



CPM

in Construction Management

Addendum to 8th Edition

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CPM in Construction Management

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**Abstract of the 9th Edition in progress
and Commentary to the 8th Edition**

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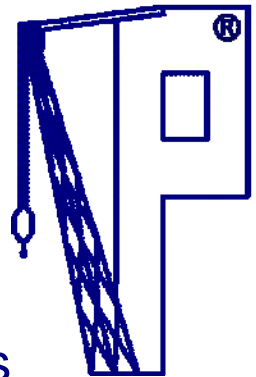
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Instruction on Use of this Addendum to 8th Edition

This interim 9th Edition is meant as an Addendum to the 8th Edition and must be read with the 8th Edition. If you do not already have a copy of the 8th Edition, you need to purchase a copy to properly utilize this Addendum. The 8th Edition may be purchased via McGraw-Hill at <https://www.mhprofessional.com/9781259587276-usa-cpm-in-construction-management-eighth-edition> and via Amazon at <https://www.amazon.com/exec/obidos/ASIN/1259587274/ref=nosim/enprinc> *
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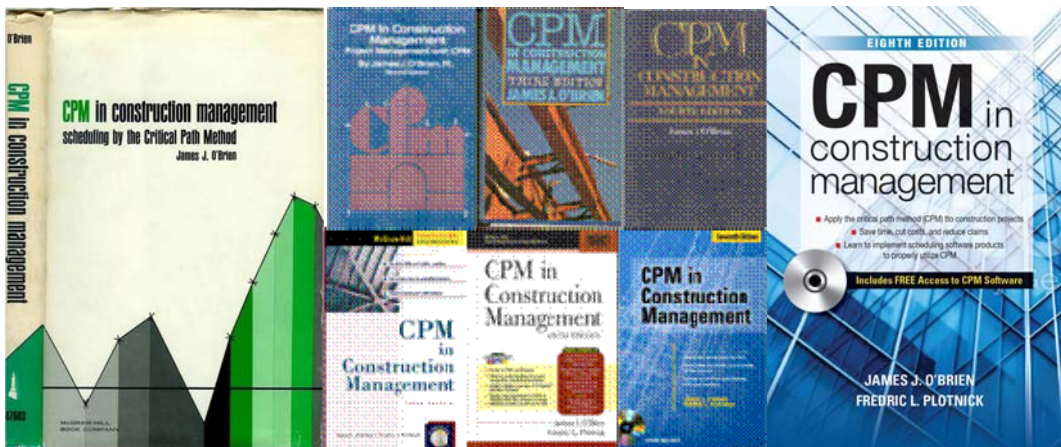
Why an “interim 9th” and “addendum to 8th” rather than merely publishing a new full 9th Edition is a matter of the economics of the publishing industry, and current reorganization of and within McGraw-Hill. However, sufficient readers of this text have requested a new 9th Edition such that Jim and Fred discussed the issue with our editors at McGraw-Hill and mutually determined that this new format is to be preferred at this time until McGraw-Hill’s publishing cycle warrants a new full 9th. .

The Authors of the 8th Edition, James O’Brien and Fredric Plotnick, met and spoke often in the years since publication of the 8th Edition in 2016, with many discussions upon what should be considered for a 9th Edition slated for 2021. The realities of publishing since 2016 and Jim’s passing in 2020 have placed much in limbo, and so this Addendum is now needed to avoid further delay. After all – a new Edition for a book on CPM in Construction Management should brook no delay.

Our Addendum first relates the discussions of Jim and Fred for each Chapter and what should be restated, amended, corrected, or added to that provided in previous Editions. Several new Sections or sub-chapters were suggested and then to be researched, developed and written. The increasing acceptance of AI and multiple simulation software solutions invites new concepts of which the authors previously dreamed. A new approach to the previously troubled attempt to consider the impact of weather is but one of these areas of inquiry.

We repeat this interim 9th Edition is meant as an Addendum to the 8th Edition, is not a stand-alone volume, and must be read with the 8th Edition. Those familiar with pre-computerized legal research may consider this text as a “pocket part” to be purchased after acquiring volumes of reported legal cases and thence to be inserted at the back of the appropriate volume until enough new cases warrant printing a full replacement.

But we have attempted to make this more than just analogous to the old “pocket parts” by harnessing the power of eprinting to include hyper-links to additional materials whether of print, video or other media. An example of bringing more than the printed word to an ebook, consider that, in January of 2015 at the Construction CPM Conference, Jim and Fred shared a session discussing “**50 Years of CPM in Construction Management 1st to 8th Edition**” with such recorded at: <http://www.fplotnick.com/constructioncpm/2015Videos/SAT35.html>.



