BUSI 2710

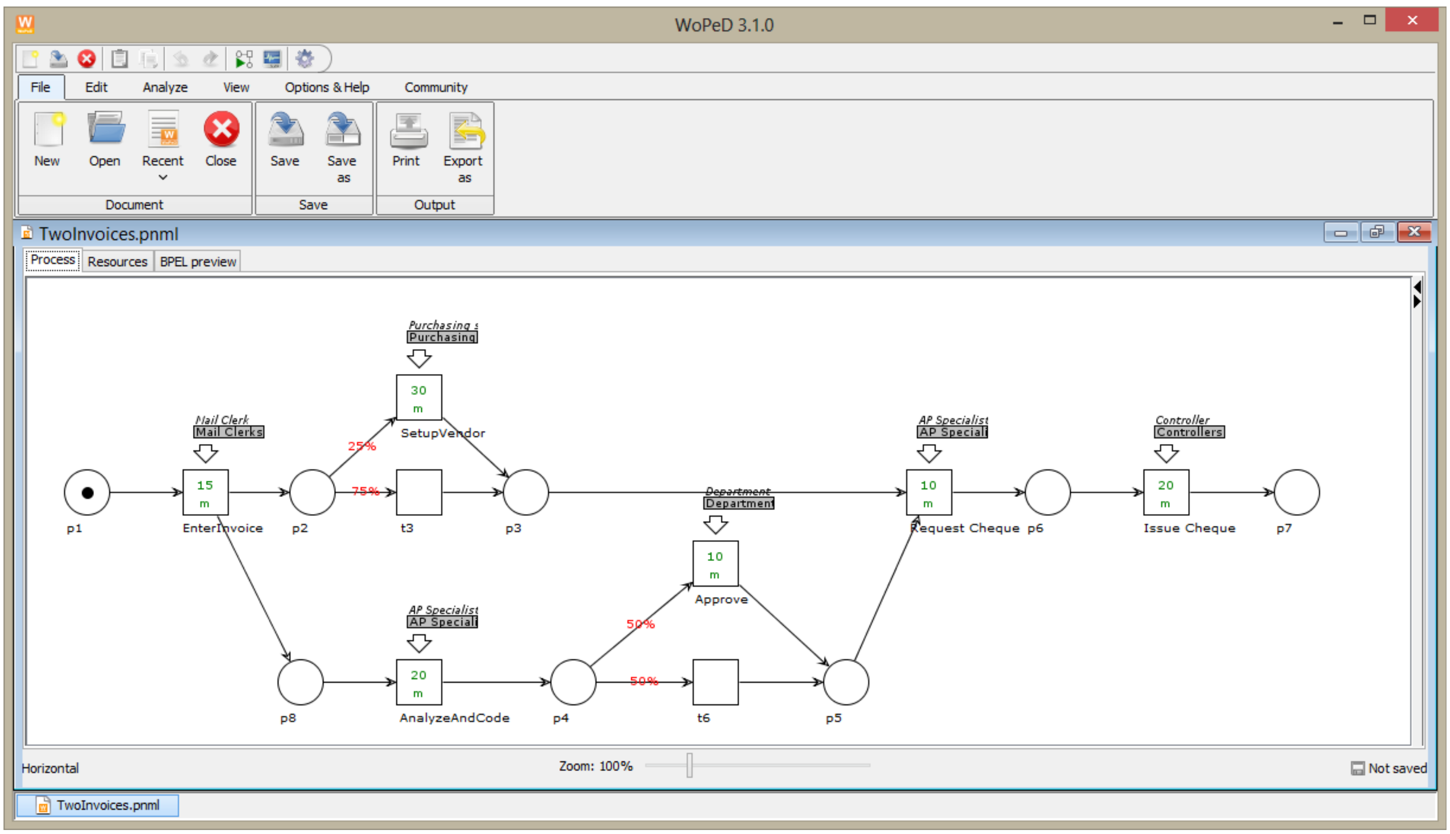
Computer Lab Exercises: Process Simulation with WoPeD

Class 12

You can do these exercises in groups of 2 (two) and discuss!

