DISCLAIMER

Although each program has been tested by its contributor, no warranty, express or implied, is made by the contributor or any User's Group, as to the accuracy and functioning of the program and related program material, nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the contributor or any User's Group, in connection therewith.

COMMON USERS GROUP PROGRAM REVIEW AND EVALUATION

(fill out in typewriter, ink or pencil)

Program No._____ Date_____

Program Name:_____

1. Does the abstract adequately describe what the program is and what it does? Yes____ No____
   Comment_____

2. Does the program do what the abstract says? Yes____ No____
   Comment_____

3. Is the description clear, understandable, and adequate? Yes____ No____
   Comment_____

4. Are the Operating Instructions understandable and in sufficient detail? Yes____ No____
   Comment_____
   Are the Sense Switch options adequately described (if applicable)? Yes____ No____
   Are the mnemonic labels identified or sufficiently understandable? Yes____ No____
   Comment_____

5. Does the source program compile satisfactorily (if applicable)? Yes____ No____
   Comment_____

6. Does the object program run satisfactorily? Yes____ No____
   Comment_____

7. Number of test cases run_____. Are any restrictions as to data, size, range, etc. covered adequately in description? Yes____ No____
   Comment_____

8. Does the Program meet the minimal standards of COMMON? Yes____ No____
   Comment_____

9. Were all necessary parts of the program received? Yes____ No____
   Comment_____

10. Please list on the back any suggestions to improve the usefulness of the program. These will be passed onto the author for his consideration.

Please return to:

IBM Corporation
Program Information Department
40 Saw Mill River Road
Hawthorne, New York 10532
Attn: PREP FORM COORDINATOR

Your Name _____
Company _____
_____
Address _____
_____
Users Group Code _____

THIS REVIEW FORM IS PART OF THE COMMON ORGANIZATION'S PROGRAM REVIEW AND EVALUATION PROCEDURE. NONMEMBERS ARE CORDIALLY INVITED TO PARTICIPATE IN THIS EVALUATION.

1620 10.3.031 January 3, 1964

Statement 231 IW1 = A4 (L) + .5 in program 1 has been replaced by statements:

```
231     IF (A4(L) - 99999.) 701,125, 125

701     IW1 =A4 (L) + .5
```

This correction eliminates the possibly of getting an Error E9 when A4(L) becomes larger than 99999.

PERT - LESS

L. Standlee Steenrod
Computer Research Center
9 B & PA
University of Missouri
Columbia, Missouri

1620 Users Group Code 3211

August 30, 1963

Modifications or revisions to this program, as they occur, will be announced in the appropriate Catalog of Programs for IBM Data Processing Systems. When such an announcement occurs, users should order a complete new program from the Program Information Department.

Deck Labeling Sheet

Deck 1 - Fortran Program 1
Hash Total 75367450954418300571

Deck 2 - Fortran Program 2
Hash Total 58007769218123676099

Deck 3 - Sample Problem - Input to Program 1
Hash Total 73730844640539713845

Deck 4 - Output from Program 1
Hash Total 78920772480045238602

Deck 5 - Output from Program 2
Hash Total 54307502721721210377

The above decks were Hash Totaled with the 1620 Users Group Program 1.6.031.

5

ABSTRACT

1. Title: PERT-LESS

   Classification: Management Science

2. Author: Organization: L. Standlee Steenrod,
   Computer Research Center, University of Missouri

   Date: August 20, 1963

   Users Group Membership Code: 3211

3. Direct Inquiries to name: L. Standlee Steenrod, Computer Research Center, 9 B & PA, University of Missouri, Columbia, Missouri
   Phone: GI 9-9533

4. Description/purpose:
   This is a critical path program devised to compute schedules of paths and their associated "least cost" through a network of activities of a large project. The schedules are generated between the project's normal time and crash time and each contains start and finish times, costs and floats for each activity. These schedules enable a time and its associated " least cost" to be chosen.

5. Method: Critical Path Programming by Mauchly Associates; other information - not available

6. Restriction/range: Not applicable
7. Specifications:
   a. Storage used by program: 60 K
   b. Equipment required by program:
      Card system
      Auto divide, Indirect addressing,
      Floating point hardware

      Program can be used on lesser machine if dimensions are reduced or part of labeling in program deck 2 is removed
   c. Programming type
      Fortran II

8. Remarks: a. This program is a modification of SHARE program 1188 PA GMCP.
   b. Program consists of two (2) decks. Deck I gives intermediate output, Deck II gives final output for listing.

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Table of Contents

All inquiries concerning the following program should be directed to:

L. Standlee Steenrod
Computer Research Center
9 B & PA
University of Missouri
Columbia, Missouri

Users Group Code 3211

Note

These programs (2) are a translation of the SHARE program 1188 PA GM XP for the 7090 to a form usable on the 1620. Because of this much of the mathematical method is unavailable.

Summary

Critical Path Programming is a method devised to plan and control large projects composed of many activities that must be completed in certain sequences. In these programs the critical path method has been programmed in the FORTRAN language. This permits the computer to accept a description of a project structure and time-cost information for each activity in order to generate a series of project schedules.

Each project schedule has a certain duration and cost associated with it. This cost arises from assigning to each activity in the project a scheduled duration and related cost. In general, the shorter the activity, the higher the activity cost.

The project time related to a schedule results from the durations assigned the various activities together with the precedence relationships binding the activities. For each schedule generated, its project cost is the least possible for that project time.

The FORTRAN programs are designed for flexibility. Various types of computer runs can be made, and alternative forms of output are obtainable. These are described in detail under Input.

Discussion

I. Background

The basis of these programs is PERT (Project Evaluation and Review Technique) developed for the U. S. Navy to help measure and control progress on the Polaris System.

The PERT model assumes that a project can be broken down into activities (or sub - projects) and that the sequence relationship between these activities can be specified. A graphical representation of a project can be obtained by depicting activities as arrows, each beginning and ending at a point called a benchmark or event. Several activities may begin or end at a single event.

Figure I is used as an example of such a graphical representation

of a small project.

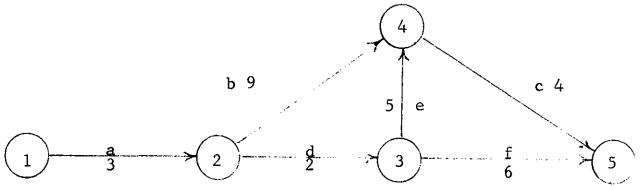


FIGURE I

In this example, a network of 6 activities (arrows a,b,c,d,e,f) defined by 5 events (circles) might represent a small project. The project begins with activity "a" is completed, event "2" is realized and activities "b" and "d" are immediately begun in parallel. When "d" is complete at at event "3", activities "e" and "f" are begun in parallel. Event "4" is realized, or occurs, only when both "b" and "e" are completed.

The same structure represented by Figure I can be described by listing the 6 pairs of event numbers describing the 6 activities; let us also list a sample completion time for each of these activities.

	Activity	Completion Time in Weeks
(a)	1,2	3
(d)	2,3	2
(b)	2,4	9
(e)	3,4	5
(f)	3,5	6
(c)	4,5	4

FIGURE II

Thus, Figure II is logically equivalent to Figure I. In the PERT System it is only necessary to supply information of the type in Figure II to analyze the status of a project.

Project completion time can be obtained by tracing all paths connecting the first event (1) to the last event (5), and adding together the completion times of activities along each given path.

The path giving the largest sum would be called the "critical path" and its sum would be the project duration. In Figure I, three paths connect events (1) and (5). These are:

a-b-c	(3+9+4=16)
a-d-e-c	(3+2+5+4=14)
a-d-f	(3+2+6=11)

Path a-b-c is critical, and project time is 16. By giving three time estimates for each activity, uncertainty is incorporated by the PERT method into the overall project completion time.[1]

This program employs a network representation and also activity costs. Each activity is assumed to have a "normal time" for completion and an associated "normal cost". Likewise, each activity is assumed to have a "crash time", generally less than the normal, and on associated "crash cost" - generally higher than normal cost. The Critical Path Programming Method assumes that in the time - cost plane, the "normal point" can be connected by a straight line to the "crash point" to define an activity cost function. Figure III below represents this relationship.

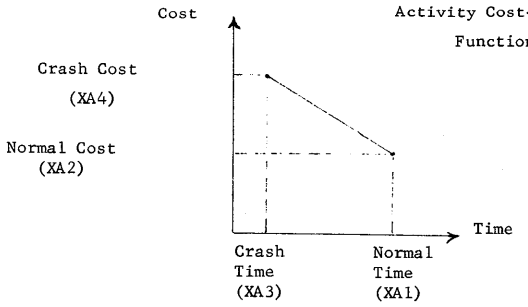


FIGURE III

The Method assigns each activity a duration between crash and normal XA3,XA1 , at the associated cost.

[1] See PERT, Summary Report Phase1, Special Projects Office, Bureau of Naval Weapons, Department of the Navy, Washington, D.C.

An algorithm developed by J. E. Kelly, Jr. of Mauchly Associates generates a series of project schedules (assignments of times to activities) such that for each project schedule, its associated cost is the least possible for the related total project time.

The first schedule generated is the "normal" project schedule which results from setting all activities at their normal times. This is clearly the least cost and longest project schedule. Then, successive schedules are generated down to a "crash" time project schedule which is the shortest possible time and the least expensive for that time. The number of schedules is unknown in advance, depending on project structure as well as activity cost-time curves.

This generates a project cost-time function which when linearly connected, is like Figure IV below.

