CSC 354S
SYSTEMS MODELING AND DISCRETE SIMULATION

SPRING 1997
UNIVERSITY OF TORONTO

PROBLEM SET 3

Purpose: To share the berthing experience.

General Comments: This is the big one, the one your mother warned you about. Start early.

Specific comments: The electronic submission for this problem must be done by 2:00 p.m. on Thursday, April 3. The hard-copy handin for this problem set is due in tutorial on Thursday, April 3. Hand in hard-copy answers for this problem set in some secure package; check the newsgroup for specific handin requirements. Remember to hand in a signed equality sheet with your hard-copy.

[This problem statement is derived from problems 2.23, 2.24, and 2.25 in Law and Kelton. Changes have been made, so regard this document as definitive.]

A port in Africa loads tankers with crude oil for overwater shipment and the port has facilities for loading as many as 3 tankers simultaneously. The tankers, which arrive at the port every 11 +/- 7 hours, are of 3 different types. (All times given as a "+/-" range are distributed uniformly over the range in a continuous manner.) The relative frequency of the various types and their loading-time requirements are:

Type	Rel. freq.	Loading time (hours)
1	0.25	18 +/- 2
2	0.25	24 +/- 4
3	0.50	36 +/- 4

There is 1 tug at the port. Tankers of all types require the services of a tug to move from the harbour into a berth, and later to move out of a berth into the harbour. When the tug is available, any berthing or deberthing activity takes about an hour. It takes the tug 0.25 hours to travel from the harbour to the berths, or vice versa, when not pulling a tanker. When the tug finishes a berthing activity, it will deberth the first tanker in the deberthing queue if this queue is not empty. If the deberthing queue is empty but the harbour queue is not, the tug will travel to the harbour and begin berthing the first tanker in the harbour queue. (If both queues are empty, the tug will remain idle at the berths.) When the tug finishes a deberthing activity, it will berth the first tanker in the harbour queue if this queue is not empty and a berth is available. Otherwise, the tug will travel to the berths, and if the deberthing queue is not empty, will begin deberthing the first tanker in the queue. If the deberthing queue is empty, the tug will remain idle at the berths.

If all that is not enough to make your head spin, the situation is further complicated due to the fact that the area experiences frequent storms that last 4 +/- 2 hours. The time between the end of one storm and the onset of the next is an exponential random variable with mean 48 hours. The tug will not start a new activity when the storm is in progress but will always finish an activity already in progress. (The berths will operate in a storm.) If the tug is traveling from the berths to the harbour without a tanker when the storm begins, it will turn around and head for the berths.

Consider this as the **baseline** case and simulate it for a 1 year (8760 hours) period. Do 5 replications and estimate:

a) the expected proportion of time the tug is idle, is traveling without a tanker, and is engaged in either a berthing or deberthing activity
b) the expected proportion of time each berth is unoccupied, is occupied but not loading, and is loading
c) the expected time-average number of tankers in the deberthing queue and in the harbour queue

d) the expected average in-port residence time of each type of tanker
e) the number of storms over the life of the simulation

Normally with a baseline model you would validate the heck out of it. Assume (for no good reason except to make life easier for you) that your output results for the baseline are consistent with measured results. (Your results may be wrong and you will lose marks for that, but the assumption allows you to proceed to the next steps.)

Consider 2 possible new operating protocols. In protocol **P1**, suppose the tug has a two-way radio giving it the position and status of each tanker in the port. As a result, the tug changes its operating policies, as follows. If the tug is traveling from the harbour to the berths without a tanker and is less than halfway there when a new tanker arrives, it will turn around and go pick up the new tanker. If the tug is traveling from the berths to the harbour without a tanker and is less than halfway there when a tanker completes its loading, it will turn around and go pick up (deberth) the loaded tanker. Run your model for 5 replications and obtain estimates as above.

In protocol **P2**, on top of protocol P1, suppose in addition that if the tug is traveling from the harbour to the berths without a tanker and the deberthing queue is empty when the new tanker arrives, it will turn around and go pick up the new tanker, regardless of its position. Run your model for 5 replications and obtain estimates as above.

Comment on your results and on how they can provide insight about the relative goodness of the operating policies. Perform additional experiments as you deem necessary. Assume you want to make your statements with a confidence level of 95 percent.