MODELLING CONSTRUCTS OF SIMSCRIPT II.5®

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This tutorial will present the highlights of the SIMSCRIPT II.5 approach to building discrete event simulation models. The approach will be to construct a small example problem, implement the program in SIMSCRIPT II.5, and then to display the modularity which is possible with SIMSCRIPT by adding several "real-world" complexities to the model.

1. BACKGROUND

Simulation languages are (or should be) more than extensions of general-purpose programming languages designed to ease the burden of programming simulation problems. The influence of a good simulation language should be felt during the specification and model design stages of simulation as well as during computer implementation. If the "world-view" of the simulation language is well understood, and if that world-view is appropriate for a given problem, then the language should aid immeasurably in reducing the effort (and consequently elapsed time) in transforming model from concept to realization.

2. SIMSCRIPT II.5 WORLD-VIEW

SIMSCRIPT is a discrete-event language (Figure 1.) Actions are modelled in terms of events. Sequences of events describing actions of a single object (or entity) are modelled as processes. Many important relationships are described dynamically in terms of entities-attributes-sets. This very powerful data structuring is one of the unique features of the language. The implementation in SIMSCRIPT of the classical simulation problems, such as small queueing models or job-shop simulations, have been described elsewhere (see References).

3. SIMSCRIPT II.5 IMPLEMENTATIONS

SIMSCRIPT II.5 has been implemented on seven different manufacturer's computers including IBM, Honeywell, CDC, Univac, VAX, NCR, and PRIME. A major emphasis is to achieve portability of models from one machine to another since the type of models typically written in SIMSCRIPT have a fairly long lifetime and are often shared among a community of users with different computers.

4. SIMSCRIPT II.5 AVAILABILITY

SIMSCRIPT II.5 is the proprietary product of CACI and is available from them for lease or purchase. SIMSCRIPT is also available on Boeing Computer Services, Control Data-Cybernet, Service Bureau Corporation, and United Computing Services. A university program is supported by CACI in which SIMSCRIPT is supplied to educational institutions for the cost of distribution.

5. THE TUTORIAL EXAMPLE

The tutorial is built around a simple queuing problem first presented in (SCHRIEBER) and later revised in (FISHMAN 1976). An African Port consists of three docks serviced by a single tug (Figure 2). Ships which arrive to be loaded must use the tug to enter and leave the docks. The ships arrive according to an exponential distribution of inter-arrival times with a mean of eleven hours. The ships are of three sizes distributed as follows:

- 25% have a mean loading time of 18 hours
- 55% have a mean loading time of 24 hours
- 20% have a mean loading time of 36 hours
The times are all exponentially distributed about these means. The time for moving a ship into or out of a dock is also exponentially distributed with a mean of one hour. Ships queue for the tug and/or the dock on a first-come-first-served basis.

The first task is to model this existing situation and measure the utilization factors for the tug and the dock. In addition, the congestion in the harbor (queueing statistics for the tug and dock) are to be measured. Finally, statistics on the in-port time for the ships should be collected.

After this simple model is developed, the next phase is to superimpose a new category of tanker. These new tankers belong to a fixed-size fleet. They have a mean loading time of 21 hours and require the same tug and dock services as the other tankers. When they leave the port, they make a round-trip to their destination in a mean time of ten days (again exponentially distributed). The same statistics should be reported as above in order to determine the impact of the new tankers on the port.

The next complication to be added to the model is the effect of external interruptions such as storms and smog. A storm serves to delay the arrival of ships and to detain them when ready to depart. Smog alerts cause the unloading of ships to be interrupted until the smog alert is lifted. Since storms and smog are fairly rare occurrences, these phenomena are to be represented as they actually occurred over some historical period.

Finally, in order to verify the correct execution of the model, the SIMSCRIPT tools for debugging will be added to the model.

The tutorial shall be comprised of a detailed walkthrough of the original model and a discussion of the evolution to the completed model in the following steps:

1) original simple model with only old tankers (Figure 3);
2) additions for statistical output (Figure 4);
3) additions for the new tankers; (Figure 5);
4) additions for storms and smog; (Figure 6);
5) additions for debug (Figure 7).

