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le of Study: THE FOUR PRINCIPAL STAGES INVOLVED IN PROJECT PLANNII

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or Field: Civil Engineering

pe of Study: A model of construction project planning is introduce and described. The model consists basically of the general planning phase, two detailed planning phases, and the evaluation phas The second phase is applied to a practical numerical example (a County Highway construction project). The Critical Path Method is used and illustrates the complexity of even a relatively simpl planning problem.

clusions: Systematic planning, record keeping, and evaluation of terminated projects should be a prime concern to every contractoı Consistency of success is a direct function of the above, since only tight but reliable estimates lead to success in the competitive market of today.

ISER'S APPROVAL: ____________________

THE FOUR PRINCIPAL STAGES INVOLVED
IN PROJECT PLANNING

By

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IN PROJECT PLANNING

Report Approved:

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llwater, Oklahoma

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CHAPTER I

INTRODUCTION

.. Planning Theory

In the literature, planning is defined in many different ways. ·ever, the following definition seems to be particularly precise an· ·ropriate: "Planning is predetermining a course of action" (1).

In most cases there are several ways in which a certain project · be executed. Planning consists of defining and analyzing all ·sible courses of action with regard to the overall result that is · achieved, and finally selecting one course of action that promises · best result. In business the highest profit is usually considere· be the most desired objective, but any other objective, e.g., spee· ·idance of pollution, etc., may be achieved through proper planning

While the principles of planning can be taught, the ability to ·n effectively is developed only through experience. However, ther· · numerous planning aids, patterns, models, and guides such as ·agement-organization charts, flow charts of responsibilities, time· ·ion networks, which can help the inexperienced as well as the ad-·ced planner to obtain better and more reliable results. This stud· ·roduces a very simple but effective planning model for a constructi· ·ration or project. It is the purpose of this report to show the ·uential progress of this planning procedure.

:. General Planning

A plan as a predetermined course of action may include several ›ps in series. Combinations of these steps can be summarized and .led stages or phases of the planning procedure. Depending upon th› ›e of enterprise, various combinations of steps may form quite dif- ·ent phases or stages.

;. Application in the Construction Industry

Within a construction company itself, the planning stages can 'fer very much, depending upon the goal to be achieved. However, f› : purpose of this report, project planning will be emphasized. Und› ›se circumstances, the four principal stages of the planning model ::

(a) general planning before bid opening

(b) detailed planning and scheduling before and after being awarded the contract

(c) planning and adaptation of plans during job execution

(d) evaluation of earlier project planning as a basis for future planning.

·. Limitations and Simplifications

(a) This study will be limited to public projects, thus involvin› : policies, regulations, and requirements of public construction wo:

(b) The communication flow within the company, especially the munication feedback, is omitted from the analysis of this planning lel. Since communications and its consequences are management pro- ›ms, it is assumed that staff and line members of the company ıcluding manager, planner, estimator, finance manager, and accounta: ꞓ represented by the same person, so that provision for communicati unimportant or unnecessary.

