Survivability study of a Water Cleaning Facility using Fluid Stochastic Petri Nets

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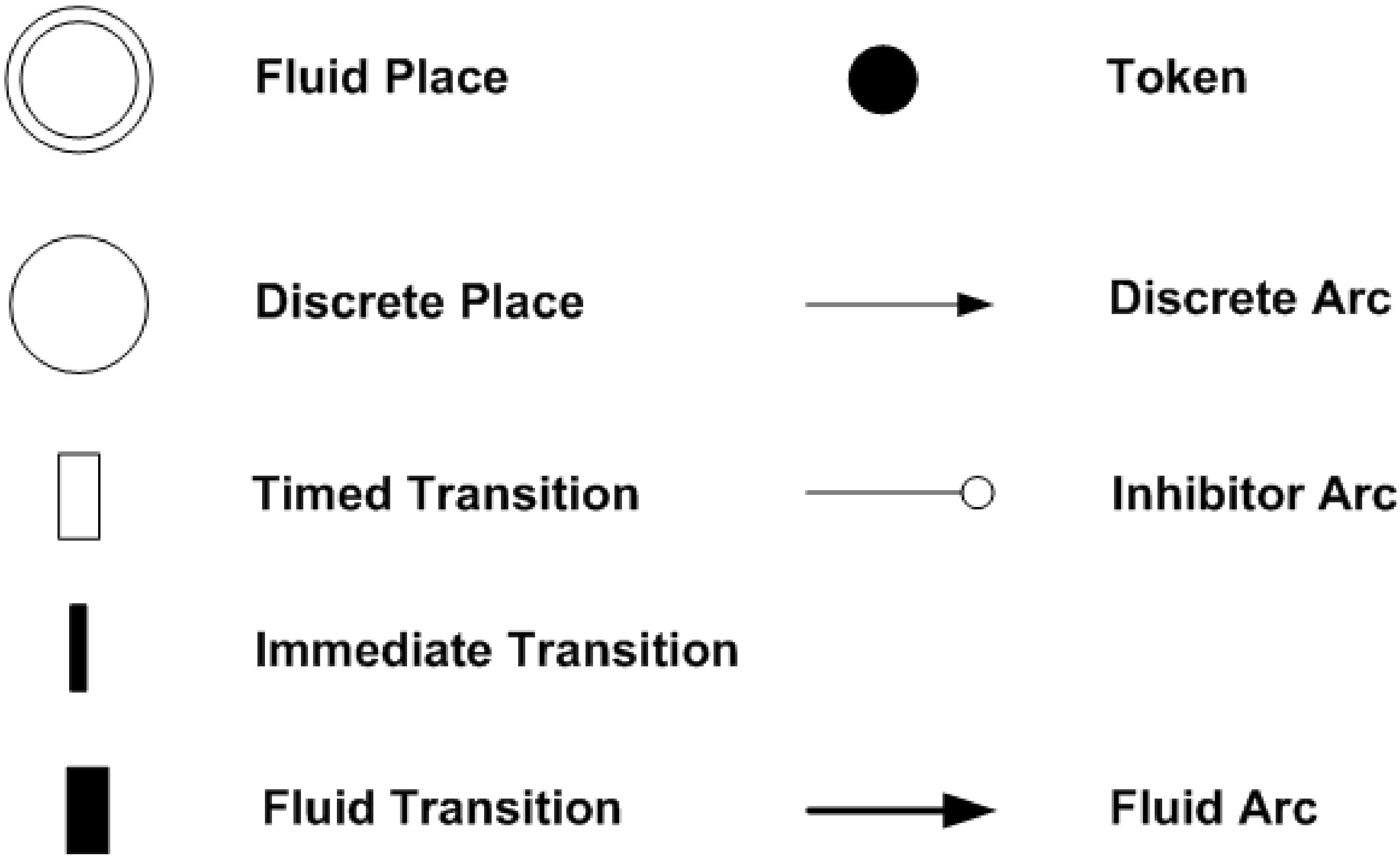
Fluid Stochastic Petri Nets (FSPNs)

- Extension of Generalized Stochastic Petri Nets

- Fluid places hold continuous amount of fluid
- Fluid levels change with fluid transitions

- High-level graphical representation of mixed continuous/discrete-state stochastic processes

