«»«»«»«»«» 57:022 Principles of Design II «»«»«»«»«»
Homework Assignments, Spring 1993
Prof. Dennis L Bricker, Dept. of Industrial Engineering

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #1 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

*Be sure to state what probability distribution you assume in each problem. You may find the necessary probabilities in tables, compute them manually with a calculator, or use the APL workspace "PROBLIB" which can be found on the ICAEN fileserver (in the folder for IE). (Using the APL workspace requires that you have a disk containing APL*PLUS, an interpreter for the APL language. If one is not available in the lab, and you wish to use APL, see the instructor or TA for the course. APL*PLUS runs only on a Mac Plus, Classic, or SE, not a Mac II.)*

1. (a) Find the probability of throwing a "7" at least twice in five throws of a standard pair of dice.
   (b) What is the expected number of 7's obtained in 5 throws of a pair of dice?
   (c) What is the expected number of throws of a pair of dice required in order to obtain a 7?

2. A certain production process has a fraction defective of 12%. Four good pieces are required. Pieces are produced until the 4 good pieces are obtained.
   a. What are the expected value and standard deviation of the number of pieces produced?
   b. Compute the probabilities of producing no more than 6 pieces in order to obtain 4 good pieces.
   c. Suppose that instead of producing until 4 good pieces are obtained, a batch of size **n** is produced, and then the pieces are inspected. How large should **n** be in order to be 95% certain of obtaining at least 4 good pieces?

3. A telephone exchange contains 10 lines. A line can be busy or available for calls and all lines act independently. If each line is busy 80% of the noon period (so that the probability that a line will be busy at any given time during the noon period is 80%), what is the probability of there being at least three free lines at any given time during this period? What is the expected number of free lines at any time during this period?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #2 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

*Be sure to state what probability distribution you assume in each problem. You may find the necessary probabilities in tables, compute them manually with a calculator, or use the APL workspace "PROBLIB" which can be found on the ICAEN fileserver (in the folder for IE). (Using the APL workspace requires that you have a disk containing APL*PLUS, an interpreter for the APL language. If one is not available in the lab, and you wish to use APL, see the instructor or TA for the course. APL*PLUS runs only on a Mac Plus, Classic, or SE, not a Mac II.)*

(1.) The probability that a given driver stops to pick up a hitchhiker is p=0.05; different drivers, of course, make their decisions to stop or not independently of each other.
  (a) Given that a hitchhiker has counted 30 cars passing him without stopping, what is the probability that he will be picked up by the 37^{th} car or before?

Suppose that the cars arrive according to a Poisson process, at the average rate of 5 per minute. Then "success" for the hitchhiker occurs at time t provided that both an arrival occurs at t **and** that car stops to pick him up. Let T be the time (in seconds) that he finally gets a ride, when he begins his wait at time zero.
  (b) Find the distribution of T; compute E(T) and Var(T).
  (c) Given that after 4 minutes (during which 20 cars pass by) he is still there waiting for a ride, compute the expected value of T.

(2.) (a.) Using the last four digits of your ID# as the "seed" for the "Midsquare" technique, generate a sequence of 10 pseudo-random numbers uniformly distributed in the interval [0,1].

(b.) Using the "Inverse Transformation" technique and the 10 numbers generated in (a.), generate the interarrival times for 8 vehicles which form a Poisson process with arrival rate l=5/minute.
(c.) What is the expected number of arrivals during the first minute? What is the actual # of arrivals in your simulation? What is the probability that you would observe *exactly* this number of arrivals in this Poisson process?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #3 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Consider again the problem of designing the drive-in teller windows at the bank branch office See pages D5 & D6 of your notes, as well as the Hypercard stack "Simulation Intro" on the engineering library fileserver. (The stack on the fileserver includes screens with the SLAM input & output for the problem.)

(1.) According to observations of 100 cars, the average observed time between arrivals is 5 minutes, and the average observed service time is 2 minutes. Perform chi-square goodness-of-fit tests (with a = 5%) to test whether it is appropriate to use EXPON(5.0) and EXPON(2.0) in the SLAM simulation model of this bank.

In questions (2.) and (3.) below, use EXPON(5.0) and EXPON(2.0), regardless of your conclusions in (1.) above.

