Evaluating the Performance of a Batch Activity in Process Models

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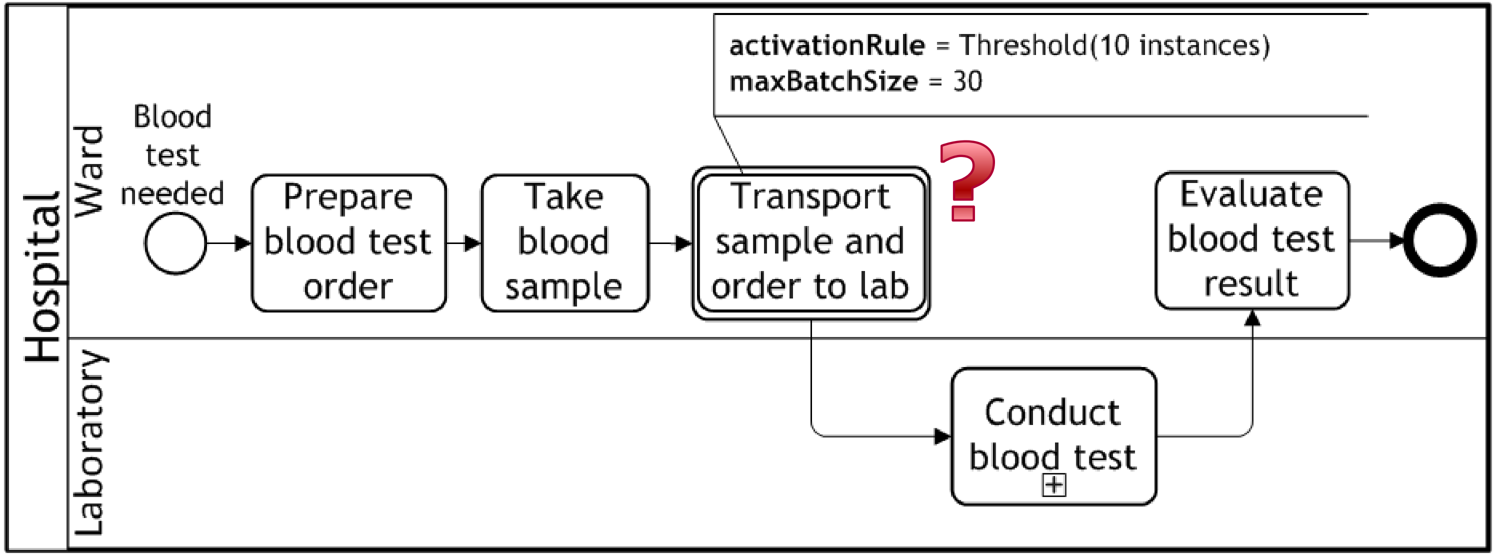
Research Goals



- Compare batch execution with usual activity execution;
- Compare different configurations of a batch activity

Approach based on:

L. Pufahl and M. Weske. *Batch Activities in Process Modeling and Execution.* In ICSOC, pages 283–297. Springer, 2013.

Why to Evaluate the Batch Activity Performance?

Usual activity

Arrival rate:

5 blood samples/h

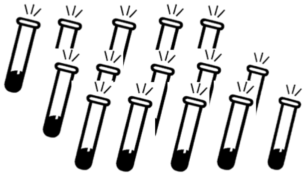
Transportation:

1 sample (FIFO)

Costs/sample:

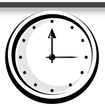
5 €

no expired samples

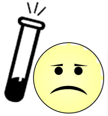


Nurse

30 €/h



10 min



Expiration in 4 hrs

Why to Evaluate the Batch Activity Performance?

Batch activity

Arrival rate:

5 blood samples/h

Transportation:

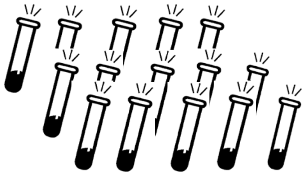
10 samples/batch,

every 2 hours

Costs/sample:

0.5 €

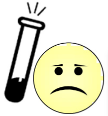
no expired samples



Nurse

30 €/h

10 min



Expiration in 4 hrs

Ekaterina Bazhenova

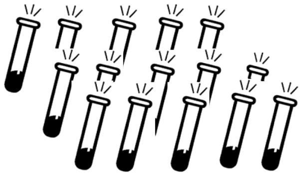
Why to Evaluate the Batch Activity Performance?