FSPN model primitives



Toolset FSPNedit

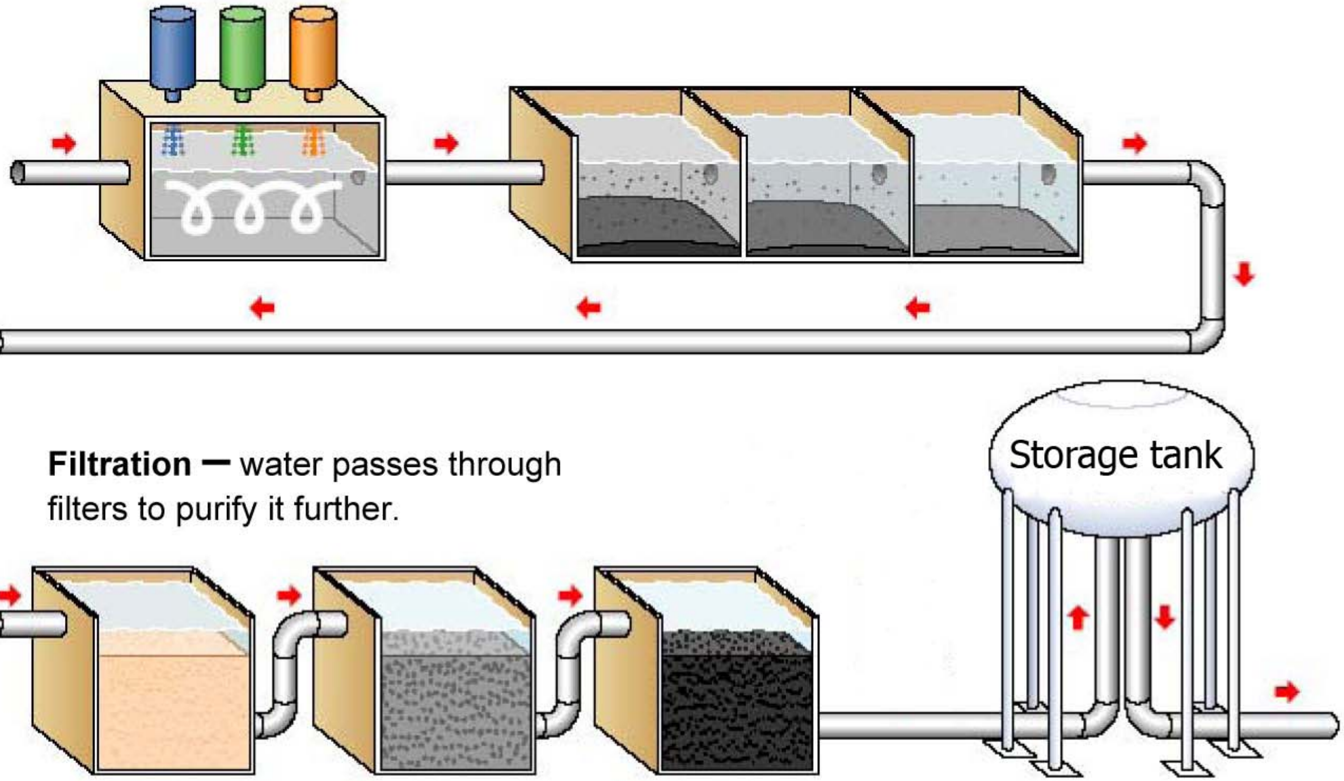
- Graphical user interface for the modeling of FSPNs
- Numerical analysis
  - With semi-discretization limited to one or two fluid places
- Simulator
  - Discrete–event simulation taking into account the fluid dynamics
- Limitations
  - Limited number of fluid places allowed
  - Large amount of memory required for analysis

How a Water Treatment Plant Works

Coagulation – special compounds remove the dirt particles from the water

Sedimentation – the dirt settles to the bottom and the water becomes cleaner

From wells or lakes or rivers to the plant….



Filtration – water passes through filters to purify it further.