CHAPTER II

THE CONSTRUCTION PROJECT PLANNING MODEL

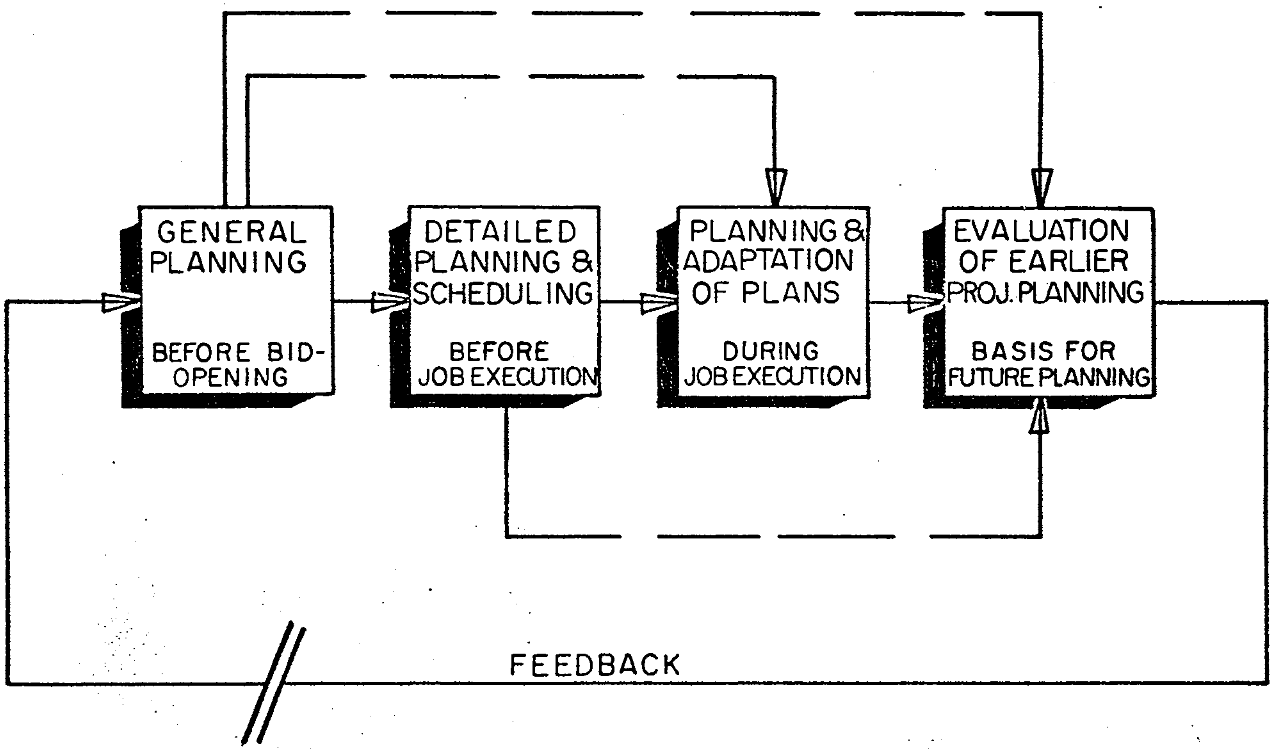

Figure 1. The Simplified Planning Model

. General Planning Before Bid Opening

A major consideration in the contractor's decision whether or not bid on a certain project will be the amount of money to be tied up ing its execution. It therefore must be one of the first concerns :he contractor to determine the funds to be used during the con- uction. These funds depend mainly upon the duration of the project kind of equipment to be used, the location of the job site, and ɔ upon the other involvements of the company (2).

If the approximate itemized work quantities are not available fro plans and specifications, a rough calculation of the quantities ha ɔe made. At the same time, a general and approximate list of con- ɹction equipment to be purchased must be assembled.

From prior experience and other information furnished by the ɔany's records, average and standard costs for certain items on ȝ carried out under similar circumstances are available. These :s, gathered from earlier jobs, will be discussed more extensively ȝection 2.4. Based on all this information, a reasonable deter- ɪtion of the approximate job cost and project duration is possible. ȝ and the evaluated equipment list provide the basis for the sub- ɪent financial and time planning. The maximum allowable duration :e often is stipulated in the specifications and represents an ɪtional constraint to the bidder.

Since the project, most probably, is only one of several jobs in preparation phase, its material resources (including financial in- ɾement) are limited by the contractor's overall policies and size ɪis total operation.

. Detailed Planning and Scheduling Before Project Execution

This stage of planning, in most cases, involves the largest amour time and effort. In certain instances it might be sufficient to ex d the general planning little or not at all and still receive rathe urate estimated values for time and costs. In the majority of case ever, it is necessary to explore detailed variations of constructic hods.

O'Brien (3) calls the average construction project a race against e. This statement implies that by reducing the duration of the prc t, the contractor's costs are usually decreased. This is only e up to a certain point, which is determined to a large extent by articular contractor's limited resources.

The detailed project planning consists of a listing of activities a logical sequence, assigning a duration to each activity. Since development of CPM, a network presentation seems to be the most ely used. For a graphical presentation, however, the bar chart is d and still provides better and easier understanding than the net- k presentation.

Depending upon the weight and importance a bidder assigns to a tain potential project, greater or fewer studies will be made. The nner and estimator have to work closely together. Parts of rations can be broken down into single activities or, in a more eral application, into series of activities, the former allowing s insight into the construction procedure (See Fig. 2).

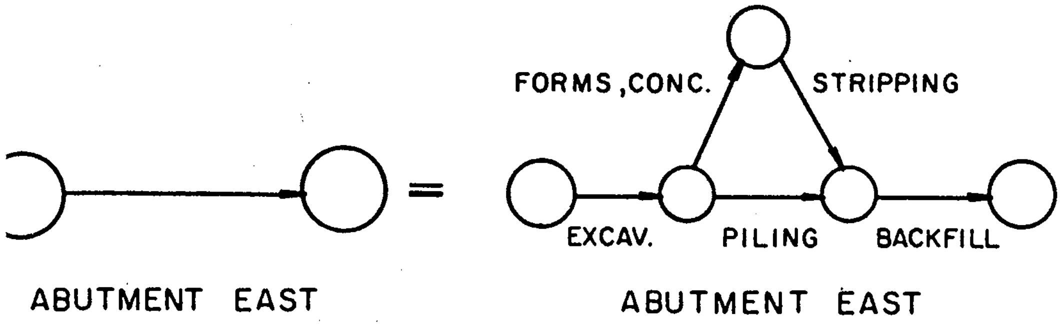

Figure 2. Activity Analysis

more detailed the planning is made the better the chance that the imated time and consequently the estimated cost of the project will respond to the actual figures. It should be empahsized that a loss the field due to neglected planning generally far exceeds the cost additional and more careful planning.

, Planning and Adaptation of Plans During Job Execution

The project manager must obtain all possible project information, ns, and specifications in order to be able to act as the planners ended. Less expensive procedures or different equipment can of rse be used, but the overall plan has to be revised accordingly.

Unexpected difficulties and delays may result in extended or anded activities. The critical and subcritical activities have to watched closely and, if delayed, the time-cost trade-off procedure can be applied to determine the least additional cost to the pro-:.

Experience shows that the communication flow between planner and ject manager very often breaks down or does not take place as ex-sively as it should. This usually leads to an unnecessary diminuti profit.

Planning, previously defined as a predetermined course of action, closely related to forecasting (1) and foreseeing. Since there is ractical limit to this process, there will always be a considerable unt of work which is not predetermined, and which must be left to discretion of the project manager. It is the responsibility of th ject manager to break down a main activity into several substeps indicated in the flow diagram of Fig 1. The time schedule of the n activity must be followed. At this point, project cost accountin to be introduced. After charging all project expenditures to the ropriate project, a breakdown into the individual items must be e. Every bill, time card, invoice, equipment list, in short, every ord concerning the project in any way should carry the item numbers is dealing with. Record-keeping and cost accounting form the basis the evaluation of plans which will be discussed in section 2.4.