Batch activity

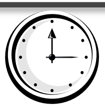
Arrival rate:
2 blood samples/h

Transportation:
2 samples/batch,
every 5 hours

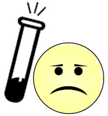
Costs/sample:
2.5 €
expired samples



Nurse
30 €/h



10 min

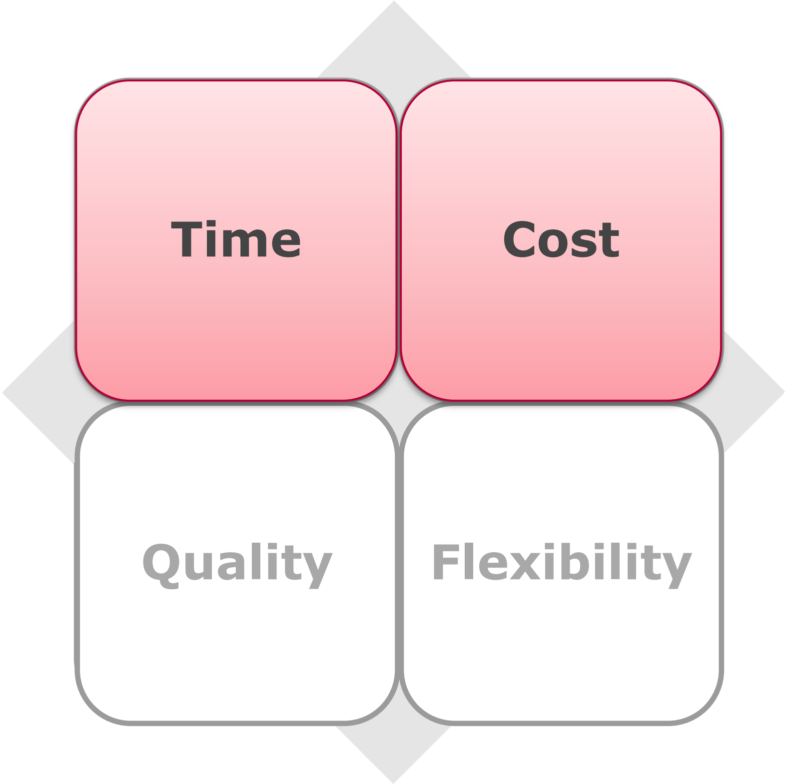


Expiration in 4 hrs

Different Configurations of an Activity Incur Different Costs

Scenario	Arrival rate	Batch parameters	Costs	Expired samples
Usual activity	5 samples/h	no batch	**5 €**	no
Batch activity 1	5 samples/h	10 samples, every 2 hours	**0.5 €**	no
Batch activity 2	2 samples/h	2 samples, every 5 hours	**2.5 €**	yes

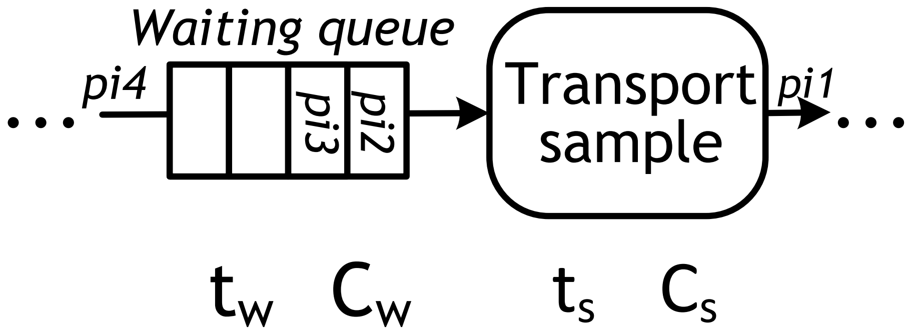
Process Performance Measures Taken Into Account



Approach based on:

H. A. Reijers, S. Liman Mansar. *Best practices in business process redesign: an overview and qualitative evaluation of successful redesign heuristics.* Omega, The International Journal of Management Science, 2005

Usual Process Activity as a Queuing System



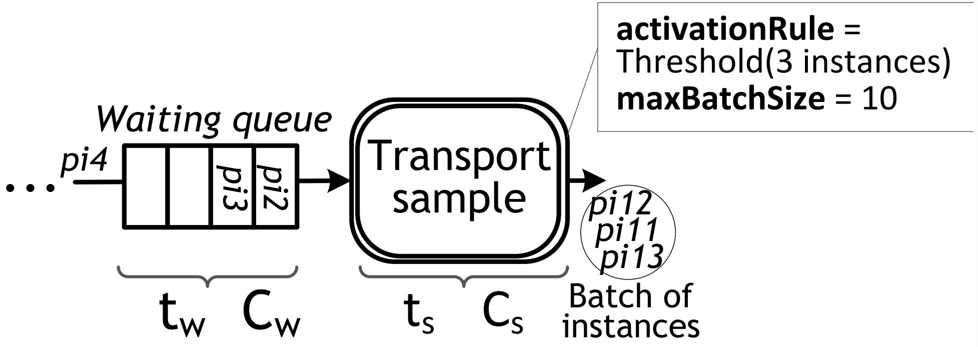
<u>Queue parameters</u>
<u>(per instance):</u>

t_w - waiting time
C_w - waiting costs
t_s - service time
C_s - service costs
C - total activity costs

Total cost function (per instance):

$$\mathbf{C = C_w(t_w) + C_s}$$

Batch Process Activity as a Queuing System



Queue parameters (per instance):

- t_w - waiting time
- C_w - waiting costs
- t_s - service time
- C_s - service costs
- Y - batch size
- C_b – total activity costs

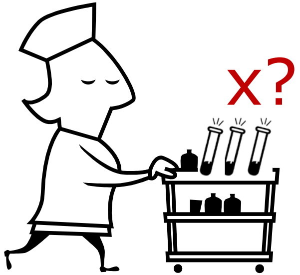
Total cost function (per instance):

$$C_b = C_w(t_w) + C_s / Y$$

Applications of Cost Functions for Performance Analysis

1) Comparison of total costs for usual and batch activities

2) Optimal batch activity threshold



Analytical Analysis of Usual / Batch Activities

Queuing system in *Kendall's notation*:

A/B/s

A – inter-arrival time distribution

B – service time distribution

s – number of task performers

Usual activity

M/M/1

- Poisson arrival distribution;
- Exponential service time;
- Single task performer

Batch activity

M/M(a, b)/1

- Poisson arrival distribution;
- Exponential time of service;
- Service in batches:
  threshold *a*, capacity *b*, $1 \leq a \leq b$;
- Single task performer