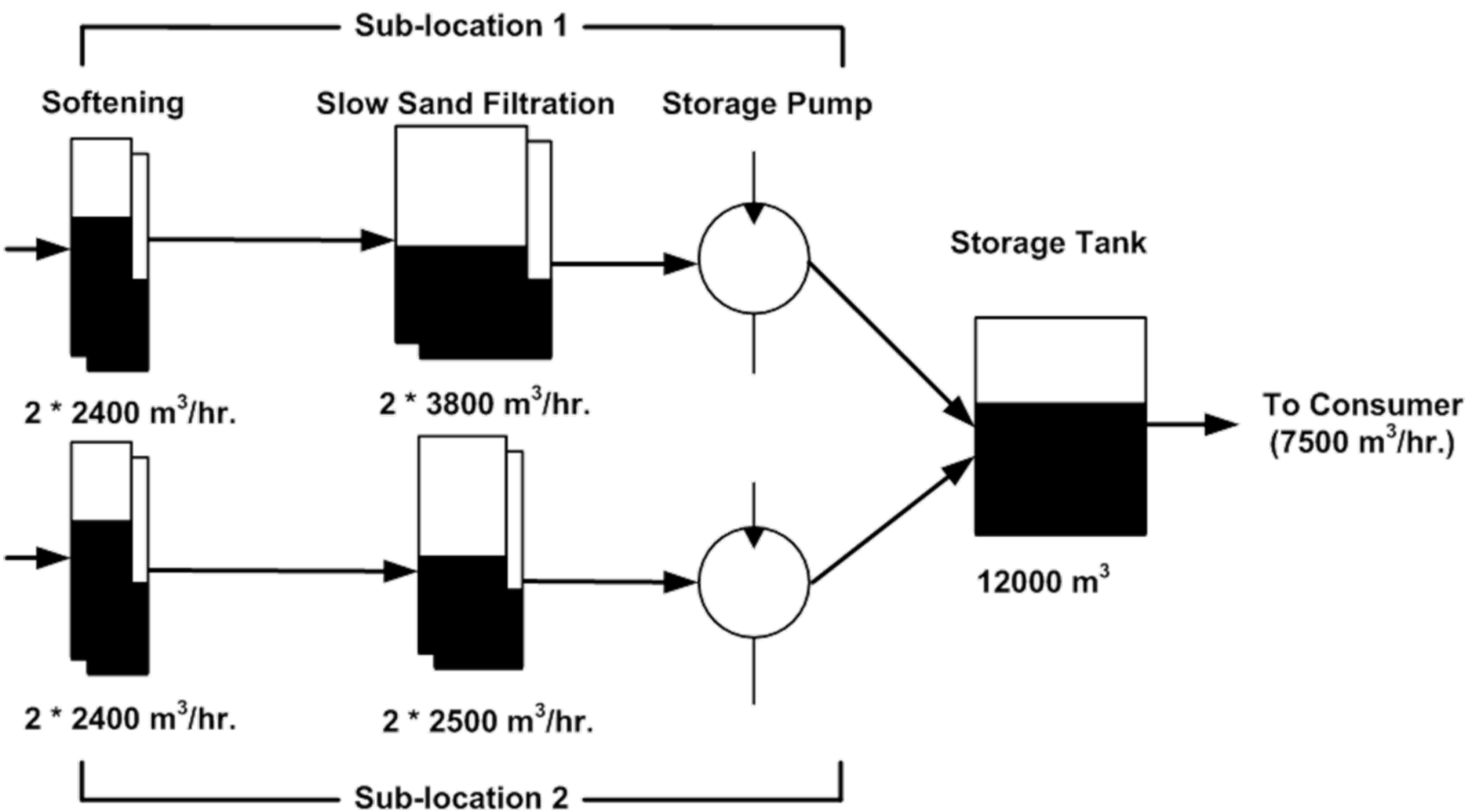
From the water tower to your home!