(2.) Run the SLAM simulation model with single teller window and with queue capacity equal to 4, but simulate 5 days by specifying 5 runs on the GEN card at the beginning of the input file:

```
GEN,yourname,BANKTELLER,month/day/year,5;
LIM,1,1,50;
INIT,0,480;
NETWORK;
    CREATE,EXPON(5.0);
    QUE(1),0,4;
    ACT(1)/1,EXPON(2.0);
    TERM;
    END;
FIN;
```

(a.) Verify that the results of the *first* day are identical to the results shown in the Hypercard stack. Explain how this can be. (Aren't the interarrival and service times *random* ?)
(b.) How many cars were unable to enter the queue each day, because the queue was filled to capacity?
(c.) What fraction of the time was the teller busy each day?

Suppose that, after seeing the results of the simulation above, the board of directors has decided to consider the possibility of redesigning the layout so that the driveway for cars wishing to visit the teller window would be extended for a waiting capacity of 5 cars (not including the car at the window), if, in doing so, a single teller window would be sufficient.

(3.) Again run the SLAM simulation model (specifying 5 runs on the GEN card) with the single teller window but with the queue capacity increased to 5.
(a.) How many cars were not able to enter the queue each day?
(b.) What was the maximum number of cars waiting in the driveway each day?
(c.) What fraction of the time was the teller busy each day?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #4 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1.) Consider again the system in exercise (2) of HW#3 (the drive-up bank teller window).
(a.) From the output which follows, estimate the mean (average) time in the system.
(b.) Test the "goodness-of-fit" of the exponential probability distribution having this mean value. (Use alpha = 10%, and group the cells as necessary so that there are at least 5 observations in each cell.)

(c.) What fraction of the customers spend more than 5 minutes (total of both waiting and being served) at the bank?

```
GEN,BRICKER,BANKTELLERS,2/11/1993,,,,,,,72;
LIM,2,1,50;
INIT,0,480;
NETWORK;
     CREATE,EXPON(5.0),,1;
     QUE(1),0,4,BALK(OVFLO);
     ACT(1)/1,EXPON(2.0);
     COLCT,INTVL(1),CUSTOMER_TIME,20/.5/.5;
      TERM;
OVFLO COLCT,FIRST;
      TERM,1;
      END;
FIN;
```

```
           S L A M   I I   S U M M A R Y   R E P O R T
SIMULATION PROJECT BANKTELLERS            BY BRICKER

DATE  2/ 1/1993                   RUN NUMBER    1 OF    1


CURRENT TIME   0.4081E+03
STATISTICAL ARRAYS CLEARED AT TIME  0.0000E+00

        **STATISTICS FOR VARIABLES BASED ON OBSERVATION**

              MEAN    STANDARD  COEFF. OF  MINIMUM    MAXIMUM  NO.OF
              VALUE   DEVIATION VARIATION   VALUE      VALUE    OBS

CUSTOMER_TIME   0.303E+01 0.286E+01 0.944E+00 0.345E-01 0.110E+02    88
              0.408E+03 0.000E+00 0.000E+00 0.408E+03 0.408E+03     1

        **FILE STATISTICS**

FILE               AVERAGE  STANDARD   MAXIMUM  CURRENT AVERAGE
NUMBER  LABEL/TYPE     LENGTH   DEVIATION  LENGTH   LENGTH  WAIT TIME

  1       QUEUE        0.300     0.724       4        4      1.317
  2                    0.000     0.000       0        0      0.000
  3       CALENDAR     1.439     0.496       3        2      2.669

        **SERVICE ACTIVITY STATISTICS**

ACT ACT LABEL OR  SER AVERAGE    STD  CUR AVERAGE MAX IDL MAX BSY  ENT
NUM START NODE    CAP   UTIL     DEV  UTIL BLOCK  TME/SER TME/SER  CNT

 1     QUEUE      1   0.439   0.50   1    0.00   17.35   29.23   88
                    **HISTOGRAM NUMBER 1**
                        CUSTOMER_TIME

OBS  RELA   UPPER
FREQ FREQ  CELL LIM 0       20       40       60       80       100
                  +    +    +    +    +    +    +    +    +    +    +
 10 0.114 0.500E+00 +******                                  +
  9 0.102 0.100E+01 +*****     C                             +
 16 0.182 0.150E+01 +*********          C                     +
 13 0.148 0.200E+01 +*******                C                 +
```

```
  4 0.045 0.250E+01 +**                      C                 +
  7 0.080 0.300E+01 +****                       C               +
  5 0.057 0.350E+01 +***                         C             +
  1 0.011 0.400E+01 +*                           C            +
  3 0.034 0.450E+01 +**                            C          +
  0 0.000 0.500E+01 +                             C          +
  2 0.023 0.550E+01 +*                              C         +
  1 0.011 0.600E+01 +*                              C         +
  3 0.034 0.650E+01 +**                               C        +
  0 0.000 0.700E+01 +                                C       +
  4 0.045 0.750E+01 +**                                 C     +
  1 0.011 0.800E+01 +*                                  C    +
  2 0.023 0.850E+01 +*                                   C   +
  2 0.023 0.900E+01 +*                                    C  +
  2 0.023 0.950E+01 +*                                     C +
  2 0.023 0.100E+02 +*                                      C+
  0 0.000 0.105E+02 +                                      C+
  1 0.011    INF    +*                                    C
 ---              +    +    +    +    +    +    +    +    +    +    +
 88               0         20        40        60        80       100

        **STATISTICS FOR VARIABLES BASED ON OBSERVATION**

              MEAN    STANDARD  COEFF. OF  MINIMUM   MAXIMUM  NO.OF
              VALUE   DEVIATION VARIATION   VALUE     VALUE    OBS

 CUSTOMER_TIME   0.303E+01 0.286E+01 0.944E+00 0.345E-01 0.110E+02    88
Fortran STOP
```

