PROJECT THEMIS

Systems Research Center
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PROJECT MANAGEMENT USING GPSS/360

Technical Report No. 19

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ABSTRACT

A number of examples of complex precedence relationships in project management networking are considered employing the GPSS/360 program. The examples illustrate that GPSS/360 can be employed to develop project management information not readily attainable employing standard project management programs.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

The purpose in undertaking this research was to determine if GPSS/360 could be used for network project management and to determine if it possessed unique capability not presently available in most standard project management programs. Typical shortcomings of existing programs to be considered in employing GPSS/360 were:

1. A limitation to either a constant in CPM or a beta distribution description in PERT for activity times.
2. An assumed deterministic path through a network based on the path with the largest sum of means of sequential activity times.
3. An inability to predefine certain specific precedence relationships in a probabilistic fashion.
4. Pre-defined precedence relationship independent of the dynamic state of the system.

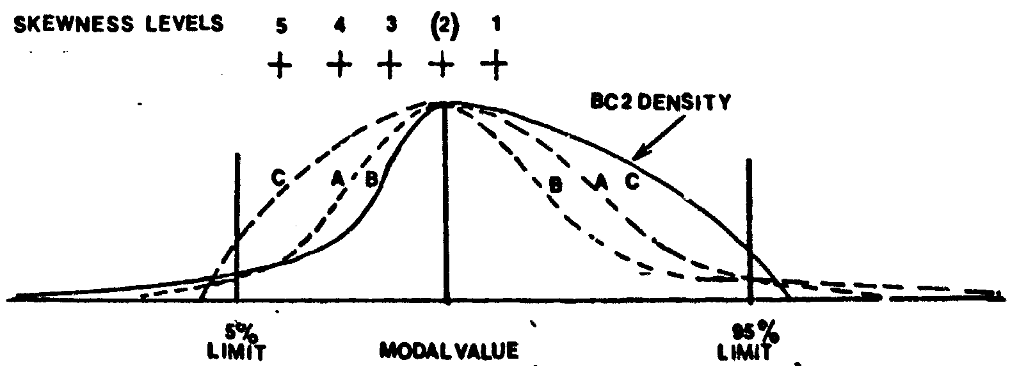
This paper contains examples developed to show how the above limitations can be overcome by employing GPSS/360 simulation. It is not proposed that project management programs be replaced by GPSS/360 programs, but rather that GPSS/360 models be employed to develop project management information not presently attainable employing standard network programs.

EXAMPLES OF GPSS/360 PROJECT MANAGEMENT CAPABILITY

Inputting Subjective Density Functions

A prior paper by the author [1] describes a method that was developed for inputting a density which fits a subjective description of the underlying density function for an activity time. The method involves selecting one curve from a family of 81 density functions by a process of elimination.

The family of 81 density functions is a consistent set of smooth unimodal density functions. The family has four levels of left and right skewness and one symmetrical set. Three levels of kurtosis for left and right segments of the distribution are provided. Figure 1 is one of the 81 curves skewed to the left at a level of 2 with a first level (i.e., B level) peakedness on the right segment and third level peakedness (i.e., C level) on the right side.



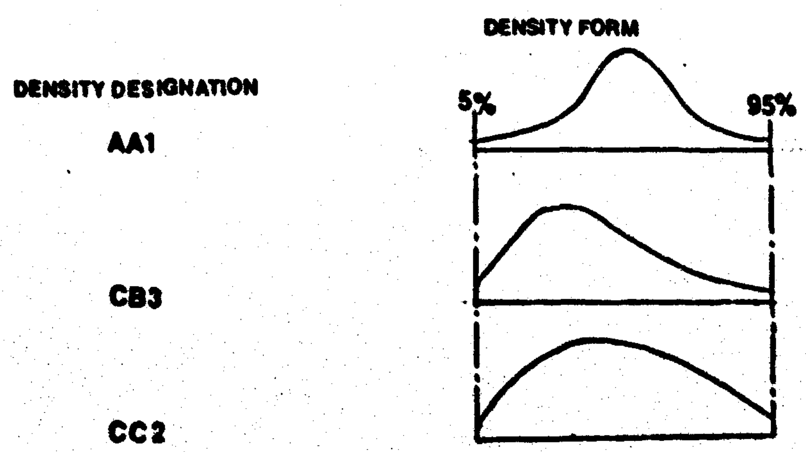
A SAMPLE SUBJECTIVE DENSITY FUNCTION

FIG 1

The BC2 curve shown in Figure 1 would have been selected by asking five questions concerning time for a specific activity. Answers to the five questions represent subjective estimates as to the modal lower 5% limit, upper 95% limit, and dispersion of the extreme values at both ends of the distribution as a clue to appropriate skewness level. Specific estimates for the five questions result in selection of one of the 81 curves as a closest approximation.