Efficient and proper record-keeping is one of the most important ters to be done during the job execution. It is the best and most ropriate basis for future bidding and, serves as a control for the sent project as well. The project manager must be as much concerne ut this part of his job as he is about the successful managing of roject.

. Evaluation of Earlier Project Planning as a Basis for the Future

During construction and after a project is completed, the evalua- n process, also called analysis, must take place. Accumulated ords, if used properly, can provide exact and valuable information future planning.

Evaluation is a comparison of the estimated with the actual :eved time, cost, profit, success, goodwill, assets, etc. The .ler the deviation the more successful the plan has proven to be. ıin a certain deviation-range, prices, estimated times, failure rat equipment, etc. will represent relevant data and will be recorded filed accordingly. Under normal circumstances, this data collecti ıld be made as a matter of routine. The more interesting evaluatio those in which rather large differences between estimated and actu ıes have occurred. From experience we know that in case of a loss, evaluation is usually done more thoroughly since someone has to the blame and bear the consequences. However, it should be em-ized that the causes and reasons both for failure and success must etermined exactly and recommendations made. The more detailed the ysis, the more valid information a succeeding planner will have at disposal.

Revised plans, sketches, and rescheduled and adapted networks and/ archarts will serve the analysis well. One of the methods used is CPM or PERT cost control procedure. Groups of interrelated vities forming single work packages are re-estimated and checked nst the actual costs. This procedure applies to direct costs as as indirect costs or a combination of the two. Thus, a clear proper record keeping and file system of old jobs will contribute to the success of a contractor.

CHAPTER III

APPLICATION

l. Explanation and Description of the Project

The example project consists of 0.75 miles of County Highway ıcArthur Avenue) in a residential area of Oklahoma City. The road is crossed by U.S. Highways 66 (270) and by a one-track railroad. ıt residential streets form T intersections with the project.

The construction work to be done includes:

1. removal of old pavement, widening and compacting the road bed,
2. placing 3 layers of sand-asphalt base and 2 layers of asphaltic concrete pavement,
3. installation of concrete curb and gutter and sections of concrete median strip and sidewalks,
4. construction of the entire road drainage system, including a large connection line to a nearby ditch,
5. all traffic signals, including electric and electronic device road signs, traffic markings, etc.

A site plan of the project is shown in Figure 3. A typical surıng section and section of the drainage structure is shown in ıre 4.