Focus on last two phases

Softening

Slow sand filtration

Last three phases of the cleaning facility



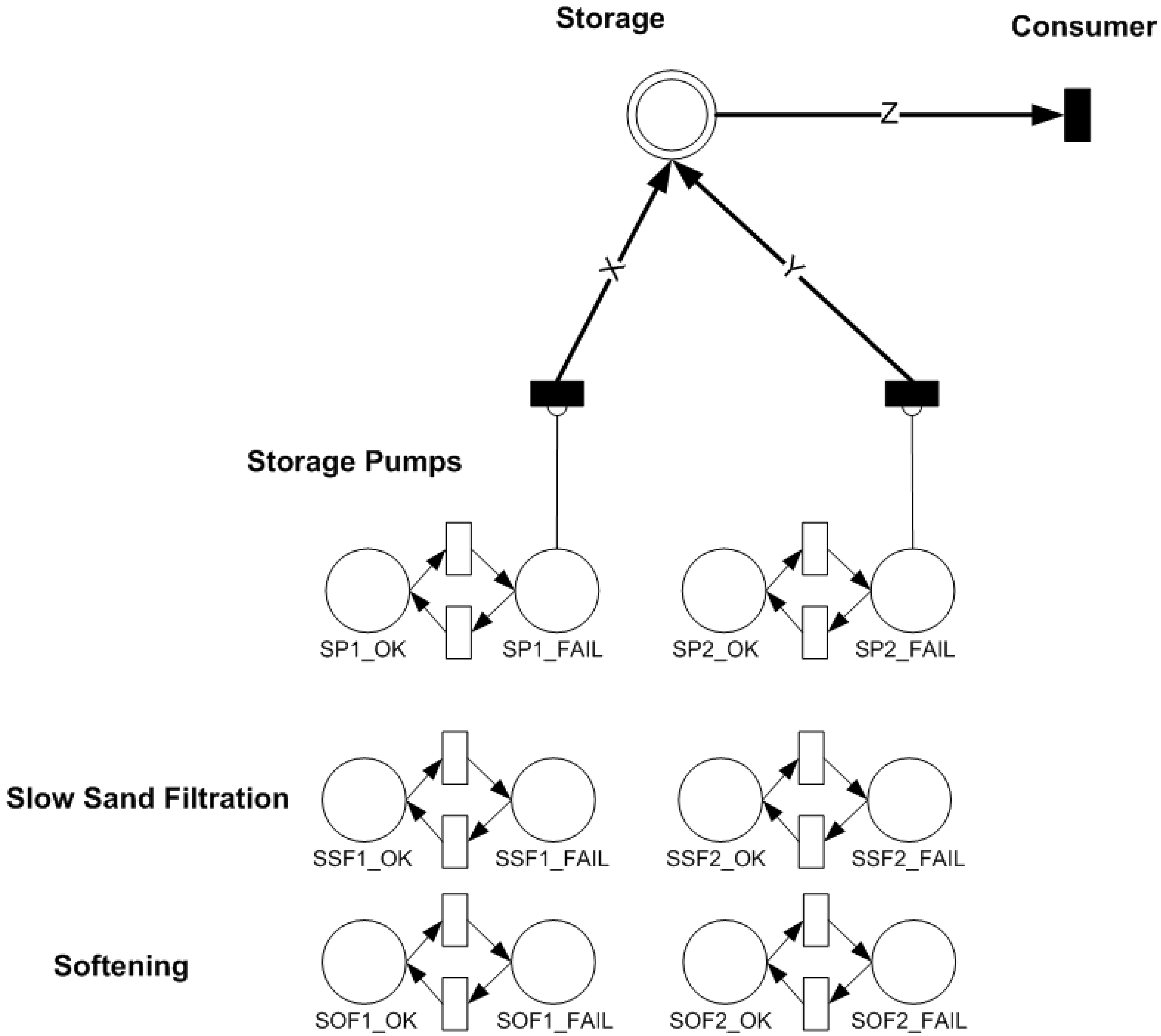
Survivability

- Is the ability of a system
- To recover in predefined service levels
- In a timely manner
- Given the occurrence of Disasters

Survivability in our case

- After the occurrence of a disaster
- Storage tank should not be below 500m^3, as
- Delivery of drinking water not guaranteed

FSPN model



Storage
Consumer
Z
X
Y
Storage Pumps
SP1_OK
SP1_FAIL
SP2_OK
SP2_FAIL
Slow Sand Filtration
SSF1_OK
SSF1_FAIL
SSF2_OK
SSF2_FAIL
Softening
SOF1_OK
SOF1_FAIL
SOF2_OK
SOF2_FAIL