Although only one of the 81 curves is a mathematically expressable function (i.e., AA1 is normal between the 5% and 95% limits), the curves were drawn as a consistent set of density functions possessing smooth unimodal, variable skewness and variable kurtosis shapes.

When subjective estimates are the basis for the specification of an activity time density function, the above method is believed to permit more accurate specifications of the underlying density function. The methodology above also provides data cards for the density functions selected which meet the format requirements for inputting density functions into GPSS/360. Figure 2 illustrates three of the 81 density functions as example activity time distributions.



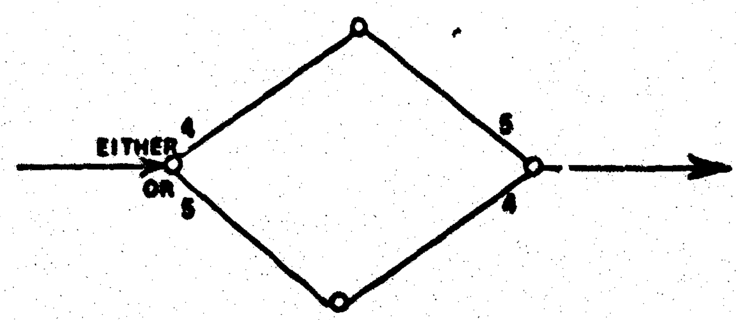
Example Activity Distributions

FIG 2

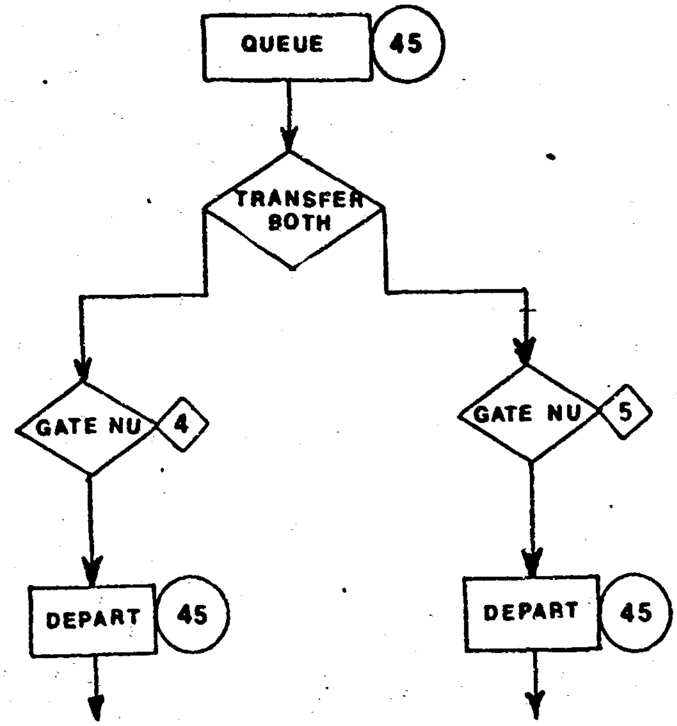
The function cards shown at the beginning of the program in Figure 4 are cards produced by a FORTRAN program employing the methodology mentioned above.

Either-Or Precedence Relationship

In CPM or PERT the order in which activities are to be performed is fixed in drafting the network. However, in many practical situations, the specific order in which two or more activities are to be sequentially performed may be relatively unimportant. Any fixed precedence relationship as would be required in CPM or PERT would be unnecessarily restrictive. A less restrictive precedence relationship is shown in Figure 3. The segment of a flow chart shown in Figure 4 would permit testing whether activity 4 or 5 can be entered. If one of the activities is blocked (e.g., a prior unit may be performing activity 4) then the other activity can be entered to hopefully shorten the time of completion for activities 4 and 5.