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Preface

Why are we writing, and why do our readers need a 9th edition? After our first eight editions, what more may be said about CPM planning and scheduling for the construction and other time-centric industries?

In the 7th edition, we said the mighty ship *USS Scheduling* had come about 180 degrees. In the 8th edition, we suggested it had continued to a full 360-degree circle. Three events or series of events now suggest we are moving again, but perhaps in a new direction away from the entire 360-degree plane surface and up into a third dimension. Up and into the Cloud.

One is the passing of James J. O'Brien to whom this 9th edition is dedicated, December 31st 2020. Jim did not write the mathematical algorithm or protocols of CPM, but he did personally recognize how this academic exercise would be valuable to the construction industry and promote it to the world.

In the period 1956 up into the early 1980s CPM was a product by, of and primarily for experts or "priests" who would feed what they deemed relevant information to the large mainframe computer oracle and then explain or translate the oration emanating therefrom. In the early 1980s a new path was created by the development and mass dissemination of personal computers and personal computing so that mere mortal ordinary people could collect and enter the data of the logic of the project, and compute and read the then calculated initial schedule. More importantly management at the jobsite could visually assess current status, directly enter such information to their personal computer and then calculate and read an updated schedule. Power had been moved from the "priests" to the people.

You will read in this text that this had a cost; the less powerful personal computers ran a watered down version of the algorithms used on the big mainframes; the ability to obtain the fastest or most accurate possible schedule was degraded. The upside was that the mainframe process required several days of data entry and hundreds of dollars for each update; this was reduced now to only a few hours to collect and enter data and minutes to calculate and print reports, and for only pennies for the electricity. The savings were time and money which is our whole focus for our projects.

The mighty ship *USS Scheduling* continued on course for another decade or two with emphasis by software developers to make the process easier, more intuitive, and more useful to the primary end user being the construction superintendent and team. But seeds of course correction began with also seeking to raise sales by providing ancillary services to project owners and contractor home office facilities managers with enterprise issues where the schedule for one project could be compromised for other projects of the target buyer's enterprise. Complexities were added requiring special training and software company "university" courses for trained clerks (and not "priests") to operate the product (and yet another source of revenue) who may be posted (and charged) to the field but were in reality home office clerks. Often the superintendent would send these parasites off to produce required reports but meet with forepersons to actually plan work falling back upon the 1910s technology of bar-charts.

By 2010 in our 7th Edition, Jim wrote our mighty ship *USS Scheduling* had turned 180 degrees. The push for software as a service (SAAS) had largely triumphed with contractors required to maintain teams of scheduling clerks on the jobsite who rarely spoke with the superintendent or any foreperson, and had little knowledge of actual construction practice, working full time to maintain the official schedule. I would be invited to fly out to jobsites and meet with the superintendent and his team of graphic schedulers, and then later the "official" schedulers who maintained the "official" schedule. The two teams of schedulers refused to talk to each other. The official schedule with "activities" tied to accounting codes bore little resemblance to the graphic schedule activities relating to efforts by the forepersons. Work continued to be performed, invoiced and paid for with little progress shown on official schedules; neither team nor contractor nor owner had any idea whether the project was progressing towards a promised date of final delivery.

But by 2016 in our 8th Edition Jim suggested the mighty ship *USS Scheduling* had continued to a full 360-degree circle, perhaps as in the *Caine Mutiny* cutting her own tow line. Superintendents and their project teams continue to manage using their 1910s bar-charts while looking for some form of computer assistance. The plethora of push, pull, graphic, group-think, and other mostly short term scheduling systems and softwares is a testament to a vastly underserved industry. The construction team desires an improvement over the bar-chart for their one project.

Even the big established “scheduling” software giants were promoting their version of computer enhanced graphic scheduling. But instead of standing around a large pad of paper or whiteboard, the forepersons should meet weekly to stand around a rather expensive large touch enabled screen in a dusty construction trailer and connected to Cloud Services to “plan” the work they would “like” to do in the coming weeks. Some software providers also continued to reluctantly sell their legacy product so that the team may be told what they “should” do in the coming weeks to promote project completion, but despite promises have invested little or nothing to update that 1990s era software.

As we enter the 2020s we are starting a new phase based upon the latest buzzwords of Cloud and Artificial Intelligence. This is a new direction neither forward to assist the team to plan and schedule with computer assistance nor return to manual graphic solutions. I compare it to now aiming off the 360 degree plane to a third dimension. The general concept is to develop an artificial intelligence that can read the thought process of the superintendent and team, or many superintendents and teams, and mimic that thinking process to create a plan and schedule. Thus you do not need to read this book because the AI will plan and schedule your project for you, directly from the BIM file. You do not need that experienced superintendent nor team, but may simply hire a bunch of recent high school attendees (graduates preferred?) to act as the clerks for the AI who will direct the labor of crafts or robots.

