Simulation Theory and Applications - Exam August 2019

(The exam was exactly the same as the one in January 2019)

The exam consists of 6 main questions with a lot of sub-questions, with one Extra/Bonus question which was not harmful if we did not answer. You're given 3 hours to finish the exams.

1. (Model from Homework 4 was presented, fully captured)
   Can you give examples if you can find these in the model, if present? How do you know it was in the model? If you are not sure, elaborate why you are not sure.
   i. An Entity
   ii. A Resource
   iii. A Queue set
   iv. A Station set
   v. A Sequence
   vi. Level and rate
   vii. A Schedule

2. (Still referring to the same model, from Homework 4)
   a. In the model there is a "Hold until container or time" module which has the expression:
      … || ((TNOW < (24*AINT(TNOW/24) + ExtraTransportFrom) ||
      TNOW > (TNOW > (24*AINT(TNOW/24 + ExtraTransportUntil) && …)
      Explain the meaning of the expression and what is the module is doing.
   b. Still at the same question above (b), is it completely correct to model it that way? Why and why not?
   c. Where are the containers in the model while being transported on the vessel?
   d. What is the purpose of modelling lock as transporter in the lower part of canal traffic?

3. INPUT ANALYZER
   a. The interarrival and waiting times in the above model are expressed by using exponential (e.g. EXPO(15), EXPO(60), etc). So the exponential distribution is expected. However, some experts claim that beta distribution is more appropriate to be used. What do you think about this? Which one is more appropriate, and why? You can give some arguments but don't overdo since the space is limited.
   b. (Given the following SIMAN output excerpt - *these are just the random numbers to illustrate, not exactly what on the exams, to have an idea what's going on*)
      These are the results of the run length of 1 week, 1 year, and 10 years. Why is there are INSUF for the first two half width value?

	...	Half width	...
TruckA.Utilization	...	(INSUF)	...
TruckB.Utilization	...	(INSUF)	...
TruckA.Utilization	…	0.562	...
TruckB.Utilization	…	0.021	...
TruckA.Utilization	…	0.084	...
TruckB.Utilization	…	0.000321	...

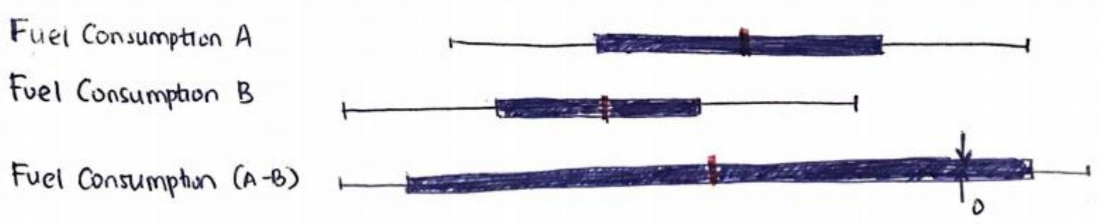
c. Is the decrease of half width value expected?

d. However we are not interested in the Truck Utilization as our performance measure. We are interested in fuel consumption yearly and percent containers late. Suppose that steady simulation is preferred. What is the more appropriate method: truncated replications or batch means approach? Or are both methods can be applied to get the desired performance measure?

e. Do we consider this as terminating or non-terminating simulation?

4. OUTPUT ANALYZER

a. Running 10 replications with run length of 1 year give the following results with the mean difference of two scenarios (A and B).



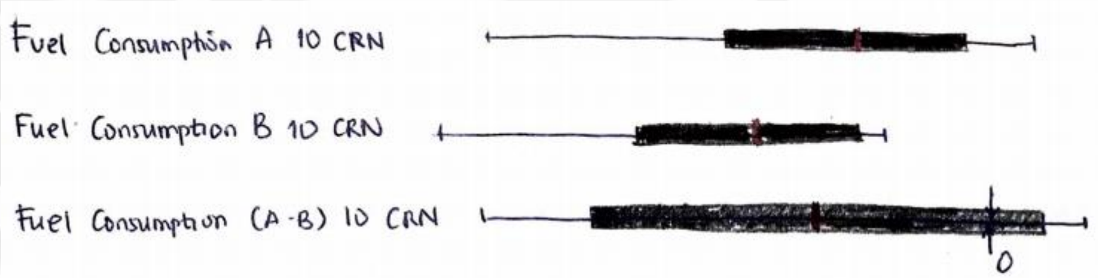
How to interpret this result? What can be concluded?

b. There are two ways to synchronizing the random number, please explain:

   i. Synchronize by entity

   ii. Synchronize by source of randomness

c. These are the results of applying CRN with 10 replications. Is the result expected?

