A SYSTEMATIC DEMAND LEVELING PROCEDURE FOR CPM

By

MAX WADE HAMPTON

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1964

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF BUSINESS ADMINISTRATION
August, 1965

A SYSTEMATIC DEMAND LEVELING

PROCEDURE FOR CPM

Research Report Approved:

Research Report Adviser

Dean of the Graduate School

PREFACE

A project is a specific undertaking which will be performed only one time. Hence, it is required that a different schedule and control scheme be formulated for each one. In 1958, the critical path method (CPM) for planning and controlling project schedules was introduced. In CPM, a project is broken down into the basic work units or activities which comprise the total project. By explicitly specifying the nature of the interrelationships between these component activities, it is possible to develop a formal method for management planning and control.

With the introduction of CPM has come the necessity to deal with the solution of several very difficult associated problems. The resource leveling problem is one of these. This paper is concerned with the problem of leveling, or smoothing, the demand for input over the life of a project.

Indebtedness is acknowledged to Dr. W. W. Thompson, Oklahoma State University, without whose aid this paper could not have been prepared.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Statement of the Problem

Since its introduction in 1958, the critical path method (CPM) of planning, scheduling, and controlling projects has received rapid acceptance throughout industry.[1] It has been very difficult to simplify and standardize the original theory into a simple, workable body of principles which could be universally applied to project management. However, acceptable solutions have been found to all of the original difficulties except the one involving the leveling of resource demands.

The resource demand leveling problem involves an attempt to reduce the fluctuation in the demand for a resource over the life of the project. Originally CPM was not concerned with this problem. It was assumed that unlimited resources were available and that there was no cost associated with fluctuations in their uses. Clearly, these assumptions are unrealistic when applied to the everyday business world. The ideal project schedule should utilize each resource at a constant level throughout the life of the project with perhaps an

---

[1] In this paper CPM will be used as a general term to include such methods as PERT, PEP, CPA, and Network Analysis. The same basic theory underlies all of these methods. Since this paper deals with basic networking theory, it is equally applicable to all of the networking methods.

initial buildup period and a terminal tapering off period. This would make possible the efficient utilization of the resources.

Objective of the Study

There are two basic problems associated with leveling resource demands; one deals with leveling demand without changing the completion date of the entire project, the other deals with the minimization of the project duration with a constraint on the total availability of resources. This paper will deal only with the first problem. The objective here will be to develop and test an efficient method of leveling resource demand over the life of the project, without changing its completion date. Once an efficient method has been found, an attempt will be made to formalize it by formulating a set of rules for its application. This would facilitate the programming of the process for application to the digital computer.

Definition of Terms

The terminology associated with CPM has not been standardized. Various authors use different terms and definitions in their writing. It is, therefore, necessary to examine the terminology that is being used each time a new method is studied. The terminology used in this paper, unless otherwise specified, will be the same as that used by Levy, Thompson, and Wiest.[2] A few of these basic terms and definitions

---

[2] F. K. Levy, G. L. Thompson, and J. D. Wiest, "Introduction to the Critical-Path Method," published in, John F. Muth and Gerald L. Thompson, Industrial Scheduling (Englewood Cliffs, 1963), pp. 331-346.

will be introduced at this point to facilitate the discussion.

An activity is a specific work effort of the project. It represents the work that is required to move from one event to the next. An event is a point in time representing the beginning or end of an activity. Events do not consume time or resources. They are used as the basis for status monitoring as work proceeds through the project. A CPM network is a graphic description of a project plan showing the sequential steps needed to reach the stated objective. It includes all of the significant interdependencies and interactions required to perform the project. The term sequence constraint is used in connection with the CPM network to describe a relationship between activities and events. It indicates that a specific event may not occur until all of the preceding activities have been completed. It also indicates that an activity may not start until its preceding event has occurred.

Slack is a measure of the time flexibility available for an activity. The total slack for an activity is the number of time units the finish date of the activity can exceed the earliest possible finish date without affecting overall project completion. Free slack is the number of time units by which the finish date of an activity can exceed its earliest possible finish date without affecting any other activity's start time. Interfering slack is the difference between total slack and free slack. It indicates that, while activity completion in this time range does not affect project completion time, it does affect some subsequent activities by changing their starting times and thus decreasing their total slack.

Types of Networks

There are two types of networks currently in use in CPM analysis. They are event-centered and activity-centered networks. The event-centered network has the events represented by the nodes or arrowheads. The activity-centered network has the activity represented by the node.