REFERENCES


SIMSCRIPT II.5 TUTORIAL MODEL
AN AFRICAN PORT STUDY

PREAMBLE

PROCESSES INCLUDE GENERATOR AND SHIP
RESOURCES INCLUDE DOCK AND TUG

THE SYSTEM HAS A LOADING TIME RANDOM STEP VARIABLE
DEFINE LOADING TIME AS A REAL VARIABLE

ACCUMULATE AVG.DOCK.QUEUE AS THE AVERAGE OF N.DOCK
ACCUMULATE AVG.TUG.QUEUE AS THE AVERAGE OF N.TUG

TALLY AVG.IN.PORT.TIME AS THE AVERAGE
AND MAX.IN.PORT.TIME AS THE MAXIMUM OF INPORT.TIME

DEFINE .END.OF.SIMULATION TO MEAN TIME.V >= 365.

END "PREAMBLE"

MAIN

READ TYPE,DISTRIBUTION
PRINT 1 LINE THUS
AFRICAN PORT TANKER STUDY

SKIP 1 LINE
CREATE EVERY DOCK(1)
LET U.DOCK(1) = 3
CREATE EVERY TUG(1)
LET U.TUG(1) = 1

END "MAIN"

PROCESS GENERATOR
UNTIL .END.OF.SIMULATION,
DO
ACTIVATE A SHIP NOW
WAIT EXPONENTIAL.F(11.0, 2) HOURS
LOOP
STOP
END "PROCESS GENERATOR"

INPUT DATA:
0.25 18 0.55 24 0.2 36 *

PROCESS GENERATOR
UNTIL .END.OF.SIMULATION,
DO
ACTIVATE A SHIP NOW
WAIT EXPONENTIAL.F(11.0, 2) HOURS
LOOP
STOP
END "PROCESS GENERATOR"

PROCESS SHIP
REQUEST 1 DOCK(1)
REQUEST 1 TUG(1)
WAIT EXPONENTIAL.F(1.0,3) HOURS
RELINQUISH 1 TUG(1)
WORK EXPONENTIAL.F(LOADING.TIME, 4) HOURS
REQUEST 1 TUG(1)
WAIT EXPONENTIAL.F(1.0,5) HOURS
RELINQUISH 1 TUG(1)
RELINQUISH 1 DOCK(1)
END "PROCESS SHIP"

AFRICAN PORT TANKER STUDY
AFTER 365.02 DAYS
803 SHIPS HAVE BEEN LOADED.
THE AVERAGE IN-PORT TIME FOR A SHIP WAS 45.24 HOURS.
THE MAXIMUM IN-PORT TIME FOR A SHIP WAS 206.28 HOURS.
THE DOCK UTILIZATION WAS .77 (X 100 %)
THE AVERAGE QUEUE FOR THE DOCK WAS 1.82 SHIPS
THE TUG UTILIZATION WAS .19 (X 100 %)
THE AVERAGE QUEUE FOR THE TUG WAS .03 SHIPS

FIGURE 3

FIGURE 4
SIMSCRIPT 1.5 TUTORIAL MODEL
AN AFRICAN PORT STUDY

PREAMBLE
PROCESSES INCLUDE GENERATOR AND SHIP
EVERY SHIP HAS A TYPE
DEFINE TYPE AS AN ALPHA VARIABLE
RESOURCES INCLUDE DOCK AND TUG
DEFINE NO.NEW.Ships AS AN INTEGER VARIABLE
THE SYSTEM HAS A LOADING,TIME RANDOM STEP VARIABLE
DEFINE LOADING,TIME AS A REAL VARIABLE
ACCUMULATE AVG.DOCK,QUEUE AS THE AVERAGE OF N.Q.DOCK
ACCUMULATE DOCK,UTILIZATION AS THE AVERAGE OF N.Q.DOCK
ACCUMULATE TUG,UTILIZATION AS THE AVERAGE OF N.Q.TUG
ACCUMULATE AVG.TUG,QUEUE AS THE AVERAGE OF N.Q.TUG
TALLY AVG.IN.PORT,TIME AS THE AVERAGE
AND NO. OF SHIPS,SERVED AS THE NUMBER
AND MAX.IN.PORT,TIME AS THE MAXIMUM IN PORT,TIME
DEFINE IN.PORT,TIME AS THE MAXIMUM VARIABLE
DEFINE END OF SIMULATION TO MEAN TIME.V > = 305.

