Problem 1 - 50 points) A construction job consists of the following operations:

A concrete batch plant mixes 1 cubic yard (cy) of concrete each minute starting at 8:00 a.m. and works for 24 hours. It dumps the mixed concrete into a loading hopper. The loading hopper has 2 outlets, or unloading chutes, under which concrete trucks drive to be loaded. The loading hopper has a concrete capacity of 100 cy yd.

On this job we are proposing to use 5 concrete trucks to transport concrete from the batch plant to the job site. Each truck holds 10 cy of concrete. If the driver of a concrete truck pulls up to the batch plant and sees that there is less than 10 cy in the hopper, they must wait 3 minutes and check again. When there is at least 10 cy of concrete in the hopper they are permitted to offload concrete. It takes a truck 4 to 5 minutes uniformly distributed to load concrete into the truck. Travel time to the job site takes from 12 to 26 minutes distributed normally. Once at the job site the truck pulls under one of three available unloading cranes and pours the concrete into a concrete bucket. Each unloading crane operates a single bucket, such that there are a total of three buckets - one located at each unloading station. These buckets only hold 2 cy, so the truck will have to wait while the crane raises the concrete to the 40th floor, dumps it and returns for more concrete, until the concrete truck is empty. The return trip to the batch plant takes half as long as the time it takes to go from the batch plant to the job site.

As previously stated, three cranes are used at the job site to raise and lower the concrete buckets. At each of these three unloading docks the trucks fill the lifting buckets which each hold 2 cy of concrete. It takes from 30 to 40 seconds distributed normally to load the lifting bucket. The crane then lifts the bucket to the 40th floor, taking from 1 to 2 minutes, distributed normally. Dumping the concrete takes a mean of 20 seconds, distributed exponentially. The crane then returns the bucket to the unloading dock on the ground floor which takes 1/2 to 1 minute, and loads another 2 cy of concrete from the truck. When the truck is empty it leaves the job site and returns to the batch plant for another load.

Write a BOSS program to compute the total quantity of concrete placed on the 40th floor by this system in a 24 hour period.
Problem 2 - 20 points) Considering the system of problem 1, state which variables might limit the total quantity of concrete placed in a 24 hour period and how you might alter these variables to study the increased production. State clearly:

a) each variable which might limit the system,
b) how your output could tell you if this variable was indeed limiting the system,
c) how you might change the actual properties of that variable if it was found to limit the system.
d) what changes you would make in your model to reflect these actual changes.

A printout of typical BOSS output from another problem is attached on the following sheets for your use. If you wish to discuss what output might answer the above questions, simply mark the location on the output as "A" or "B" or etc. I.e. if something on the following example output sheets would tell you where a "bottleneck" is located in the system, simply mark it and refer your discussion to that location in the output. I will then go to this output and see what you are talking about.

Note that I do not want just one or two maybe things that might help. I want a list of each and every possible thing that could be altered in this problem to increase the amount of concrete hauled, and how you would reflect this change in your code.

```
MOR/DS 1.00

Date:  7/20/95                                   Time: 07:07:39
d:\homework\422\bestmac2.bos

MODEL DESCRIPTION
******************************************************************************

PROGRAM
"McDonalds with two counters - more sophisticated"

DEFINITION
que1:QUEUE={CAPACITY=12, DISCIPLINE=FIFO};
que2:QUEUE={CAPACITY= 3, DISCIPLINE=LILO};
counter1:RESOURCE = {CAPACITY=2,QUEUE=que1};
counter2:RESOURCE = {CAPACITY=1,QUEUE=que2};
LABELS = {getcounter1,getcounter2,leavemad};

CONTROL
STOPTIME=240;
WATCHLIST = {counter1:'a',counter2:'b',que1:'q',que2:'Q'};
RANDOMIZE = ON;

LOGIC
[ 1] ARRIVE {TIME=CUNIFORM(0.5,1)}; "NOTE THAT .5 IS ILLEGAL!!!!!"
[ 3]   GOTO getcounter1;  "CAN ENTER MANY STATEMENTS!"
                     END
[ 4]                     ELSE BEGIN
[ 5]   GOTO getcounter2;
[ 6]                     END;
[ 7] getcounter1: SEIZE{NAME = counter1,QEXCESS = leavemad};
[ 8]   WAIT{TIME = CUNIFORM(1.0,3.0)};
[ 9]   RELEASE {NAME = counter1};
[10]  DEPART;
[12]   WAIT {TIME = CUNIFORM(2,3)};
[13]   RELEASE {NAME = counter2};
[14] leavemad: DEPART;
[15] END.
```
Simulation Clock : 240.00

Block Information

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<th>Line</th>
<th>Label</th>
<th>Name</th>
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<tr>
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<td>312</td>
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<tr>
<td>3</td>
<td>3</td>
<td></td>
<td>GOTO</td>
<td>233</td>
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<tr>
<td>4</td>
<td>6</td>
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<td>GOTO</td>
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<td>RELEASE</td>
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<td>WAIT</td>
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<td>RELEASE</td>
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<td>12</td>
<td>16</td>
<td>LEAVEMAD</td>
<td>DEPART</td>
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Resources

**COUNTER1**
Capacity = 2
Total Number = 232
Maximum Capacity = 2

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<th>Units</th>
<th>Average Util.</th>
<th>Average Units</th>
<th>Average Units</th>
<th>Std Dev</th>
<th>Average Time</th>
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<tr>
<td>2</td>
<td>0.973</td>
<td>1.95</td>
<td>0.25</td>
<td>2.03</td>
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**QUE1**
Capacity = 12
Current Number = 1

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<td>0.58</td>
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**COUNTER2**
Capacity = 1
Total Number = 78
Maximum Capacity = 1

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<th>Average Units</th>
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<td>0.80</td>
<td>0.40</td>
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**QUE2**
Capacity = 3
Current Number = 1

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<th>Std Dev</th>
<th>Average Time</th>
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</thead>
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<tr>
<td>2</td>
<td>51</td>
<td>0.25</td>
<td>0.44</td>
<td>1.22</td>
</tr>
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</table>
Problem 3 - 30 points) Set up the first tableau only to solve the following LP problem:

Min $Z = 12A + 2B + 8E + 10F$
ST  \[ A + E + F = 6 \]
\[ 3E + 4F \geq 2 \]
\[ 2A + 3B + E \leq 5 \]

From your set-up of the tableau, determine the entering and leaving variables, and show why you think they are entering or leaving.

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<th>RHS</th>
<th>RHS/ENT</th>
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<tr>
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<td></td>
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<tr>
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