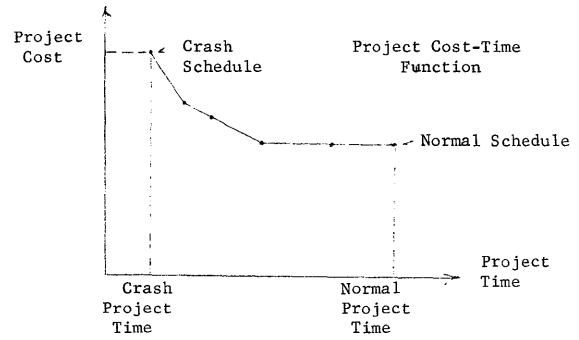


Figure IV

The project's cost-time curve can then be scanned and the appropriate duration and cost point for the project can be selected. Corresponding to each point on the curve (Figure IV), a schedule is generated and each activity set at a completion time between normal and crash times. Schedules between indicated points can be computed from the schedules associated with the two neighboring points.

II. Program Description

This program is composed of two decks. The first deck does the major part of the computation and provides intermediate output to be used as input into program II. Program II primarily arranges and labels the final output. This output must be listed on a special board described later.

III. Input Data

The input for Program I is divided into four simple parts. Let us assume that a project has "N" events and "LL" activities.

a) The first data card for a computer run has an integer punched in column 2. In the program it sets the value of a control variable called "I9". This variable defines three possible types of computer runs related to the project. I 9 = 1 : Generates all possible characteristic project schedules.
= 2 : Generates "normal" schedule only (the longest possible project duration)
= 3 : Generates "normal" and "crash" project schedules. The "crash" schedule in this case results when all activities are set at "crash" time.

b) The second part of the input data consists of four cards (cards 2 through 5 of the data input deck) containing project description information that will subsequently appear on the schedule printouts.

The first of these four cards contains the date to appear on all schedules from this machine run. It is punched in columns 1-12, in any convenient manner (e.g., 2 MARCH 61 or 3/1/61, etc.).

The second of these cards has punched into columns 1-36 the division or entity involved in the project. Any format within columns 1-36 is permissible.

The third card contains the project description punched in columns 1-72, in any desired manner.

The fourth card has punched in column 1 through 6 the time units (e.g., "WEEKS") appropriate to the input data for this computer run. In columns 7-18 are punched the appropriate cost units (e.g., "DOLLARS" or "1000 DOLLARS").

c) The third part of the input data consists of "LL" activity cards followed by a trailer card with a negative, non-zero integer punched in columns 6-10. One card should be present for each activity in the project. The card format, for each activity, is as follows:

1) Columns 1-5: Preceding event number.

2) Columns 6-10: Succeeding event number. This must be larger than the number in columns 1-5.

3) Columns 12-40: Activity description (any format).

4) Columns 41-45: "Normal" activity time. A decimal "XA1" point is assumed between columns 44 and 45. Do not punch the point.

5) Columns 46-55: "Normal" activity cost. A decimal "XA2" point is assumed between columns 54 and 55. Do not punch the point.

6) Columns 56-60: "Crash" activity time. Decimal point "XA3" assumed between 59 and 60 - do not punch it.

7) Columns 61-70: "Crash" activity cost. Decimal point "XA4" assumed between 69 and 70, do not punch it.

8) Columns 71-72: This field is normally not punched, hence is treated as a zero. Any non-zero integer in this field causes the activity to be set at either "normal" or "crash" time, but at no point in between.

When all "LL" activity cards are prepared, they must be sorted in ascending sequence: major sort on columns 1-5, minor on columns 6-10. Finally, the trailer card follows with a negative integer in columns 6-10.

The following conditions on XA1, XA2, XA3 and XA4 must hold for each activity card.

1) $XA3 \leq XA3$ (crash time $\leq$ normal time)
2) $XA2 \leq XA4$ (normal cost $\leq$ normal time)
3) if $XA3 = XA1$, cannot have $XA4 \neq XA2$ (infinite slope on time - cost function)

d) The fourth part of the input data consists of "N" event cards followed by a trailer card with a negative, non-zero integer punched in columns 6-10. One card should be prepared for each event in the project - punched as follows:

1) Columns 6-10: Event number

2) Columns 12-71: Event description-any format

The "N" event cards must be sorted in ascending sequence on columns 6-10. The trailer card follows.

This concludes the input for Program I.

The input for Program II is the intermediate output from Program I plus a header card which contains parameters that specify what schedules are to be drawn from the data for output printing.

The intermediate output consists of partially completed schedules. The last card of the intermediate output deck contains "N" - the number of events, "LL" - the number of activities, "MIK" - the maximum schedule count (k=0, 1,2,---,MIK), "I 9" - for this computer run. This card must be moved to the front of the intermediate output deck. The header card is then placed in front of this card.

During a machine run, if I 9 =1, all characteristic schedules are generated; this set begins with the normal and terminates with the crash. Each schedule has a characteristic project time and project cost. In this case, the above mentioned parameters permit a selection of these schedules for printout according to several criteria that will become evident in the following descriptions.

If I 9 = 1, the leader card is punched in the following manner.

Columns 1-5 (KE) =1 print every "KD" schedule
=2 selects only such schedules for printing that differ from their predecessor by "DT" in project duration or "DC" in project cost.
=3 selects only such schedules for printing that differ from their predecessor by "DT" in project duration.
=4 no output printing of schedules.

Columns 6-10 (KD)=1,2,...; if "KE" -1, KD is the sampling interval for printing out schedules. Thus, if KD=3, schedules 0,3,6,9,... would be printed.

Columns 11-15 (IR) = 0

Columns 16-20 (INDIR) = 0 will eventually be used to incorporate indirect project costs.

Columns 21-30 (DT) = A ten digit time increment with a decimal point assumed or punched before column 40 (see "KE" above).

Columns 31-40 (DC) = A ten digit project cost increment with a decimal point assumed or punched before column 50 (see "KE" above). Don't punch if KE=1,4.

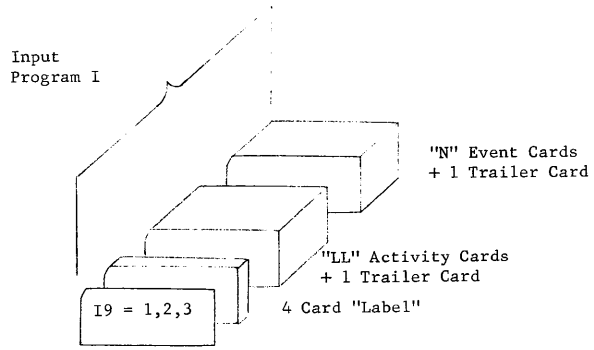
If 19 = 2 or 3, the columns 26-50 (INDIR,DT,DC) are ignored. KE and KD are both punched one, IR is punched zero.

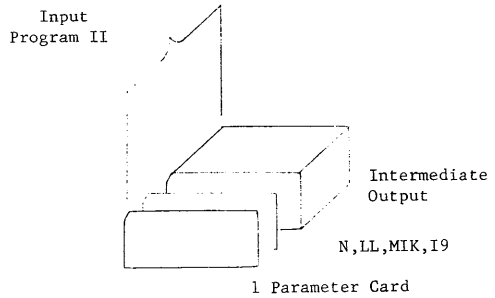
Most of the options for preparing printer output are summarized in the following table.

EDITING OPTIONS

Desired Schedules	Variable Settings on Parameter Card					
	KE	KD	IR	INDIR	DT	DC
All Schedules	1	1	0			
Normal, Every ΔK^{th}, Crash	1	ΔK	0			
Normal, ΔT or ΔC, Crash	2		0		ΔT	ΔC
Normal, ΔT AND ΔC, Crash	3		0		ΔT	ΔC
No Schedules	4					

SUMMARY OF INPUT DATA





IV. Output

All the selected schedules are printed and then the project time-cost curve is printed at the end.

Each schedule selected for output printing is arranged into three parts. Common project information is shown on every page.

a) Activity List
The first part of every schedule report contains a detail line for each activity. Printed with each activity is the minimum schedule information: the activity "Duration" and "Direct Cost". In addition, the report provides the earliest start and finish, the latest start and finish, and three floats - total, free, and independent. Exact definitions of these quantities can be found in "Definitions".

b) Event List
The second part of every schedule report contains a detail line for each event. A detail line is prepared for each event giving its earliest and latest occurrence times.

c) Critical Activities
The third part of every schedule contains a detail line for each critical activity. Since such activities have zero float values are not printed. The other information that appeared for these critical activities under "activity List" is repeated here for convenience.

All output is to be listed with a special 407 Panel Board (diagram in Appendix A) or the "FORGO" panel board.

V. Miscellaneous Details

a) Constraints on Project Size
Number of activities (LL) $\leq$ 50
Number of events (N) $\leq$ 50

These restrictions are due to the dimension statements. The size may be increased somewhat with no overlap or if Disk File is available the number can easily be increased.

b) Program Stops

Only one stop besides the ones at the end of each program is provided. It appears in Program I on the typewriter as

ERROR - CORE 3

STOP

If this error occurs, or any other irregularity, first check the input data as the error will usually be found here.

c) Scaling of Input Data

J. E. Kelley's algorithm is an "integer" algorithm. Hence, to assure convergence, it is necessary to scale input data. To be safe, activity costs as described under III - c, should be kept less than 10^5 in magnitude. Should they be larger, we would suggest a change of cost units (e.g., substitute "Thousands of Dollars" for "Dollars").

d) Event Numbering

The events of the project network must be numbered such that the "head" of an activity arrow has a larger event number than its "tail".

e) Accuracy

Since the algorithm is an "integer" algorithm some errors occur due to truncation. These errors should be expected and in relation to the total should be small.