There are advantages and disadvantages associated with each type. The main advantage of the event-centered network is that, in conjunction with computers, it is much easier to list activities in the order in which they occur, i.e., an activity will not appear in the list until all of its predecessors have already appeared. All that is required to derive such a list is to list the activities, using an ij subscript notation, so that the j's are in ascending order. However, this same thing can be done with the activity-centered network if a little care is used in numbering the activities. If the activities are numbered with the number at the head of an arrow always larger than the number at the tail of the same arrow, the activities can then be listed in ascending order and no activity will occur in the list until all of its predecessors are already in the list. The main advantage of the activity-centered network is that it is simpler, i.e., it has fewer arrows and nodes.

Up to now, all authors who have considered the resource demand leveling problem have used event-centered networks in deriving their solutions. However, it would seem that the advantages of the activity-centered network outweigh those of the event-centered network.

Therefore, in this paper, the activity-centered network will be used in the derivation of a method of leveling resource demand.

CHAPTER II

REVIEW OF EXISTING METHODS

Since the demand leveling problem is the only major area in CPM theory that has not been adequately solved, there is currently a large amount of effort being expended in search of an acceptable answer to the problem. Several solutions have already been advanced. A few have even been computerized. However, at this time, there is no method described in current literature which is completely satisfactory. The solutions thus far presented fall into one of several broad categories: intuitive methods, chart techniques, least sum of the squares method, and combination of methods.

Intuitive Methods

The intuitive methods are the oldest answer to the resource leveling problem. Simply stated, they are an attempt by the CPM scheduler to take resource demands into account when planning the project. No rules or techniques are possible with these methods. They cannot, therefore, be taught nor programmed for use on computers. They are merely trial and error methods which are developed by an individual for his own use.

Chart Techniques

Chart techniques offer fairly comprehensive methods for leveling resource demand throughout a project. J. E. Kelley, Jr.,[1] John W. Fondahl,[2] and Joseph J. Moder,[3] have done a large amount of the work to develop and introduce these techniques. Chart techniques were the first methods that could be programmed and several programs for their application are currently available.[4]

The chart techniques are all similar in that they portray the project on some form of a bar-chart. Each activity is represented by a single bar. The length of the bar is determined by the duration of the activity plus the total slack for the same activity. It is drawn starting at the activity's early start time and extending to its late finish time. The activity can then be scheduled within the confines of its bar as long as all sequence constraints are observed.

Once the bar-chart has been drawn, the total demand for the resource under consideration can be determined for each time

---

[1]J. E. Kelley, Jr., "The Critical-Path Method: Resources Planning and Scheduling," published in, John F. Muth and Gerald L. Thompson, Industrial Scheduling (Englewood Cliffs, 1965), pp. 347-378.

[2]John W. Fondahl, A Non-Computer Approach to the Critical Path Method for the Construction Industry (Stanford, California, 1964).

[3]Joseph J. Moder and Cecil R. Phillips, Project Management with CPM and PERT (New York, 1964), Chapter 6.

[4]For example see, H. N. Perk, Man Scheduling, (IBM 650 Program Library, File No. 10.3.009, and 1620 Program Library, File No. 10.3.013.).

period by summing the resource requirements for all activities occurring within the time period under consideration. Various methods can then be applied to attempt to reduce the time-unit to time-unit variations in resource demand. All of these methods consist of rules for "shuffling" activities within the confines of their bars and sequence constraints until the schedule is made as "smooth" as possible.

These chart techniques have some difficulties which have led to a search for a more acceptable method of leveling demand for a resource. They provide no measure for comparing alternative schedules to see if one is actually better than the other one. Also, they all attempt to schedule each activity as late as possible in order to increase the slack in preceding activities. However, with activities scheduled as late as possible, any slippage of an activity is likely to affect the completion date of the project adversely.

Another problem that the chart techniques do not answer is, if it is impossible to get a perfectly smooth demand schedule for the resource over the duration of the project, i.e., if there is some time-unit to time-unit variation in demand, there is no method for adjusting the variation so that there is an initial buildup and terminal tapering off in demand rather than random variation. A firm can easily handle variations in demand if there is a smooth initial buildup period and then a smooth terminal tapering off period. It is the random fluctuations in demand that are costly and undersirable.

Least Sum of the Squares Method

The newest answer to the resource leveling problem is the least sum of the squares method. It was developed and introduced mainly by A. R. Burgess.[5] The method consists of summing the squares of the resource demands for each time-unit. The sum of the squares has the property of decreasing as the variation in time-unit to time-unit demand decreases. For example, if in the current schedule, time-unit 12 has a requirement for 14 units of the resource, time-unit 13 requires 6 units, and time-unit 14 requires 11 units, the sum of the squares would be 353.