Characteristic Parameters of M/M/1 system

Input parameters

Poisson arrival time, $\boldsymbol{\lambda}$ samples/hr

service time exponential, $\boldsymbol{\mu}$ samples/hr

constant service costs, $\mathbf{C_s}$ €

Queuing theory

Waiting time $\boldsymbol{t_w}(\lambda, \mu)$

$$E[t_w] = \lambda / [\mu(\mu - \lambda)]$$

Total cost function: $\boldsymbol{C = C_w(t_w) + C_s}$

$$E[C] = E[C_w] + E[C_s] = C_w(E[t_w]) + C_s$$

Use case specific

Waiting cost function $\boldsymbol{C_w}$

Characteristic Parameters of M/M(a,b)/1 system

Input parameters

Poisson arrival time, $\boldsymbol{\lambda}$ samples/hr

service time exponential, $\boldsymbol{\mu}$ samples/hr

constant service costs, $\mathbf{C_s}$ €

batch threshold, ***a*** samples

batch capacity, ***b*** samples

Queuing theory

waiting time $\boldsymbol{t_w}(\lambda, \mu)$

average batch size $\boldsymbol{Y}(\lambda, \mu, a, b)$

Total cost function: $\boldsymbol{C_b = C_w(t_w) + C_s / Y}$

$$E[C_b] = C_w(E[t_w]) + C_s/E[Y]$$

Use case specific

waiting cost function $\boldsymbol{C_w}$

Use Case: Input Parameters

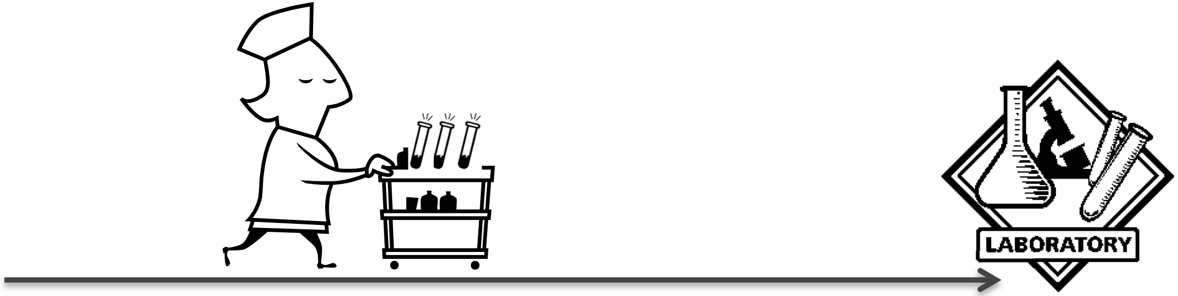
arrival time Poisson, λ = 5 samples/hr

service time exponential, μ = 6 transports/hr

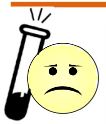
service costs C_s= 5 €

batch threshold a = 10 samples

batch capacity b = 30 samples

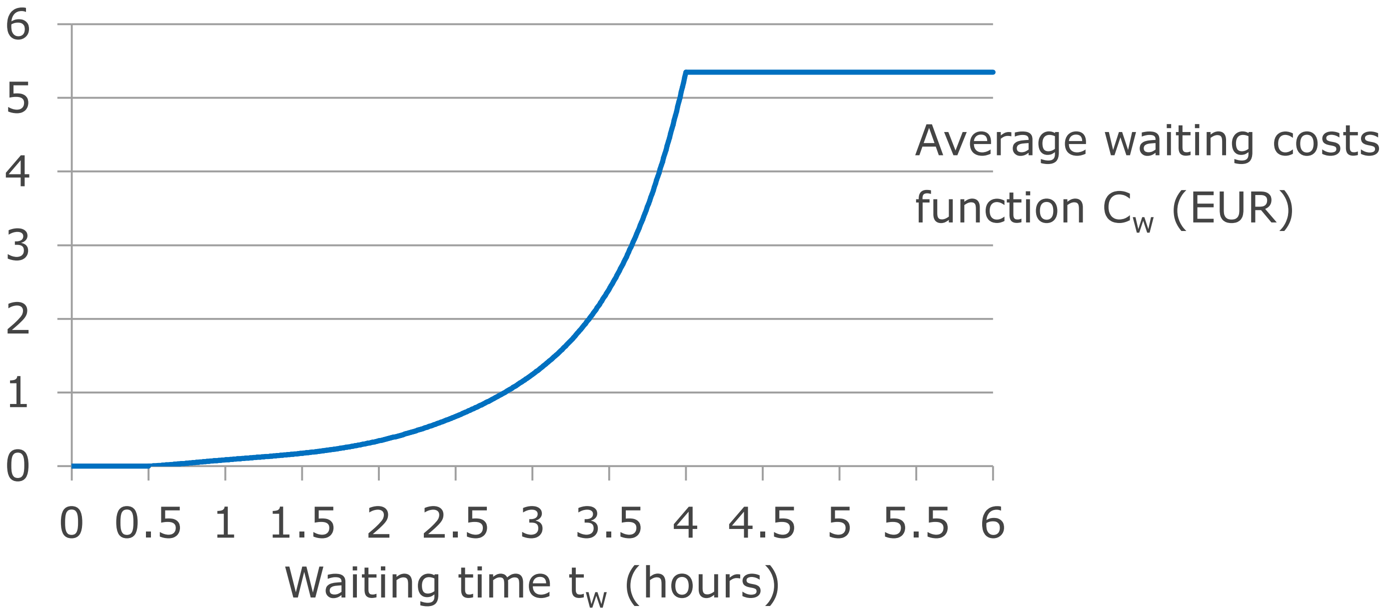


Use Case: Waiting Cost Function



Full expiration in 4 hrs;

Cost of taking new blood sample: 5.35 €



Assumptions are based on German Medical Fee Schedule for coagulation blood sample.