VI. Definitions

a) General Definitions

1. Total Float for activity (I,J) is defined to be the latest occurrence of event J minus the sum of the earliest occurrence of event I and the duration of activity (I,J).

2. Free Float for activity (I,J) is defined as the earliest occurrence for event J minus the sum of the earliest occurrence of event I and the duration of activity (I,J).

3. Independent Float for activity (I,J) is defined to be the earliest occurrence of event J minus the sum of the latest occurrence of event I and the duration of activity (I,J).

b) Definitions of Variables used in the FORTRAN Programs.

1. N: Number of events in the project network.

2. LL: Number of activities in the project network.

3. B: The total fixed, direct cost for a schedule.

4. IK: The number of a schedule (IK = 0,1,2,...,MIK)

5. IA1(L): The preceding event number of the Lth activity.

6. IA2(L): The succeeding event number of the Lth activity.

7. A4(L): Absolute value of slope of time - cost curve of activity "L"

8. A8 (L): "Crash" time for activity "L".

9. A9 (L): "Normal" time for activity "L".

10. A10(L): Duration of activity "L".

VII. Operating Instructions

First clear the computer by pressing

INSTANT STOP
RESET
INSERT

Type on the typewriter 160001000000
Then press the R-S button on the typewriter or RELEASE, START on the computer,

Wait about 15 seconds then press

INSTANT STOP
RESET

Set I/O, Parity switches to stop; overflow to program.
Place Program Deck I, Subroutine Deck* and Input Data for Program I in the 1622 Read Hopper.

Press LOAD on the 1622 and PUNCH START on the 1622.

When the typewriter types "LOAD SUBROUTINES", press START on the 1620.

When the typewriter types "ENTER DATA", press START on the 1620.

When the "READER NO FEED" light on the 1620 lights, press READER START on the 1622.

*If the last card of Program I is numbered 807 in columns 78, 79, 80, the Subroutines are not in the program and must be added separately.

When Program I is finished, the typewriter will type "END OF PROGRAM 1, LOAD PROGRAM 2, AND DATA IN PROPER ORDER - STOP".

Remove the blank cards from the Punch Hopper, press NON PROCESS RUNOUT on the 1622, remove the 2 blank cards from the end of the deck and then take the last card from this deck and place it on the front of the deck. Place the header card in front of this card. This is now the input data to Program II.

Clear the computer again as directed before.

Place Program Deck II, Subroutine Deck* and Input Data for Program II in the 1622 Read Hopper.

Press LOAD and PUNCH START on the 1622.

When the typewriter types "LOAD SUBROUTINES", press START on the 1620.

When the typewriter types "ENTER DATA", press START on the 1620.

When the "READER NO FEED" light on the 1620 lights, press READER START on the 1622.

When Program II is finished, the typewriter will type "STOP".

Remove the blank cards from the Punch Hopper, press NON PROCESS RUNOUT on the 1622, remove the 2 blank cards from the end of the deck. This is the final output ready for listing on the 407 Printer with special panel (see Appendix A).

VIII. Equipment Required

1620 computer (60 K memory)
1622 card Reader - Punch
407 Printer
Fortran II Compiler - 1620 - FO - 019 Version 1

*If the last card of Program II is numbered 717 in columns 78, 79, 80, the Subroutines are not in the program and must be added separately.

Appendix A

Panel Wiring:
This panel is to be used to list the output from Program II. The FORGO panel can also be used if the wire to the overflow (upper left section) is removed, this controls the printing of the student number, page number and the data at the top of each page.

This panel is controled by characters in column 1 and performs in the following way.

Column 1	407 Control
blank	Normal operation
c	Print a C in column 1.
+	No space before printing.
0 (zero)	Double space before printing.
I	Shift columns 25-72 of card to column 73-120 of sheet.
1-5	Skip to channels 1-5 on the 407 carriage control tape
J-n	Short skip to channels 1-5 of the 407 carriage control.

All other characters cause some combination of the above operations.

Carriage Control Tape:
This tape should be punched as follows:

Column	Punch
2	1-5
16	4
22	3
33	2,4
44	3
49	4
62	12
68	1-5
82	4
88	3
99	2,4
110	3
116	4
123	12

The tape should be 132 columns long.

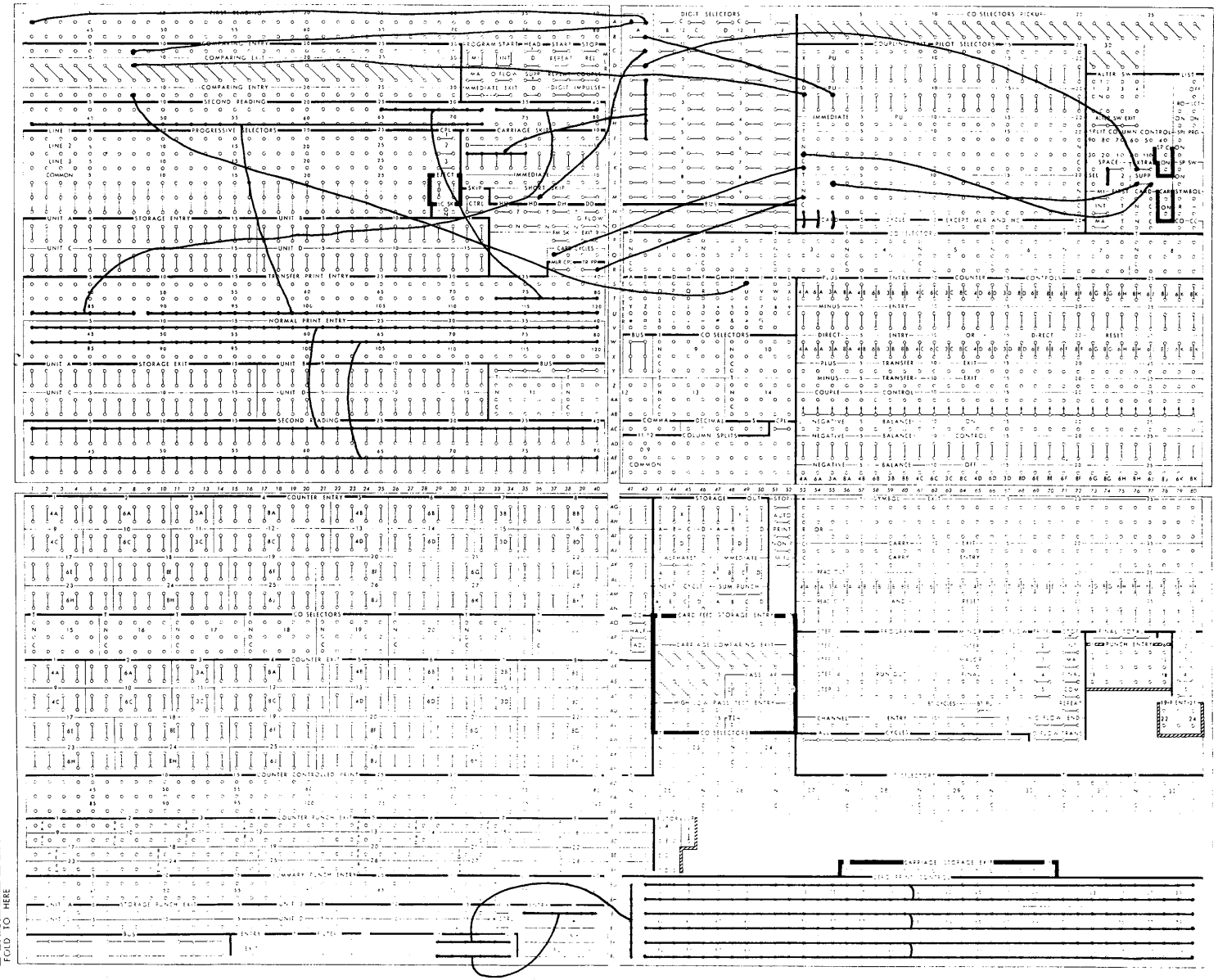
IBM

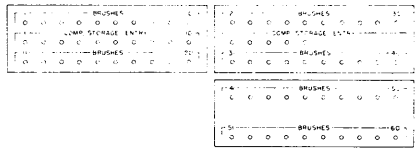
INTERNATIONAL BUSINESS MACHINES CORPORATION

Form X24-6421.0
Printed in U.S.A.

IBM 407, 408, 409 ACCOUNTING MACHINES, CONTROL PANEL DIAGRAM

FIXED 408, 409 CARRIAGE CONTROL PANEL





FOLD TO HERE

REPORT PERT-LESS

L. Standlee Steenrod

DIAGRAM NO.