	Current Schedule	New Schedule
Time-unit 12 requirement	14	10
Time-unit 13 requirement	6	11
Time-unit 14 requirement	11	10
Sum of Squares	$14^2+6^2+11^2=353$	$10^2+10^2+11^2=321$

However, by rescheduling activities, it may be possible to arrive at a demand schedule of 10, 11, and 10 for the time periods under consideration. This schedule would have a sum of the squares of 321 which is lower than that in the current schedule. The total demand is 31 in both cases, but the total sum of the squares decreases as

---

[5] A. R. Burgess, and J. B. Killebrew, "Variation in Activity Level on a Critical Arrow Diagram," Journal of Industrial Engineering, XIII No. 2 (1962), p. 148.

the variation in demand decreases. The sum of the squares can, therefore, be used as a criterion to compare alternative schedules.

The least sum of the squares method is not the final answer to the resource demand leveling problem. It fails to take into account the fact that two schedules that have the same sum of the squares may be quite different. To illustrate, in the previous example a new schedule of 10, 10, 11, or 11, 10, 10 would have had the same sum of the squares as the new schedule shown in the example. The three new schedules may have very different effects on the overall schedule, but with the least sum of the squares they are all optimum solutions. The time at which the variations in demand occur will have no effect on the sum of the squares. The only thing measured is the difference in overall variation. Another failure of the method is that it makes no provision for shifting variations that cannot be removed, so that there is an initial buildup and then a terminal tapering off in demand rather than random variation throughout the project.

Combination of Methods

The best current solution seems to lie in a combination of methods. As has been shown in the foregoing discussion, none of the "pure methods" seem capable of solving all of the problems associated with leveling resource demand. By combining two or more "pure methods" it may be possible to adequately solve all of the difficulties discussed.

Joseph J. Moder[6] has presented what is, up to now, probably the best combination of methods. He has combined all of the methods previously discussed into a fairly comprehensive answer to the demand leveling problem.

Moder's method depicts the project schedule on a bar-chart. At the start the activities are scheduled at their early start times, and then as the solution continues, the activities are moved toward their late start times. The moves in the individual activities' start times are made in such a way that the sum of the squares of the time-unit resource demands are minimized. Once the minimum possible sum of the squares has been reached, any further schedule shifts have to be made intuitively by the scheduler.[7]

Application of this method to a project schedule will result in a minimum sum of the squares schedule, but it still leaves much to the intuition of the scheduler. Also, it will result in the individual activities being scheduled as late as possible. Thus, any schedule slippages would result in a delay in overall project completion.

Problems to be Solved

As has been shown in the previous discussion, there is currently no method for leveling resource demand that solves all of the inherent difficulties. Solutions must be found to the following problems:

---

[6]Moder, Chapter 6.

[7]The Appendix contains a step-by-step rescheduling of a project using Moder's method.

(1) There must be a systematic means for shifting activities toward an optimum schedule.

(2) The method must provide for the comparison of alternative schedules so that the better one can be chosen.

(3) Once as level a schedule as possible has been derived, there must be a systematic method for further adjustments in the schedule so that the remaining variation is distributed in an initial buildup and a terminal tapering off period.

(4) All activities should be scheduled as early as possible.

(5) The method should be stated so that it could be programmed for use on an electronic computer.

CHAPTER III

SYSTEMATIC DEMAND LEVELING PROCEDURE (SDL)

Assumptions

In order to limit the scope of the following analysis, it will be necessary to make several assumptions. First, the network and all computations associated with it, such as early and late starts and finishes, slacks, etc., will be taken as given. For a good discussion of how the network is derived and how the computations are completed the reader may see one of several sources.[1] It will be assumed that the time-cost tradeoffs have already been carried out and that the optimum completion date has already been derived. Thus, the completion date of the project cannot be changed in the process of leveling demand. Also, the effect of leveling resource demands on total cost of the project will not be considered. It will be merely assumed that costs will be reduced by leveling demand as much as possible.

The network shown in Figure I will be used for the development of the method to be presented. As was stated earlier, the network is activity centered. The activities have been numbered so that the number at the head of an arrow is always larger than the activity

[1] See, for example, Fondahl, Chapters I and II.

number at the tail of the same arrow. This makes it possible to list the activities in ascending order, 1, 2, 3, etc., and still be sure that no activity appears in the list until all of its "predecessors" have occurred.

Figure II was derived from Figure I. The bars which depict each activity are of a length, measured on the time scale along the bottom, which is equal to the sum of the activity's duration, including its total slack. The bar starts at the activity's early start and extends to its late finish. The activity can be moved anywhere within the confines of its bar as long as it does not move to the left further than the finish time of any of its sequence constraints. The numbers to the left of the bar-chart were filled in directly from Figure I.

The resources required for the completion of the project should be considered one at a time. The most expensive or most critical resource should be used in the first application of the following method with less expensive ones used in subsequent applications. The numbers directly above the bar-chart represent the sum of the demand for the resource under consideration in the corresponding time period. Each of these numbers is then squared and the sum of the squares is shown in the column on the right labled Sum D^2.