EITHER OR PRECEDENCE NETWORK
FIG 3

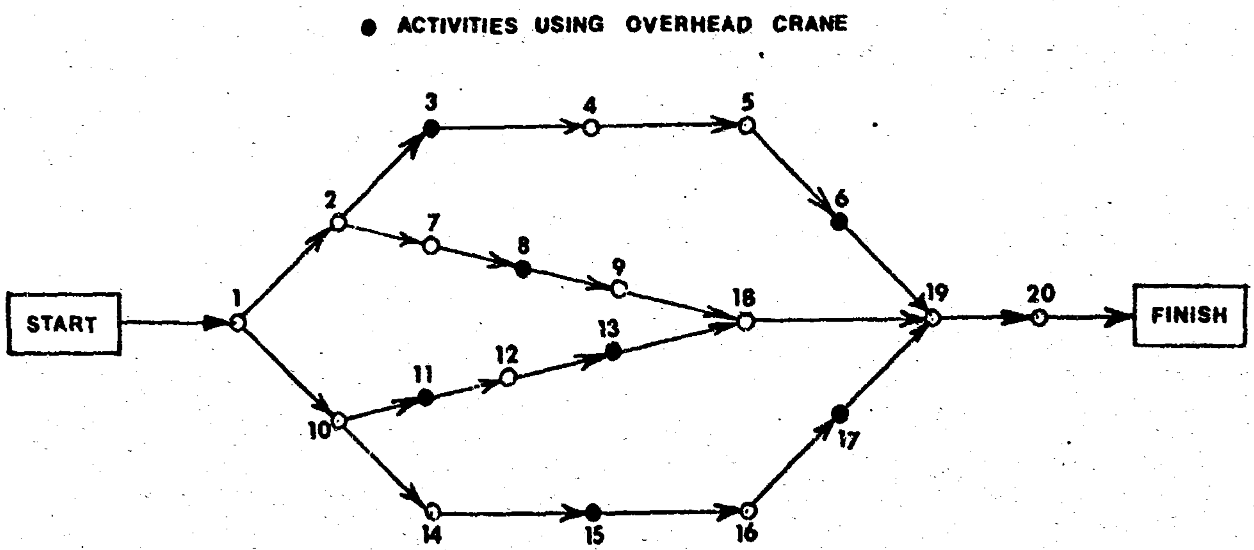


GPSS MODEL FOR EITHER-OR PRECEDENCE RELATIONSHIP

FIG 4

Probabilistic Critical Path

In CPM or PERT a unique path is designated as the critical path in a deterministic sense. In some networks, due to nearly equal sums of mean activity times, the probability of a unique path being critical is considerably less than one. In such a network, the probability of an activity being on the critical path is of considerable interest in valuing resource acquisitions in an effort to reduce the total project time. In Figure 5, any of the four paths in the network could conceivably be critical if each path has a near equal sum of mean times, and activity times for a single item passing through the network are determined by sampling from the respective distributions for the activity times in a Monte Carlo fashion. For distributions specified by the method discussed in the previous section, the mean time for an activity may not even be known. Appendix A is a GPSS program for Figure 5 which permits specification of subjective density functions for activity times and also provides for Monte Carlo simulation of the network to determine the probability that an activity is on the critical path. For example, the probability that activity 5



PRODUCT ASSEMBLY NETWORK

FIG 5

is on the critical path can be readily determined by observing the percentage of non-zero time assignments to the parameters associated with activity 5. If in 100 starts there are 95 non-zero assignments to the activity 5 parameter, it is estimated that activity 5 has a 95% probability of being on the critical path. The program in Appendix A goes beyond estimating the probability of an activity being on the critical path as will be indicated in the next example.

Limited Resource Allocation

Assume that Figure 5 is a network for fabricating a product consisting of four assemblies. Assume also that operations 3, 6, 8, 11, 13, 15, and 17 represent handling operations employing an overhead crane. Appendix A is a GPSS/360 program developed to determine the effect on the distribution of the project completion times for the following three cases:

1. Each activity is assumed to have its own crane.
2. A common pool of cranes is assumed, with the size of the pool variable.
3. Assume there are two common pools, with the size of each pool variable.

In case 1, every activity has its own equipment and it is evident that the completion time for the project will be a minimum in this case. This is due to the fact that the waiting time, and hence the process completion time, which is the sum of all the processing times and waiting times for activities on the critical path, will be minimum.

Once again, the critical path was not fixed due to variable processing times and almost equal mean completion times for the 4 different assembly routes. By running the simulation until a steady state was reached it was possible to find the probability that a certain path was critical. It was found that path A had the greatest chance of being critical, and hence the common equipment was allocated first to an activity on this path, so that the overall completion time would be minimized. As shown in Table I, the minimum completion time for the project was approximately 186 days. This is the case when each activity has its own independent crane.