END "PREAMBLE

MAIN
READ LOADING.TIME
PRINT 1 LINE
AFRICAN PORT TANKER STUDY
SKIP 1 LINE
READ NO.NEW.Ships
PRINT 1 LINE WITH NO.NEW.Ships THUS
NO. OF NEWS SHIPS IS .
SKIP 1 LINE
CREATE EVERY DOCK(1)
LET U.DOCK(1) = 3
CREATE EVERY TUG(1)
LET U.TUG(1) = 1
ACTIVATE A GENERATOR NOW
START SIMULATION
END "MAIN

INPUT DATA:
5
.25 18 0.56 24 0.2 30

PROCESS GENERATOR
DEFINE AS AN INTEGER VARIABLE
FOR I = 1 TO NO.NEW.Ships,
DO
ACTIVATE A SHIP IN 2 * 1 DAYS
LET TYPE(SHIP) = "NEW"
LOOP
UNTIL END OF SIMULATION,
DO
ACTIVATE A SHIP NOW
LET TYPE(SHIP) = "OLD"
WAIT EXPONENTIAL.F(110, 2) HOURS
LOOP
SKIP 2 LINES
PRINT 11 LINES WITH TIME.V, NO. OF SHIPS,SERVED,
AVG.IN.PORT,TIME, MAX.IN.PORT,TIME,
DOCK,UTILIZATION(1), AVG.DOCK.QUEUE(1),
TUG,UTILIZATION(1) AND AVG.TUG.QUEUE(1) THUS
AFTER "*** DAYS
* SHIPS HAVE BEEN LOADED.
THE AVERAGE IN-PORT TIME FOR A SHIP WAS "*** HOURS.
THE MAXIMUM IN-PORT TIME FOR A SHIP WAS "*** HOURS.
THE DOCK UTILIZATION WAS "*** (X 100 %)
THE AVERAGE QUEUE FOR THE DOCK WAS "*** SHIPS
THE TUG UTILIZATION WAS "*** (X 100 %)
THE AVERAGE QUEUE FOR THE TUG WAS "*** SHIPS
STOP
END "PROCESS GENERATOR

PROCESS SHIP
DEFINE ARRIVAL.TIME AS A REAL VARIABLE
DEFINE MEAN LOAD,TIME AS A REAL VARIABLE
IF TYPE(SHIP) = "OLD"
LET MEAN LOAD,TIME = LOADING,TIME
ELSE
LET MEAN LOAD,TIME = 21
ALWAYS
UNTIL END OF SIMULATION
DO
LET ARRIVAL.TIME = TIME.V
REQUEST 1 DOCK(1)
REQUEST 1 TUG(1)
WAIT EXPONENTIAL.F(1,0,5) HOURS
RELINQUISH 1 TUG(1)
WORK EXPONENTIAL.F(MEAN LOAD,TIME,4) HOURS
REQUEST 1 TUG(1)
WAIT EXPONENTIAL.F(1,0,5) HOURS
RELINQUISH 1 DOCK(1)
LET IN.PORT,TIME = TIME.V - ARRIVAL.TIME * HOURS.V
IF TYPE(SHIP) = "OLD"
LEAVE
ELSE
WAIT EXPONENTIAL.F(240,0,6) HOURS
LOOP
END "PROCESS SHIP

AFRICAN PORT TANKER STUDY
NO. OF NEW SHIPS IS 5.
AFTER 365.02 DAYS
905 SHIPS HAVE BEEN LOADED.
The average in-port time for a ship was 137.69 HOURS.
The maximum in-port time for a ship was 464.80 HOURS.
The dock utilization was .95 (X 100 %)
The average queue for the dock was 11.64 SHIPS
The tug utilization was .21 (X 100 %)
The average queue for the tug was .03 SHIPS