Utopia or dystopia? The AI with millions or billions of inputs may negotiate and write subcontracts and purchase orders, track procurement and documentation of compliance with all socially approved mandates, as well as communicate with the AI of the owner or other entities in a higher language than understood by us mere humans. But despite the hype, I do not think we are there yet and still require human wisdom and insight to deal with all that cannot be encoded by that army of clerks. The challenge to our developers of software is to utilize AI to assist the knowledge and intuition of the experienced superintendent charged with project success rather than consider this person simply another clerk performing to the command of Central Planning.

It remains the purpose and goal of this text to educate and assist project professionals to plan and then schedule their projects to be completed as expeditiously and cost effectively as possible. We rededicate this ninth edition to this effort and to the proposition that training in CPM logic networks and scheduling software to support solutions shall have a new birth of freedom—and that construction software of construction professionals, by construction professionals, for construction professionals, shall not perish from the earth



Dedication to James Jerome O'Brien

This Abstract of 9th / Commentary to 8th Edition is dedicated to the memory of James Jerome O'Brien, P.E., PMP, October 20, 1929 to December 31, 2020.

James J. O'Brien, PE, PMP, did not invent CPM. Nor did Thomas Edison invent the light bulb. But one developed the first commercially practicable incandescent light, and the other brought an academic oddity of a practical use for an electronic computer to the world. Jim graduated Cornell University in 1952. The mathematics and marriage to the computer of Critical Path Method (CPM) planning and scheduling was developed in 1956. Jim joined the team in 1958 and literally took this new tool for speeding project delivery to the moon by introducing CPM to NASA.

Jim's first textbook CPM in Construction Management was published in 1964 and brought this concept to the world of construction. This text, now in Eighth Edition, is still considered the highest selling text of any of the McGraw-Hill Professional series. Jim also authored at least twelve other texts including upon Value Engineering and Change Orders.

Jim also helped found PMI, the Project Management Institute, and SAVE, the Society for Advancement of Value Engineering, and made many other contributions to technical and professionals associations. He created the nationally renowned construction consulting firm, O'Brien-Kreitzberg & Associates, Inc., then again bringing CPM to prominence to renovate and rebuild the cable car system of San Francisco.

No, Jim did not create CPM, but the name James J. O'Brien is synonymous with Critical Path Method and its use in project management.

Jim passed peacefully on December 31, 2020 at age 91.



Chapter 1

Introduction to Logic Based Planning and Scheduling

Abstract of 9th and Comment to 8th Edition for Chapter 1

The 7th Edition of this text was prepared in 2008 and 2009 in the depths of a downturn of the economy, and published with copyright of 2010. The 8th Edition was prepared in 2014 and 2015 and published with a copyright of 2016. Authors Jim O'Brien and Fred Plotnick met often and discussed a 9th Edition in 2018 through 2020 with Jim passing December 31st 2020. Our discussions relating to what may be done to update or improve each Chapter are provided in these Chapter Comments.

No serious changes need be made to this first Chapter. With the increased and increasing reliance upon a global supply chain in many industries, the concepts of logistics and scheduling are more applicable to everybody than ever before. And the differences between types of scheduling for earliest completion or for best allocation of resources or other for other purposes are also more important to be understood as the same words in this enlarged field have different meaning to different actors or situations.

Despite claims of the increasing omnipotence of touted AI systems, it is important to understand that the basis of preparing a good schedule is first preparing a good plan. Therefore our text hopes to instill skills and the mindset to prepare a good plan rather than merely how to navigate software. "We Teach Carpentry—Not "How to Use Your New Power Saw."

1.0 Introduction to Chapter 1

This introduction discusses some factors that make the case for why planning and scheduling are best performed by the critical path method (CPM). It covers some of the history behind the development of CPM planning and scheduling and relays some thoughts on where the process may go in the future. The interplay between the theory of mathematics that underlies the methodology and the modifications needed to make the methodology more practical is a theme that is woven throughout the text. The reader will see that it is the scheduler who must balance these two ideals, mathematics and engineering, to provide a useful and user-friendly tool to the users of CPM in construction management, manufacturing, and software design, and to other users of projects that must be finished on time and within budget.