In Case 2, the minimum number of common pool equipment desired was limited by the number of activities competing for the equipment. Therefore, the simulation was initially run with 7 cranes on hand. The number of cranes was gradually reduced to two. Table I shows the shift in the completion times as the number of cranes is decreased.

At no time were more than 5 cranes required simultaneously. The mean project completion time was not appreciably affected by decreasing the number of cranes to three, and the utilization of the cranes improved. As the number of cranes were decreased from three to two, however, we find that the mean project time increases considerably, indicating that three may be the desirable number of cranes to provide. This is further illustrated in Figure 6 which shows the distribution of completion times for a varying number of cranes. The distribution gradually shifts to the right, but for two cranes it suddenly shifts out of range (i.e., 125 to 270).

In case 3, it was assumed that activities 6, 13, and 17 were provided with a pool of equipment of its own. Thus, two groups of equipment were made as shown in Table I. In this case, it was found that a minimum of 4 cranes distributed as 2:2 between the two groups appeared to provide the most desirable results.

TABLE I

Crane Problem Output

No. of Cranes in Group 1	No. of Cranes in Group 2	Max Project Completion Time for 100 Trials	Mean Time	Utilization Group 1	Utilization Group 2	Std. Dev. About Mean	Max No. of Cranes Required Group 1	Max No. of Cranes Required Group 2
7	-	240	185.75	0.390	-	17.62	5	-
6	-	245	186.85	0.457	-	17.62	5	-
5	-	240	185.75	0.549	-	17.62	5	-
4	-	225	184.94	0.686	-	16.56	4	-
3	-	225	188.80	0.915	-	17.25	3	-
2	-	2790	2190.51	0.979	-	1146.0	2	-
4	3	235	190.18	0.289	0.382	17.62	3	3
4	2	240	195.08	0.292	0.583	16.43	3	2
3	3	250	197.09	0.392	0.386	19.25	3	3
3	2	250	198.38	0.385	0.576	22.12	3	2
2	2	250	197.45	0.578	0.574	19.37	2	2
2	1	923	888.33	0.487	0.971	406.00	2	1