Analysis

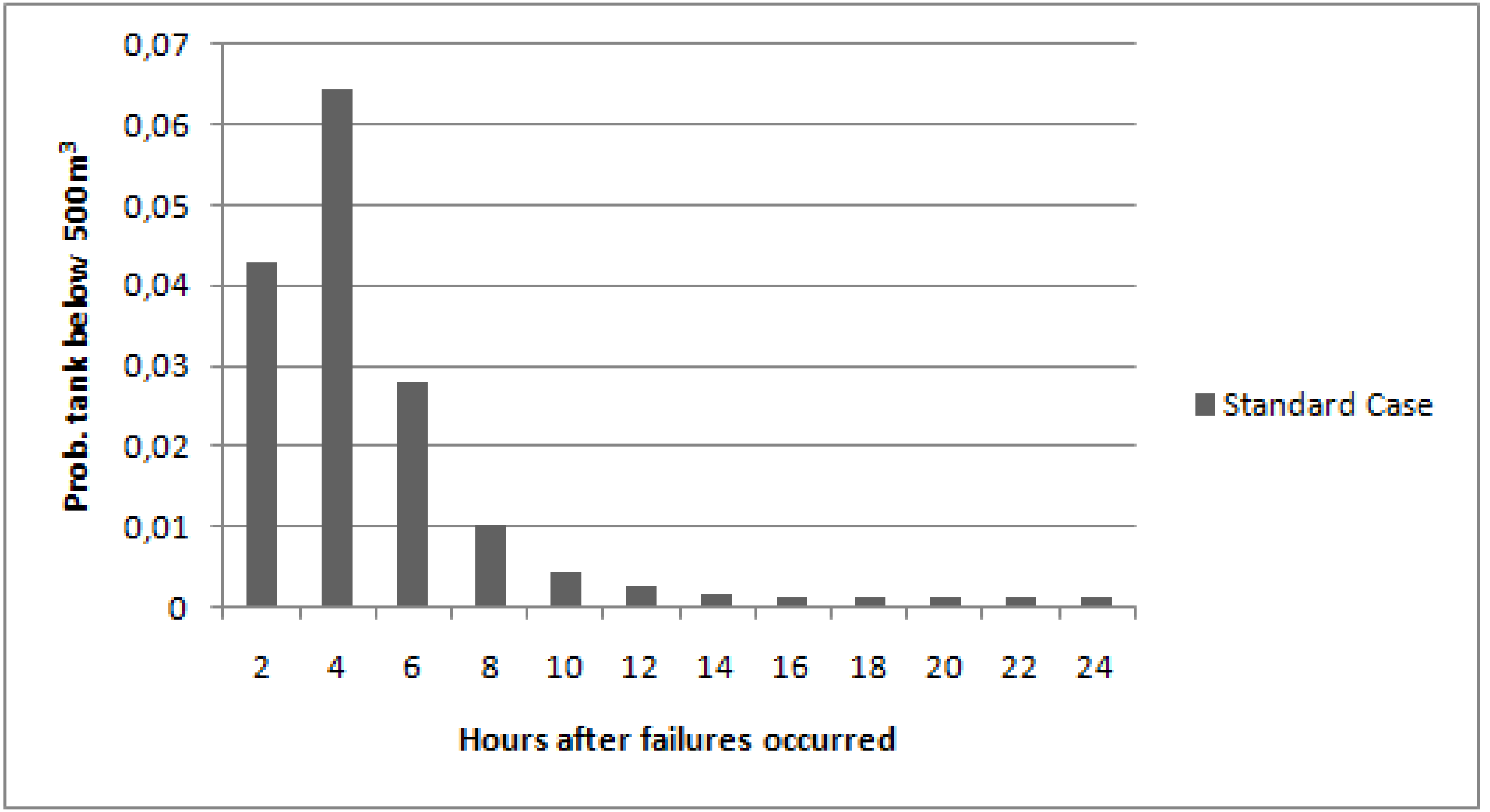
- Transient analysis of the state-distribution
  - Considering both discrete and continuous components
- Solved using FSPNEdit Numerical Analysis component
  - With semi-discretization
- Parameters have been chosen to be meaningful

	Storage pump	Filtration	Softening
Failure rate	1 / 24 hours	1 / 24 hours	2 / 24 hours
Mean repair time	30 minutes	60 minutes	15 minutes

Standard case

- Initially storage tank is full
- Simultaneous failure of
  - two filtration beds,
  - two softening tanks and
  - one storage pump
- Determine prob. of service failure
  - at various time points
  - starting from the failure state