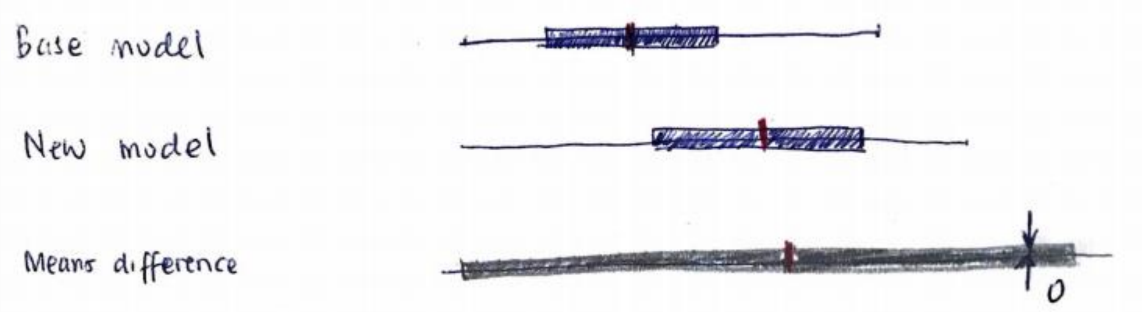


(*ps. I tried my best to draw the Confidence Intervals. To give you a better idea, the CI of Fuel Consumption A with CRN decreases very little compared to Fuel Consumption A without CRN (see (a)). The CI of Fuel Consumption B stays the same width. The CI of means difference of A-B decreases quite a bit. All the means (red stripes in the middle) increase a bit with the CRN (move to right slightly on the picture*).

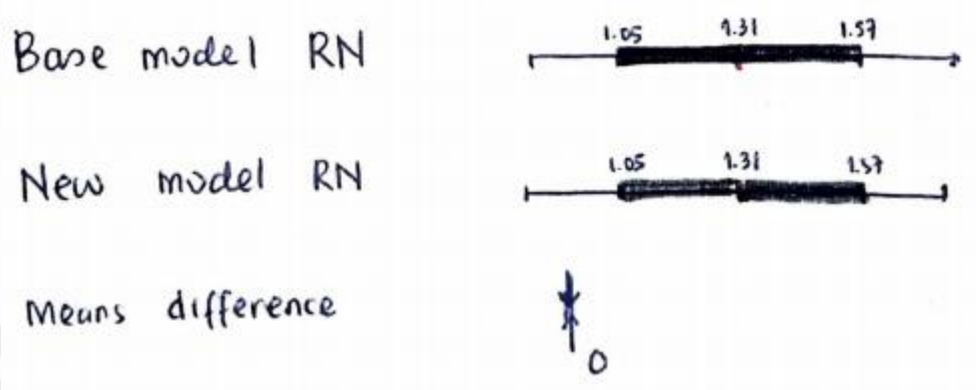
d. What might be the cause of CRN behaving this way?

5. Adapting the model - a new model yet very similar to the Homework 4 model is presented. The management has now interested in another alternative: Allowing the empty truck to be brought back by vessel instead of driving back to the origin. Truck requires 2 spaces in the vessel (compared to container which only requires 1 space). Assume that the same crane that is used for load and unload the container is also used to load and unload the truck and the time requires also stays the same. The container on the truck need to be unloaded first using the crane, before the crane loads the truck to vessel. The management is interested to know if the new model is able to deliver the same or better performance as the previous alternative or not.

   a. The mean difference between the base scenario and the newly adapted model is captured below. What can be concluded?



   b. How can be explained that the confidence interval is not identical?
   c. Modifying the model by synchronizing the random number generates this output.