FIGURE 5

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**SIMSCRIPT IIL TUTORIAL MODEL**

**AN AFRICAN PORT STUDY**

**PREAMBLE**

- PROCESSES INCLUDE GENERATOR AND SHIP
- EVERY SHIP HAS A TYPE AND A SHIP STATUS AND BELONGS TO THE FLEET
- DEFINE TYPE AS AN ALPHA VARIABLE
- DEFINE SHIP STATUS AS AN ALPHA VARIABLE
- EXTERNAL PROCESSES ARE SMOG AND STORM
- EXTERNAL EVENT UNIT ID 7

**RESOURCES INCLUDE DOCK AND TUG AND PERMIT**

- DEFINE NO.NEW.SIPS AS AN INTEGER VARIABLE
- THE SYSTEM HAS A LOADING TIME RANDOM STEP VARIABLE AND OWNS THE FLEET
- DEFINE LOADING TIME AS A REAL VARIABLE
- ACCUMULATE AVG.DOCK.QUEUE AS THE AVERAGE OF N.DOCK
- ACCUMULATE DOCK.UTILIZATION AS THE AVERAGE OF N.DOCK
- ACCUMULATE TUG.QUEUE AS THE AVERAGE OF N.TUG
- ACCUMULATE AVG.TUG.QUEUE AS THE AVERAGE OF N.TUG
- TALLY AVG.IN.PORT.TIME AS THE AVERAGE AND MAX.IN.PORT.TIME AS THE MAXIMUM OF IN.PORT.TIME
- DEFINE IN.PORT.TIME AS A REAL VARIABLE