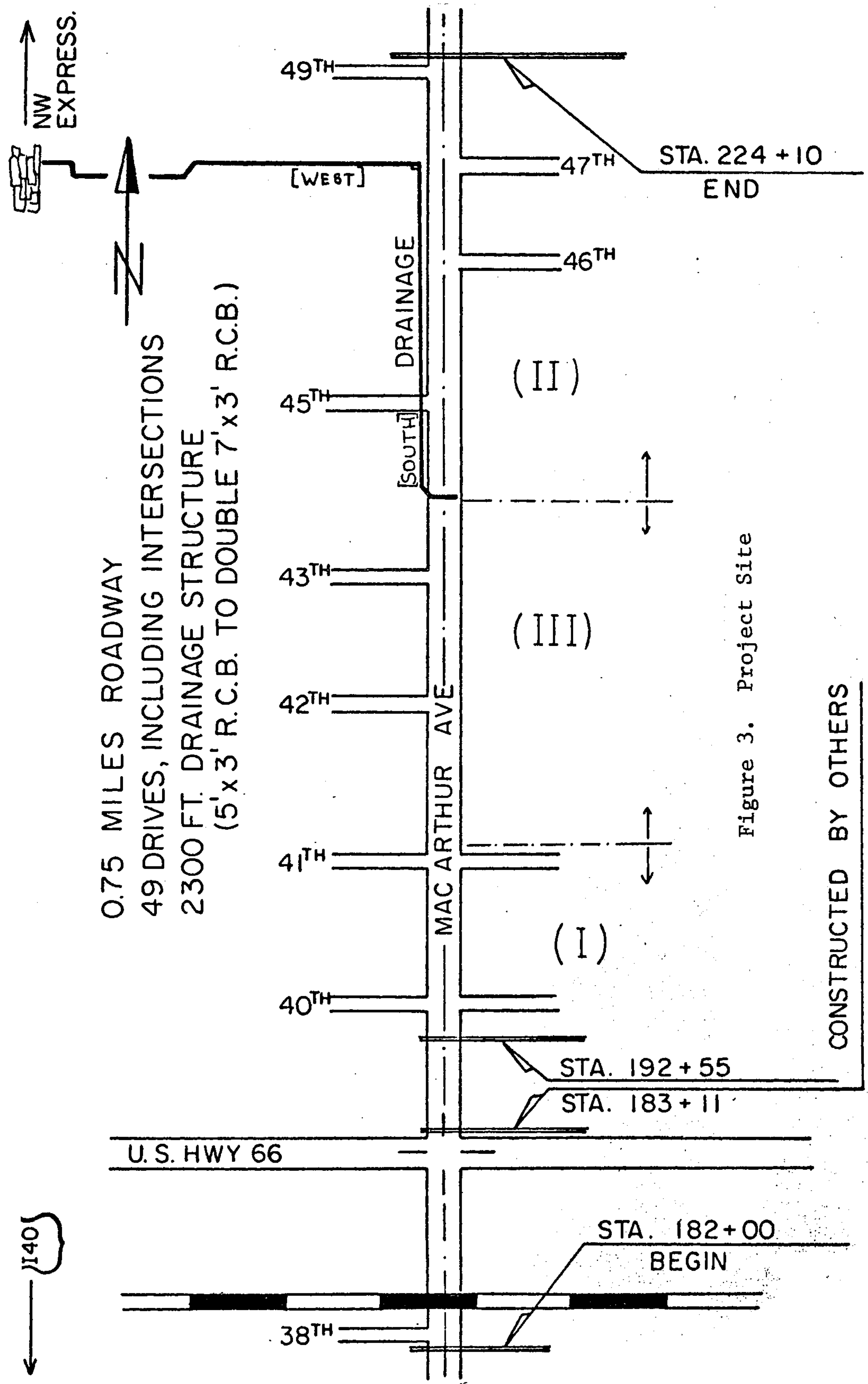

Figure 3. Project Site

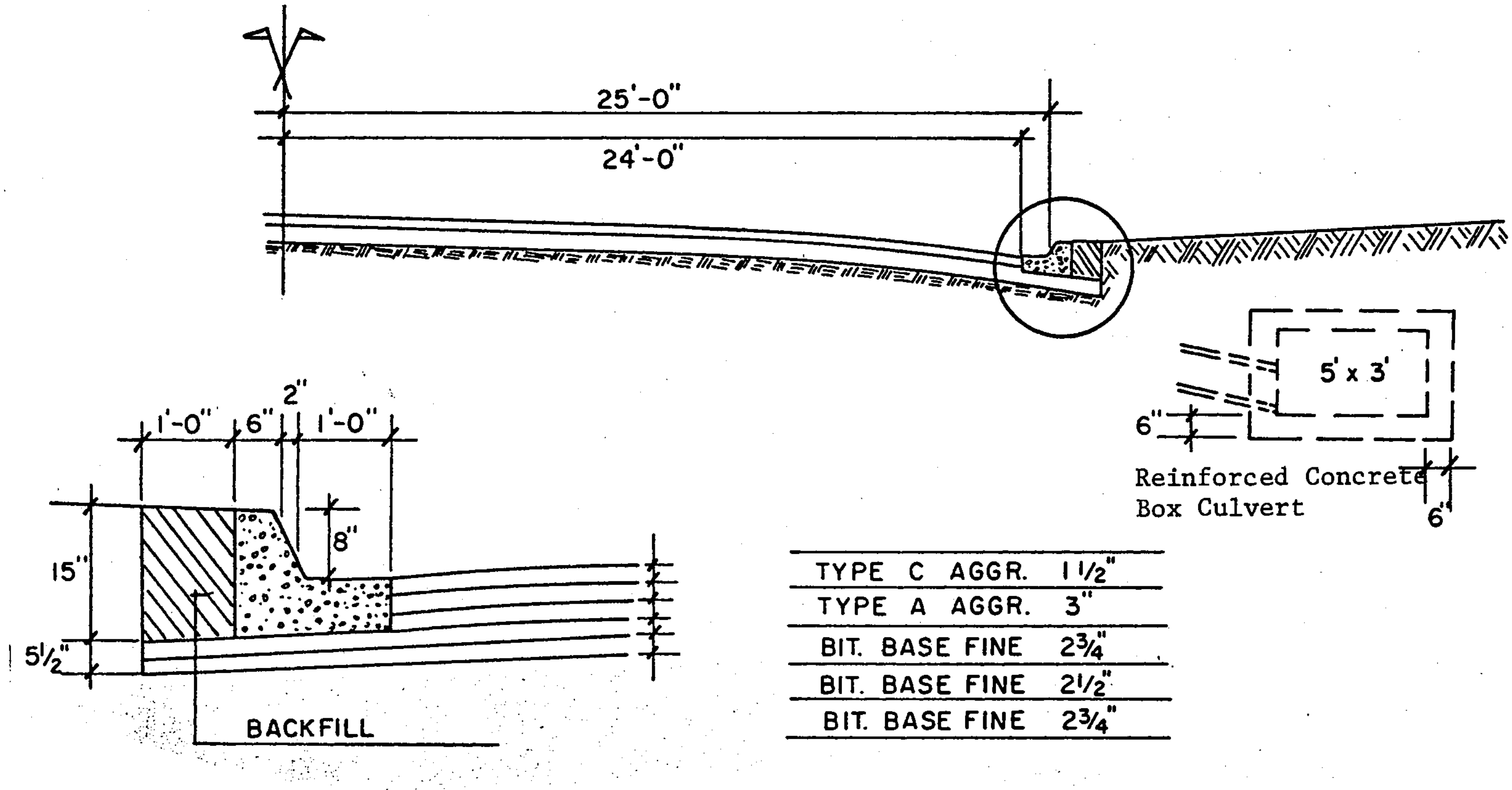

Figure 4. A Typical Road Section

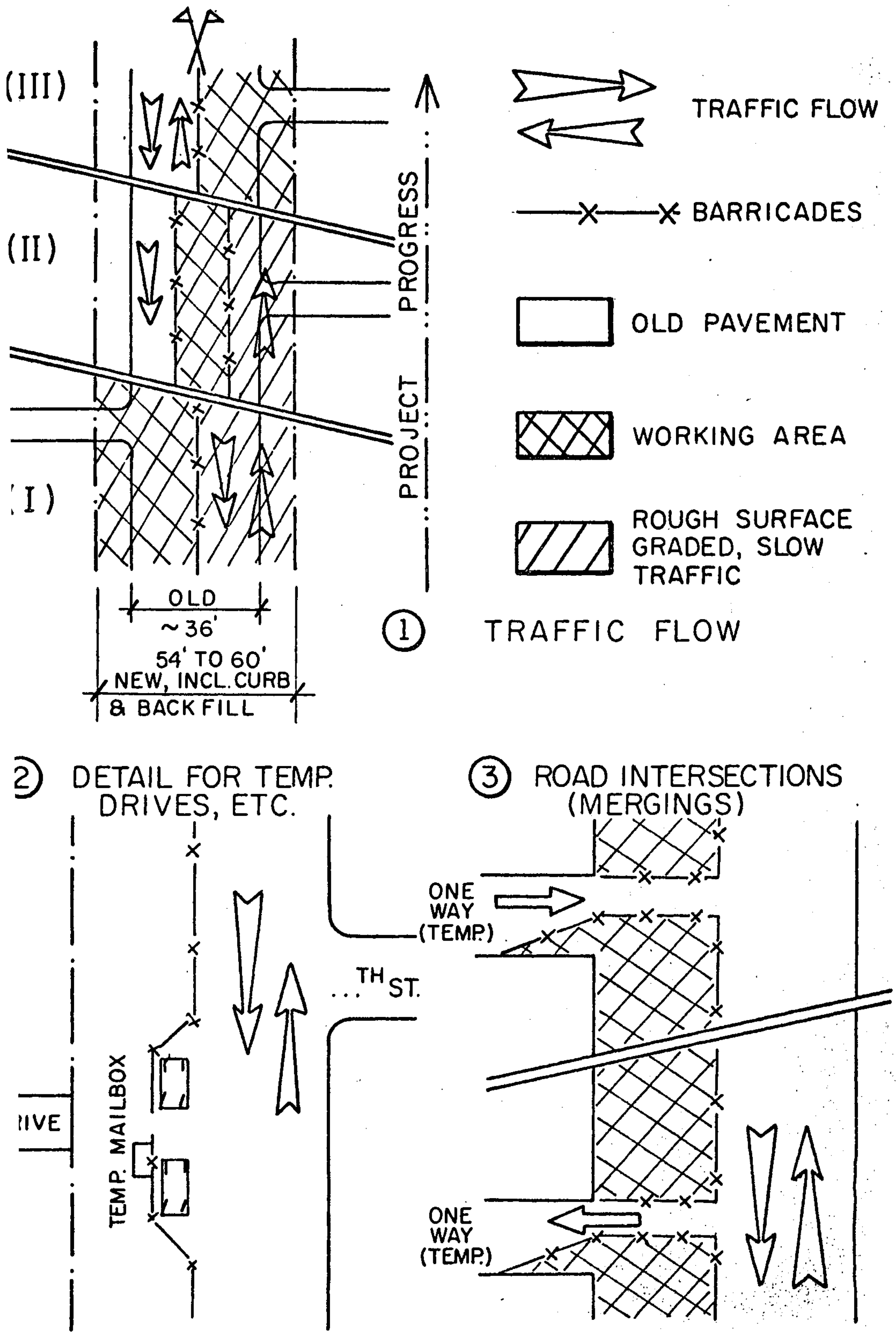

Figure 5. Diagram of Traffic Flow During Project Execution

)etailed Planning Including CPM Time Analysis and Cost Estimation

:ng Considerations

.. The entire paving, road signalization and electrical installa-
rill be subcontracted. Within a certain range, the scheduling
ese subprojects will be assumed to be at the prime contractor's
ience.

!. The weather conditions will presumably be optimal since the
rill be accomplished during Summer and Fall.

}. The job-site happens to be very close to the contractor's
office. This allows frequent inspections by contractor's staff
:s. Labor, equipment, and material will be supplied from the
ma City area.

;. Considering the actual traffic conditions and State Highway
:ications as well as the relations with the residents in the area,
dations for local traffic through the project must be planned
mounced well in advance. A schematic description of the proposed
.c flow during the project execution is shown in Figure 5.

'k Logic and Time Analysis

'he network logic presented in Figure 6 and Table I is the result
:ing into account conventional highway and concrete construction
.s, the above considerations, and the detailed project plans. The
.dual estimated activity durations are based on the author's ex-
ice.