   How can this be realized/explained?

6. **PROCESS ANALYZER** and **OPTQUEST**

(Given 17 scenarios in PAN (1 base with 4 controls). The performance measures are still fuel consumption and percent containers late. There are two box and whiskers diagrams. One for Fuel Consumption, and the other for percent containers late. The four best scenarios (which is the least value for fuel consumption) are the ones with the following: +--+, ++-+, +-++, ++++; while I only identified two of the best scenarios of the percent containers late which have < 1.5% of containers late (actually only one value having below 1 percent, as desired by the management): ++--, +-+-)

   a. Explain the effect that can be identified from the above diagrams. You are free to choose one scenario if necessary.
   b. Any important interaction effect that you can identify? If not, why not?
   c. Using OptQuest, we are running 1000 configurations with 10 replications each configuration. *(There are three Constraints, 4 or 5 control which have intervals (e.g. 20 ≤ ExtraTransportUntil ≤ 24; 0 ≤ ExtraTransportFrom ≤ 8; etc).* It gives us about 50 feasible configurations before the infeasible configuration occurs. *(The list of feasible configurations are listed on one full page).* Could these results be predicted using PAN?

7. (Bonus question, no harm if you are not confident in answering)

Given the screenshot of the quadcore CPU 2.6GHz while running OptQuest. During running OptQuest, all the quadcore CPU are busy.

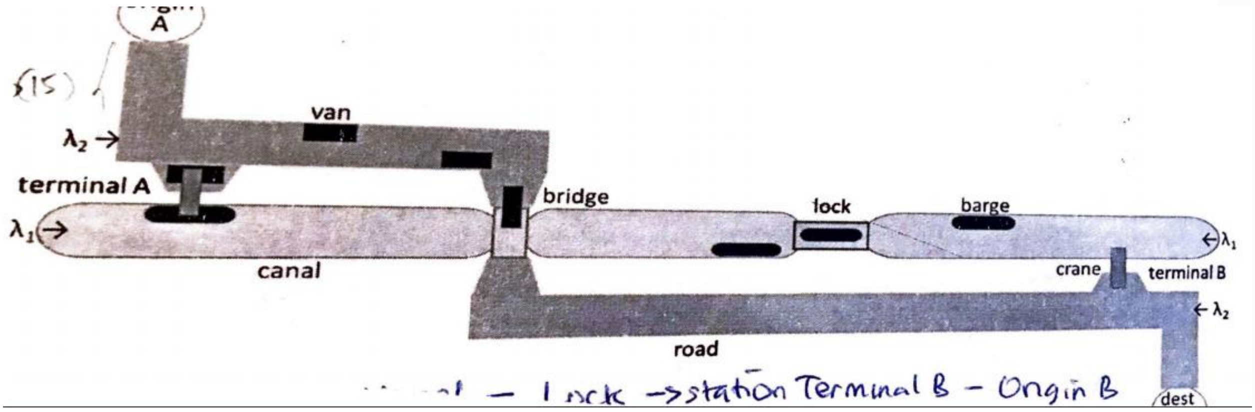
   a. Aren't the 1,000 configurations executed sequentially, one after another? Aren't the 10 replications executed sequentially?
   b. Then why all four cores of CPU remains busy 70% during running OptQuest?

Homework Assignment 4

Containers are filled at A, and have to be transported to destination B. For this purpose, a vessel and **a number of trucks** are available.

On average, one container is filled per hour at the origin (A), but only during the day, between 8:00 and 20:00. **Trucks**(with capacity one) are used to transport these containers to terminal A. At that point, a choice must be made, depending on the policy selected: the trucks can continue their journey along the road, all the way to destination B (policy 2), or a crane (with capacity one) can load the containers on a vessel (**with a certain capacity**), at least if the vessel is berthed at terminal A (policy 1). The loaded vessel departs upstream to terminal B. There, a crane (with capacity one) will unload the containers on **trucks** (with capacity one), to transport the containers to destination B. A crane can load or unload a container in approximately 5 minutes. If the vessel is not used to transport containers (policy 2), then **all trucks** can be used to transport containers from A to B. Anyway, the empty trucks and the empty vessel will always return to their original location (terminal A for the vessel, origin A for part of the trucks, terminal B for the other trucks, unless policy 2 without a vessel is selected: then all trucks return to origin A).