Steps in SDL

Once the diagram has been drawn, the actual steps in the derivation of the smoothed schedule are:

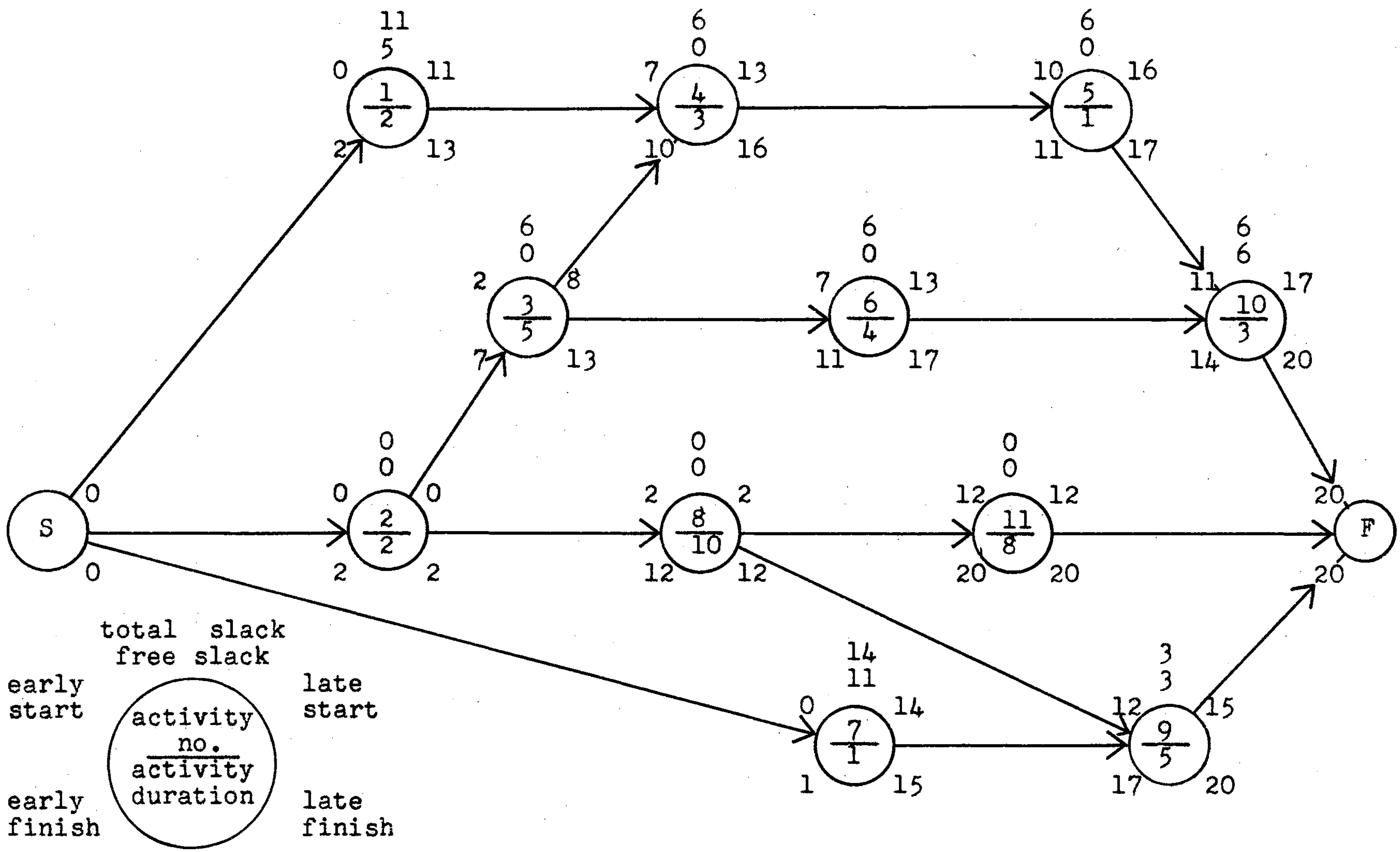


Fig. 1.--The project network

constraints	activity no.	resource demand	duration	late start	late finish	ealry start	early finish	total slack	free slack
---	1	3	2	11	13	0	2	11	5
---	2	-	2	0	2	0	2	-	-
2	3	2	5	8	13	2	7	6	-
1,3	4	-	3	13	16	7	10	6	-
4	5	4	1	16	17	10	11	6	-
3	6	2	4	13	17	7	11	6	-
---	7	4	1	14	15	0	1	14	11
2	8	6	10	2	12	2	12	-	-
7,8	9	5	5	15	20	12	17	3	3
5,6	10	-	3	17	20	11	14	6	6
8	11	2	8	12	20	12	20	-	-