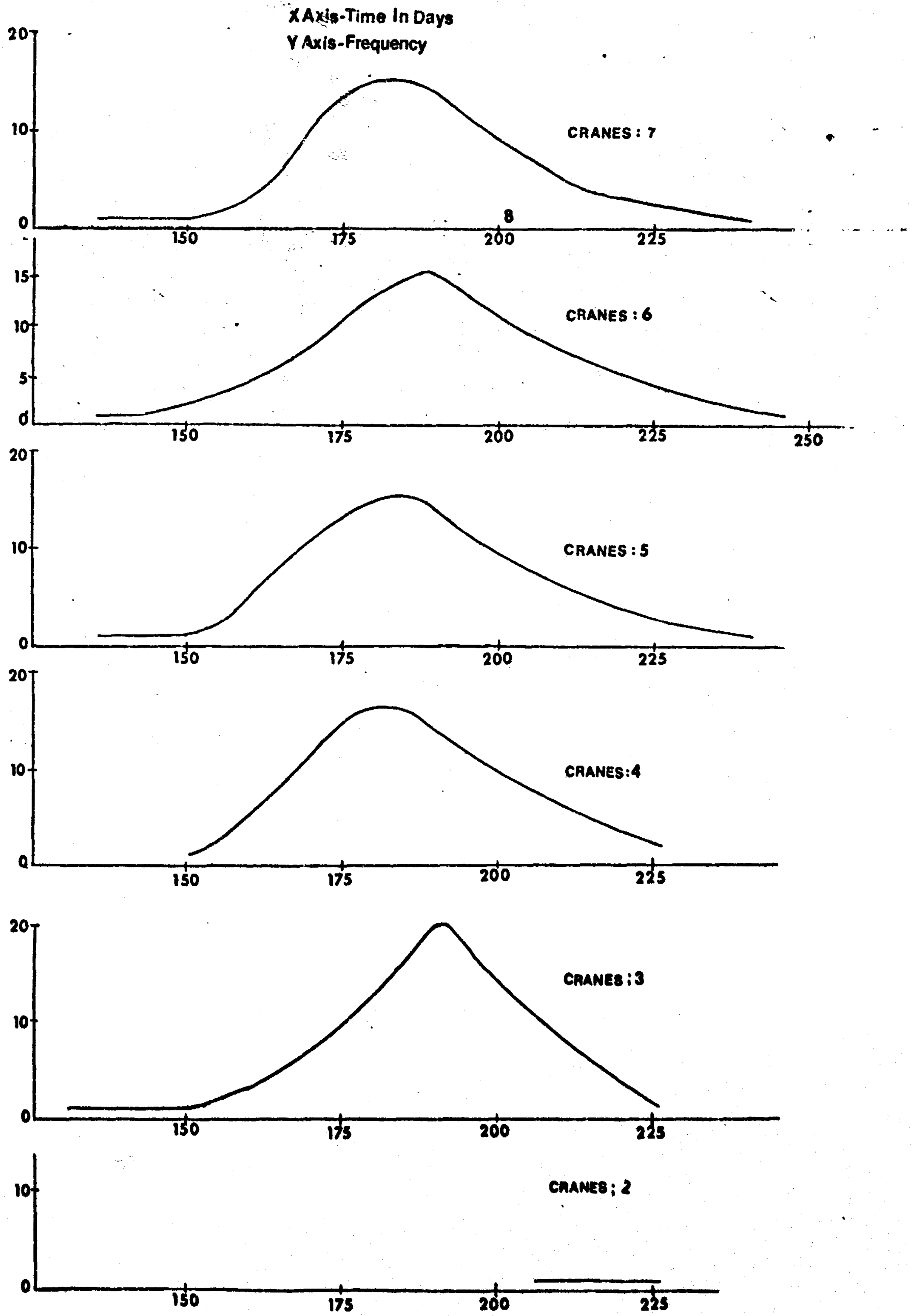

X Axis-Time In Days
Y Axis-Frequency
CRANES : 7
CRANES : 6
CRANES : 5
CRANES:4
CRANES ;3
CRANES ; 2
0
5
10
15
20
150
175
200
225
250

FIG 6

Two groups of common equipment for this example proved to be preferable to one group. This would be true particularly where the distances between the various activity locations are large. However, a greater number of total equipment was required and the overall project completion time was increased by 5 to 7%. The time required to move the equipment from one location to another would also make the single pool less desirable.

CONCLUSIONS

The preceding examples serve to illustrate that considerable flexibility exists in utilizing the GPSS/360 program capability to derive project management information not readily attainable from standard project management programs.

BIBLIOGRAPHY

1. Hicks, Philip E., "Estimation of Manpower Forecast Variation by GPSS Simulation," Proceedings of Second Conference on Applications of Simulation, Joint Conference of SHARE, ACM, IEEE and SCi, New York, 1968.

2. Moder, Joseph and Phillips, C., Project Management with CPM and PERT, Reinhold Publishing Corporation, New York 1964.

3. General Purpose Simulation System/360 User's Manual, Application Program H 20-0326, IBM Corporation, White Plains, New York, 1968.