Exercise 0 (Load and Configure Process Model)

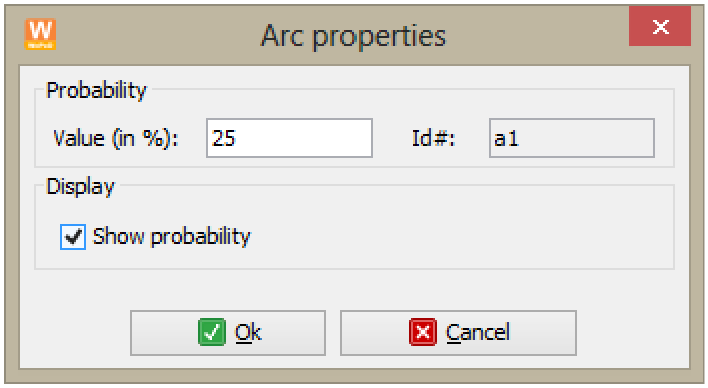
Load the petri net model for the "**Tale of Two Invoices**" video case that you have created in the last computer lab into WoPeD. Alternatively, you can use the process model provided on the course web site.



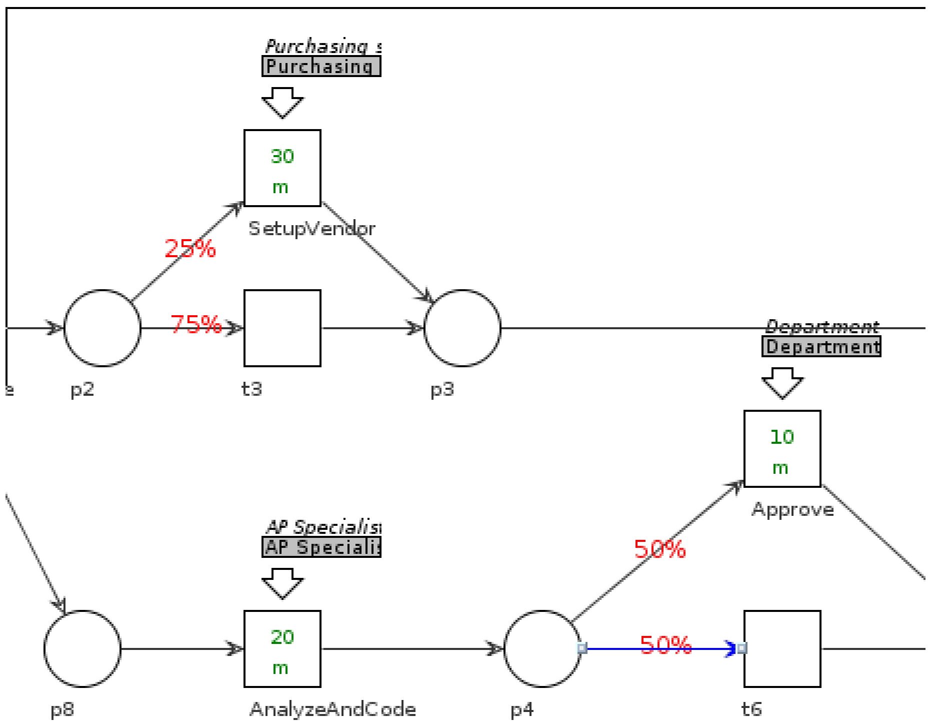
When a place has multiple outgoing arcs, there is a choice to be made as to which direction to proceed in. For simulation purposes, you need to indicate how often the process goes along each of the outgoing arcs.

This is already done in the process model you downloaded, but you must do this if you use your own models.

Right-click on each arc to bring up the dialog box. Enter the percentage (reflects probability). The sum of the percentages for all outgoing arcs from each place must add up to 100.



If you choose to show the probabilities in the diagram, they will be displayed as in the example below:



You are now ready to simulate your process!