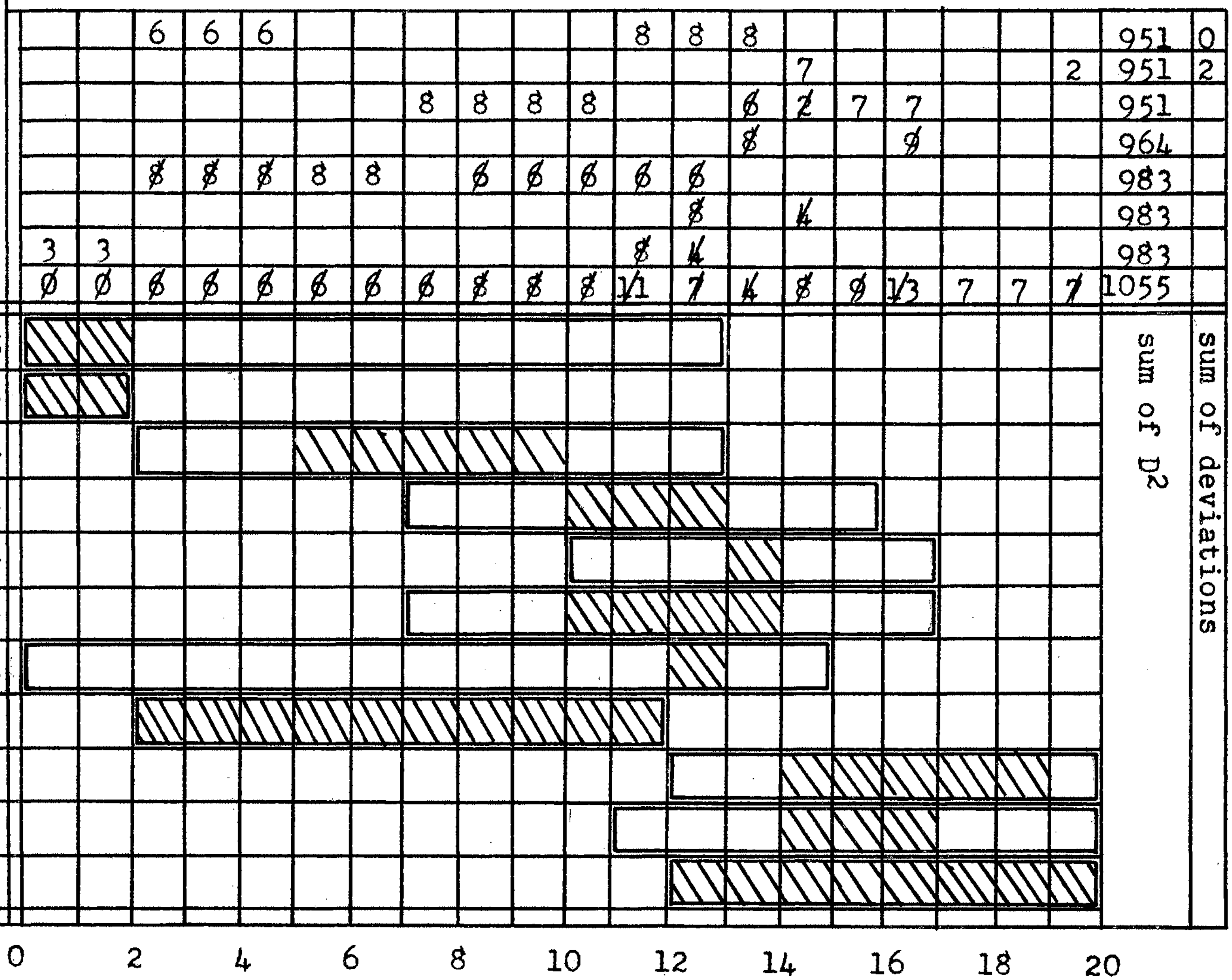


Fig. 2.--SDL chart

Step 1. Schedule each activity to start at its late start. (Activity 1 is scheduled to start at time 11 and extend to 13. All other activities are scheduled in the same manner.)

Step 2. Starting with the first activity (top of the bar-chart), schedule it to give the lowest total sum of the squares for the time-units affected.[1] (If activity one is rescheduled to begin at time 0 and end at time 2, the resource demand, 11 and 7, for periods 11 and 12, respectively, will be reduced to 8 and 4 and the demand for periods 1 and 2 will be increased from 0 to 3. This change will reduce the total sum of the squares from 1055 to 983.) If more than one schedule gives the same lowest sum of the squares, schedule the activity as early as possible. If the activity can be scheduled in more than one location without affecting the sum of the squares, all of the locations other than the one in which it is actually scheduled are slack locations which can be utilized in the scheduling of other resources.