(2.) Again consider the SLAM simulation model (above), with single teller window and with queue capacity equal to 4. Make the following modification to the SLAM network and input file:

(a.) Customers who come and cannot immediately enter the queue for the drive-up teller window because it is full should travel around the block, requiring between 3 and 5 minutes (uniformly distributed), and then again attempt to enter the queue. (This is repeated as many times as necessary.)

(b.) Collect statistics on the total time spent by a customer in the system, in order to determine how many customers must spend more than 5 minutes in the system. (For those who must travel around the block to wait for space in the queue, this time in the system can include the time to drive around the block.)

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #5 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

1. The failure time of a light bulb is the minimum of the failure times of the individual elements (all nonnegative random variables). We will therefore assume that the failure time of the light bulb has approximately a Weibull distribution. Suppose that 500 of a new type of bulb are operated simultaneously, and every 100 hours the total number of failed bulbs is recorded. These are:

time (hrs.)	# failures
100	42
200	98
300	141
400	177
500	214
600	248

We wish to estimate the Weibull distribution parameters u & k, without obtaining the mean and standard deviations of the failure times of all 500 bulbs, which would require an excessive amount of time.

a. Enter the observed values of t and R (failure time & reliability, i.e., the fraction surviving) into the Cricket Graph program.

b. Using "transform" on the menu:
   - compute ln t and place it into column 3 of the data matrix.
   - compute R^{-1} and place it into column 4 of the data matrix.
   - compute ln R^{-1} and place it into column 5 of the data matrix.
   - compute ln (ln R^{-1}) and place it into column 6 of the data matrix.

c. Plot the scatter graph of the data, with ln t (column 3) on the horizontal axis, and ln (ln R^{-1}) (column 6) on the vertical axis. Do the points appear to lie on a straight line?

d. Fit a line to the points, using the Cricket Graph program. What is the line?

e. Based upon the fitted line, what are the parameters u & k of the Weibull distribution?

f. According to these estimates of u & k, at what time should 5% of the bulbs have failed? ... 50% of the bulbs? ... 90% of the bulbs?

g. According to the value of k, is the failure rate *increasing* or *decreasing* with time?

h. Suppose that 6 of these bulbs are installed in ceiling lamps in an office. What is the probability that, after 150 hours of continuous operation, at least 3 bulbs are still functioning? *Hint: Use the binomial distribution... what is the probability p that a single bulb has not failed after 150 hours? What is the probability of 3 "successes" in 6 "trials"?*

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #6 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

A system has 6 components which are subject to failure, each having lifetimes with exponential distributions. The average lifetimes are:

Component	Average Lifetime
A	2000 days
B	3000 days
C	800 days
D	800 days
E	500 days
F	500 days
G	500 days