Exercise 1 (Quantitative Simulation)

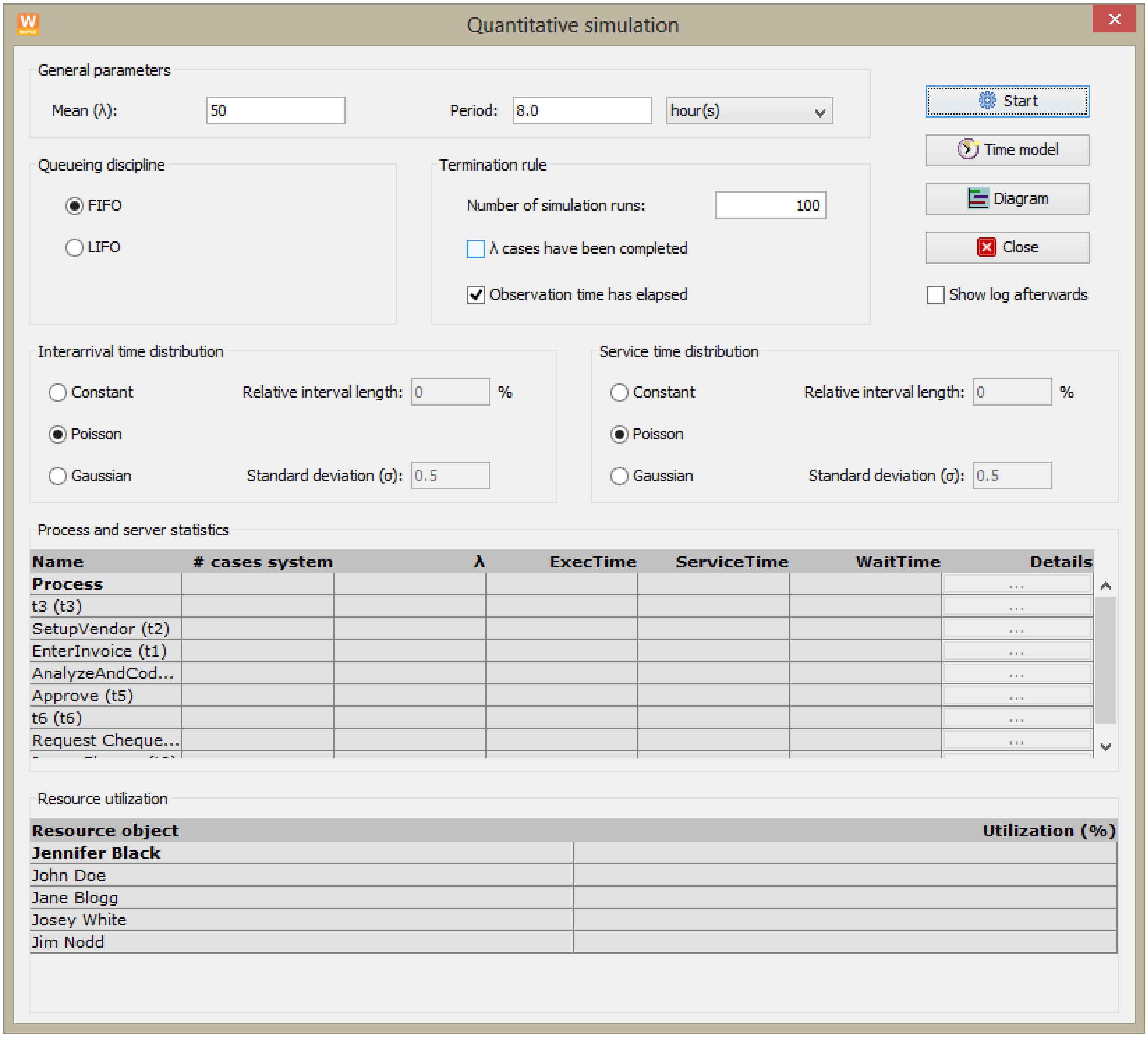
Simulation is a technique in which a process is evaluated without actually implementing the process in an organization. It is useful for evaluating new or existing business processes and for identifying ways to improve a given business process.

While the correctness of a process, using concepts such as liveness, boundedness, and soundness, can be evaluated simply by examining the workflow model, as we have done previously, the evaluation of *performance metrics* or performance characteristics, typically requires that the process actually be run/executed, because these can be derived from the workflow model only for simple cases, and it is often easier to simulate the process instead. Typical performance metrics of a process are

- time (e.g. time to completion, waiting time, service time, etc.)
- utilization (e.g. bottlenecks, underutilized resources, etc.)
- cost and revenue

Just like in the real world, there is a random element to every process execution in a simulation. For example, cases (e.g. customers, patients, invoices, etc.) do not arrive at regular intervals but somewhat randomly. Similarly, the tasks in a process do not always take exactly the same time, but this “service time” has a random element to it: Sometimes a task takes a little more time, sometimes a little less. Therefore, every one simulation will be different from any other one. Thus, one cannot draw conclusions from only a single simulation, but should use many (e.g. 100 or more) simulations and then evaluate the average of the performance metrics across these simulations.