Evaluation of Performance (1): Comparisons of Usual and Batch Activity Performance

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Usual activity

Total cost function

$C = C_w(t_w) + C_s$

→ *Average waiting time:* ***49.8 min***

Total costs: ***10.35 €***

Input parameters

λ, μ, C_s, a, b

Batch activity

Total cost function

$C_b = C_w(t_w) + C_s / Y$

→ *Average waiting time:* ***54.0 min***

Total costs: ***0.57 €***

Evaluation of Performance (2): Searching Optimal Threshold in a Batch Activity

All parameters are fixed; threshold *a* is changing

Optimal configuration:

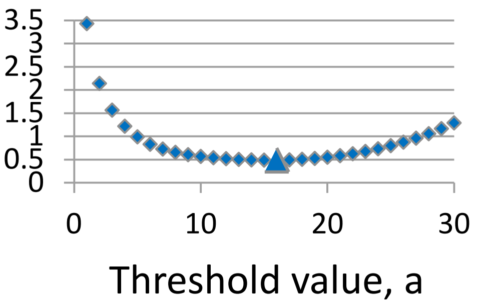
threshold value *a* = 16 samples

total costs *C* = 0.49 €

average waiting time t_w = 1.5 hours

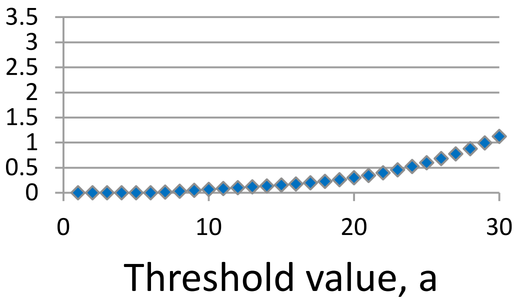
$C_b = C_w + C_s$

Total expected costs, EUR



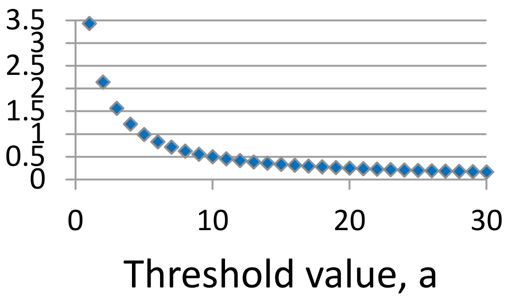
C_w

Expected waiting costs, EUR

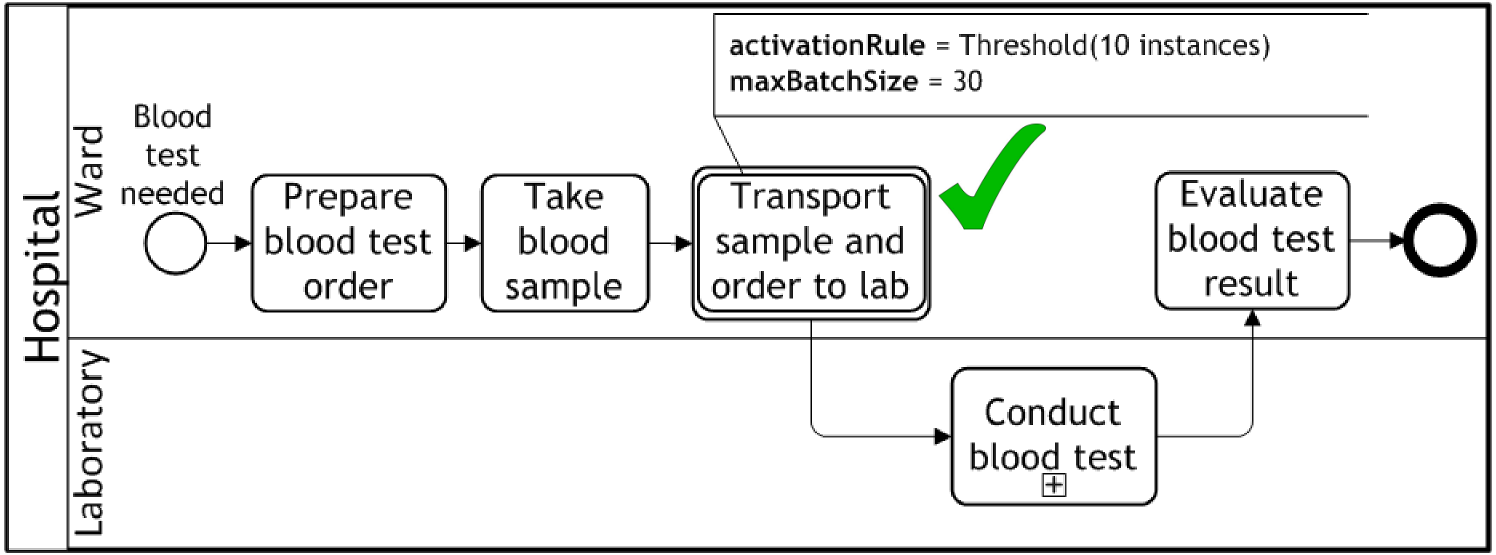


C_s

Expected service costs, EUR



Results of the Evaluation



- Batch activity execution is beneficial and it will save the costs almost up to 20 times
- It is advised to take the threshold of 16 instances

Limitations

- Approach is provided for specific type of a queuing system, e.g. 1 task performer

- For complex queuing configurations, the queuing theory becomes quite complicated