DATE Aug. 29, 1963

(9-61:20M-S)

Appendix B
The following are the program listings.

```
C     PROGRAM 1
      DIMENSION Z1(50),IA1(50),IA2(50),A4(50),A8(50),A9(50),IE1(50)
      DIMENSION IE2(50),A3(50)
      DIMENSION IE4(50),IA5(50),E5(50),A6(50),A7(50)
    1 FORMAT(I2)
    3 FORMAT(2I5,7A4,A2,2(F5.0,F10.0),F2.0)
    4 FORMAT(5X,I5,10(A4,A2))
    8 FORMAT(2I5,7A4,A2,2(F5.0,F10.0),F10.0)
  106 FORMAT(2(A4,A2)/6(A4,A2)/12(A4,A2)/3(A4,A2))
C     READ AND PUNCH JOB DESCRIPTION CARD
      READ 1,I9
      READ 106,(Z1(I1),I1=1,46)
      PUNCH 106,(Z1(I1),I1=1,46)
      NNA=1
      L=0
      B=0
  125 L=L+1
      READ 3,IA1(L),IA2(L),(Z1(I),I=1,8),XA1,XA2,XA3,XA4,XA5
      XA2=100.*XA2
      XA4=100.*XA4
      IF(IA2(L))173,132,132
  132 IF(XA1-XA3)148,148,133
  133 IF(XA4-XA2)148,148,155
  148 A4(L)=0.0
      Z=XA2
      GO TO 161
  155 VV=1.
      IF(XA5)146,147,146
  146 VV=-1.
  147 A4(L)=VV*(XA4-XA2)/(XA1-XA3)
      Z=XA4+A4(L)*XA3*VV
  161 B=B+Z
      A8(L)=XA3
      A9(L)=XA1
      Z=Z/1000.
      XXA1=XA1
      XXA2=XA2/100.
      XXA3=XA3
      XXA4=XA4/100.
      PUNCH 8,IA1(L),IA2(L),(Z1(I),I=1,8),XXA1,XXA2,XXA3,XXA4,Z
      IF(A4(L)-1.)75,75,231
   75 IF(A4(L))225,76,225
   76 IF(XA5)77,78,77
   77 VM=-1.
      GO TO 90
   78 VM=1.
      GO TO 90
  225 VM=ABSF(A4(L))/A4(L)
   90 IF(VM)226,228,228
  226 IF(A4(L)+1.)125,227,227
```



```
  227 A4(L)=-1.
      GO TO 125
  228 IF(A8(L)-A9(L))230,229,230
  229 A4(L)=0.0
      GO TO 125
  230 A4(L)=1.
      GO TO 125
  231 IW1=A4(L)+.5
      A4(L)=IW1
      GO TO 125
  173 LL=L-1
      N=1
  110 READ 4,IE1(N),(Z1(I),I=1,20)
      IF(IE1(N))122,113,113
  113 PUNCH 4,IE1(N),(Z1(I),I=1,20)
      N=N+1
      GO TO 110
  122 N=N-1
      I2=1
      IE4(1)=1
C     RENUMBERING  NODES
      DO 210 I3=1,LL
  206 IF(IA1(I3)-IE1(I2))207,210,207
  207 I2=I2+1
      IE4(I2)=I3
      GO TO 206
  210 IA1(I3)=I2
      I3=1
  217 DO 222 I2=1,N
  218 IF(IA2(I3)-IE1(I2))217,219,222
  219 IA2(I3)=I2
      I3=I3+1
      IF(I3-LL)218,218,223
  222 CONTINUE
  223 DO 224 I2=1,N
      E5(I2)=0.0
  224 IE1(I2)=I2
      IE4(N)=LL+1
 1500 GO TO(1505,1735,1735),I9
 1505 N0=N-1
      DO 1570 I=1,N0
      K1=IE4(I)
      K2=IE4(I+1)-1
      DO 1560 K=K1,K2
      J=IA2(K)
      X=A9(K)+E5(I)
      IF(E5(J)-X)1550,1560,1560
 1550 E5(J)=X
 1560 CONTINUE
 1570 CONTINUE
```

```
      IK=0
 1590 DO 1595 L=1,LL
      A3(L)=0.0
      IA5(L)=0.0
 1595 A6(L)=0.
      DO 1690 I=1,N0
      K1=IE4(I)
      K2=IE4(I+1)-1
      DO 1680 L=K1,K2
      J=IA2(L)
      A6(L)=A9(L)+E5(I)-E5(J)
      A7(L)=A8(L)+E5(I)-E5(J)
      IF(A7(L)) 1650,1675,1650
 1650 IF(A6(L)) 1655,1665,1655
 1655 IA5(L)=1
      GO TO 1680
 1665 IA5(L)=2
      GO TO 1680
 1675 IA5(L)=3
 1680 CONTINUE
 1690 CONTINUE
C     1735 STARTS CORE 3
      DIMENSION A90(50),A100(50),E6(50)
 1735 DO 1952 L=1,LL
      A100(L)=A9(L)
 1952 A90(L)=A9(L)
      IK=0
 2000 TC=0.
      DO 2011 J=1,LL
      IF(A4(J))2002,2007,2007
 2002 V=-1.
 2003 IF(A100(J)-A90(J))2006,2004,2004
 2004 IF(A4(J)+1.)2010,2005,2005
 2005 A90(J)=0.0
      GO TO 2011
 2006 A100(J)=A8(J)
      GO TO 2004
 2007 V=1.
      IF(A4(J)-1.)2009,2009,2010
 2009 A90(J)=0.
      GO TO 2011
 2010 A90(J)=A100(J)*A4(J)*V
      TC=TC+A90(J)
 2011 CONTINUE
      TC=B-TC
      DO 2050 I=1,N
      E5(I)=0.
 2050 E6(I)=.95E37
      NO=N-1
      DO 2100 I=1,NO
```

25


```
      K1=IE4(I)
      K2=IE4(I+1)-1
      DO 2090 K=K1,K2
      J=IA2(K)
      X=A100(K)+E5(I)
      IF(E5(J)-X)2071,2090,2090
 2071 E5(J)=X
 2090 CONTINUE
 2100 CONTINUE
      E6(N)=E5(N)
      DO 2140 I=1,NO
      I0=N-I
      K1=IE4(I0)
      K2=IE4(I0+1)-1
      DO 2130 K=K1,K2
      J=IA2(K)
      X=E6(J)-A100(K)
      IF(E6(I0)-X)2130,2111,2111
 2111 E6(I0)=X
 2130 CONTINUE
 2140 CONTINUE
      TC=TC/1000.
      X=E6(N)/10.
      PUNCH 5,IK,TC,X,B
    5 FORMAT (I4,3E12.6)
      DO 2180 J=1,LL
 2180 A90(J)=A90(J)/1000.
      PUNCH 9,(A100(I),I=1,LL)
      PUNCH 9,(A90(I),I=1,LL)
      DO 2220 I=1,NO
      K1=IE4(I)
      K2=IE4(I+1)-1
      DO 2220 L=K1,K2
      A90(L)=E5(I)
      J=IA2(L)
 2220 A100(L)=E6(J)
      PUNCH 9,(A90(I),I=1,LL)
      PUNCH 9,(A100(I),I=1,LL)
      DO 2270 I=1,NO
      K1=IE4(I)
      K2=IE4(I+1)-1
      DO 2270 L=K1,K2
      A90(L)=E6(I)
      J=IA2(L)
 2270 A100(L)=E5(J)
      DO 2278 J=1,N
      E5(J)=E5(J)/10.
 2278 E6(J)=E6(J)/10.
      PUNCH 9,(A90(I),I=1,LL)
      PUNCH 9,(A100(I),I=1,LL)
```