Given a workflow model to which resources have been assigned, WoPeD can perform simple and easy to understand simulations. Click on the button for “Quantiative Simulation”. You should see the following dialog screen:



In the "General Parameters" section, the "Mean" value is the average number of cases that are simulated. The duration of the simulation period can be set in the "Period" field. Thus, a mean of 50 and a period of 8 means that on average, there will be 50 cases arriving per work day.

In the "Termination rule" setting, you can determine how many simulation runs you wish to make and when each simulation should end. This is important because the arrival time of cases to the process, as well as the service time for the transitions may be probabilistic, rather than constant. The more simulation runs you make, the more generalizable the results. S**et the number of simulation runs to 100.**

Depending on the purpose of the simulation, you may wish to keep simulating until all cases have been processed, so that your results will include only completed cases, rather than cases that are still in progress. This is typically the case if you wish to examine metrics related to cases, e.g. completion time, wait time, etc. On the other hand, sometimes you wish to focus on the simulation period (e.g. a work day) and it doesn't matter that some cases are still in progress. This is typically the case if you wish to examine metrics related to utlization and capacities. The longer your simulation period, the less the difference between the two typies of simulation. You can set a simulation to end once either all cases have been processed, or the simulation period has ended, or either of these two conditions. **Uncheck the box for "λ cases have been completed".**

In the "Queuing discipline" section, you can set how the different cases that "wait" at a place are selected when the transition fires next. FIFO means "first in, first out", i.e. they are worked on in the order in which they arrive. LIFO means "last in, first out", i.e. the latest arrival is selected first.

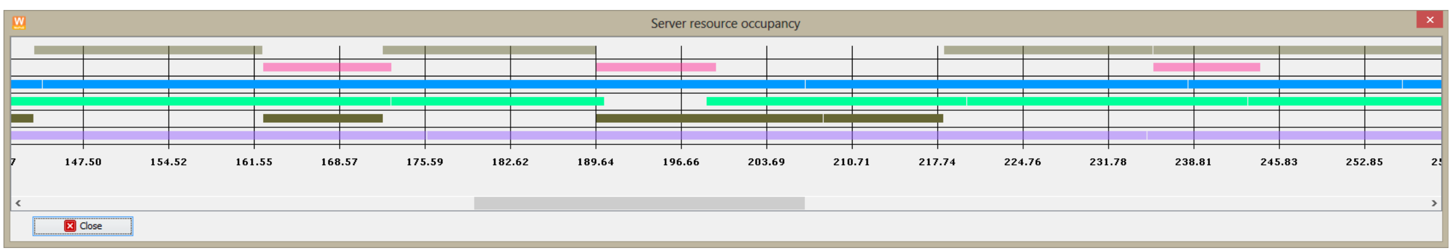
In the "Interarrival time distribution" you can select the time between the arrival of cases. You can either make this constant, or probabilistic. A constant interarrival time is unrealistic, and a common assumption is that of a Poisson-distributed interarrival time.

In the "Service time distribution" you can select how the time that a transition takes is calculated, based on the timing information you have provided for each transition. Again, a constant service time is unrealistic, and a common assumption is that of a Poisson-distributed service time. In this case, the service time you specified for the task will be the average of the service times.

When you **click the "Start" button**, a dialog box about the progress of the simulations will briefly appear. Once the simulations are done, the sections "Process and server statistics" and "Resource utilization" have the results of the simulations.