**DEFINE DEPART TO MEAN 1**

**DEFINE UNLOAD TO MEAN 2**

**DEFINE END OF SIMULATION TO MEAN TIME V >= 385.**

**END "PREAMBLE"**

**MAIN**

**CALL ORIGIN.R(1,1,80)**

**READ LOADING.TIME**

**PRINT 1 LINE**

**AFRICAN PORT TANKER STUDY**

**SKIP 1 LINE**

**READ NO.NEW.SIPS**

**PRINT 1 LINE WITH NO.NEW.SIPS THUS NO. OF NEWSIPS IS**

**SKIP 1 LINE**

**CREATE EVERY DOCK(1)**

**LET U.DOCK(1) = 3**

**CREATE EVERY TUG(1)**

**LET U.TUG(1) = 1**

**CREATE EVERY PERMIT(2)**

**LET U.PERMIT(0) = 1**

**LET U.PERMIT(DEPART) = 1**

**ACTIVATE A GENERATOR NOW**

**START SIMULATION**

**END "MAIN"**

**INPUT DATA: 5**

**0.25 18 0.55 24 0.2 36**

**PROCESS GENERATOR**

**DEFINE I AS AN INTEGER VARIABLE**

**FOR I = 1 TO NO.NEW.SIPS**

**DO**

**ACTIVATE A SHIP IN 2-1 DAYS**

**LET TYPESHIP = "NEW"**

**LET SHIP.STATUSSHIP = "AT.SEA"**

**FILE SHIP IN FLEET**

**LOOP**

**UNTIL END OF SIMULATION**

**DO**

**ACTIVATE A SHIP NOW**

**LET TYPESHIP = "OLD"**

**LET SHIP.STATUSSHIP = "AT.SEA"**

**FILE SHIP IN FLEET**

**WAIT EXPONENTIAL.F(1,1,2) HOURS**

**LOOP**

**SKIP 2 LINES**

**PRINT 1 LINES WITH TIME, V, AD.OF.SIPS SERVED, AVG.IN.PORT.TIME, MAX.IN.PORT.TIME**

**DOCK.UTILIZATION(3), AVG.DOCK.QUEUE(1), TUG.QUEUE(1) AND AVG.TUG.QUEUE(1) THUS AFTER "***" DAYS**

**SHIPs HAVE BEEN LOADED**

**THE AVERAGE IMPORT TIME FOR A SHIP WAS "***" HOURS**

**THE MAXIMUM IN-PORT TIME FOR A SHIP WAS "***" HOURS**

**THE DOCK UTILIZATION WAS "***" (X 100%)**

**THE AVERAGE QUEUE FOR THE DOCK WAS "***" SHIPS**

**THE TUG UTILIZATION WAS "***" (X 100%)**

**THE AVERAGE QUEUE FOR THE TUG WAS "***" SHIPS**

**STOP**

**END "PROCESS GENERATOR"**

**PROCESS SHIP**

**DEFINE ARRIVAL.TIME AS A REAL VARIABLE**

**DEFINE MEAN.LOAD.TIME AS A REAL VARIABLE**

**IF TYPESHIP = "OLD"**

**LET MEAN.LOAD.TIME = LOADING.TIME**

**ELSE**

**LET MEAN.LOAD.TIME = 21**

**ALWAYS**

**UNTIL END OF SIMULATION**

**DO**

**LET ARRIVAL.TIME = TIME.V**

**LET SHIP.STATUSSHIP = "IN.HARBOR"**

**REQUEST 1 DOCK(1)**

**REQUEST 1 TUG(1)**

**WAIT EXPONENTIAL.F(1,0,3) HOURS**

**RELINQUISH 1 TUG(1)**

**REQUEST 1 PERMIT(UNLOAD)**

**RELINQUISH 1 PERMIT(UNLOAD)**

**LET SHIP.STATUSSHIP = "UNLOADING"**

**WORK EXPONENTIAL.F(1,0,4) HOURS**

**LET SHIP.STATUSSHIP = "IN.HARBOR"**

**REQUEST 1 TUG(1)**

**WAIT EXPONENTIAL.F(1,0,5) HOURS**

**RELINQUISH 1 TUG(1)**

**RELINQUISH 1 DOCK(1)**

**REQUEST 1 PERMIT(DEPART)**

**RELINQUISH 1 PERMIT(DEPART)**

**LET SHIP.STATUSSHIP = "AT.SEA"**

**REMOVE THIS SHIP FROM FLEET**

**LEAVE**

**ELSE**

**LET SHIP.STATUSSHIP = "AT.SEA"**

**WAIT EXPONENTIAL.F(0,0,6) HOURS**

**LOOP**

**END "PROCESS SHIP"**

**PROCESS STORM**

**DEFINE DURATION AS A REAL VARIABLE**

**READ DURATION**

**REQUEST 1 PERMIT(DEPART) WITH PRIORITY 1**

**FOR EACH SHIP IN FLEET**

**WITH SHIP.STATUSSHIP = "AT.SEA"**

**INTERRUPT SHIP**

**WAIT DURATION DAYS**

**RELINQUISH 