26

```
      PUNCH 10,(E5(I),I=1,N)
      PUNCH 10,(E6(I),I=1,N)
    9 FORMAT(8E10.4)
   10 FORMAT ( 8E10.4)
 2500 GO TO(2510,9000,2505,9000),I9
 2505 DO 2507 L=1,LL
 2507 A100(L)=A8(L)
      I9=4
      IK=IK+1
      GO TO 2000
 2510 IF(NNA-1)2514,2512,2514
 2512 IK=0
 2514 CONTINUE
 4000 DO 4005 I=2,N
 4005 IE1(I)=4
      IE2(1)=-1
      E6(1)=.95E37
      IE1(1)=2
 4030 NO=N-1
      DO 4175 I=1,NO
      ISW=IE1(I)
      GO TO(4175,4050,4175,4175),ISW
 4050 K1=IE4(I)
      K2=IE4(I+1)-1
      DO 4160 K=K1,K2
      KSW=IA5(K)
      GO TO(4160,4075,4100),KSW
 4075 IF(A4(K))4076,4078,4078
 4076 Z=-A4(K)
      GO TO 4079
 4078 Z=A4(K)
 4079 IF(A3(K)-Z)4080,4160,4160
 4080 Z=Z-A3(K)
      IF(E6(I)-Z)4081,4082,4082
 4081 ERS=E6(I)
      GO TO 4105
 4082 ERS=Z
      GO TO 4105
 4100 ERS=E6(I)
 4105 J3=IA2(K)
      J3SW=IE1(J3)
      GO TO(4160,4160,4120,4135),J3SW
 4120 PRINT 4125
 4125 FORMAT (13H ERROR-CORE 3)
      STOP 3
 4135 IE1(J3)=2
      E6(J3)=ERS
      IE2(J3)=I
      IF(J3-N)4160,5000,4160
 4160 CONTINUE
```



```
      IE1(I)=1
 4175 CONTINUE
      LBSW=1
      DO 4340 I=1,NO
      ISW=IE1(I)
      GO TO(4340,4120,4120,4215),ISW
 4215 K1=IE4(I)
      K2=IE4(I+1)-1
      DO 4325 K=K1,K2
      KSW=IA5(K)
      GO TO(4325,4235,4253),KSW
 4235 IF(A3(K))4325,4325,4240
 4240 UC=A3(K)
      GO TO 4265
 4253 Z=A4(K)
 4254 IF(A3(K)-Z)4325,4325,4255
 4255 UC=A3(K)-Z
 4265 J3=IA2(K)
      J3SW=IE1(J3)
      GO TO(4295,4120,4120,4325),J3SW
 4295 IF(E6(I)-UC)4296,4296,4297
 4297 E6(I)=UC
 4296 IE2(I)=-J3
      IE1(I)=2
      LBSW=2
      GO TO 4340
 4325 CONTINUE
      IE1(I)=3
 4340 CONTINUE
      IE1(N)=3
      GO TO(6000,4355),LBSW
 4355 DO 4395 I=1,N
      LSW=IE1(I)
      GO TO(4395,4395,4385,4120),LSW
 4385 IE1(I)=4
 4395 CONTINUE
      GO TO 4030
 5000 IF(E6(N)-.9E37)5005,9000,9000
 5005 IF(E6(N))4120,5010,5010
 5010 IF(IE2(N))4120,5014,5014
 5014 J0=N
 5015 IF(IE2(J0))5020,5045,5045
 5020 Z=-1.
      J1=-IE2(J0)
      I0=J0
      J0=J1
      GO TO 5060
 5045 Z=1.
      J1=IE2(J0)
      I0=J1
```

```
5060 K1=IE4(I0)
     K2=IE4(I0+1)-1
     DO 5095 L=K1,K2
     IF(IA2(L)-J0)5095,5080,5095
5080 A3(L)=A3(L)+Z*E6(N)
     J0=J1
     IF(J0-1)5015,4000,5015
5095 CONTINUE
6000 IK=IK+1
     MMA=2
6005 Q1=.95E37
     Q2=.95E37
     Q3=.95E37
6010 DO 6086 I=1,NO
     K1=IE4(I)
     K2=IE4(I+1)-1
     KSW1=IE1(I)
6020 DO 6085 K=K1,K2
     J=IA2(K)
     KSW2=IE1(J)
6030 GO TO (6031,6031,6034,6034),KSW1
6031 GO TO (6085,6085,6040,6040),KSW2
6034 GO TO (6035,6035,6085,6085),KSW2
6035 IF(A6(K))6085,6085,6037
6037 IF(Q2-A6(K))6085,6085,6043
6043 Q2=A6(K)
     GO TO 6085
6040 IF(A6(K))6060,6070,6070
6060 X=-A6(K)
     IF(Q1-X)6085,6085,6062
6062 Q1=X
     GO TO 6085
6070 IF(A7(K))6080,6085,6085
6080 X=-A7(K)
     IF(Q3-X)6085,6085,6082
6082 Q3=X
6085 CONTINUE
6086 CONTINUE
     IF(Q1-Q2)6091,6091,6092
6091 IF(Q1-Q3)6093,6093,6095
6092 IF(Q2-Q3)6094,6095,6095
6093 Q4=Q1
     GO TO 6089
6094 Q4=Q2
     GO TO 6089
6095 Q4=Q3
6089 DO 6162 I=1,NO
     K1=IE4(I)
     K2=IE4(I+1)-1
     KSW1=IE1(I)
```



```
6090 DO 6161 K=K1,K2
     J=IA2(K)
     KSW2=IE1(J)
6100 GO TO (6101,6101,6104,6104),KSW1
6101 GO TO (6110,6110,6103,6103),KSW2
6103 A6(K)=A6(K)+Q4
     A7(K)=A7(K)+Q4
     GO TO 6110
6104 GO TO (6106,6106,6110,6110),KSW2
6106 A6(K)=A6(K)-Q4
     A7(K)=A7(K)-Q4
6110 IF(A7(K))6130,6159,6130
6130 IF(A6(K))6150,6155,6150
6150 IA5(K)=1
     GO TO 6161
6155 IA5(K)=2
     GO TO 6161
6159 IA5(K)=3
6161 CONTINUE
6162 CONTINUE
     DO 6201 K=1,LL
     A90(K)=A9(K)
     IF (A6(K)) 6171,6171,6172
6171 A100(K)=A9(K)
     GO TO 6201
6172 A100(K)=A9(K)-A6(K)
6201 CONTINUE
6230 GO TO 2000
9000 MIK=IK
     IF(I9-4)9002,9001,9001
9001 I9=3
9002 PUNCH 6451,N,LL,MIK,I9
     PRINT 6450
6450 FORMAT(58HEND OF PROGRAM 1, LOAD PROGRAM 2, AND DATA IN PROPER ORD
    1ER)
6451 FORMAT(3I5,I2)
9008 STOP
     END
```

```
C      PROGRAM 2
       DIMENSION Z1(50),A100(50),CHECK(50)
       DIMENSION Z3(8),Z2(20),SMLC(50),SMLTI(50),CAPTJ(50),CAPTI(50)
       DIMENSION SMLTX(50),XXA4(50),XXA6(50),KKK(50),ZZ2(20,50)
       DIMENSION KK(50),MM(50),ZZ3(8,50),XXA1(50),XXA2(50),XXA3(50)
       DIMENSION A100A(50),COSTA(50),SMLTIA(50)
       DIMENSION CAPTJA(50)
       DIMENSION IKB(50),TCB(50),EEB(50),MCOUNA(50)
       READ  103,KE,KD,IR,INDIR,DT,DC
  103  FORMAT(4I5,2F10.1)
       IF(KE-4) 105, 310, 310
  105  READ  106,N,LL,MIK,I9
  106  FORMAT(3I5,I2)
       READ  26,(Z1(I1),I1=1,46)
   26  FORMAT(2(A4,A2)/6(A4,A2)/12(A4,A2)/3(A4,A2))
       DO  114 I2=1,LL
  114  READ 8,KK(I2),MM(I2),(ZZ3(I1,I2),I1=1,8),XXA1(I2),XXA2(I2),XXA3(I2
      1),XXA4(I2),XXA6(I2)
       DO  118 I3=1,N
  118  READ 4,KKK(I3),(ZZ2(I1,I3),I1=1,20)
    8  FORMAT(2I5,7A4,A2,2(F5.0,F10.0),F10.0)
    4  FORMAT(5X,I5,10(A4,A2))
       KSW2=1
       KCOUNT=0
       KSW1=KE
       READ 5,IK,TC,EE,B
    5  FORMAT(I4,3E12.6)
       K0=0
       J1=42
       T2=EE
       JCOUNT=0
       T3=EE
       ARG1=0.0
       TC2=TC
       TC3=TC
       NOPGE=1
       JHEAD=1
  146  NCOUNT=0
       NHEAD=1
       N1=42
    9  FORMAT(8E10.4)
       READ 9,(A100(I1),I1=1,LL)
       READ 9,(SMLC(I1),I1=1,LL)
       READ 9,(SMLTI(I1),I1=1,LL)
       READ 9,(CAPTJ(I1),I1=1,LL)
       READ 9,(CAPTI(I1),I1=1,LL)
       READ 9,(SMLTX(I1),I1=1,LL)
  154  MCOUNT=0
       DO  204 ILL=1,LL
  158  IF(NCOUNT) 184, 159, 184
```



```
  159  PUNCH  160,NOPGE
  160  FORMAT(1H1,45X,26HA C T I V I T Y    L I S T/1HI,23X,37X,4HPAGE,I6
      1)
       NOPGE=NOPGE+1
       IF(NHEAD) 163, 178, 163
  163  NHEAD=0
       PUNCH  165,(Z1(I1),I1=5,16),(Z1(I1),I1=1,4)
  165  FORMAT(13H0 DIVISION - ,6(A4,A2),5X,2(A4,A2))
       PUNCH  167,(Z1(I1),I1=17,40)
  167  FORMAT(18H  PROJECT TITLE - ,9(A4,A2)/1HI,23X,3(A4,A2))
       PUNCH  169,Z1(41),Z1(42)
  169  FORMAT(14H0 TIME UNIT - ,A4,A2)
       PUNCH  171,(Z1(I1),I1=43,46),IK
  171  FORMAT(14H  COST UNIT - ,2(A4,A2),46X/1HI,37X,8HSCHEDULE,12X,I6)
       PUNCH  173,TC
  173  FORMAT(/1HI,23X,14X,11HDIRECT COST,F15.1)
       PUNCH  175,LL,EE