Exercise 2 (Evaluating the Simulation Results)

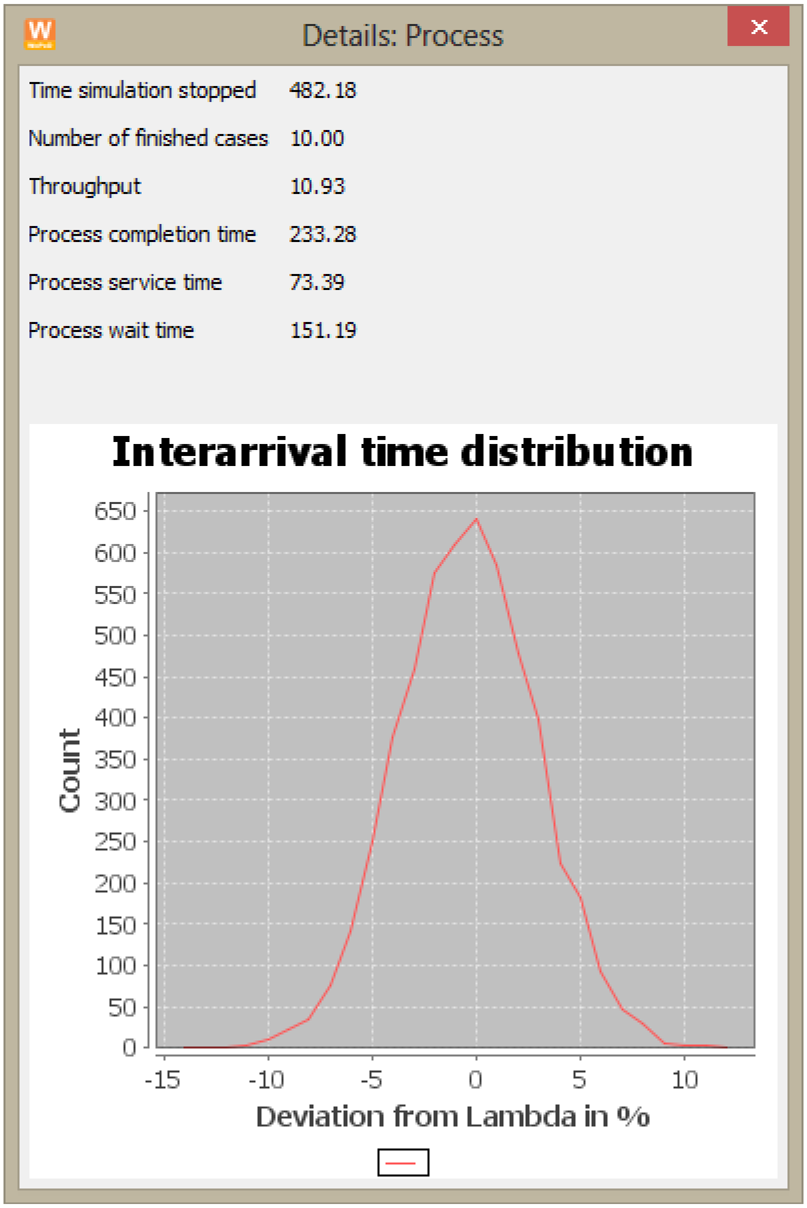
Select the "Diagram" button to show a diagram of when each transition was active throughout the simulation period we examined. The resources involved are colour-coded in different colours and hovering the mouse pointer will show more detail about each activity.



The simulation dialog box now contains the results of the simulation runs. The first table ("Process and server statistics") shows results for the process and each transition, whereas the second table ("Resource Utilization") shows results for each resource.

The service time shown in the first table is the *average* time duration for with that transition was actively serving a case. The wait time is the *average* time during which a case had to wait for resources for this transition. The execution time is always the sum of service and wait time. Note that the service times are not exactly as you specified them, but will only be so *on average*.

Click on the “Details” button in the last column of the first table to see more details about the process and each transition. The details for the process look like this:

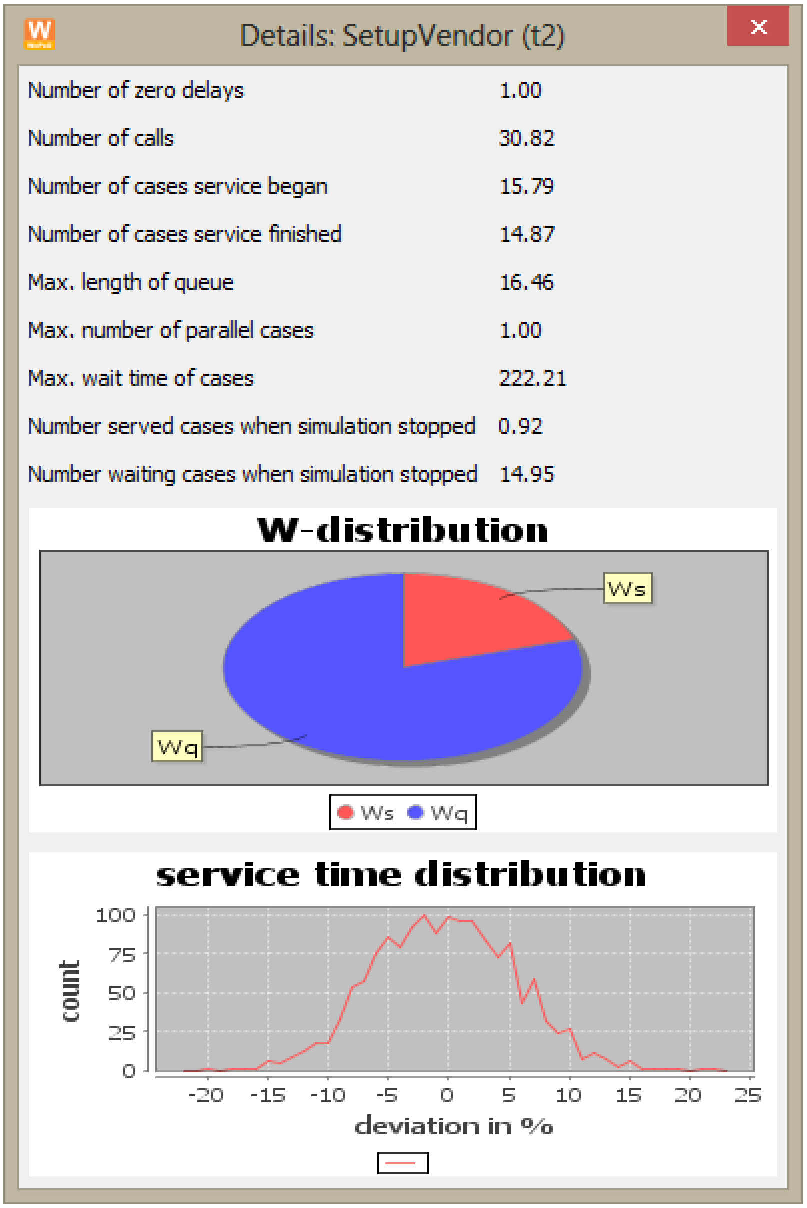


They show the number of finished cases (in this case, significantly less than the number of arrived cases), the throughput, average case completion time, average service time, and average wait time. It also shows the distribution of interarrival times as deviations from the average interarrival time.

Question: Why do you think there are fewer finished cases, even though we specified 50 cases arriving per day?

Question: Why do you think the averages for wait and service time do not add up to the average completion time?

Clicking on the “Details” button for a transition, shows the following information, most of which does not require any explanation.



Note that the values are averaged over all simulation runs. The maximum length of the queue is the maximum number of cases that were waiting for this activity at the same time. The diagram shows the distribution of waiting time (“Wq”) and service time (“Ws”).

Question: Why is there exactly one case for which there was zero delay?
Question: Why is there at most one parallel case?
Question: Why is the number of finished cases for this transition higher than the number of finished cases for the overall process?

The resource utilization table provides the resource utilization for the resources over the entire simulation period.