Step 3. Repeat Step 2 on the next activity until all activities have been rescheduled to give the lowest possible sum of the squares. Care must be taken not to exceed any sequence constraints in moving each activity to the left. (In other words, no activity may start before all of its sequence constraints, the activities listed in the constraints

---

[1]If the activity is moved one day at a time, the resource demand for only two days, for each move, will be affected. Thus, the total sum of the squares will be affected only at the two ends of the activity.

column, have been completed. Therefore, since activity 4 is constrained by 1 and 3, it can start no earlier than time 11, since 3 is not completed until the end of time 10.)

Step 4. Repeat Steps 2 and 3 until no further reduction in the total sum of the squares is possible. (In the example shown, the smoothing required two repetitions of Steps 2 and 3.)

Step 5. Identify the largest single demand for the resource under consideration. (In the example, this would be 8.) If more than one time period has this same maximum demand, locate the earliest one, the one farthest to the left. (In the example, this would be the 8 in time period 5.)

Step 6. Starting with the demand and time period found in 5, subtract the number (the 8 in the example) from the demand for the immediately preceding time period. (The 8 for period 5 is subtracted from the 6 for period 4.) If the difference is negative or zero, drop it. If it is positive, add it to the number in the column labeled Sum of Deviations.

Step 7. Moving to the left one time period per step, repeat 6 (in the example, the second step would be the subtraction of the 6 for period 4 from the 6 for period 3; the next step would be the subtraction of the 6 for period 3 from the 6 for period 2, etc.) until the demand for the second time period has been subtracted from the demand for the first time period.

Step. 8 Starting again, at the demand and time period identified in 5, subtract the number (the 8) from the demand for the immediately following time period. (Subtract the 8 for period 5 from the 8 for period 6.) If the difference is negative or zero, drop it. If it is positive, add it to the number in the column labeled Sum of Deviations.

Step 9. Moving one time period at a time to the right, repeat Step 8 until the demand for the next to the last time period has been subtracted from the demand for the last time period. (This step is the same as Step 7 except that the movement is to the right rather than to the left.)

Step 10. By shifting either one, two, or more activities at a time, attempt to minimize the number in Sum of Deviations without changing the total sum of the squares (the number in Sum D^2). If a smooth initial buildup and terminal tapering off period is considered more important than overall variations, remove the restriction that the total sum of the squares cannot be changed. (In the example, the figure in the Sum of Deviations is 2 after Step 9 is completed. By shifting activities 3 and 6 three time periods to the right, which does not change the figure in Sum D^2, the 2 in Sum of Deviations was reduced to 0.)

Step 11. The schedule thus derived will minimize the overall variation in demand for the resource under consideration. It will also spread the remaining deviation so that there is as smooth an initial buildup and terminal-tapering period as possible. The activities that have no remaining slack should be held fixed.

The next less critical resource may now be considered by application of Steps 2 through 10.

CHAPTER IV

EVALUATION AND CONCLUSION

Evaluation of SDL

SDL has several features which satisfy all of the problems, listed at the end of Chapter II, that an adequate resource leveling procedure must solve.

(1) Through the procedure described in Chapter III and by using a bar-chart, the method provides a systematic means for shifting activities toward an optimum schedule.

(2) By using the sum of the squares of the resource demand, SDL makes it possible to compare alternative schedules. (The one with the smallest sum of the squares is the most desirable.)

(3) The application of Steps 5 through 10 provides a systematic means for redistributing any variation in demand so that there is a smooth initial buildup and terminal tapering off of demand.

(4) SDL schedules all activities as early as possible consistent with a leveled demand schedule.

(5) Without too much difficulty, SDL could be programmed for use on a digital computer.

(6) A further feature of the method, of Steps 5 through 10, for redistributing the remaining variation in demand is, it takes into account the fact that having two or more "deviations" next to each

other, so that there is in effect only one deviation, is more desirable than having the deviations scattered out into individual deviations, i.e., the demands of 6 in periods 11, 12, and 13 are deviations; but, since they are together, they only add 2 to the Sum of Deviations column. (Had they been separated, they could have added 6 to the Sum of Deviations.) This feature illustrates the desirability of having the deviations together rather than spread out.

Conclusion

SDL satisfies all of the objectives stated for it. It is not an entirely original procedure, since it is somewhat like the method developed by J. J. Moder,[1] which is the most comprehensive procedure appearing in current literature. However, it is a new procedure and several of its features are significant.

SDL starts with the first activity and works toward the last one. Moder starts with the last one and works toward the first. The procedure described schedules all activities as early as possible, consistent with leveled resource demand, while Moder's method schedules all activities as late as possible.

SDL is based upon the simpler activity-centered network while Moder's method is based upon the event-centered network. A means to reschedule remaining variation into smooth initial buildup and terminal tapering off periods is included in SDL, while Moder's procedure

---

[1]Moder, p. 88.

completely ignores this problem. Therefore, the Systematic Demand Leveling procedure appears to be the best method thus far developed for leveling resource demand.