3

1.1 Scheduling Is for Everyone

1.2 We Teach Carpentry—Not "How to Use Your New Power Saw"

1.3 History of Scheduling Systems

1.4 The Ordered "To-Do" List

1.5 Gantt Charts and Bar Charts

1.6 Development of the Critical Path Method of Scheduling

1.7 Development of the PERT Method of Scheduling

1.8 Comparison of CPM and PERT

1.9 Precedence Diagramming Method

1.10 SPERT and GERT

1.11 Relationship Diagramming Method

Chapter 2

The Pure Logic Diagram

Abstract of 9th and Comment to 8th Edition for Chapter 2

A discussion between authors Jim and Fred in 2019 suggested several minor changes to this chapter to emphasize the importance of events and recast their importance in the original ADM format. Jim continued to be adamant that the original format (now recast as ADM or Arrow Diagramming Method) was essential to the concept and teaching of CPM. Jim opined that ADM required each carefully defined activity to start only after the 100% completion of some other carefully defined activity, rather than after some loosely defined partial performance of another activity. Fred converted to a mathematical expression noting that ADM carefully defined an activity as to be from point-to-point, rather than a loosely defined about-from-here-to-there.

The pure logic diagram, without reference to dates, is still the basis of the mathematics of CPM scheduling as to be compared to its bar-chart predecessor or other forms of scheduling. Hand drawn pure logic diagrams (see Figure 2.5.4) or drafted drawings (see Figure 4.6.1 or 4.7.1 or 4.8.1 in RDM, ADM and PDM formats) were at one point not only the first step and basis of the contractor's effort but also demanded by owners to a real permit review of that logic. Difficulty by many software product developers to emulate such hand drafted clarity to a CAD computer aided drafted rendering (see Figure 4.8.3) perhaps led to "Software University" training to de-emphasize the pure logic drawing, thus removal from recommended (by that software product sales staff) model specifications, and to the current state where perhaps most Users do not know nor use such step in Logic development.

To recap, note the preparation of the logic diagram furnishes a number of advantages, including:

- It is a disciplined method of preparing a plan.
- It is a method of considering the project in detail.
- It is a graphic record of the plan, which can be useful in exchanging opinions and constructive criticism about the plan.

2.0 Pure Logic Network Construction

Chapter 1 discussed the concept and the fundamentals of construction of the CPM network. This chapter covers the practical mechanics of network construction. Since CPM is a logical and organized planning system, it is important that the physical layout of the network reflect the same logical organization. The thought required to separate the network's parts into practical subdivisions enhances the overall plan. The network is often used to present the plan to strangers to the project. If the physical layout is clear, concise, and well arranged, first impressions will be good. However, CPM can also expose poor planning. Figure 2.1.1 shows two networks with the same information. Both are logically correct, but the top network was drawn directly from a problem description without careful attention to physical layout. The bottom network is a rearrangement of the top one. It has only 12 activities. In a project network, the differences between network layouts and the possible resulting confusion would be multiplied 100-fold.

2.0 Pure Logic Network Construction

2.1 The Logic of the Logic Network

2.2 Pure Logic Diagrams

2.3 Technical Issues for Pure Logic Diagrams

2.4 Logical Loop

2.5 Form and Format for Pure Logic Networks

2.6 Events {This Section has been modified and split to 2.6 and 2.6a}

In the original creation of CPM, now known as ADM (“Arrow Diagramming Method”) the intersection of two or more activity arrows is termed an *event*. An event has a zero time dimension. However, all activities leading into an event must be completed before any of the activities leading out of the event can be started. This is just a restatement of the rules of network logic. Certain key events are called *milestones*; they represent important intermediate goals within the network. For instance, “ready to advertise for bids” (Figure 2.6.1) is an important event. It represents an instant in time but has no time dimension of its own. To reach this particular event, all activities pertaining to the design and specifications for the project must first be completed. No action toward getting a contract can be taken until the logic flow has passed through the event.

On the CPM diagram, important events can be identified by name. Event titles are not emphasized; instead, events are assigned numbers. In the original ADM variant of CPM, each activity is bounded by a starting and a completing event. Mathematically, the starting event occurs before the start of the activity; the completing event occurs after the finish of the activity.

2.6a Form and Format for Networks in ADM

In the original ADM variant of CPM, each activity is bounded by a starting and completing event. Because each event can be identified by the number, the activity may be identified by a pair of numbers representing the events at the start and finish of each activity. It was this compact means of identification of an activity, greatly reducing the data required to be stored for such purpose, which enabled the developers of CPM to do so utilizing the limited memory and processing power of early computers.

In ADM, the number assigned to the starting event is referred to as the i ; the number assigned to the completion event is the j . (These designations were used by the founders of CPM and have remained in general use, probably because of their brevity.) Thus, the typical activity looks like:

The $i-j$ number for an activity can be used as an abbreviated name for the activity. A number of rules must be followed in assigning event numbers to a network.