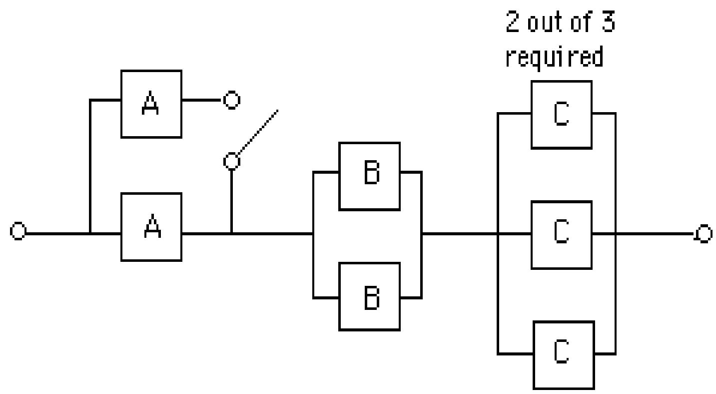
The system will fail if any of the following occur:
- A fails
- B fails
- Both C and D fail
- Components E, F, and G all fail.

1. Draw a diagram showing the series/parallel configuration of the components, as in the Hypercard Stack "System Reliability".
2. Suppose that the system is required to survive for 1000 days. What is the reliability of each component, i.e., the probability that it survives 1000 days?
3. What is the reliability of the system, i.e., the probability that the system survives 1000 days?
4. Draw a SLAM network which can simulate the lifetime of this system.
5. Run the SLAM simulation model, using 500 runs, collecting statistics on the time of system failure. Request that a histogram be printed. Select about 15 cells, with HLOW and HWID parameters which will give you a "nice" histogram with the mean approximately in the center and with small tails.
6. Suppose you will offer a warranty on this system, such that 95% of the systems will survive past the length of the warranty. What should be the length of the warranty?
7. If the time to system failure has a Weibull distribution with the mean and standard deviation obtained from the simulation model, what are the two parameters (shape and location) of the model?
8. Based upon the Weibull model with these parameters, what is the probability that the system survives 1000 days? (Compare with the answer in (3.)) What is the probability that the system survives the warranty period which you specified in (6)?

•*The APL workspace "PROBLIB" can be used for the calculation of the probabilities and the Weibull parameters. (Recall that an Exponential distribution is a special case of Erlang, with k=1.)*
•*You might find helpful the solutions to HW#8 which was assigned in this course in spring '92.*

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #7 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

A system has 3 types of components (A, B, & C) which are subject to failure. As shown below, the system requires at least one of components A and B, and at least two of component C. One of component A is in stand-by. When the first component A has failed, the second is to be switched on. Assume that the sensor/switch has 99% reliability.



The lifetime distributions of the three component types are:

Component A: Weibull, with expected lifetime 100 days, and standard deviation 25 days.
Component B: Exponential, with expected lifetime 150 days.
Component C: Exponential, with expected lifetime 200 days.

1. Draw a SLAM network which can simulate the lifetime of this system.

   Note: The table on page 108 of the SLAM text specifies that you should use WEIBL(BETA, ALPHA) for the lifetime, where BETA is the scale parameter which we've called u and ALPHA is the shape parameter which we've called k.

2. Enter the network into the computer, and simulate the system 1000 times, collecting statistics on the time of system failure. Request that a histogram be printed. Specify about 15-20 cells, with HLOW and HWID parameters which will give you a "nice" histogram with the mean approximately in the center and with small tails.

   Note: As in HW#6, be sure to specify on the GEN statement that you do NOT want intermediate results, and that the SUMMARY report is to be printed only after the 1000th run. Also specify on the INITIALIZE statement that the statistical arrays should not be cleared between runs.

3. What is the average lifetime of the system?

4. Can you think of a convenient way to modify the network so as to determine what fraction of the 1000 system failures was due to failure of A, B, C, and the switch? (You need not re-run the simulations.)

5. Suppose that the system is required to survive for a 100-day mission. What is the reliability of the system, i.e., the probability that the system survives 100 days?