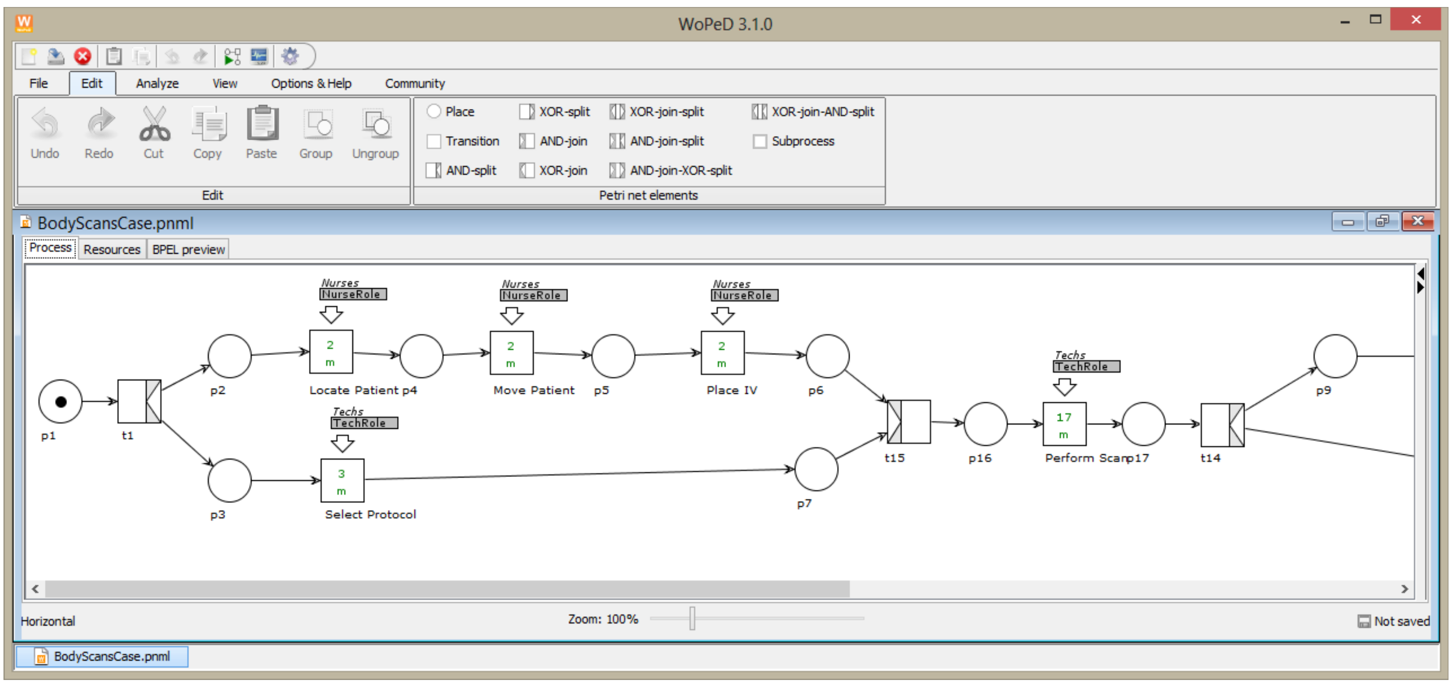
Question: Is there a bottleneck in this process? If so, which resource is a bottleneck?

Question: Why are none of the utilizations at 100% even though not all cases could be serviced?

Question: In class 7 we suggested that ProductIff Inc. wants to handle 15 cases per 8-hour work day). Is this possible?

Exercise 3 (Load and Configure Workflow Model)

Load the workflow model for the "**Body Scans and Bottlenecks**" case that you have created in the last computer lab into WoPeD. Alternatively, you can use the workflow model provided on the course web site.



In the resources tab for the model, **configure the resources so that only a single nurse and single tech are available.**

Question: Why do we not need to specify probabilities for the two branching transitions in this model?

Exercise 4 (Scenario Analysis)

The case suggests that the 6 current scanners are able to make 55,000 scans per year using multiple shifts per day. Assuming that a year has approx. 300 working days (including Saturdays), this means that the hospital should be able process 30 cases per day, perhaps in multiple shifts. Run the simulation with 30 cases per 16 hour period using 100 simulation runs to see whether this is possible. Answer the following questions:

- What is the utilization of the technician and the nurse?
- What is the throughput? What is the average waiting time?
- Run the simulation until all cases are processed: How long do tech and nurse have to stay late to finish their work?

YOU SHOULD WORK THROUGH EXERCISES 5 THROUGH 8, BUT IF TIME IS SHORT, SKIP TO EXERCISE 9!!