These rules and the remainder of the Chapter have been left unchanged and may be viewed in the 8th Edition on pages 35 through 54.

2.7 Problems with Multi-Sheet Networks

2.8 Form and Format for Networks in PERT

2.9 Form and Format for Networks in PDM

2.10 Form and Format for Networks in RDM

2.11 Non-Construction Examples

2.12 Summary

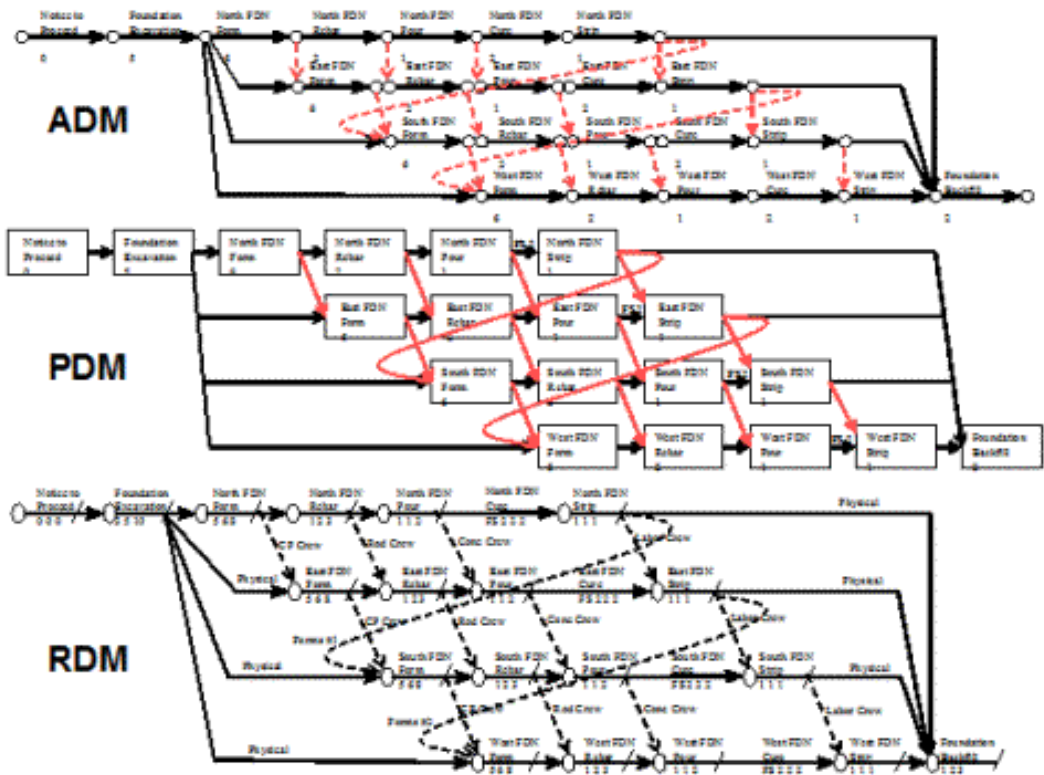
This chapter discussed the concept of the network, as well the premise that CPM can encourage decision making but cannot make decisions itself. Preparing arrow and logic diagrams helps the planner understand a project by clearly defining the activities required to complete it.

CPM is particularly applicable to construction work, but its usefulness is by no means limited to the construction field. This chapter also discussed the practical mechanics of network construction in the traditional ADM and

PERT formats, as well as the newer PDM and RDM formats. Primarily, the network layout must be logical and organized. A confused diagram exposes confused planning. The drawing size should be reasonable, and multiple sheets should be used if necessary.

Activity descriptions should be on horizontal lines. Avoid wide-sweeping lines or random lines. Center significant chains of activities to form a network backbone. Space the arrows so that additions may be made. Crossovers of logic lines can take a number of forms, but the form used should be consistent.

For ADM networks, $i-j$ event number pairs are abbreviated activity designations and must be unique for each activity. For PERT the event numbers represent and are abbreviation for the described event, and the unstated activity between events is merely noted by the logic. For PDM networks, one unique "activity number" replaces the two $i-j$ event numbers. For RDM networks, one unique "activity number" replaces the two $i-j$ event numbers, but the events are still addressable by unique "event numbers" at the start, finish, or within the activity. The careful assignment of event numbers makes the network easier to use and avoids unintended logical loops. Random is used here in its literal sense, "without direction, rule, or method."