6. Suppose you will offer a warranty on this system, such that 95% of the systems will survive past the length of the warranty. What should be the length of the warranty?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #8 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Project Scheduling, Part One

The Walker-Portland Company is currently in the process of planning to construct a new warehouse faciilty to reduce the company's inventory storage problems. Most of the work will be performed by the company's own construction division, but certain portions of the project, such as electrical and plumbing work, will be subcontracted.

Assume that you have been retained by the company as a consultant to aid in the planning and administrative control of the project. You called a meeting with the general foreman, estimator, and chief engineer, all from the company's construction division. Together, you have prepared time estimates for the various activities of the project. These include an optimistic, pessimistic, and most likely time for each activity, shown below. Assuming a beta distribution of activity durations, you then compute the mean and variance of each.

In addition, the estimator and foreman discussed in some detail how these activities should be sequenced, since the list in the table below does not necessarily indicate the order in which the work should be performed. During their discussion, you made the following notes:

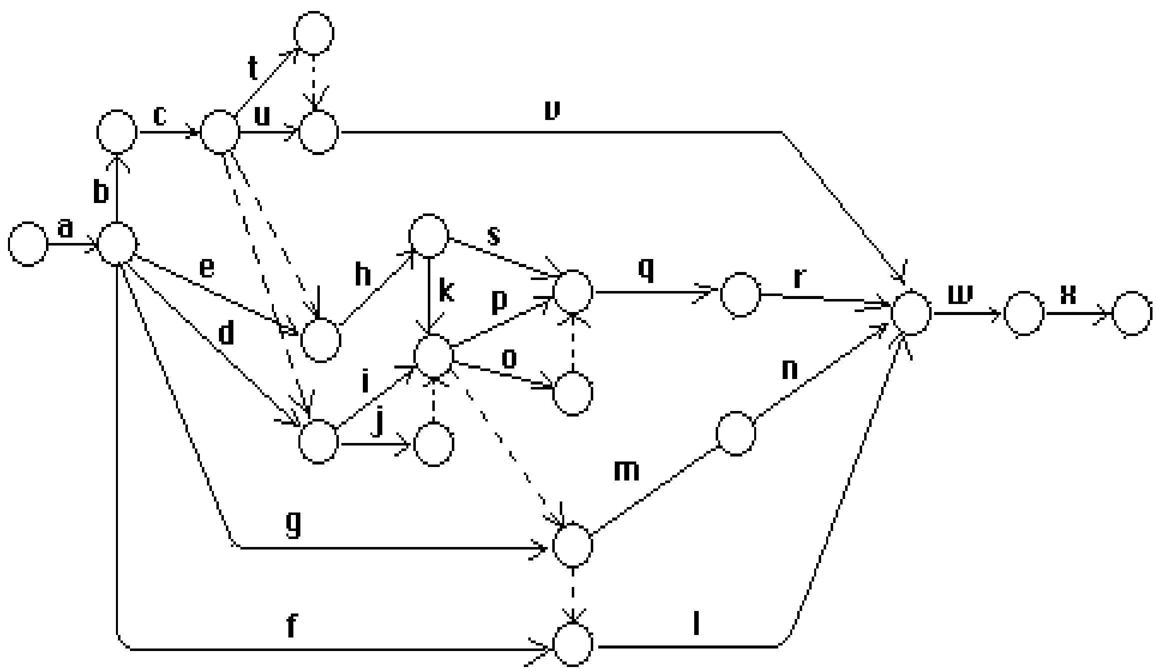
- Corporate management approval must be obtained before any work or procurement of supplies can begin.
- Procurement of materials and subcontracting negotiations can begin as soon as approval is obtained.
- Grading can begin as soon as subcontracting negotiations are completed.
- Foundation can be poured following excavation and after concrete arrives.
- Building footings can be poured as soon as excavation work is completed.
- Framework must be erected in conjunction with (simultaneously) pouring of building footings.
- Floor slab can be poured at completion of foundation pouring. Extra time is allowed in estimates for safety reasons so that floor work does not interfere with framework construction.
- Exterior walls can be put up following completion of steel framework and arrival of supplies.
- Roof can be installed after steel framework is up. Roof slab pouring must precede roofing installation.
- Electrical and plumbing work can commence as soon as steel framework is up.
- Insulation and interior walls can be put up after electrical and plumbing work.
- Interior painting must await installation of interior walls.
- Work for sewer drain, driveway, and parking lot can begin as soon as building site is graded and excavated. Final backfilling and grading must await completion of these activities.
- Installation of fuel oil tank and heating system must be started after the foundation has been poured. It must be completed before the interior walls are put in.
- Cleanup is the final work before job acceptance.