1 PERMIT(DEPART)**

**FOR EACH SHIP IN FLEET**

**WITH SHIP.STATUSSHIP = "AT.SEA"**

**RESUME SHIP**

**END "STORM"**

**PROCESS SMOG**

**DEFINE DURATION AS A REAL VARIABLE**

**READ DURATION**

**REQUEST 1 PERMIT(UNLOAD) WITH PRIORITY 1**

**FOR EACH SHIP IN FLEET**

**WITH SHIP.STATUSSHIP = "UNLOADING"**

**INTERRUPT SHIP**

**WAIT DURATION DAYS**

**RELINQUISH 1 PERMIT(UNLOAD)**

**FOR EACH SHIP IN FLEET**

**WITH SHIP.STATUSSHIP = "UNLOADING"**

**RESUME SHIP**

**END "SMOG"**

**AFRICAN PORT TANKER STUDY**

**NO. OF NEW SHIPS IS 5.**

**AFTER 385.02 DAYS**

**928 SHIPS HAVE BEEN LOADED.**

**THE AVERAGE IMPORT TIME FOR A SHIP WAS 112.49 HOURS.**

**THE MAXIMUM IMPORT TIME FOR A SHIP WAS 461.85 HOURS.**

**THE DOCK UTILIZATION WAS .95 (X 100 %)**

**THE AVERAGE QUEUE FOR THE DOCK WAS 9.12 SHIPS**

**THE TUG UTILIZATION WAS .22 (X 100 %)**

**THE AVERAGE QUEUE FOR THE TUG WAS .04 SHIPS**

**FIGURE 6**
SIMSCRIPT I.5 TUTORIAL MODEL
AN AFRICAN PORT STUDY

PREAMBLE

PROCESSES INCLUDE GENERATOR AND SHIP
EVERY SHIP HAS A TYPE
AND A SHIP STATUS
AND A SHIP ID
AND BELONGS TO THE FLEET
DEFINE TYPE AS AN ALPHA VARIABLE
DEFINE SHIP STATUS AS AN ALPHA VARIABLE
DEFINE SHIP ID AS AN INTEGER VARIABLE
EXTERNAL PROCESSES ARE SMOG AND STORM
EXTERNAL EVENT UNIT IS 7
RESOURCES INCLUDE DOCK AND TUG
AND PERMIT
DEFINE NO.NEW.SHIPS AS AN INTEGER VARIABLE
THE SYSTEM HAS A LOADING TIME RANDOM STEP VARIABLE
AND OWNS THE FLEET
DEFINE LOADING TIME AS A REAL VARIABLE
ACCUMULATE AVG.DOCK.QUEUE AS THE AVERAGE OF N.DOCK
ACCUMULATE DOCK UTILIZATION AS THE AVERAGE OF N.DOCK
ACCUMULATE TUG.UTILITY AS THE AVERAGE OF N.TUG
ACCUMULATE AVG.TUG.QUEUE AS THE AVERAGE OF N.TUG
TALLY AVG.IN.PORT TIME AS THE AVERAGE
AND NO.OF.SHIPS.SERVED AS THE NUMBER
AND MAX.IN.PORT.TIME AS THE MAXIMUM
DEFINE IN.PORT.TIME AS A REAL VARIABLE
DEFINE DEPART TO MEAN 1
DEFINE UNLOAD TO MEAN 2
DEFINE END.SIMULATION TO MEAN TIME.V > = 365.
END "PREAMBLE"

MAIN

LET BETWEEN.V = "DETAIL"
CALL ORIGIN.R(1,1.50)
READ TYPE.DISTRIBUTION
PRINT 1 LINE THUS
AFRICAN PORT TANKER STUDY
SKIP 1 LINE
READ NO.NEW.SHIPS
PRINT 1 LINE WITH NO.NEW.SHIPS THUS
NO. OF NEWSHIPS IS *.
SKIP 1 LINE
CREATE EVERY DOCK(1)
LET U.DOCK(1) = 1
CREATE EVERY TUG(1)
LET U.TUG(1) = 1
CREATE EVERY PERMIT(2)
LET U.PERMIT(1) = 1
LET U.PERMIT(2) = 1
ACTIVATE A GENERATOR NOW
START SIMULATION
END "MAIN"

INPUT DATA:
5 0.25 18 0.55 24 0.2 36 *

PROCESS GENERATOR
DEFINE I AS AN INTEGER VARIABLE
DEFINE SHIP.COUNT AS AN INTEGER, SAVED VARIABLE
FOR I = 1 TO NO.NEW.SHIPS,
DO
ACTIVATE A SHIP IN 2 * 1 DAYS
LET TYPE(SHIP) = [NEW]
LET SHIP.STATUS(SHIP) = "AT.SEA"
ADD 1 TO SHIP.COUNT
LET SHIP.COUNT(SHIP) = SHIP.COUNT
END LOOP
UNTIL END.SIMULATION,
DO
ACTIVATE A SHIP NOW
LET TYPE(SHIP) = [NEW]
LET SHIP.STATUS(SHIP) = "AT.SEA"
ADD 1 TO SHIP.COUNT
LET SHIP.COUNT(SHIP) = SHIP.COUNT
FILE SHIP IN FLEET
WAIT EXPONENTIAL(FL1,0,2) HOURS
END LOOP