Exercise 5 (Scenario Analysis)

Change your model to reflect the implementation of the new scanners, for which the scanning only takes 2.5 minutes on average, the image reconstruction only takes 2 minutes on average, and the time to select the scan protocol is 1 minute. Still a**ssuming 30 cases per 16 hour period,** answer the following questions:

- What is the utilization of the technician and the nurse? Is there a bottleneck in the process? Where?
- Our earlier analysis (class 8) showed that the nurse is the bottleneck in this new process? Why does your answer to the previous question differ from that earlier result?
- By increasing the case arrival rate, find the maximum throughput for the process until a bottleneck occurs?
- Our earlier analysis (class 8) showed that the maximum throughput is 4.29 cases per hour. This is approx. 69 cases per 16-hour period. Does this agree with your answer to the previous question? Why or why not?
- Simulate the process **using 69 cases per 16 hour period.**
    - What is the utilization of the resources? In class 8 we calculated the nurses to be utilized at 100%, the tech to be utilized at 46%. Are your simulation results different? If so, why?
    - How long does each case take?
    - What is the task with the longest wait time?
    - How many chairs does the waiting room have to provide?
    - Which task had the worst ratio of wait time to service time? Which task had the best ratio?
    - How long do tech and nurses have to work late to complete all cases?

Exercise 6 (Scenario Analysis)

The next scenario that we examined in the earlier class (class 8) was to hire an additional nurse. Change your resource model to add the nurse. Simulate the process again **assuming 69 cases per 16 hour period.** Answer the following questions:

- What is the utilization of the technician and the nurses? Is there a bottleneck in the process?
- By increasing the case arrival rate, find the maximum throughput for the process until a bottleneck occurs?
- Our earlier analysis (class 8) showed that the maximum throughput is 8.57 cases per hour. This is approx. 137 cases per 16-hour period. Does this agree with your answer to the previous question? Why or why not?
- Simulate the process **using 137 cases per 16 hour period.**
    - What is the utilization of the resources? In class 8 we calculated the technician to be utilized at 100%, the nurses to be utilized at 93%. Are your simulation results different? If so, why?
    - How long does each case take?
    - What is the task with the longest wait time?
    - How many chairs does the waiting room have to provide?
    - Which task had the worst ratio of wait time to service time? Which task had the best ratio?
    - How long do tech and nurses have to work late to complete all cases?

Exercise 7 (Scenario Analysis)

The next scenario that we examined in the earlier class (class 8) was to shorten some of the nursing tasks. Change your model to a single nurse, but shorten some nursing tasks so that a total of 3 minutes are saved. Simulate the process again **assuming 69 cases per 16 hour period.** Answer the following questions:

- How do your results differ from those for Exercise 5?
- By increasing the case arrival rate, find the maximum throughput for the process until a bottleneck occurs?
- Our earlier analysis (class 8) showed that the maximum throughput is 8.57 cases per hour. This is approx. 87 cases per 16-hour period. Does this agree with your answer to the previous question? Why or why not?
- Simulate the process **using 87 cases per 16 hour period.**
  - What is the utilization of the resources? In class 8 we calculated the nurse to be utilized at 100%, the technician to be utilized at 60%. Are your simulation results different? If so, why?

Exercise 8 (Scenario Analysis)

The next scenario that we examined in the earlier class (class 8) was to shift some of the nursing tasks to the technician. Change your model to a single nurse, but shift the tasks “Locate Patient” and “Move Patient” tothe technician. Simulate the process again **assuming 69 cases per 16 hour period.** Answer the following questions:

- How do your results differ from those for Exercise 5?
- By increasing the case arrival rate, find the maximum throughput for the process until a bottleneck occurs?
- Our earlier analysis (class 8) showed that the maximum throughput is 5.71 cases per hour. This is approx. 91 cases per 16-hour period. Does this agree with your answer to the previous question? Why or why not?
- Simulate the process **using 91 cases per 16 hour period.**
  - What is the utilization of the resources? In class 8 we calculated the nurse to be utilized at 71%, the technician to be utilized at 75%. Are your simulation results different? If so, why?

Exercise 9 (Reflection on Simulation)

Having simulated a number of scenarios and analyzed the simulation results, answer the following questions:

- How is simulation different from mathematical analysis of the process (as done in class 8)?
- What additional information does simulation provide?
- What do you find difficult to capture in a simulation model? Do you think these are limitations only in WoPeD or in simulation in general?
- What assumptions have you made in your simulation? How realistic do you think these are?
- Compare the simulation assumptions with the assumptions we had to make for the mathematical analysis? Which are more realistic?