Activity Code	Activity	Optimistic time	Most likely time	Pessimistic time	m	s^2
a	Obtain corporate mgmt. approval	2	5	8	5	1
b	Complete subcontractor negotiations	1	3	7	3.3	1
c	Grade building site & excavage for foundation	5	7	9	7	0.4
d	Procure structural steel for framework	10	15	20	15	2.8
e	Procure concrete for foundation	1	3	5	3	0.4
f	Procure exterior window & door frames	5	7	11	7.3	1
g	Procure supplies for exterior walls & roofing	1	3	5	3	0.4
h	Pour concrete for foundation	9	10	15	10.7	1
i	Pour building footings	4	5	10	____	____
j	Erect steel framework	8	11	14	11	1
k	Pour floor slab & lay concrete flooring	5	9	13	9	1.8
l	Erect exterior walls	21	24	27	24	1
m	Pour roof slab	9	12	15	12	1
n	Lay roofing	2	3	8	3.7	2

o	Electrical work--subcontracted	8	10	14	10.3	1
p	Plumbing--subcontracted	7	10	13	10	1
q	Install insulation & interior walls	10	15	20	15	2.8
r	Paint interior	3	5	9	5.3	1
s	Install fuel tank & heating system	8	10	16	10.7	1.7
t	Excavate & lay sewer drain	5	8	11	8	1
u	Driveway & parking lot--subcontracted	9	12	15	12	1
v	Backfill around building & grade	6	8	10	8	0.4
w	Clean up building and grounds	2	2	2	2	0
x	Obtain job acceptance	3	5	9	___	___

Time is in working days.

1. Verify that the A-O-A network below adequately represents the project.
2. Number the nodes, so that if there is an arrow from node i to node j, then i<j.
3. Compute the expected duration and variance of activities (i) and (x).
4. Using the expected durations, apply the forward pass algorithm to compute, for each node i, ET(i), and the expected completion time of the project.
5. Apply the backward pass algorithm to compute, for each node i, LT(i).
6. Indicate on the network the critical path.
7. Find the variance of the completion time of the project.
8. Estimate the probability that the project can be completed in 80 working days (16 weeks).



Project Scheduling, Part Two

9. Draw a SLAM network to simulate the project. Assume a triangular distribution for activity durations. Include a COLCT node to collect statistics on the completion time and to prepare a histogram.
10. Simulate the project 1000 times. What is the average project completion time, in days? What is the standard deviation? Compare with the values found in Part One.
11. Using the histogram of project completion times, estimate the probability that the project will be completed within 80 working days. Compare to the value computed in Part One.

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #9 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Project Scheduling, Part Three

Consider again the Walker-Portland Company's warehouse construction project discussed in Homework #8.

1. Draw the A-O-N ("activity-on-node") network for this project.

2. Using the MacProject II software (on ICAEN's Macintosh fileserver), enter the project network.

   a. Enter a node to represent the beginning of the project, and (using the "task" menu) change to a "milestone".

   b. Enter each of the project activities, plus a node to represent the end of the project (which you should also change to a "milestone".) Each box in the network should contain at least the alphabetic letter for the activity as listed in the table in Homework #8. Also, each activity should appear at least slightly to the right of its predecessors, in order that MacProject will understand which is predecessor and which is successor.

   c. Click the mouse on the boundary of each activity (so that the "handles" appear), and then select "Show task info" from the "task" menu. A window should appear, in which you can enter the expected activity duration.

   d. For each predecessor/successor relationship, click the mouse in the predecessor node and drag to the successor node in order to add an arrow to the network.

   e. Click the mouse on the boundary of the beginning node and display the task info window. Scroll down to the "Earliest Start" box and indicate a starting date of May 3, 1993.

   f. From the "Layout" menu, choose "Show attributes...", and indicate that you wish "Latest start" times displayed on the network diagram.

   g. Obtain a "Gantt" chart by selecting "Task timeline" from the "Chart" menu.

3. What is the earliest completion date of the project? (Keep in mind that the default calendar for MacProject II has only 5 working days per week.)