. computer program was developed*, having network logic and

.cknowledgements

DESCRIPTION OF ACTIVITIES
SEE NEXT PAGE

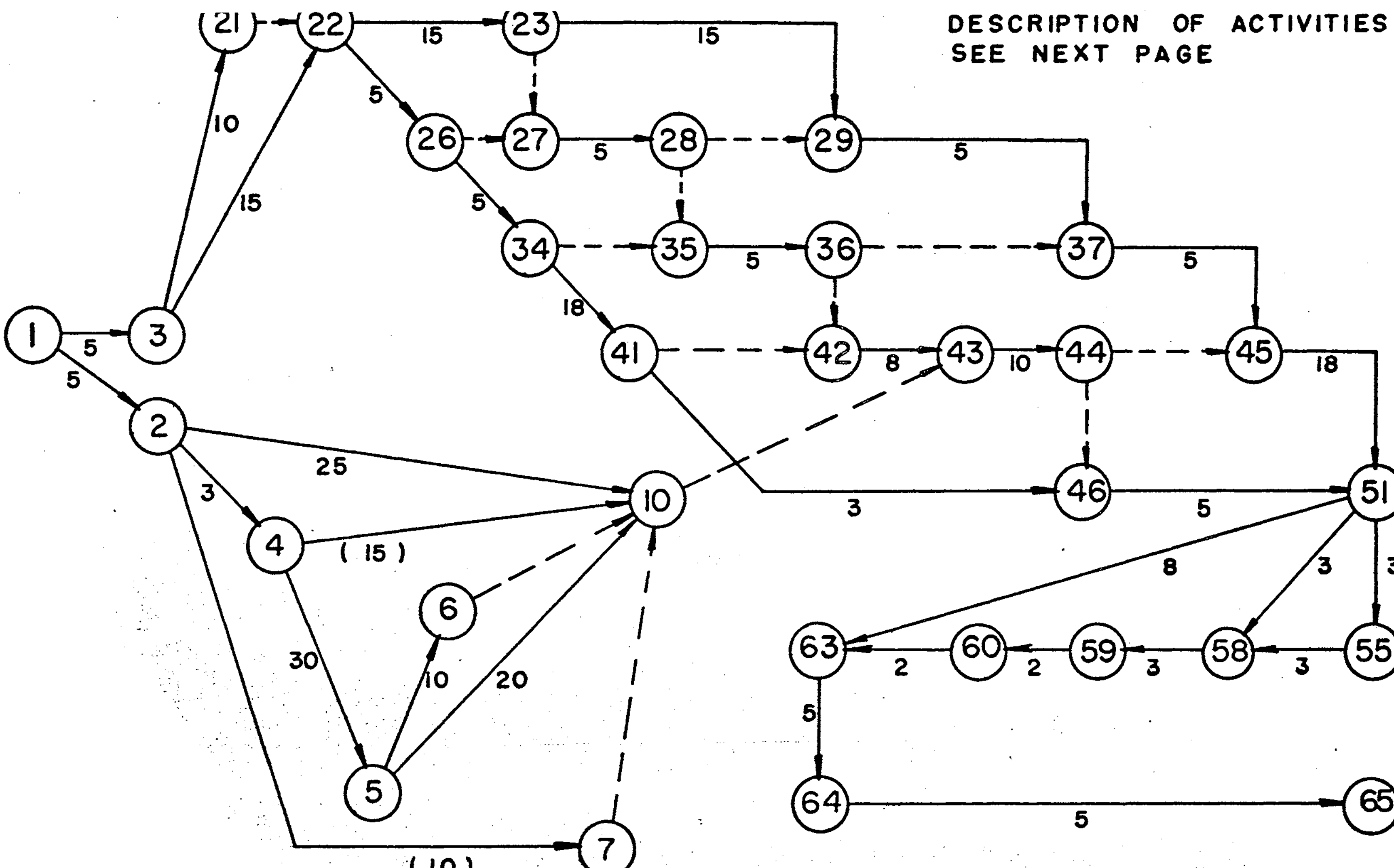

Figure 6. Network Logic

TABLE I

ACTIVITY DESCRIPTION

.vity	Description
2	Move In (Drainage)
3	Move In (Roadway)
4	Excavation (Drainage West, 300 c.y.)
10	Excavation (Drainage West, remainder; Drainage South)
5	Drainage, Line West
10	Drainage, Line South
10	Storm Sewer Inlets East and Reinforced Concrete Pipe
6	Storm Sewer Inlets West
7	Backfill
21	Lane Change U.S. Highway 66
22	Pavement Removal, Compacting, Enlarging (Location I)
23	Pavement Removal, Compacting, Enlarging (Location II)
29	Pavement Removal, Compacting, Enlarging (Location III)
26	Base Course 1 (Location I)
28	Base Course 1 (Location II)
37	Base Course 1 (Location III)
34	Base Course 2 (Location I)
36	Base Course 2 (Location II)
45	Base Course 2 (Location III)
41	Curb, Gutter, Drives (Location I)
43	Curb, Gutter, Drives (Location II East)
44	Curb, Gutter, Drives (Location II West)
51	Curb, Gutter, Drives (Location III)
46	Base Course 3 (Location I)
51	Base Course 3 (Location II)
55	Base Course 3 (Location III)
58	Electrical Installation for Signalization
63	Road Signs and Signalisation
58	Surface Course 1 (East)
59	Surface Course 1 (West)
60	Surface Course 2 (East)
63	Surface Course 2 (West)
64	Clean Up, Removal of Barricades
65	Move Out

Activity Duration

Activity Duration; step by step; concurre
with drainage

For Locations See Figures 3 and 4

TABLE II

CPM SCHEDULE

CPM SCHEDULE 48 ACTIVITIES COMPLETION DATE IS DAY 109

I	J	DURATION	EARLY START	LATE START	EARLY FINISH	LATE FINISH	TOTAL SLACK	FREE SLACK
1	2	5	0	0	5	5	0	0
1	3	5	0	0	5	7	2	0
2	4	3	5	5	8	8	0	0
2	7	10	5	5	15	58	43	0
2	10	25	5	5	58	58	28	28
3	21	10	5	7	15	22	7	0
3	22	15	5	7	20	22	2	0
4	5	30	8	8	38	38	0	0
4	10	15	8	8	58	58	35	35
5	6	10	38	38	48	58	10	0
5	10	20	38	38	58	58	0	0
6	10	0	48	58	58	58	10	10
7	10	0	15	58	58	58	43	43
10	43	0	58	58	58	58	0	0
21	22	0	15	22	20	22	7	5
22	23	15	20	22	35	40	5	0
22	26	5	20	22	25	27	2	0
23	27	0	35	40	35	40	5	0
23	29	15	35	40	50	58	8	0
26	27	0	25	27	35	40	15	10
26	34	5	25	27	30	32	2	0
27	28	5	35	40	40	45	5	0
28	29	0	40	45	50	58	18	10
28	35	0	40	45	40	45	5	0
29	37	5	50	58	55	63	8	0
34	35	0	30	32	40	45	15	10
34	41	18	30	32	48	50	2	0
35	36	5	40	45	45	50	5	0
36	37	0	45	50	55	63	18	10
36	42	0	45	50	48	50	5	3
37	45	5	55	63	68	68	8	8
41	42	0	48	50	48	50	2	0
41	46	3	48	50	68	81	30	17
42	43	8	48	50	58	58	2	2
43	44	10	58	58	68	68	0	0
44	45	0	68	68	68	68	0	0
44	46	0	68	68	68	81	13	0
45	51	18	68	68	86	86	0	0
46	51	5	68	81	86	86	13	13
51	55	3	86	86	89	89	0	0
51	58	3	86	86	92	92	3	3
51	63	8	86	86	99	99	5	5
55	58	3	89	89	92	92	0	0
58	59	3	92	92	95	95	0	0
59	60	2	95	95	97	97	0	0
60	63	2	97	97	99	99	0	0
63	64	5	99	99	104	104	0	0
64	65	5	104	104	109	109	0	0