BIBLIOGRAPHY

Burgess, A. R. and J. B. Killebrew. "Variation in Activity Level on a Critical Arrow Diagram." Journal of Industrial Engineering, XIII No. 2 (March-April, 1962), 148.

Dooley, A. R. "Interpretations of Pert." Harvard Business Review, XCII (March, 1964), 64.

Fondahl, John W. A Non-Computer Approach to the Critical Path Method for the Construction Industry. Stanford: Stanford University Press, 1964.

Kelley, J. E., Jr. "The Critical-Path Method: Resources Planning and Scheduling." published in: Muth, John F. and Gerald L. Thompson. Industrial Scheduling. Englewood Cliffs: Prentice Hall, 1965.

Levey, F. K., G. L. Thompson, and J. D. Wiest. "Introduction to the Critical-Path Method." published in: Muth, John F. and Gerald L. Thompson. Industrial Scheduling. Englewood Cliffs: Prentice Hall, 1965.

Moder, Joseph J. and Cecil R. Phillips. Project Management with PERT and CPM. New York: Reinhold, 1964.

Navy Department. The Pert/Cost System. Washington, D. C.: Special Projects Office, Navy Department, 1962.

Perk, N. H. Man Scheduling. IBM 650 Program Library, File No. 10.3.009, and 1620 Program Library, File No. 10.3.013.

U.S.A.F. Pert Implementation Manual. Washington, D. C.: PERT Orientation and Training Center, 1964.

Wiest, J. D. "Some Properties of Schedules for Large Projects with Limited Resources." Operations Research, XII (May, 1964), 395-418.

APPENDIX

Moder's Method[1]

Step 1. List the project activities in order of precedence by arranging the arrowhead numbers in ascending order, and when two or more activities have the same head number, list them so that the arrow tail numbers are also in ascending order. [This first sentence applies to event-centered networks; Figure III was derived from an activity-centered network. However, the procedure still applies to it.] Next prepare a bar-chart for the activities showing their total slack and their current schedule which should be as early as possible [see Figure III]. If certain activities have schedules fixed by previous resource allocations or total project duration time constraints, they should be drawn on the chart with no slack.

Step 2. Starting with the last activity (the one at the bottom of the diagram), schedule it to give the lowest total sum of squares of resource requirements for each time unit. If more than one schedule gives the same total sum of squares, then schedule the activity as late as possible to get as much slack as possible in all preceding activities.

Step 3. Holding the last activity fixed, repeat Step 2 on the next to the last activity in the network, taking advantage of any slack that may have been made available to it by the rescheduling in Step 2. In general, this slack availability check is made by observing the scheduled start times of all activities having a tail number equal to the head number of the activity in question. [Again, this applies to the

---

[1]The method described, except for examples in square brackets, is quoted directly from Joseph J. Moder and Cecil R. Phillips, Project Management With CPM and PERT (New York, 1964), p. 88.

event-centered network. Check the constraints in the case of an activity-centered network./ These activities will always be found below the one in question. The earliest of the observed scheduled start times is then the latest allowable finish time of the activity in question.

Step 4. Continue Step 3 until the first activity in the list has been considered; this completes the first rescheduling cycle.