4. What is the critical path? Is it the same as that found in Part One of Homework #8?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #10 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

This homework assignment may be done in teams of two, with one solution handed in per team.

Petersen General Contractors is currently preparing a bid for the erection of a 225-foot television antenna tower and the construction of a building adjacent to the tower that will be used to house transmission and electrical equipment. Petersen is bidding only on the tower and its electrical equipment, the building, the connecting cable between the tower and building, and site preparation. Transmission equipment and other equipment to be housed in the building are not to be included in the bid and will be obtained separately by the television station. The site for the tower is at the top of a hill to minimize the required height of the tower, with the building to be constructed at a slightly lower elevation than the base of the tower, and near a main road. Between the tower and building will be a crushed-gravel service road and an underground cable. Adjacent to the building, a fuel tank will be installed above ground on a concrete slab.

Prior to preparing the detailed cost estimates, Petersen's estimator met with the company's general foreman to go over the plans and blueprints for the job. In addition to preparing a cost estimate, the estimator was also preparing an estimate of the time it would take to complete the job. The television station management was very concerned about the time factor. It requested that bids be prepared on the basis of the most likely time for completing the job and also for the most optimistic and pessimistic times for completing the job. During the conference between the estimator and general foreman, it was determined that the activities shown in the table below would be necessary to complete the job. The estimator prepared time estimates for these activities as shown.

Activity Code	Activity	Most likely time	Optimistic time	Pessimistic time
a	Sign contract and complete subcontractor negotiations	5	5	5
b	Survey site	6	4	8
c	Grade building site & excavate for basement	8	6	10
d	Grade tower site	30	21	39
e	Procure structural steel for tower	85	85	85
f	Procure electrical equipment for tower & connecting underground cable	120	120	120
g	Pour concrete for tower footings & anchors	42	25	59
h	Erect tower & install electrical equipment	38	25	51
i	Install connecting cable in tower site	8	4	12
j	Install drain tile & storm drain in tower site	35	18	52
k	Backfill and grade tower site	8	4	12
l	Pour building footings	29	21	37
m	Pour basement slab & fuel tank slab	14	11	17
n	Pour outside basement walls	34	30	38
o	Pour walls for basement rooms	9	7	11
p	Pour concrete floor beams	11	10	12
q	Pour main floor slab & lay concrete block walls	12	10	14
r	Pour roof slab	15	13	17
s	Complete interior framing & utilities	42	30	54
t	Lay roofing	3	2	4
u	Paint building interior, install fixtures, and clean up	19	13	25
v	Install main cable between tower site & building	35	25	45
w	Install fuel tank	3	2	4
x	Install building septic tank	12	8	16
y	Install drain tile & storm drain in building site	15	10	20
z	Backfill around building, grade, and surface with crushed rock	9	7	11
aa	Lay base for connecting road between tower and building	15	13	17
bb	Complete grading and surface connecting road	8	5	11
cc	Clean up tower site	5	3	7
dd	Clean up building site	3	2	4
ee	Obtain job acceptance	5	5	5

In addition to determining the list of activities, the estimator and foreman discussed in detail how these activities could be sequenced, since the list of activities in the table did not necessarily indicate the order in which the work could be performed. In the course of the discussion, the estimator made the following notes:

- Survey work and procurement of the structural steel and electrical equipment can start as soon as contract is signed.
- Grading of tower and building sites can begin when survey is completed.
- After tower site is graded, footings and anchors can be poured.
- After building site is graded and basement excavated, building footings can be poured.
- Septic tank can be installed when grading and excavating of building site is done.
- Construction of connecting road can start as soon as survey is completed.
- Exterior and interior basement walls can be poured as soon as footings are in.
- Basement floor and fuel tank slab should go in after basement walls.
- Floor beams can go in after the basement walls and basement floor.
- Main floor slab and concrete block walls go in after floor beams.
- Roof slab can go on after block walls are up.
- Interior can be completed as soon as roof slab is on.
- Put in fuel tank any time after slab is in.
- Drain tile and storm drain for building go in after septic tank.
- As soon as tower footings and anchors are in and tower steel and equipment available, tower can be erected.
- Connecting cable in tower site, drain tile, and storm drain can be put in as soon as tower is up.
- Main cable between building and tower goes in after connecting cable at tower site is in and basement walls are up.
- Tower site can be backfilled and graded as soon as storm drain, connecting cable, and main cable are in.
- Clean up tower site after backfilling and grading is done.
- Backfill around building and grade after main cable is in and after storm drain is in.
- Clean up building site after backfilling and grading is done.