  175  FORMAT(19H  ACTIVITY COUNT - ,I5,48X/1HI,23X,14X,8HDURATION,F18.1)
       PUNCH  177,N
  177  FORMAT(19H  EVENT COUNT -    ,I5/////)
  178  PUNCH  179
  179  FORMAT(12H0PREC. SUCC.,47X,13HDIRECT    EAR/1HI,23X,5HLIEST,9X,6HL
      1ATEST,15X,5HFLOAT)
       PUNCH  182
  182  FORMAT(12H EVENT EVENT,7X,11HDESCRIPTION,15X,8HDURATION,6X,13HCOST
      1   START /1HI,23X,48H- FINISH  START - FINISH  TOTAL    FREE   IND
      2EP.///)
  184  IF(NCOUNT-N1) 188, 185, 185
  185  NCOUNT=0
       N1=55
       GO TO  189
  188  NCOUNT=NCOUNT+1
  189  K=KK(ILL)
       M=MM(ILL)
       DO  36 I1=1,8
   36  Z3(I1)=ZZ3(I1,ILL)
       XA1=XXA1(ILL)
       XA2=XXA2(ILL)
       XA3=XXA3(ILL)
       XA4=XXA4(ILL)
       XA6=XXA6(ILL)
       COST=XA6-SMLC(ILL)
       EF=SMLTI(ILL)+A100(ILL)
       SL=CAPTJ(ILL)-A100(ILL)
       TF=CAPTJ(ILL)-SMLTI(ILL)-A100(ILL)
       FF=SMLTX(ILL)-SMLTI(ILL)-A100(ILL)
       ARG2=SMLTX(ILL)-CAPTI(ILL)-A100(ILL)
       IF(ARG1-ARG2) 092, 093, 093
  092  FI=ARG2
       GO TO  094
```

```
093 FI=ARG1
094 X=TF
    EF=EF/10.
    SL=SL/10.
    TF=TF/10.
    FF=FF/10.
    SMLTX(ILL)=SMLTX(ILL)/10.
    CAPTI(ILL)=CAPTI(ILL)/10.
    CAPTJ(ILL)=CAPTJ(ILL)/10.
    A100(ILL)=A100(ILL)/10.
    SMLTI(ILL)=SMLTI(ILL)/10.
    FI=FI/10.
    PUNCH  199,K,M,(Z3(I1),I1=1,8),A100(ILL),COST,SMLTI(ILL),EF,SL,CAP
   1TJ(ILL),TF,FF,FI
199 FORMAT(1X,I5,I6,1X,7A4,A2,F10.1,F11.1,F8.1/1HI,23X,6F8.1)
200 IF(X) 201, 201, 204
201 MCOUNT=MCOUNT+1
    CHECK(MCOUNT)=ILL
    A100A(MCOUNT)=A100(ILL)
    COSTA(MCOUNT)=COST
    SMLTIA(MCOUNT)=SMLTI(ILL)
    CAPTJA(MCOUNT)=CAPTJ(ILL)
204 CONTINUE
    N1=42
    NCOUNT=0
    NHEAD=1
    READ 9,(A100(I1),I1=1,N)
    READ 9,(SMLC(I1),I1=1,N)
    DO  233 INN=1,N
    IF(NCOUNT) 227, 210, 227
210 PUNCH  211,NOPGE
211 FORMAT(1H1,49X,20HE V E N T    L I S T,2X/1HI,23X,37X,4HPAGE,I6)
    NOPGE=NOPGE+1
    IF(NHEAD) 213, 222, 213
213 NHEAD=0
    PUNCH  165,(Z1(I1),I1=5,16),(Z1(I1),I1=1,4)
    PUNCH  167,(Z1(I1),I1=17,40)
    PUNCH  169,Z1(41),Z1(42)
    PUNCH  171,(Z1(I1),I1=43,46),IK
    PUNCH  173,TC
    PUNCH  175,LL,EE
    PUNCH  177,N
222 PUNCH  223
223 FORMAT(1HO,71X/1HI,23X,5X8HEARLIEST,9X,6HLATEST)
    PUNCH  225
225 FORMAT(7H  EVENT,27X,11HDESCRIPTION,27X/1HI,23X,4X10HOCCURRENCE,6X
   1,10HOCCURRENCE//)
227 IF(NCOUNT-N1) 231, 228, 228
228 NCOUNT=0
    N1=55
```



```
    GO TO  232
231 NCOUNT=NCOUNT+1
232 K=KKK(INN)
    DO   46 I1=1,20
 46 Z2(I1)=ZZ2(I1,INN)
233 PUNCH  234,K,(Z2(I1),I1=1,20),A100(INN),SMLC(INN)
234 FORMAT(1X,I6,2X,10(A4,A2),3X/1HI,23X,F13.1,F16.1)
240 NCOUNT=0
    N1=42
    NHEAD=1
    IF(MCOUNT) 273, 273, 243
243 DO  272 IM=1,MCOUNT
    IF(MCOUNT) 265, 245, 265
245 PUNCH  246,NOPGE
246 FORMAT(1H1,40X,31HC R I T I C A L    A C T I V I /1HI,23X,7HT I E
   1S,30X,4HPAGE,I6)
    NOPGE=NOPGE+1
    IF(NHEAD) 250, 258, 250
250 NHEAD=0
    PUNCH  165,(Z1(I1),I1=5,16),(Z1(I1),I1=1,4)
    PUNCH  167,(Z1(I1),I1=17,40)
    PUNCH  169,Z1(41),Z1(42)
    PUNCH  171,(Z1(I1),I1=43,46),IK
    PUNCH  173,TC
    PUNCH  175,LL,EE
    PUNCH  177,N
258 PUNCH  259
259 FORMAT(70X,2HEA/1HI,23X,23HRL. START   LAT. FINISH)
    PUNCH  261
261 FORMAT(12H PREC. SUCC.,50X,10HDIRECT    /1HI,23X,21HTIME FOR     T
   1IME FOR)
    PUNCH  263
263 FORMAT(12H EVENT EVENT,9X,11HDESCRIPTION,16X,8HDURATION,7X,4HCOST,
   15X/1HI,23X,21HACTIVITY     ACTIVITY//)
265 IF(NCOUNT-N1) 269, 266, 266
266 NCOUNT=0
    N1=55
    GO TO  270
269 NCOUNT=NCOUNT+1
270 J2=CHECK(IM)
    K=KK(J2)
    M=MM(J2)
    DO   56 I1=1,8
 56 Z3(I1)=ZZ3(I1,J2)
    XYZ=A100A(IM)
    COST=COSTA(IM)
    YZX=SMLTIA(IM)
    ZXY=CAPTJA(IM)
272 PUNCH  303,K,M,(Z3(I1),I1=1,8),XYZ,COST,YZX,ZXY
303 FORMAT(1X,I5,I6,3X,7A4,A2,2F12.1,F11.1/1HI,23X,8X,F14.1)
```

```
    GO TO( 273, 310, 271),I9
271 I9=2
    READ 5,IK,TC,EE,B
    GO TO  146
273 KCOUNT=KCOUNT+1
    IKB(KCOUNT)=IK
    TCB(KCOUNT)=TC
    EEB(KCOUNT)=EE
    MCOUNA(KCOUNT)=MCOUNT
274 IF(KSW2-1) 276, 316, 276
276 DO  308 I2=1,KCOUNT
    IF(JCOUNT) 369, 278, 369
278 PUNCH  279,NOPGE
279 FORMAT(1H1,41X,30HT I M E -- C O S T    F U N C /1HI,23X,7HT I O N
   1,30X,4HPAGE,I6)
    NOPGE=NOPGE+1
    IF(JHEAD) 283, 293, 283
283 JHEAD=0
    PUNCH  165,(Z1(I1),I1=5,16),(Z1(I1),I1=1,4)
    PUNCH  167,(Z1(I1),I1=17,40)
    PUNCH  169,Z1(41),Z1(42)
    PUNCH  288,(Z1(I1),I1=43,46)
288 FORMAT(14H  COST UNIT - ,2(A4,A2))
    PUNCH  290,LL
290 FORMAT(1H0,18H ACTIVITY COUNT - ,I6)
    PUNCH  292,N
292 FORMAT(19H  EVENT COUNT -    ,I6/////)
293 PUNCH  294
294 FORMAT(15X,7HOPTIMAL)
    PUNCH  296
296 FORMAT(72H  SCHEDULE      DIRECT        PROJECT   CRITICAL       IN
   1DIRECT          T/1HI,23X,4HOTAL)
    PUNCH  299
299 FORMAT(76H   NUMBER         COST       DURATION  ACTIVITIES
   1COST             COST//)
369 IF(JCOUNT-J1) 373, 370, 370
370 JCOUNT=0
    J1=55
    GO TO  301
373 JCOUNT=JCOUNT+1
301 IK=IKB(I2)
    TC=TCB(I2)
    EE=EEB(I2)
    MCOUNT=MCOUNA(I2)
306 COSTIN=0.0
307 TOTCOS=TC+COSTIN
308 PUNCH  309,IK,TC,EE,MCOUNT,COSTIN,TOTCOS
309 FORMAT(1X,I7,2F14.1,I9,4X,2F14.1)
310 PUNCH 66
 66 FORMAT(1H0,10HEND OF JOB)
```



```
    GO TO  999
316 READ 5,IK,TC,EE,B
324 IF(MIK-IK) 325, 325, 333
325 KSW2=2
    GO TO  146
333 GO TO( 334, 354, 362),KSW1
334 K1=K0+KD
    IF(IK-K1) 338, 336, 338
336 K0=IK
    GO TO  146
338 READ 9,(A100(I1),I1=1,LL)
    READ 9,(SMLC(I1),I1=1,LL)
    READ 9,(SMLTI(I1),I1=1,LL)
    READ 9,(CAPTJ(I1),I1=1,LL)
    READ 9,(CAPTI(I1),I1=1,LL)
    READ 9,(SMLTX(I1),I1=1,LL)
    READ 9,(SMLTX(I1),I1=1,N)
    READ 9,(SMLTX(I1),I1=1,N)
    MCOUNT=0
    DO  351 I2=1,LL
    TF=CAPTJ(I2)-SMLTI(I2)-A100(I2)
    IF(TF) 351, 350, 351
350 MCOUNT=MCOUNT+1
351 CONTINUE
    GO TO  273
354 T21=T2-DT
    IF(EE-T21) 356, 356, 358
356 T2=EE
    TC21=TC2+DC
    IF(TC-TC21) 146, 357, 357
357 TC2=TC
    GO TO  146
358 TC21=TC2+DC
    IF(TC-TC21) 338, 360, 360
360 TC2=TC
    GO TO  146
362 T31=T3-DT
    TC31=TC3+DC
    IF(EE-T31) 365, 365, 338
365 IF(TC-TC31) 338, 366, 366
366 T3=EE
    TC3=TC
    GO TO  146
999 STOP
    END
```