Chapter 3

The Durations of the Logic Network

Abstract of 9th and Comment to 8th Edition for Chapter 3

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter.

Our discussions focused mainly upon the need to distinguish a CPM activity from a WBS or accounting activity, and that the duration to be recorded and used for calculation must be based upon the time after 100% of the prior ADM activity (or well defined internal milestone of a PDM activity) up until the activity is consider 100% complete to permit the start of the next activity.

Preparatory work while the predecessor activity is still being performed does not count. Finishing and perhaps cosmetic work after the activity has progressed to the point the next activity may start does not count. The total number of hours calculated from CPM durations should not be equal to that used by estimators or accountants.

3.0 Introduction to Chapter

One thing that the logic diagram lacks thus far is the dimension of time. It might be said that the portion of CPM described thus far has been qualitative but not quantitative.

The logic network may determine the order in which activities must be performed, but not when. To determine the earliest time each activity may be first performed and the latest time each activity must be performed requires not only logic, but also durations. Similarly, setting minimum and maximum limits upon the duration of an activity will have an impact upon the level of detail and the definition of specific activities. But keep in mind the order in which this material is presented—the accuracy of the pure logic network is paramount in a CPM analysis.

Thus an inspector, reading a specification limiting durations to 20 days or less, may reject a submission in which certain activities have greater durations. But keep in mind that every specification has the added provision (either explicitly in writing or implicitly by law) that such limitations are “subject to the sound discretion of the engineer.” An engineer is expected to understand the reason for this limitation and relax the limitation appropriately

Strict reliance upon the specification without understanding the rationale of it can be treated in this, or any other review situation, as “practice outside the engineer’s field of expertise,” contrary to the obligations of licensure and placing the engineer at risk for discipline.

3.1 Definition of an Activity

3.2 Setting a Minimum and Maximum Duration

3.3 Estimating versus Scheduling Durations

3.4 CPM versus PERT Durations

3.5 Lags in PDM and RDM—Durations between Activities

3.6 Summary

Activity durations are based upon the project manager’s estimate of the scope of work, resources to be assigned, and other factors and assumptions, all of which should be recorded by the scheduler. A proper activity is a set of instructions, given to a competent foreman, who is then expected to complete them without further supervision or interaction with other than his or her own subordinates. The maximum scope and duration for an activity should also be based on the ability of junior personnel to assess partial completion. The duration estimates of the project manager should be fresh, based upon the resources that the project manager intends to assign to the activity, and should not be influenced by the estimates based upon quantity takeoff or some other method prepared by an estimating department during the bid process. Asking for pessimistic, optimistic, and most likely estimates of duration may be of use in obtaining unpadding and more accurate estimates, even if the extra information is not recorded.

Chapter 4

Example Project: The John Doe Project

Abstract of 9th and Comment to 8th Edition for Chapter 4

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. Often a means of instruction is teaching by doing, and the building of logic network for the example John Doe Project has been included from the first edition of this text.

In this chapter, a basic network is planned for the construction of a combination plant-office-warehouse for a small industrial firm, the John Doe Company. The network is first prepared in a pure logic format, with sections later depicted in the ADM, PDM, and RDM formats. The reason for this is the importance, in teaching the preparation of a logic network, to obtain and record all possible information without pre-filtering to the demands of a specific format designed to meet the limitations of specific software.

4.0 Introduction to Chapter

A plan of the entire complex is shown in Figure 4.3.1, and a perspective of the building and exterior elevations are shown in Figure 4.3.2. Figure 4.3.3 shows a site plan section of the electrical service and sewer. The floor plan for the plant is shown in Figure 4.3.4, the office in Figure 4.3.5, and the warehouse in Figure 4.3.6. The list of activities is broken down by building area where applicable. Exterior elevation views of the building are shown in Figure 4.3.2, and interior sections are shown in Figures 4.3.7 and 4.3.8.

4.1 Acquiring Information to Initial Schedule

4.2 Choosing Appropriate Codes

4.3 Activity List

4.4 Could We Prepare a Bar Chart?

4.5 Pure Network Logic

4.6 John Doe Project Pure Network Logic

4.7 Network Logic in ADM

4.8 Network Logic in PDM

4.9 Network Logic in RDM

4.10 Summary

In this chapter, a sample light industrial project was planned with CPM. The activities involved in each section of the project were defined, and the CPM network for each section was drawn in a "hand-drafted" format. These were then converted to formats required for subsequent data entry to software. In describing the network construction, an index or dictionary approach was used. This can be very useful in CPM, but it is not often employed because of the additional effort required. Moreover, once the effort has been made to list all possible activities, there may be pushback to add, combine, or modify such while building the network.