The road from A to B is bumpy and narrow, and consists of a number of segments of approximately the same length: from the origin (A) to terminal A, from terminal A to the bridge, from the bridge to the lock, from the lock to terminal B, from terminal B to the destination (B). Each segment can be travelled in both directions, in approximately 15 minutes (with a lot of variability). Further obstacles that involve a delay are only possible at a junction of two segments. For example, at the terminal to load or unload a container, at the narrow bridge (only one car can pass the bridge in approximately one minute) if priority must be given to vessels (always) or to other vehicles (traveling upstream). However, for road vehicles there is no obstacle at the lock.



There are a few bottlenecks on the canal, when sailing upstream from terminal A to terminal B. First, there is a low and narrow bridge. Because there is not enough space under the bridge, the deck must be lifted before one or more boats can pass**. It takes five minutes (constant) to lift the deck of the bridge, and then boats can pass one by one (5 minutes constant per boat). Finally, after the last boat has passed the bridge, another five minutes (constant) is required to put the deck again in place, and reopen the bridge for road traffic.** Assume upstream traffic has priority over downstream traffic. Boats always get priority over road traffic.

Next, there is a small and narrow lock, with a capacity to hold one boat. A boat at the right water level always gets priority. If there are only boats waiting in the other direction, then the water level must be adapted anyway. It takes exactly 15 minutes to fill or to empty the lock (in both directions).

It takes approximately an hour (with a lot of variability) to sail each stretch of water: from terminal A to the bridge, from the bridge to the lock, and from the lock to terminal B (always in both directions).

Besides the vessel and the two trucks, there is a lot of other traffic, both on the road and on the canal, in two directions. At both sides of the canal, barges arrive according to a Poisson arrival process, one barge per hour. During the night hours however (between 22:00 and 6:00), this rate (λ_1) drops to 0.25. Also at both ends of the road, all kinds of cars and vans arrive according to a Poisson arrival process, four cars per hour, but during the night hours, this rate (λ_2) drops to one.

Remark that all interarrival times (of containers, barges and vans) and all travel times (on each road segment and each water stretch) are exponentially distributed, thus causing a lot of variability. Exceptions are the time to lift or lower the bridge, the time for a boat to pass under the bridge, the time to fill or empty a lock (all constant).

Performance measures of interest are: total fuel consumption per year and percent containers arriving late.

The trucks and the vessel consume fuel while travelling. Assume it doesn't make a difference whether they are travelling empty or loaded, fast or slow. A truck consumes one unit of fuel per hour, while the vessel consumes three times as much fuel. A truck or a vessel are not consuming fuel, while they are loaded or unloaded, or while a vessel is (waiting at or) in the lock. **Also while waiting at the bridge, engines of trucks and vessel might be switched off.** The intention is to minimize fuel consumption.

A container is considered late if it arrives at the destination (B) more than 24 hours after it became available in A. The percentage containers late should be less than 1%. (Because of the big variability in traveling times, and the obstacles underway, it can never be guaranteed that not a single container will arrive late.)

Construct a model using Basic and Advanced Process Panels and **Advanced Transfer Panel**.

Controls used by OptQuest:

- Transport mode: vessel and trucks (1), or trucks only (2)
- Number of trucks: lowerbound 2, upperbound 6 (?)
- Vessel capacity: lowerbound 6, upperbound 20 (?)
- Extra transport is possible from (a partly loaded vessel might depart anyway after this time): minimum is 20:00, maximum is 24:00 (midnight)
- Extra transport is possible until (at least if loading of the available containers can finish before this time, the next morning): minimum is 0:00 (midnight), maximum is 8:00
- **Extra transport threshold** (minimum number of containers on board to justify an extra transport): minimum is 1, maximum is vessel capacity