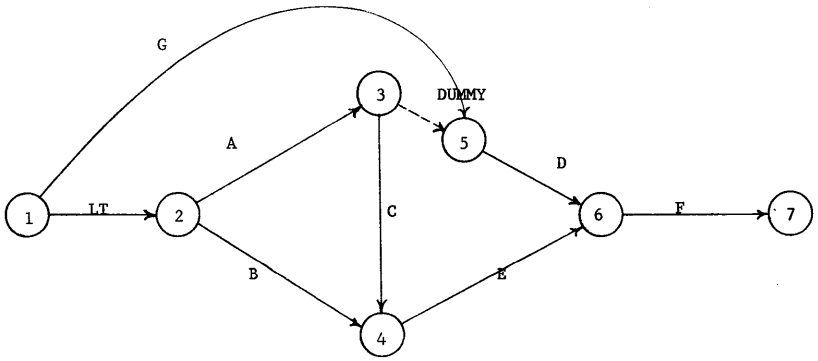
Appendix C

The following is a sample problem and its results.

Input for program I

```
+1
17 JULY 63
COURSE CE 453
CONSTRUCTION PROJECT NETWORK
DAYS  DOLLARS
    1    2 LEAD TIME                00          00    00          00
    1    5    G                     40          00    10         500 1
    2    3    A                     80       24000    20       60000
    2    4    B                     80       40000    40       72000
    3    4    C                     60       17000    30       29000
    3    5 DUMMY                    00          00    00          00
    4    6    E                     50       15000    10       51000
    5    6    D                     90       27000    70       33000
    6    7    F                    140       28000   140       28000
  -100
       1 START
       2
       3
       4
       5
       6
       7 FINISH
  -100
```


SAMPLE PROJECT



Input for program II in its proper order.

```
    1    1
    7    9    4 1
17 JULY 63
COURSE CE 453
CONSTRUCTION PROJECT NETWORK
DAYS  DOLLARS
    1    2 LEAD TIME                          0.       0.   0.       0.       0.
    1    5    G                              40.       0.  10.     500.      66.
    2    3    A                              80.   24000.  20.   60000.    7200.
    2    4    B                              80.   40000.  40.   72000.   10400.
    3    4    C                              60.   17000.  30.   29000.    4100.
    3    5 DUMMY                             0.       0.   0.       0.       0.
    4    6    E                              50.   15000.  10.   51000.    6000.
    5    6    D                              90.   27000.  70.   33000.    5400.
    6    7    F                             140.   28000. 140.   28000.    2800.
         1 START
         2
         3
         4
         5
         6
         7 FINISH
  0 .151000E+05 .330000E+02 .359666E+08
.0000E-99 .4000E+02 .8000E+02 .8000E+02 .6000E+02 .0000E-99 .5000E+02 .9000E+02
.1400E+03
.0000E-99 .6666E+02 .4800E+04 .6400E+04 .2400E+04 .0000E-99 .4500E+04 .2700E+04
.0000E-99
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .8000E+02 .8000E+02 .1400E+03 .8000E+02
.1900E+03
.0000E-99 .1000E+03 .8000E+02 .1400E+03 .1400E+03 .1000E+03 .1900E+03 .1900E+03
.3300E+03
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .8000E+02 .8000E+02 .1400E+03 .1000E+03
.1900E+03
.0000E-99 .8000E+02 .8000E+02 .1400E+03 .1400E+03 .8000E+02 .1900E+03 .1900E+03
.3300E+03
.0000E-99 .0000E-99 .8000E+01 .1400E+02 .8000E+01 .1900E+02 .3300E+02
.0000E-99 .0000E-99 .8000E+01 .1400E+02 .1000E+02 .1900E+02 .3300E+02
  1 .159000E+05 .310000E+02 .359666E+08
.0000E-99 .4000E+02 .8000E+02 .8000E+02 .4000E+02 .0000E-99 .5000E+02 .9000E+02
.1400E+03
.0000E-99 .6666E+02 .4800E+04 .6400E+04 .1600E+04 .0000E-99 .4500E+04 .2700E+04
.0000E-99
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .8000E+02 .8000E+02 .1200E+03 .8000E+02
.1700E+03
.0000E-99 .8000E+02 .8000E+02 .1200E+03 .1200E+03 .8000E+02 .1700E+03 .1700E+03
.3100E+03
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .8000E+02 .8000E+02 .1200E+03 .8000E+02
.1700E+03
.0000E-99 .8000E+02 .8000E+02 .1200E+03 .1200E+03 .8000E+02 .1700E+03 .1700E+03
.3100E+03
```



```
.0000E-99 .0000E-99 .8000E+01 .1200E+02 .8000E+01 .1700E+02 .3100E+02
.0000E-99 .0000E-99 .8000E+01 .1200E+02 .8000E+01 .1700E+02 .3100E+02
  2 .183000E+05 .270000E+02 .359666E+08
.0000E-99 .4000E+02 .4000E+02 .8000E+02 .4000E+02 .0000E-99 .5000E+02 .9000E+02
.1400E+03
.0000E-99 .6666E+02 .2400E+04 .6400E+04 .1600E+04 .0000E-99 .4500E+04 .2700E+04
.0000E-99
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .4000E+02 .4000E+02 .8000E+02 .4000E+02
.1300E+03
.0000E-99 .4000E+02 .4000E+02 .8000E+02 .8000E+02 .4000E+02 .1300E+03 .1300E+03
.2700E+03
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .4000E+02 .4000E+02 .8000E+02 .4000E+02
.1300E+03
.0000E-99 .4000E+02 .4000E+02 .8000E+02 .8000E+02 .4000E+02 .1300E+03 .1300E+03
.2700E+03
.0000E-99 .0000E-99 .4000E+01 .8000E+01 .4000E+01 .1300E+02 .2700E+02
.0000E-99 .0000E-99 .4000E+01 .8000E+01 .4000E+01 .1300E+02 .2700E+02
  3 .205500E+05 .250000E+02 .359666E+08
.0000E-99 .1000E+02 .2000E+02 .8000E+02 .6000E+02 .0000E-99 .3000E+02 .9000E+02
.1400E+03
.0000E-99 .1666E+02 .1200E+04 .6400E+04 .2400E+04 .0000E-99 .2700E+04 .2700E+04
.0000E-99
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .2000E+02 .2000E+02 .8000E+02 .2000E+02
.1100E+03
.0000E-99 .2000E+02 .2000E+02 .8000E+02 .8000E+02 .2000E+02 .1100E+03 .1100E+03
.2500E+03
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .2000E+02 .2000E+02 .8000E+02 .2000E+02
.1100E+03
.0000E-99 .2000E+02 .2000E+02 .8000E+02 .8000E+02 .2000E+02 .1100E+03 .1100E+03
.2500E+03
.0000E-99 .0000E-99 .2000E+01 .8000E+01 .2000E+01 .1100E+02 .2500E+02
.0000E-99 .0000E-99 .2000E+01 .8000E+01 .2000E+01 .1100E+02 .2500E+02
  4 .229500E+05 .230000E+02 .359666E+08
.0000E-99 .1000E+02 .2000E+02 .8000E+02 .6000E+02 .0000E-99 .1000E+02 .7000E+02
.1400E+03
.0000E-99 .1666E+02 .1200E+04 .6400E+04 .2400E+04 .0000E-99 .9000E+03 .2100E+04
.0000E-99
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .2000E+02 .2000E+02 .8000E+02 .2000E+02
.9000E+02
.0000E-99 .2000E+02 .2000E+02 .8000E+02 .8000E+02 .2000E+02 .9000E+02 .9000E+02
.2300E+03
.0000E-99 .0000E-99 .0000E-99 .0000E-99 .2000E+02 .2000E+02 .8000E+02 .2000E+02
.9000E+02
.0000E-99 .2000E+02 .2000E+02 .8000E+02 .8000E+02 .2000E+02 .9000E+02 .9000E+02
.2300E+03
.0000E-99 .0000E-99 .2000E+01 .8000E+01 .2000E+01 .9000E+01 .2300E+02
.0000E-99 .0000E-99 .2000E+01 .8000E+01 .2000E+01 .9000E+01 .2300E+02
```

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE 0
DIRECT COST 15100.0
DURATION 33.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT	FREE FLOAT	INDEP.
1	2	LEAD TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	G	4.0	-.6	0.0	4.0	6.0	10.0	6.0	4.0	4.0
2	3	A	8.0	2400.0	0.0	8.0	0.0	8.0	0.0	0.0	0.0
2	4	B	8.0	4000.0	0.0	8.0	6.0	14.0	6.0	6.0	6.0
3	4	C	6.0	1700.0	8.0	14.0	8.0	14.0	0.0	0.0	0.0
3	5	DUMMY	0.0	0.0	8.0	8.0	10.0	10.0	2.0	0.0	0.0
4	6	E	5.0	1500.0	14.0	19.0	14.0	19.0	0.0	0.0	0.0
5	6	D	9.0	2700.0	8.0	17.0	10.0	19.0	2.0	2.0	0.0
6	7	F	14.0	2800.0	19.0	33.0	19.0	33.0	0.0	0.0	0.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE 0
DIRECT COST 15100.0
DURATION 33.0

EVENT	DESCRIPTION	EARLIEST OCCURRENCE	LATEST OCCURRENCE
1	START	0.0	0.0
2		0.0	0.0
3		8.0	8.0
4		14.0	14.0
5		8.0	10.0
6		19.0	19.0
7	FINISH	33.0	33.0