:iated activity duration as input; earliest and latest possible : and finish time as output (Table II). The Fortran IV program :esented in the Appendix. Both network and schedule serve as a ; for further analysis which might result in changes of activity :ions and/or activity sequence. If plenty of time is available əen this planning phase and the letting, and if the contractor ;ns great importance to this potential project, the plan should əconsidered by other planners, revised and improved if possible.

Estimation

At this point, the detailed cost estimation should be carried out. contractors might decide to do without the detailed cost estima- claiming that their cost records furnish accurate enough informa- for the present project. In such a case, the detailed computation be substituted by the cost approximation, usually gathered in the 'al planning phase as pointed out in section 2.1.

It is beyond the scope of this report to show the detailed ıation which would include the determination of itemized labor-, ment-, material-, supply-, and overhead cost. Since the project nsideration does not show extraordinary difficulties or abnormal mstances, the cost approximation will suffice, providing that 'ork quantities are determined as accurately as possible. These ities have been calculated from the Engineers detailed plans.

The cost figures shown in Table III are extracted from the records Oklahoma City contractor. They represent this particular con- or's average item costs and include all direct costs as well as head and profit margin. The subcontract items and costs are not n in detail but are entered as lump sums.

TABLE III

Total Bid Cost

#	Unit	Quantity	Cost/U	Cost
Asphalt Paving, 5 courses	---	---	---	120,068
Road Signalization & Installation	---	---	---	5,819
Traffic Signs & Lane Marking	---	---	---	1,596
Unclassified Excavation	c.y.	16,820	1.00	16,820
Removal of Concrete Pavement	s.y.	4,600	1.00	4,600
Removal of Asphalt Pavement	s.y.	10,450	0.80	8,360
5" H.E.S. Concrete Paving	s.y.	430	6.50	2,795
Class "A" Concrete	c.y.	1,860	69.50	129,270
Reinforced Steel	lb.	238,400	0.13	30,992
4" Concrete Sidewalk	s.y.	140	5.00	700
1'-8" Curb and Gutter	l.f.	9,175	2.80	25,690
Concrete Header Curbing (12"x18")	l.f.	100	2.80	280
Integral Curb (6")	l.f.	180	1.00	180
5" Concrete Driveway (H.E.S.)	s.y.	580	6.20	3,596
5" Concrete Dividing Strip	s.y.	240	6.20	1,488
Manhole Frame and Cover	ea.	2	100.00	200
Inlet Brick Masonry	c.f.	350	4.10	1,435
Special Inlet Curb	l.f.	200	6.20	1,240
Inlet Frame and Grate	ea.	27	95.00	2,565
Heavy Steel Grate	lb.	11,000	0.70	7,700
18" Reinforced Concrete Pipe	l.f.	90	10.50	945
24" Reinforced Concrete Pipe	l.f.	90	11.50	1,035
Perforated Pipe Underdrain	l.f.	300	3.00	900
Non-Perforated Pipe Underdrain	l.f.	180	2.50	450
Underdrain Cover Material	c.y.	165	5.00	825
Office and Lab	ea.	1	600.00	600
	Total Bid			$370,149

Subcontract Items

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

The key to successful bidding and planning is experience. It is act the principal reliable source of information on which planning estimating is based. But to be authentic and unambiguous, ex- ence has to be carefully documented. Recordkeeping and the ful and exact interpretation of records is the only means of ing on experience. If handled by line members only, preparation dequate records very often slows down activities and interferes the current work. However, one or more staff members devoting r full time to evaluation of records and preparing recommendations instructions for future planning represents an ideal solution to problem. Frequent meetings of these staff members and the company' ect managers, close teamwork, and an exchange of ideas are essentia the success of the current and all subsequent projects.

Conclusions

It should be understood that an effective evaluation team of staff ers can provide very exact figures for future planning and bidding ost types of construction work, thus reducing the contractor's risk nprofitable operation. This again brings advantages to the project

:s because profit margins can be reduced, or at least made more
›rm within different types of construction work. In public con-
:tion, this may help save the taxpayer's money.

Despite the fact that the evaluation team represents a considerabl
ıt of non-productive work, the author believes that the consistent
ıcial success of a construction company depends substantially
ıis group.