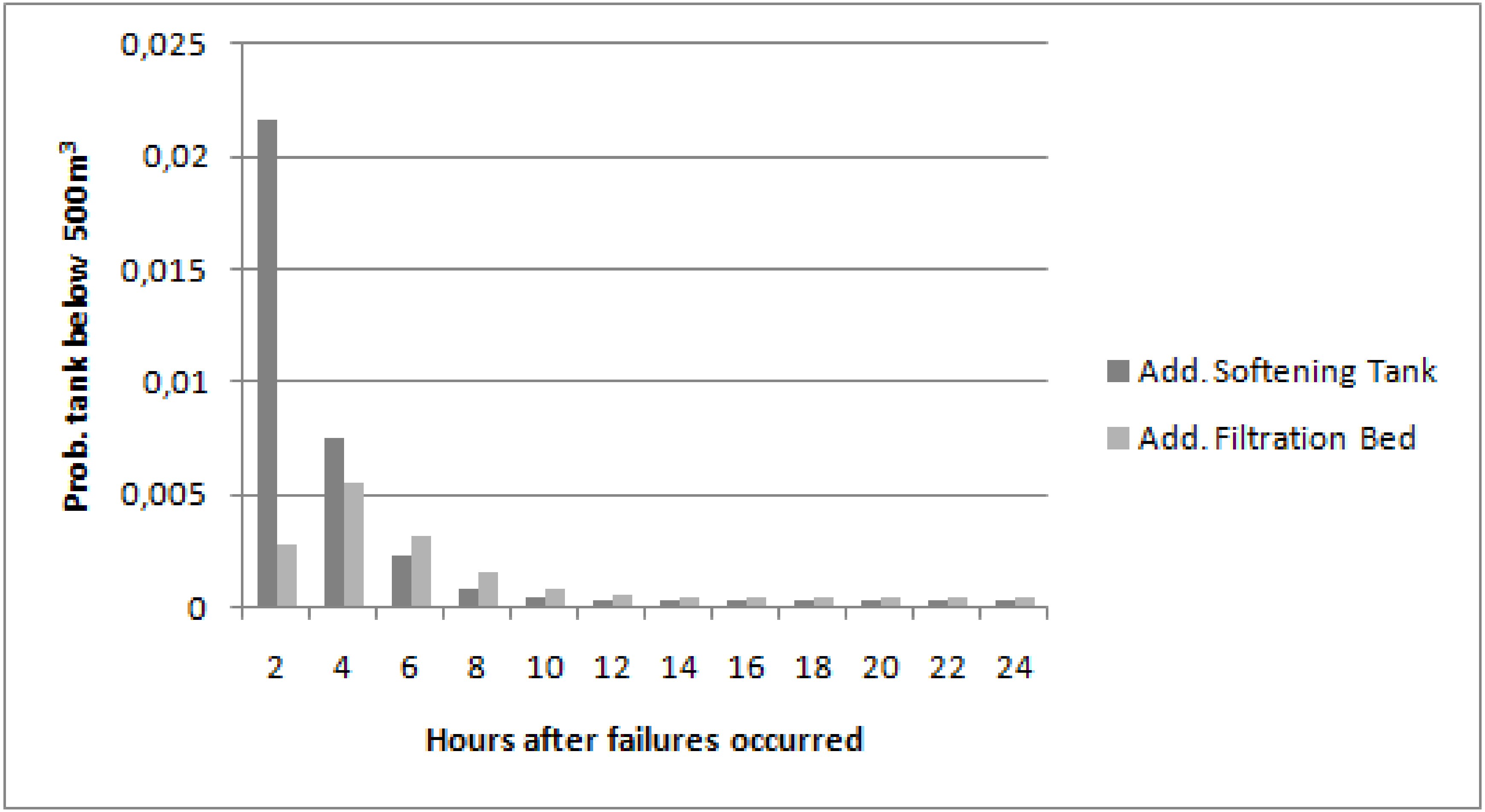
Standard case



Improving the system I

- Increasing redundancy
  - Additional softening tank
  - Additional filtration bed