SKIP 2 LINES
PRINT 3 LINES WITH TIME.V, NO.OF.SHIPS.SERVED,
AVG.DOCK.PORT.TIME, AVG.DOCK.PORT.TIME,
DOCK UTILIZATION(S), AVG.DOCK.QUEUE(S),
TUG UTILIZATION(S) AND AVG.TUG.QUEUE(S)
THUS
AFTER *** DAYS
* SHIPS HAVE BEEN LOADED,
THE AVERAGE IN.PORT TIME FOR A SHIP WAS *** HOURS,
THE MAXIMUM IN.PORT TIME FOR A SHIP WAS *** HOURS,
THE DOCK UTILIZATION WAS *** (100%)
The AVERAGE QUEUE FOR THE DOCK WAS *** SHIPS
THE TUG UTILIZATION WAS *** (100%)
The AVERAGE QUEUE FOR THE TUG WAS *** SHIPS
STOP
END "PROCESS GENERATOR"

PROCESS SHIP
DEFINE ARRIVAL.TIME AS A REAL VARIABLE
DEFINE MEAN.LOAD.TIME AS A REAL VARIABLE
IF TYPE(SHIP) = "OLD"
LET MEAN.LOAD.TIME = LOADING.TIME
ELSE
LET MEAN.LOAD.TIME = 21
END IF
ALWAYS
UNTIL END.SIMULATION
DO
LET ARRIVAL.TIME = TIME.V
LET SHIP.STATUS(SHIP) = "IN.HARBOR"
REQUEST 1 DOCK(1)
WAIT EXPONENTIAL.F(0.10,0.03) HOURS
RELEASE TUG(1)
REQUEST 1 PERMIT(1)
WAIT EXPONENTIAL.F(0,10,0.03) HOURS
REQUEST 1 UNLOAD(1)
LET SHIP.STATUS(SHIP) = "UNLOADING"
WORK EXPONENTIAL.F(MAX.LOAD.TIME, TIME, 4) HOURS
LET SHIP.STATUS(SHIP) = "IN.HARBOR"
REQUEST 1 TUG(1)
WAIT EXPONENTIAL.F(0.10,0.03) HOURS
RELEASE TUG(1)
RELEASE 1 DOCK(1)
REQUEST 1 PERMIT(1)
LET IN.PORT.TIME = (TIME.V - ARRIVAL.TIME) HOURS
V
IF TYPE(SHIP) = "OLD"
REMOVE THIS SHIP FROM FLEET
LEAVE
END IF
LET SHIP.STATUS(SHIP) = "AT.SEA"
WAIT EXPONENTIAL.F(240,0,6) HOURS
END LOOP
END "PROCESS SHIP"

PROCESS STORM
DEFINE DURATION AS A REAL VARIABLE
READ DURATION
REQUEST 1 PERMIT(DEPART) WITH PRIORITY 1
FOR EACH SHIP IN FLEET,
WITH SHIP.STATUS(SHIP) = "AT.SEA"
END IF
END IF
WAIT DURATION DAYS
RELEASE TUG(1)
REQUEST 1 DEPART(1)
END "PROCESS STORM"

PROCESS SMOG
DEFINE DURATION AS A REAL VARIABLE
READ DURATION
REQUEST 1 PERMIT(UNLOAD) WITH PRIORITY 1
FOR EACH SHIP IN FLEET,
WITH SHIP STATUS(SHIP) = "UNLOADING"
END IF
END IF
WAIT DURATION DAYS
RELEASE TUG(1)
REQUEST 1 UNLOAD(1)
END "PROCESS SMOG"

ROUTINE DETAIL
DEFINE LINE.COUNT AS AN INTEGER, SAVED VARIABLE
ADD 1 TO LINE.COUNT
IF LINE.COUNT = 25,
LET BETWEEN.V = 0
ALWAYS
IF EVENT.V = I.SHIP
PRINT 1 LINE WITH TIME.V, N.O.DOCK(1), N.O.TUG(1), N.X.DOCK(1),
x.TUG(1), U.DOCK(1)
END LOOP
END LOOP
END "ROUTINE DETAIL"
ROUTINE FOR SNAP.R
START NEW PAGE
PRINT 1 LINE
GLOBAL CONDITIONS AT SNAP
SKIP 2 LINES
FOR EACH SHIP IN THE FLEET,
PRINT 1 LINE WITH SHIP.ID(SHIP) AND TYPE(SHIP) AND LINE.(SHIP) AS SHIP
* "TYPE "** IS AWAITING EXECUTION OF LINE "*.
SKIP 2 LINES
PRINT 3 LINES WITH U.DOCK(1), N.X.DOCK(1) AND N.Q.DOCK(1) AS SHIP
THERE ARE * FREE DOCKS
THERE ARE * DOCKS IN USE
AND * SHIPS IN THE DOCK QUEUE.
SKIP 2 LINES
PRINT 3 LINES WITH U.TUG(1), N.X.TUG(1) AND N.Q.TUG(1) AS SHIP
THERE ARE * FREE TUGS
THERE ARE * TUGS IN USE
AND * SHIPS IN THE TUG QUEUE.
SKIP 2 LINES
END "SNAP.R"