DIVISION - COURSE CE 453
17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	0
DIRECT COST	15100.0
DURATION	33.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARL. START TIME FOR ACTIVITY	LAT. FINISH TIME FOR ACTIVITY
1	2	LEAD TIME	0.0	0.0	0.0	0.0
2	3	A	8.0	2400.0	0.0	8.0
3	4	C	6.0	1700.0	8.0	14.0
4	6	E	5.0	1500.0	14.0	19.0
6	7	F	14.0	2800.0	19.0	33.0

DIVISION - COURSE CE 453
17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	1
DIRECT COST	15900.0
DURATION	31.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT	FREE FLOAT	INDEP.
1	2	LEAD TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	G	4.0	-.6	0.0	4.0	4.0	8.0	4.0	4.0	4.0
2	3	A	8.0	2400.0	0.0	8.0	0.0	8.0	0.0	0.0	0.0
2	4	B	8.0	4000.0	0.0	8.0	4.0	12.0	4.0	4.0	4.0
3	4	C	4.0	2500.0	8.0	12.0	8.0	12.0	0.0	0.0	0.0
3	5	DUMMY	0.0	0.0	8.0	8.0	8.0	8.0	0.0	0.0	0.0
4	6	E	5.0	1500.0	12.0	17.0	12.0	17.0	0.0	0.0	0.0
5	6	D	9.0	2700.0	8.0	17.0	8.0	17.0	0.0	0.0	0.0
6	7	F	14.0	2800.0	17.0	31.0	17.0	31.0	0.0	0.0	0.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	1
DIRECT COST	15900.0
DURATION	31.0

EVENT	DESCRIPTION	EARLIEST OCCURRENCE	LATEST OCCURRENCE
1	START	0.0	0.0
2		0.0	0.0
3		8.0	8.0
4		12.0	12.0
5		8.0	8.0
6		17.0	17.0
7	FINISH	31.0	31.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	1
DIRECT COST	15900.0
DURATION	31.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARL. START TIME FOR ACTIVITY	LAT. FINISH TIME FOR ACTIVITY
1	2	LEAD TIME	0.0	0.0	0.0	0.0
2	3	A	8.0	2400.0	0.0	8.0
3	4	C	4.0	2500.0	8.0	12.0
3	5	DUMMY	0.0	0.0	8.0	8.0
4	6	E	5.0	1500.0	12.0	17.0
5	6	D	9.0	2700.0	8.0	17.0
6	7	F	14.0	2800.0	17.0	31.0

ACTIVITY LIST

DIVISION - COURSE CE 453
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE 2
DIRECT COST 18300.0
DURATION 27.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT	FREE FLOAT	INDEP. FLOAT
1	2	LEAD TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	G	4.0	-.6	0.0	4.0	0.0	4.0	0.0	0.0	0.0
2	3	A	4.0	4800.0	0.0	4.0	0.0	4.0	0.0	0.0	0.0
2	4	B	8.0	4000.0	0.0	8.0	0.0	8.0	0.0	0.0	0.0
3	4	C	4.0	2500.0	4.0	8.0	4.0	8.0	0.0	0.0	0.0
3	5	DUMMY	0.0	0.0	4.0	4.0	4.0	4.0	0.0	0.0	0.0
4	6	E	5.0	1500.0	8.0	13.0	8.0	13.0	0.0	0.0	0.0
5	6	D	9.0	2700.0	4.0	13.0	4.0	13.0	0.0	0.0	0.0
6	7	F	14.0	2800.0	13.0	27.0	13.0	27.0	0.0	0.0	0.0

EVENT LIST

DIVISION - COURSE CE 453
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE 2
DIRECT COST 18300.0
DURATION 27.0

EVENT	DESCRIPTION	EARLIEST OCCURRENCE	LATEST OCCURRENCE
1	START	0.0	0.0
2		0.0	0.0
3		4.0	4.0
4		8.0	8.0
5		4.0	4.0
6		13.0	13.0
7	FINISH	27.0	27.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	2
DIRECT COST	18300.0
DURATION	27.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARL. START TIME FOR ACTIVITY	LAT. FINISH TIME FOR ACTIVITY
1	2	LEAD TIME	0.0	0.0	0.0	0.0
1	5	G	4.0	-.6	0.0	4.0
2	3	A	4.0	4800.0	0.0	4.0
2	4	B	8.0	4000.0	0.0	8.0
3	4	C	4.0	2500.0	4.0	8.0
3	5	DUMMY	0.0	0.0	4.0	4.0
4	6	E	5.0	1500.0	8.0	13.0
5	6	D	9.0	2700.0	4.0	13.0
6	7	F	14.0	2800.0	13.0	27.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	3
DIRECT COST	20550.0
DURATION	25.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL	FLOAT FREE	INDEP.
1	2	LEAD TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	G	1.0	49.3	0.0	1.0	1.0	2.0	1.0	1.0	1.0
2	3	A	2.0	6000.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0
2	4	B	8.0	4000.0	0.0	8.0	0.0	8.0	0.0	0.0	0.0
3	4	C	6.0	1700.0	2.0	8.0	2.0	8.0	0.0	0.0	0.0
3	5	DUMMY	0.0	0.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0
4	6	E	3.0	3300.0	8.0	11.0	8.0	11.0	0.0	0.0	0.0
5	6	D	9.0	2700.0	2.0	11.0	2.0	11.0	0.0	0.0	0.0
6	7	F	14.0	2800.0	11.0	25.0	11.0	25.0	0.0	0.0	0.0

DIVISION - COURSE CE 453
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	3
DIRECT COST	20550.0
DURATION	25.0

EVENT	DESCRIPTION	EARLIEST OCCURRENCE	LATEST OCCURRENCE
1	START	0.0	0.0
2		0.0	0.0
3		2.0	2.0
4		8.0	8.0
5		2.0	2.0
6		11.0	11.0
7	FINISH	25.0	25.0

DIVISION - COURSE CE 453
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	3
DIRECT COST	20550.0
DURATION	25.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARL. START TIME FOR ACTIVITY	LAT. FINISH TIME FOR ACTIVITY
1	2	LEAD TIME	0.0	0.0	0.0	0.0
2	3	A	2.0	6000.0	0.0	2.0
2	4	B	8.0	4000.0	0.0	8.0
3	4	C	6.0	1700.0	2.0	8.0
3	5	DUMMY	0.0	0.0	2.0	2.0
4	6	E	3.0	3300.0	8.0	11.0
5	6	D	9.0	2700.0	2.0	11.0
6	7	F	14.0	2800.0	11.0	25.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	4
DIRECT COST	22950.0
DURATION	23.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARLIEST START	EARLIEST FINISH	LATEST START	LATEST FINISH	TOTAL FLOAT	FREE FLOAT	INDEP.
1	2	LEAD TIME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	5	G	1.0	49.3	0.0	1.0	1.0	2.0	1.0	1.0	1.0
2	3	A	2.0	6000.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0
2	4	B	8.0	4000.0	0.0	8.0	0.0	8.0	0.0	0.0	0.0
3	4	C	6.0	1700.0	2.0	8.0	2.0	8.0	0.0	0.0	0.0
3	5	DUMMY	0.0	0.0	2.0	2.0	2.0	2.0	0.0	0.0	0.0
4	6	E	1.0	5100.0	8.0	9.0	8.0	9.0	0.0	0.0	0.0
5	6	D	7.0	3300.0	2.0	9.0	2.0	9.0	0.0	0.0	0.0
6	7	F	14.0	2800.0	9.0	23.0	9.0	23.0	0.0	0.0	0.0

DIVISION - COURSE CE 453 17 JULY 63
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	4
DIRECT COST	22950.0
DURATION	23.0

EVENT	DESCRIPTION	EARLIEST OCCURRENCE	LATEST OCCURRENCE
1	START	0.0	0.0
2		0.0	0.0
3		2.0	2.0
4		8.0	8.0
5		2.0	2.0
6		9.0	9.0
7	FINISH	23.0	23.0

DIVISION - COURSE CE 453
PROJECT TITLE - CONSTRUCTION PROJECT NETWORK

17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE	4
DIRECT COST	22950.0
DURATION	23.0

PREC. EVENT	SUCC. EVENT	DESCRIPTION	DURATION	DIRECT COST	EARL. START TIME FOR ACTIVITY	LAT. FINISH TIME FOR ACTIVITY
1	2	LEAD TIME	0.0	0.0	0.0	0.0
2	3	A	2.0	6000.0	0.0	2.0
2	4	B	8.0	4000.0	0.0	8.0
3	4	C	6.0	1700.0	2.0	8.0
3	5	DUMMY	0.0	0.0	2.0	2.0
4	6	E	1.0	5100.0	8.0	9.0
5	6	D	7.0	3300.0	2.0	9.0
6	7	F	14.0	2800.0	9.0	23.0

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DIVISION - COURSE CE 453
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17 JULY 63

TIME UNIT - DAYS
COST UNIT - DOLLARS

ACTIVITY COUNT - 9
EVENT COUNT - 7

SCHEDULE NUMBER	OPTIMAL DIRECT COST	PROJECT DURATION	CRITICAL ACTIVITIES	INDIRECT COST	TOTAL COST
0	15100.0	33.0	5	0.0	15100.0
1	15900.0	31.0	7	0.0	15900.0
2	18300.0	27.0	9	0.0	18300.0
3	20550.0	25.0	8	0.0	20550.0
4	22950.0	23.0	8	0.0	22950.0

END OF JOB

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