Additional redundancy

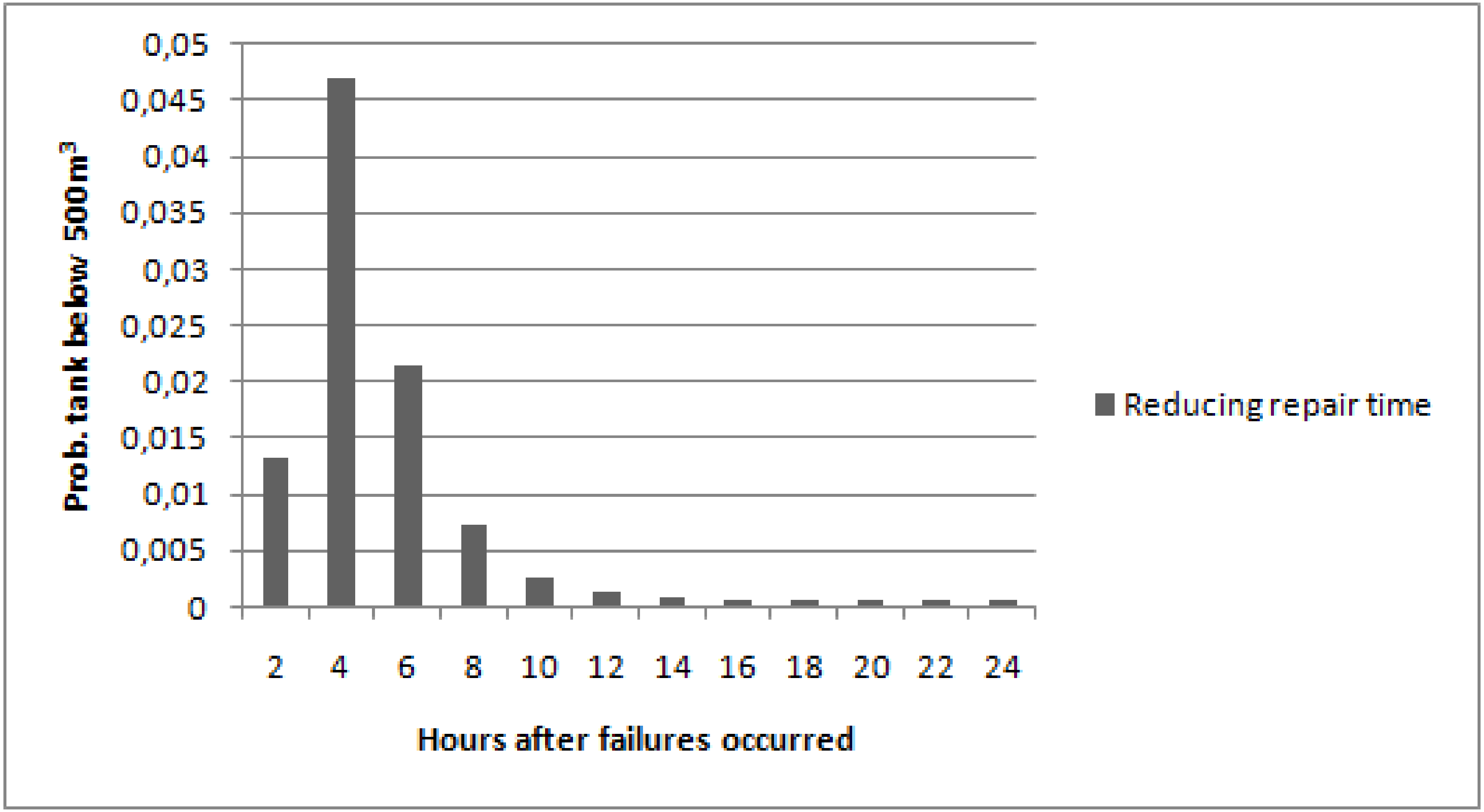


Improving the system II

- Reducing repair time
  - Reduced mean repair time of storage pump

Mean repair time	Storage pump
From	30 minutes
To	15 minutes

Reduced repair time



Conclusion & Future Work

- Conclusions
  - FSPN proved suitable for this model
  - However model not yet realistic

- Future work
  - Results for real-world failure characteristics
  - Include SCADA control networks
  - Find new non-simulative solution techniques
    - To deal with several fluid places
    - Including model-checking capabilities