@@@@ PART ONE @@@@

a. Prepare an A-O-N network that represents the project.

b. Enter the project into the MacProject II program, assuming "most likely time" for each activity.

c. Select "Calandars..." under the "Dates" menu. If the "Calandar Range" does not include 1993 & 1994, click on the years in the range and increase accordingly. The calandar dates which are blacked out are assumed to be non-working days. Click on the name of the month shown on the calandar, in order to get the calandars to specify that the following holidays are NOT working days in 1993: May 31 (Memorial Day), July 4, September 6 (Labor Day), November 25 & 26 (Thanksgiving), December 24 & 25 (Christmas), December 31 & January 1 (New Year's Day).

d. Assuming that the project can begin on May 3, working 5 days/week except as specified in (c), what is the likely completion date for the project?

e. Print a Gantt Chart showing the project schedule, by selecting "Task timeline" on the "Chart" menu. Which activities are critical, according to MacProject?

@@@@ PART TWO @@@@

f. Prepare an A-O-A network that represents the same project.

g. Simulate the project schedule with SLAM, so as to obtain a histogram of the project completion time.

h. What date should Petersen include in the bid for the project completion, if they want to be 90% certain that the project will be completed by the date specified in the bid?

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» HW #11 «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

Use results from queueing theory to answer the following questions (rather than by using a simulation study).

1. Barges arrive at the La Crosse lock on the Mississippi River at an average rate of one every two hours. It requires an average of 30 minutes to move a barge through the lock.
Assuming that the time to move the barge through the lock has exponential distribution, find:

a. The average number of barges in the system, i.e., either using or waiting to use the lock.
b. The average time spent by a barge at the lock.
c. The fraction of the time that the lock is busy.
d. The standard deviation of the time to move a barge through the lock.

If the time to move a barge through the lock has, not exponential, but normal distribution N(30,15), what are the revised values in (a), (b), and (c)?

2. In a particular manufacturing cell, one repairman has to maintain four machines. For the machines, the time between breakdowns is exponentially distributed with an average of 4 hours. On the average, it takes half an hour to fix a machine (exponentially distributed).

a. What is the steady-state probability distribution of the number of machines which are broken down?
b. What fraction of the time will the repairman be busy?
c. What is the average number of machines in need of repair (including those in the process of being repaired)?
d. What is the average time between a machine breakdown and that machine being restored to operating condition?

3. Customers arrive at a service center with two servers at the rate 10/hour. Average time for serving a customer is 10 minutes (exponentially distributed). Compare the average customer waiting times and the server utilization of two alternative systems:

a. Each server has a queue, and customers are equally likely to enter either queue (so that in effect, the arrival rate for each queue is 5/hour).
b. All customers enter the same queue, and a server selects the next customer to be served from the head of this queue.

If you wish, you may check your computations using the APL workspaces in a folder named "Queues" on the ICAEN fileserver; however, you should show your manual computations.

«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«» Extra problem «»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»«»

A product designer is trying to decide upon the best design for a particular product. Two different designs are being considered: A & B. They are being compared on the basis of three important variables: efficiency, capacity, and cost. The designer is able to define the following probabilities:

$P\{A_1\}$ = probability that A has greater efficiency than B
$P\{A_2\}$ = probability that A has greater capacity than B
$P\{A_3\}$ = probability that A costs less than B

He also has good reason to believe that efficiency is independent of capacity for a given cost, but no other independent relationship can be assumed. He is able to estimate the following probabilities:

$$P\{A_1 \text{ú} A_3\} = 0.45$$
$$P\{A_1 \text{ú} \overline{A_3}\} = 0.65$$
$$P\{A_2 \text{ú} A_3\} = 0.80$$
$$P\{A_1 \text{ú} \overline{A_3}\} = 0.60$$
$$P\{A_3\} = 0.45$$

(where the bar over an event denotes the complement of the event.) What is $P\{A_1\}$? What is $P\{A_2\}$? Which design should he choose?

«»