Chapter 5

Output of Calculations

Abstract of 9th and Comment to 8th Edition for Chapter 5

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The mathematics of the CPM algorithm creates a great deal of information beyond that depicted on a bar-chart for the timing of events, activities connecting these events and also the relationship between these activities beyond mere restraints between or ordering thereof.

Notwithstanding creation of hyperlinks within a document, creation of the internet and linking to remote websites, YouTube videos and other forms of communication, this Chapter has pretty well withstood the passage of time without a need for revision or addendum. While individual practitioners may envision better means to share information, and a view by Google or like provide many suggested solutions for sale, it remains the realm of the professional scheduler to also be the primary story teller.

5.0 Introduction to Chapter

As may be noted from the preceding pages, a good deal of effort is required to prepare the logic network and make it ready for the software to do its job. Additional practical detail on acquiring the information for the logic network is provided in Part 3 of this text. But what do we expect the software to accomplish that makes the output more useful than a bar chart and merits all this effort? A bar chart indicates when the preparer intends or hopes to perform each activity. Thus, the preparation of a bar chart calculates two attributes for each activity on the chart—the scheduled start and scheduled finish dates.

While this information is an improvement over that of a numbered to-do list, it is still somewhat limited. Other scheduling information that may be useful for management of a project includes whether and which of these activities may be capable of starting earlier than scheduled if additional resources become available or productivity exceeds expectations. A project manager may wish to know which of these activities are critical to the completion of the project and which may slip without such an impact, and to know the latest dates upon which an activity must start and be completed for the project to be completed by a specified date. Even if the completion date of the project is not imperiled, the slippage of one activity may have an impact upon the scheduling of other work, be this work by the same foreman or by another crew or subcontractor.

Therefore, a project manager may wish to know which activities may slip without impact to a successor and by how much. If a project manager is concerned with limited crews or other resources, she or he may even plan to allow some activities to slip. Some such shifts could have an impact on project completion. Others may only impact the start of another activity. And still others may merely reduce the ability to allow other activities preceding the activity to slip. But others can be shifted without any impact to a successor or reduction of options of a predecessor. As the project is being planned and scheduled at the outset, a project manager may wish to know these attributes for each activity.

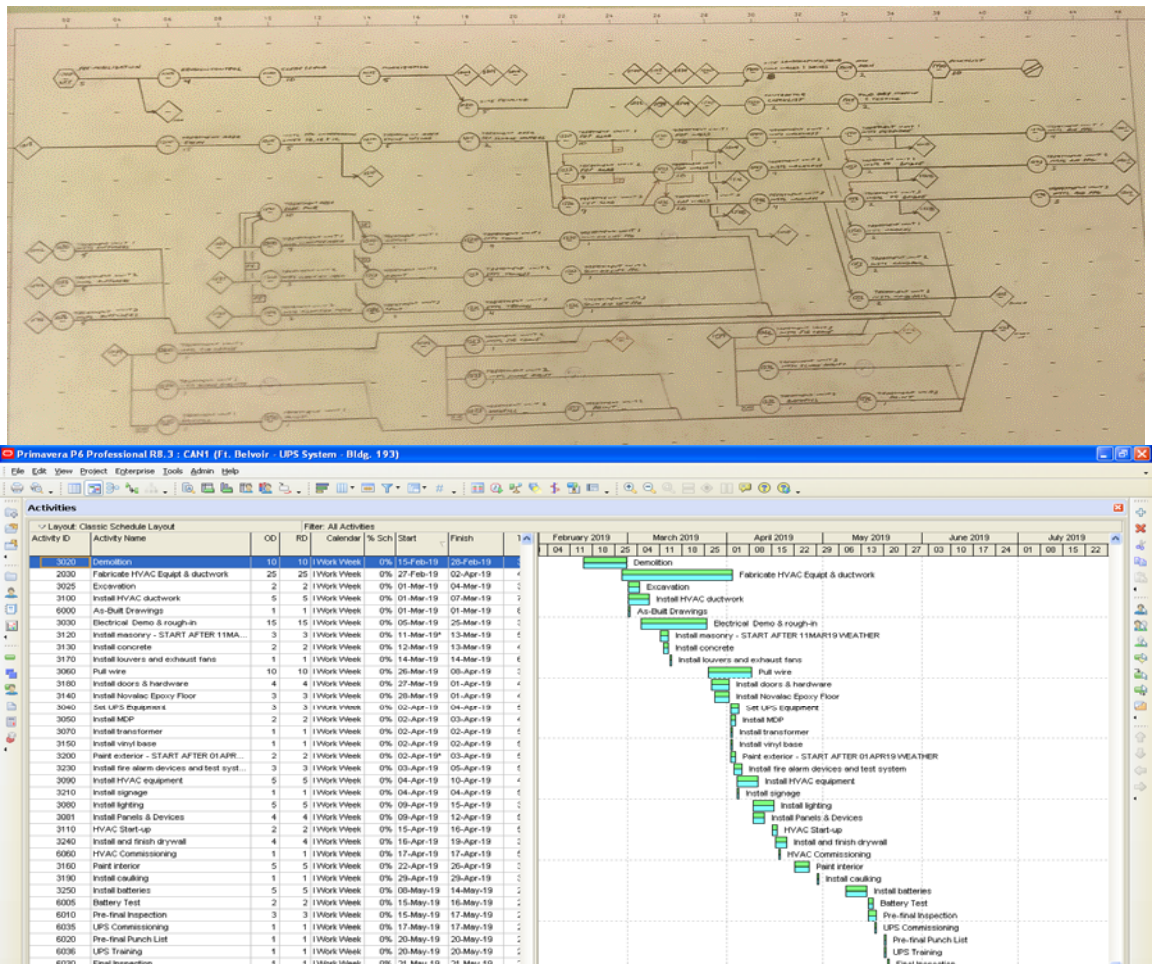
The mathematics of CPM systems expands this level of information to indicate when an activity first *may* start and *may* finish based upon a stipulated start date for a project, when an activity *must* start and *must* finish if the project is to be completed by a stipulated date or by the earliest time possible, the number of days (or other units of time) between the time when an activity *may* and *must* so start or *may* and *must* so finish, and other attributes relating to the timing of performance of the activity, and those points in time immediately preceding and following an activity.