APPENDIX A

GPSS/360 Network Model

```
* [illegible]ACTOR ANALYSIS PROBLEM (JAI : SURESH KUMAR)
        SIMULATE
*[illegible] DEFINITION CARDS
 1      FUNCTION    RN1,C17
.[illegible] [illegible] .00254-37.5 .[illegible]739-25.0 .01787-12.5 .05120  0.0 .11080 12.5
.[illegible] 25.0 .33326 37.5 .49541 50.0 .65308 62.5 .78603 75.0 .88359 87.5
.[illegible] .976[illegible]112.5 .99357125.0 .99770137.5 .99999150.0
 2      FUNCTION    RN2,C17
.[illegible] [illegible] .[illegible]-37.5 .00202-25.0 .00003-12.5 .04775  0.0 .15401 12.5
.[illegible] 25.0 .43[illegible] 37.5 .57954 50.0 .71001 62.5 .81535 75.0 .89488 87.5
.[illegible] .97629 112.5 .99169125.0 .99861137.5 .99959150.0
 3      FUNCTION    RN3,C17
.[illegible] [illegible] .00[illegible]-37.5 .00202-25.0 .00204-12.5 .04836  0.0 .13715 12.5
.[illegible] 25.0 .37177 37.5 .50043 50.0 .62963 62.5 .75281 75.0 .86406 87.5
.[illegible] .99[illegible]112.5 .99597125.0 .99598137.5 .99959150.0
 4      FUNCTION    RN4,C17
.[illegible] [illegible] .00[illegible]-37.5 .00773-25.0 .02017-12.5 .04641  0.0 .10856 12.5
.[illegible] 25.0 .42[illegible] 37.5 .58561 50.0 .71712 62.5 .82044 75.0 .89916 87.5
.[illegible] .[illegible]112.5 .99419125.0 .99916137.5 .99959150.0
 5      FUNCTION    RN5,C17
.[illegible] [illegible] .00[illegible]-37.5 .00002-25.0 .00842-12.5 .04860  0.0 .14497 12.5
.[illegible] 25.0 .46[illegible] 37.5 .61319 50.0 .73739 62.5 .83351 75.0 .90388 87.5
.[illegible] .97[illegible]112.5 .99133125.0 .99789137.5 .99959150.0
 6      FUNCTION    RN6,C17
.[illegible] [illegible] .00[illegible]-37.5 .00002-25.0 .00003-12.5 .04721  0.0 .19207 12.5
.[illegible] 25.0 .50[illegible] 37.5 .63938 50.0 .75287 62.5 .83881 75.0 .90206 87.5
.[illegible] .97[illegible]112.5 .99132125.0 .99846137.5 .99959150.0
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        MARK        26
        ASSIGN      1,V1
        QUEUE       1
        SEIZE       1
        DEPART      1
        ASSIGN      21,C11
        ADVANCE     V21
        RELEASE     1
        SPLIT       1,PATH8
        ASSIGN      2,V2
        QUEUE       2
        SEIZE       2
        DEPART      2
        ASSIGN      22,C12
        ADVANCE     V22
        RELEASE     2
        SPLIT       1,PATH2
        ASSIGN      35,V51
        ASSIGN      3,V3
        JOIN        1
        ASSIGN      37,V23
        TRANSFER    ,CHAN
PATH2   ASSIGN      7,V7
        QUEUE       7
        SEIZE       7
        DEPART      7
        ASSIGN      27,C17
        ADVANCE     V27
        RELEASE     7
        ASSIGN      8,V8
        ASSIGN      35,V52
        JOIN        2
        ASSIGN      37,V28
```

```
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PAIR3   ASSIGN     10,V13
        QUEUE      10
        SEIZE      10
        DEPART     10
        ASSIGN     30,CT10
        ADVANCE    V30
        RELEASE    10
        SPLIT      1,PAIR4
        ASSIGN     15,V35
        ASSIGN     11,V11
        JOIN       3
        ASSIGN     17,V31
        TRANSFER   ,CRAN
PAIR4   ASSIGN     14,V14
        QUEUE      14
        SEIZE      14
        DEPART     14
        ASSIGN     34,CT14
        ADVANCE    V34
        RELEASE    14
        ASSIGN     13,V13
        ASSIGN     34,V73
        ASSIGN     37,V15
        JOIN       4
        TRANSFER   ,CRAN
CRAP    QUEUE      1
        LINK       1,P32,JUL
JUL     ENTER      100
        DEPART     100
        EXAMINE    5,,PAL
        TRANSFER   ,SUP
PAL     EXAMINE    6,,TUP
        TRANSFER   ,C P
TCP     EXAMINE    7,,POP
        TRANSFER   ,CCY
PUP     ADVANCE    V16
        TRANSFER   ,CAL
CCP     ADVANCE    P31
        TRANSFER   ,CAL
CAL     LEAVE      100
        UNLINK     1,JUL,+10C
        EXAMINE    5,,SAV
        TRANSFER   ,REG
SAV     EXAMINE    6,,SAV
        TRANSFER   ,REG
RAV     EXAMINE    7,,TAV
        TRANSFER   ,REG
TAV     ASSIGN     21,CT1C0
        EXAMINE    1,,GAT
        ASSIGN     4,V4
        QUEUE      4
        SEIZE      4
        DEPART     4
        ASSIGN     24,Q14
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        RELEASE    4
        ASSIGN     5,V5
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        SEIZE      5
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        ASSIGN     25,Q15
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         RELEASE    5
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C[illegible]     ASSIGN     6,V6