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APPENDIX

NOMENCLATURE

	Critical Path Method
	Project Evaluation and Review Technique

COMPUTER NOTATION

	Start of activity
	End of activity
Start	Earliest possible activity start time
Start	Latest allowable activity start time
Finish	Earliest possible activity finish time
Finish	Latest allowable activity finish time
Slack	Amount of time that activity completion time can be delayed without affecting the earliest start of any activity on the critical path
Slack	Amount of time that activity completion time can be delayed without affecting the earliest start of any activity
cal Path	Path with zero slack. Any delay on the critical path will cause a delay of the project completion

COMPUTER PROGRAM

80/80 LIST PAGE 001

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00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

$JOB    PROJ.NO.,SS,TIME    USER'S NAME
      DIMENSION I(1000),J(1000),ID(1000),IS(1000),LS(1000),ISLK(1000),
     1 IFSLK(1000),IEF(1000),ILS(1000),IXJ(1000),JXI(1000)
C
C READ DATA
C
      READ(5,99) N
   99 FORMAT(I5)
      DO1 K=1,N
      READ(5,2)I(K),J(K),ID(K)
    2 FORMAT(3I5)
    1 CONTINUE
C
C INITIALIZE ARRAYS
C
      DO 3 K=1,N
      IXJ (K) = 0
      JXI (K) = 0
      II=I(K)
      IS(II)=0
      LL=J(K)
      IS(LL)=0
      LS(II)=1000000
    3 LS(LL)=1000000
C
C     FORWARD PASS
C
      DO4 K=1,N
      JN=J(K)
      IN=I(K)
      IE=IS(IN)+ID(K)
      IF(IE.GT.IS(JN)) IS(JN)=IE
    4 CONTINUE
      JN=J(N)
      LS(JN)=IS(JN)
C
C   BACKWARD PASS
C
      DO5 KK=1,N
      K=N-KK+1
      JN=J(K)
      IN=I(K)
      IE=LS(JN)-ID(K)
      IF(IE.LE.LS(IN))    LS(IN)=IE
    5 CONTINUE
C
C      FIND TOTAL SLACK, FREE SLACK
C
      DO6 K=1,N
      IN=I(K)
      JN=J(K)
      IFSLK(K) = IS(JN) - IS(IN) - ID(K)
    6 ISLK(K)=LS(JN)-IS(IN)-ID(K)
C
C     SET UP TABLE OF CROSSREFERENCES
```

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00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

C
      DO 21 K=2,N
      DO 20 KK = 1,N
      IF (I(K).NE.J(KK)) GO TO 20
      IXJ (K) = KK
      GO TO 21
   20 CONTINUE
   21 CONTINUE
      DO 31 K = 1,N
      DO 30 KK = 1,N
      IF (J(K).NE.I(KK)) GO TO 30
      JXI (K) = KK
      GO TO 31
   30 CONTINUE
   31 CONTINUE
C
C     FIND LATE START
C
      KI = I(1)
      DO 40 K = 1,N
      IF (IXJ(K)) 35,36,35
   35 ISUSUB  = IXJ (K)
      ISUB = J(ISUSUB)
      ILS (K) = LS (ISUB)
      GO TO 40
   36 ILS (K) = IS(KI)
   40 CONTINUE
C
C     FIND EARLY FINISH
C
      JN = J(N)
      DO 50 K = 1,N
      IF (JXI(K))41, 45, 41
   41 ISUSUB  = JXI (K)
      ISUB = I(ISUSUB)
      IEF (K) = IS (ISUB)
      GO TO 50
   45 IEF (K) = LS (JN)
   50 CONTINUE
C
C     WRITE OUT RESULTS
C
      IN=J(N)
      WRITE(6,7)  N,IS(IN)
    7 FORMAT('1','CPM SCHEDULE    ',I3,' ACTIVITIES     COMPLETION DATE
     1IS DAY ',I3,//)
      WRITE(6,10)
   10 FORMAT (19X,'EARLY  LATE  EARLY   LATE   TOTAL  FREE')
      WRITE (6,12)
   12 FORMAT (3X,'I     J DURATION START  START FINISH FINISH  SLACK  SLA
     1CK',/)
      DO9 K=1,N
      KI=I(K)
      KJ=J(K)
      WRITE(6,8) I(K),J(K),ID(K),IS(KI),ILS(K), IEF(K), LS(KJ),ISLK(K),
```

```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
12345678901234567890123456789012345678901234567890123456789012345678901234567890

     1 IFSLK(K)
    8 FORMAT (1X,I3, I5, I6, I8, 5I7)
    9 CONTINUE
      WRITE (6,11)
   11 FORMAT ('1','    ')
      STOP
      END
```

INPUT DATA

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```
00000000011111111112222222222333333333344444444445555555555666666666677777777778
23456789012345678901234567890123456789012345678901234567890123456789012345678900

  48
  01    02    05
  01    03    05
  02    04    03
  02    07    10
  02    10    25
  03    21    10
  03    22    15
  04    05    30
  04    10    15
  05    06    10
  05    10    20
  06    10    00
  07    10    00
  10    43    00
  21    22    00
  22    23    15
  22    26    05
  23    27    00
  23    29    15
  26    27    00
  26    34    05
  27    28    05
  28    29    00
  28    35    00
  29    37    05
  34    35    00
  34    41    18
  35    36    05
  36    37    00
  36    42    00
  37    45    05
  41    42    00
  41    46    03
  42    43    08
  43    44    10
  44    45    00
  44    46    00
  45    51    18
  46    51    05
  51    55    03
  51    58    03
  51    63    08
  55    58    03
  58    59    03
  59    60    02
  60    63    02
  63    64    05
  64    65    05
```

VITA

Peter Rudolf Benz

Candidate for the Degree of

Master of Science

t: THE FOUR PRINCIPAL STAGES INVOLVED IN PROJECT PLANNING

Field: Civil Engineering

aphical:

Personal Data: Born December 15, 1939, in Thalwil, Zurich, Switzerland, the son of Mr. and Mrs. Jacques Benz-Heer.

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