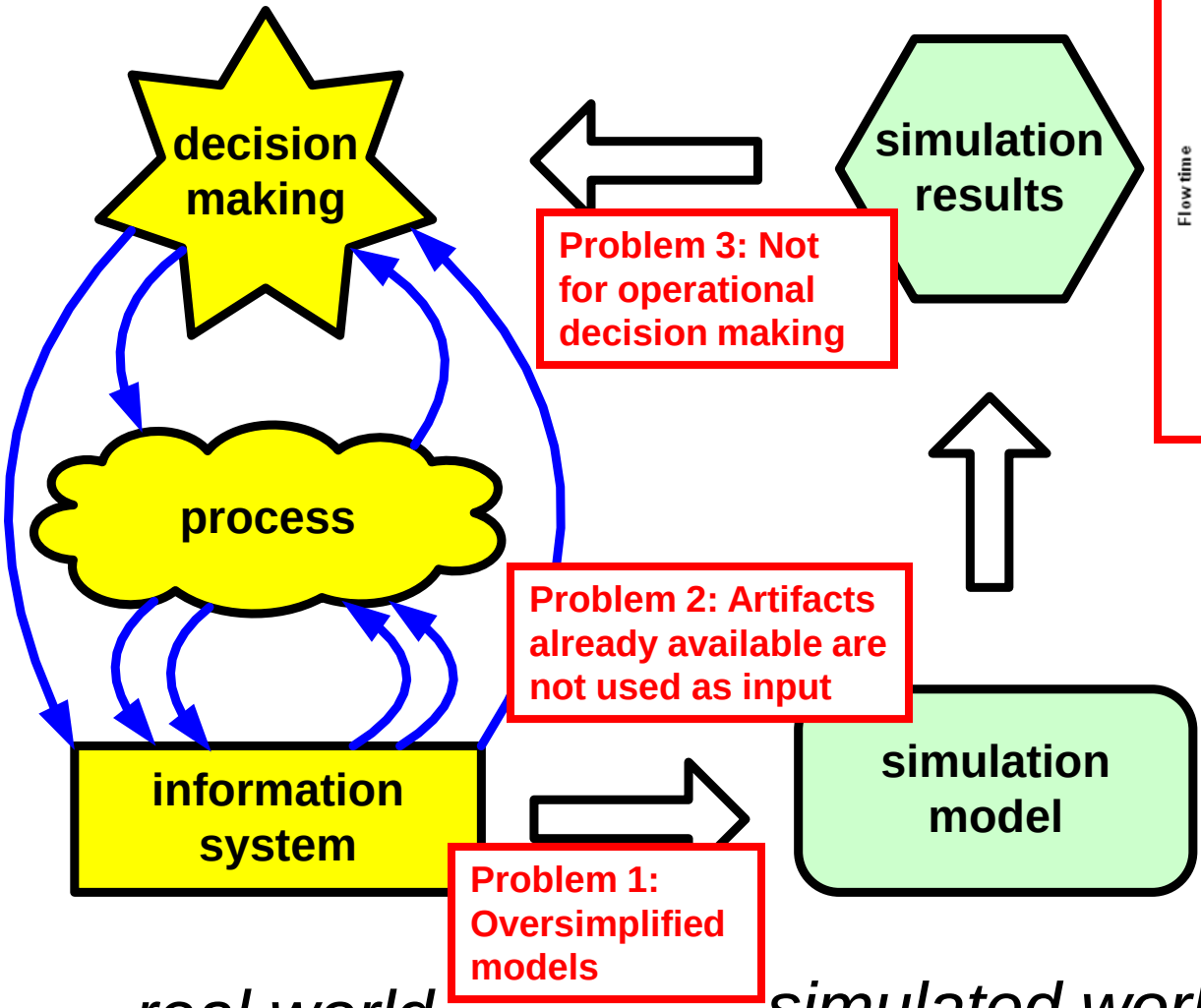
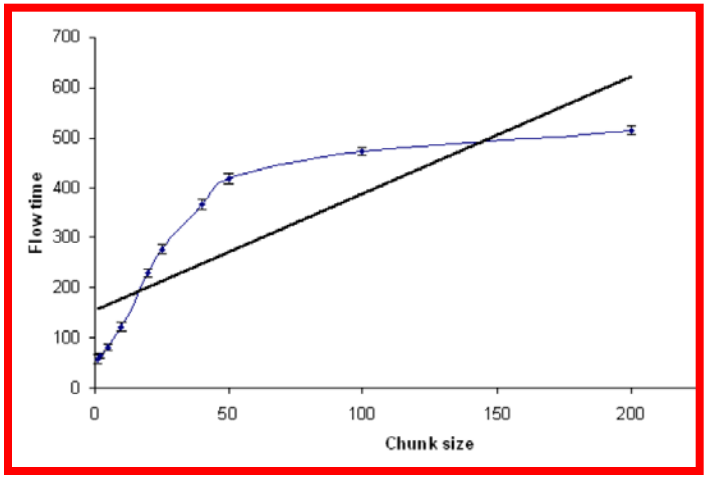
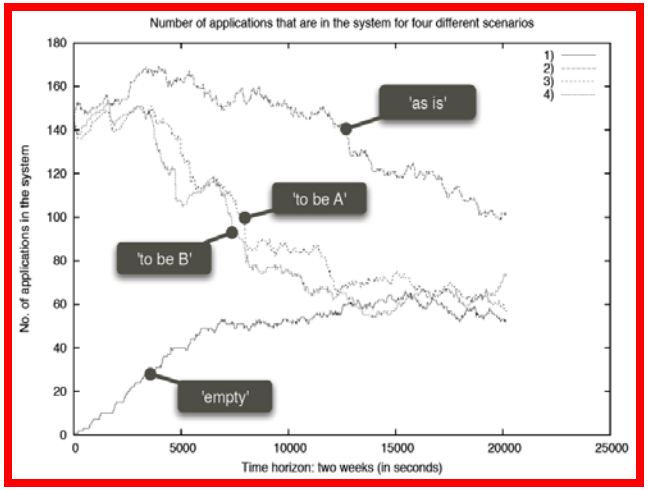
Where innovation starts

Problems and some solutions ...







Relevant WWW sites

- http://www.processmining.org
- **http://www.win.tue.nl/ieeetfpm**
- **http:// promimport.sourceforge.net**
- **http://prom.sourceforge.net**
- **http://www.workflowpatterns.com**
- **http://www.workflowcourse.com**
- **http://www.vdaalst.com**