Algorithm 1 Calculation of characteristical parameters of M/M(a,b)/1 system

Input: λ, μ, a, b
Output: $E[t_w], E[Y]$

$h(z) \equiv \mu z^{b+1} - (\lambda+\mu)z + \lambda;$ //$h(z)$ is a characteristic equation, z is an unknown variable

$r = findRoot(h(z));$ //r is a real root, $0 < r < 1$

$w = \lambda/(\lambda+\mu);$

$p = \lambda/\mu;$

$P_{0,0} = \left[\frac{a}{1-r} + \frac{r^{a+1} - r^{b+1}}{(1-r)^2}\right]^{-1};$

$E[t_w] = \frac{P_{0,0}}{\lambda(1-r)}\left[\frac{r^2(1-r^b)}{(1-r)^2} + \frac{a(a-1)}{2} + \frac{r^2(ar^{a-1}(1-r)-(1-r^a))}{(1-r)^2}\right];$

$E[Y] = a(1 + \frac{(r-w)pP_{0,0}}{wr(1-r)^2} + \frac{(1-w)r^{a+1}pP_{0,0}}{(1-r)^3}[1+r+a-ar] - \frac{(r-w)pP_{0,0}}{w(1-r)^3}[1+2b+(1-2b)r]);$

- Focus on evaluation of one activity, and not on the whole process

Conclusion

- An approach to evaluate batch activity is presented
- Cost functions are introduced in order to

(1) compare usual and batch activity execution

(2) find the optimal configuration of a batch activity

Usual activity

Total cost function

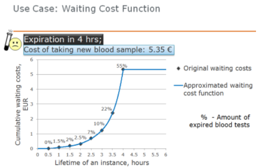
$$C = C_w(t_w) + C_s$$

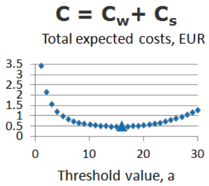
Batch activity

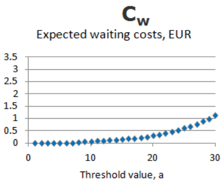
Total cost function

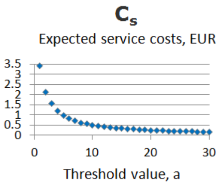
$$C_b = C_w(t_w) + C_s / Y$$

- Approach is demonstrated on a real-world healthcare use case









THANKS!

QUESTIONS?