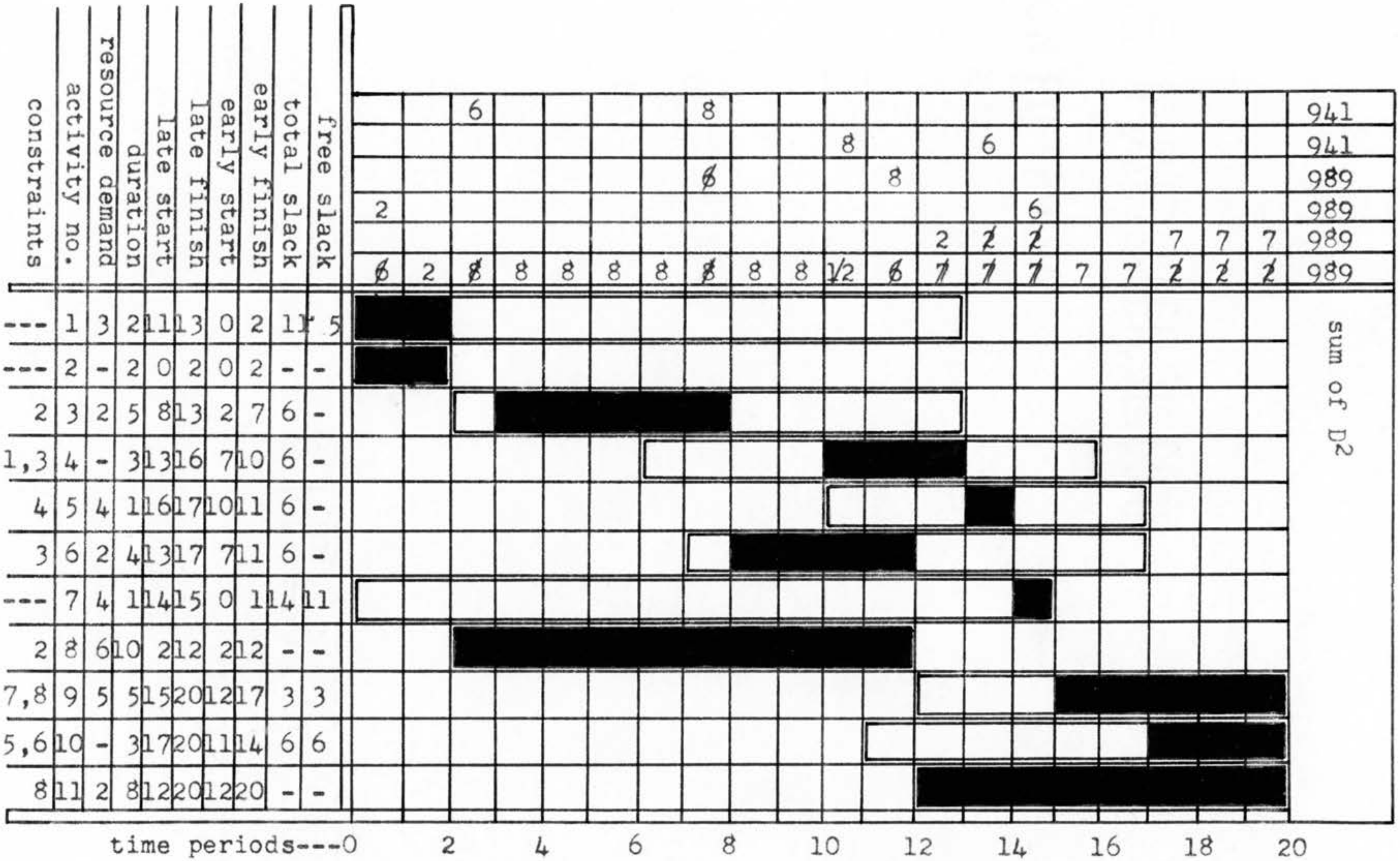
Step 5. Carry out additional rescheduling cycles by repeating Steps 2 through 4 until no further reduction in the total sum of squares of resource requirements is possible, noting that only movement of an activity to the right is permissible under this scheme. /Only one rescheduling cycle was required in the example shown./

Figure III was derived exactly as described by the method above.

Comparison of Moder's Method and SDL

By comparing Figure II, which was derived using SDL, and Figure III, which was derived using Moder's method, (both figures are based on the project described by Figure I), it is possible to see the different effects of the two methods. Moder's procedure resulted in the scheduling of activities 7, 9, and 10 at their late starts, while SDL scheduled all of the activities, except, of course, critical activities, at times earlier than their late start. Thus, any slippage within the project would be much more critical under Moder's plan than under SDL, since in the case of Moder's method, the slippage would probably result in a delay in total project completion.

As can be seen in time periods 12, 13, and 14 of Figure III, Moder's procedure allows random deviations to occur in the final



constraints	activity no.	resource demand	duration	late start	late finish	early start	early finish	total slack	free slack
---	1	3	2	11	13	0	2	11	5
---	2	-	2	0	2	0	2	-	-
2	3	2	5	8	13	2	7	6	-
1,3	4	-	3	13	16	7	10	6	-
4	5	4	1	16	17	10	11	6	-
3	6	2	4	13	17	7	11	6	-
---	7	4	1	14	15	0	1	14	11
2	8	6	10	2	12	2	12	-	-
7,8	9	5	5	15	20	12	17	3	3
5,6	10	-	3	17	20	11	14	6	6
8	11	2	8	12	20	12	20	-	-

Fig. 3.--Moder's chart

schedule. SDL redistributes these variations into smooth initial buildup and terminal tapering off periods.

These are the primary differences in the two methods.

VITA

Max Wade Hampton

Candidate for the Degree of

Master of Business Administration

Research Report: A SYSTEMATIC DEMAND LEVELING PROCEDURE FOR CPM

Major Field: Production Management

Biographical:

Personal Data: Born in Wewoka, Oklahoma, November 19, 1941, the son of Columbus F. and Era M. Hampton.

Education: Attended grade school in Stillwater and Clinton, Oklahoma; attended Clinton High School and graduated from John Marshall High School in Oklahoma City, Oklahoma, in 1960; received Bachelor of Science degree from Oklahoma State University, with a major in Production Management, in August, 1964; completed requirements for Master of Business Administration degree in August, 1965.