AFRICAN PORT TANKER STUDY
NO. OF NEW SHIPS IS 5.

AT TIME    0, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 3
SHIP 1 TYPE OLD WILL RESUME AT LINE 1.
SHIP 2 TYPE OLD WILL RESUME AT LINE 16.
SHIP 3 TYPE OLD WILL RESUME AT LINE 18.
SHIP 4 FREE DOCKS 1
SHIP 5 FREE DOCKS 2.

STORM PROCESS RESUMING ON LINE 5 AT TIME 120.
AT TIME    120, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 TYPE OLD WILL RESUME AT LINE 18.
SHIP 2 TYPE OLD WILL RESUME AT LINE 23.
SHIP 3 FREE DOCKS 1
SHIP 4 FREE DOCKS 1
SHIP 5 TYPE OLD WILL RESUME AT LINE 24.

AT TIME    126, N.Q.DOCK = 2, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 TYPE OLD WILL RESUME AT LINE 6.
SHIP 2 TYPE OLD WILL RESUME AT LINE 19.
SHIP 3 FREE DOCKS 1
SHIP 4 FREE DOCKS 1
SHIP 5 TYPE OLD WILL RESUME AT LINE 16.

AT TIME    136, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 TYPE OLD WILL RESUME AT LINE 15.
SHIP 2 TYPE OLD WILL RESUME AT LINE 16.
SHIP 3 FREE DOCKS 1
SHIP 4 FREE DOCKS 1
SHIP 5 TYPE OLD WILL RESUME AT LINE 25.

AT TIME    161, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 TYPE OLD WILL RESUME AT LINE 9.
SHIP 2 TYPE OLD WILL RESUME AT LINE 17.
SHIP 3 FREE DOCKS 1
SHIP 4 FREE DOCKS 1
SHIP 5 TYPE OLD WILL RESUME AT LINE 16.

AT TIME    184, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 TYPE OLD WILL RESUME AT LINE 16.
SHIP 2 FREE DOCKS 1
SHIP 3 FREE DOCKS 0
SHIP 4 FREE DOCKS 0
SHIP 5 TYPE OLD WILL RESUME AT LINE 24.

AT TIME    206, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 1
SHIP 1 FREE DOCKS 1
SHIP 2 FREE DOCKS 1
SHIP 3 FREE DOCKS 1
SHIP 4 FREE DOCKS 1
SHIP 5 TYPE OLD WILL RESUME AT LINE 24.

STORM PROCESS RESUMING ON LINE 5 AT TIME 233.
AT TIME    233, N.Q.DOCK = 0, N.Q.TUG = 0, IN.DOCK = 0, IN.TUG = 0, FREE DOCKS 2
SHIP 1 TYPE OLD WILL RESUME AT LINE 27.

AFTER 365.02 DAYS
929 SHIPS HAVE BEEN LOADED.
THE AVERAGE IN-PORT TIME FOR A SHIP WAS 112.49 HOURS.
THE MAXIMUM IN-PORT TIME FOR A SHIP WAS 461.69 HOURS.
THE DOCK UTILIZATION WAS .95 (X 100 %)
THE AVERAGE QUEUE FOR THE DOCK WAS 9.12 SHIPS
THE TUG UTILIZATION WAS .22 (X 100 %)
THE AVERAGE QUEUE FOR THE TUG WAS .04 SHIPS

FIGURE 7
(Continued)