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         ASSIGN     31,V26
         TRANSFER   ,CAP5
[illegible]      EXAMINE    2,,PAN
         ASSIGN     9,V9
         QUEUE      4
         SEIZE      4
         DEPART     4
         ASSIGN     [illegible],V14
         ADVANCE    [illegible]
         RELEASE    4
         TRANSFER   ,[illegible]
P[illegible]     EXAMINE    3,,[illegible]
         ASSIGN     12,V12
         QUEUE      12
         SEIZE      12
         DEPART     12
         ASSIGN     32,QF12
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         RELEASE    12
         ASSIGN     19,V19
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         ASSIGN     31,V19
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         RELEASE    16
         ASSIGN     17,V17
         ASSIGN     31,V17
         JOIN       7
         TRANSFER   ,C4A5
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         TRANSFER   ,FINA
JAN      EXAMINE    3,,SAN
         TRANSFER   ,CCP3
SAN      TRANSFER   ,FINA
CCP2     ASSEMBLE   2
         ASSIGN     18,V18
         QUEUE      18
         SEIZE      18
         DEPART     18
         ASSIGN     38,QF18
         ADVANCE    V38
         RELEASE    18
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FINA     ASSEMBLE   3
         ASSIGN     19,V19
         QUEUE      19
         SEIZE      19
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         ASSIGN     39,QF19
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         RELEASE    19
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         RELEASE     20
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         TABULATE    5
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   3     FVARIABLE   10+(FN3/100)10
   4     FVARIABLE   10+(FN4/100)8
   5     FVARIABLE   40+(FN5/100)15
   6     FVARIABLE   10+(FN6/100)20
   7     FVARIABLE   5+(FN6/100)40
   8     FVARIABLE   20+(FN3/100)20
   9     FVARIABLE   10+(FN3/100)20
  10     FVARIABLE   20+(FN4/100)20
  11     FVARIABLE   5+(FN3/100)10
  12     FVARIABLE   30+(FN5/100)20
  13     FVARIABLE   (35/10)+(FN2/100)4
  14     FVARIABLE   4+(FN3/100)8
  15     FVARIABLE   35+(FN5/100)20
  16     FVARIABLE   10+(FN1/100)20
  17     FVARIABLE   (45/10)+(FN6/100)4
  18     FVARIABLE   15+(FN6/100)40
  19     FVARIABLE   10+(FN6/100)20
  20     FVARIABLE   12+(FN2/100)8
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  22     FVARIABLE   70-V2
  23     FVARIABLE   70-V3
  24     FVARIABLE   70-V4
  25     FVARIABLE   70-V5
  26     FVARIABLE   70-V6
  27     FVARIABLE   70-V7
  28     FVARIABLE   70-V8
  29     FVARIABLE   70-V9
  30     FVARIABLE   70-V10
  31     FVARIABLE   70-V11
  32     FVARIABLE   70-V12
  33     FVARIABLE   70-V13
  34     FVARIABLE   70-V14
  35     FVARIABLE   70-V15
  36     FVARIABLE   70-V16
  37     FVARIABLE   70-V17
  38     FVARIABLE   70-V18
  39     FVARIABLE   70-V19
  40     FVARIABLE   70-V20
  42     FVARIABLE   P1+P2+P3+P4+P5+P6+P7+P8+P9+P10+P11+P12+P13+P14+P15
  43     FVARIABLE   P16+P17+P18+P19+P20
  41     FVARIABLE   V42+V43
  44     FVARIABLE   P21+P22+P23+P24+P25+P27+P29+P30
  46     FVARIABLE   P32+P33+P34+P36+P38+P39+P40
  45     FVARIABLE   V44+V46+V41
  51     FVARIABLE   P26+1
  52     FVARIABLE   P26+2
  53     FVARIABLE   P26+3
  54     FVARIABLE   P26+4
   1     TABLE       V45,270,50,10
   5     TABLE       V45,120,5,30
```

```
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        START       100
        CLEAR
100     STORAGE     6
        START       100
        CLEAR
100     STORAGE     5
        START       100
        CLEAR
100     STORAGE     4
        START       100
        CLEAR
100     STORAGE     3
        START       100
        CLEAR
100     STORAGE     2
        START       100
        REPORT
        OUTPUT
        EJECT
        GRAPH       TF,5
        ORIGIN      55,5
        X           ,1,3,125,1,30
        Y           0,1,30,1
100     STATEMENT   3,19,GRAPH OF TOTAL TIME
        ENDGRAPH
/*
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13. ABSTRACT

A number of examples of complex precedence relationships in project management networking are considered employing the GPSS/360 program. The examples illustrate that GPSS/360 can be employed to develop project management information not readily attainable employing standard project management programs.

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