The last comment is important because the initial development of CPM was as a mathematical exercise with a primary emphasis upon events, or points in time, and only a secondary emphasis upon the activities between these events. While this is downplayed by some manuals teaching PDM and software tutorials, mathematics of CPM continues to be based upon these concepts.

- 5.1 Attributes of an Event
- 5.2 Attributes of an Activity
- 5.3 The Forward Pass—T_e, ES, and EF
- 5.4 The Backward Pass—T_l, LF, and LS
- 5.5 The Backward Pass—TF, FF, and IF
- 5.6 The Backward Pass—T_j, JLF, JLS, and JTF
- 5.7 Calculating the Attributes of an Event or Activity
- 5.8 The Forward Pass—T_e, ES, and EF
- 5.9 The Backward Pass—T_l, LF, and LS
- 5.10 The Backward Pass—T_j, JLF, and JLS
- 5.11 The Backward Pass—TF, FF, JTF, and IF

5.12 Summary

By merely recording the relationships and probable durations between events, or the relationships and estimated durations of activities, the mathematics of PERT and CPM will calculate a number of attributes about the event or activity that would otherwise not be readily determined. These include, for an event, not only the earliest time that the event is expected to occur, but also the latest, as well as the difference between these two times or dates. These include, for an activity, not only the earliest time that the activity may be expected to start and finish, but also the latest time that the activity must finish if the project is to be completed in the earliest possible time. Also computed are the attributes of total float, free float, and independent float, concepts that are discussed in Chapter 6.



Input of Pure Logic versus Output of Calculations

Chapter 6

Cranking the Engine

Abstract of 9th and Comment to 8th Edition for Chapter 6

Several small additions are suggested to this chapter to cover the “engine” for calculating RDM attributes of Just-in-Time Start, Finish and Float discussed in Chapter 5. Jim noted that these “improvements” were possibly what Jim Kelley was attempting in derivation of Total and then Free Float. However the limitations of the hardware of the day, which led to the need for “dummy” activities for purposes of calculation, limited the use of the Free Float attribute.

The additional attributes in RDM of Just-in-Time Start, Finish and Float fulfilled the promise that Jim Kelley had desired. The mathematics of hand and then machine calculation have been added to this Chapter.

6.0 Introduction to Chapter

The first CPM and PERT logic networks calculated schedules by the new invention, the electronic computer. Manual simulation of the steps taken by the computer program, to prove that the model worked and to allow individuals to calculate smaller schedules, involved the use of a matrix. This was a natural step because mathematicians often used a graphic grid to solve problems. Figure 6.0.1 shows a portion of the logic network for the John Doe Project that was developed in Chapter 4 with assigned time estimates.

6.1 Manual and Computer Solutions for PERT and ADM—The Matrix Method

6.2 Manual and Computer Solution for PERT and ADM—The Intuitive Method

6.3 Activity Start and Finish Times

6.4 Critical Activities

6.5 Total Float

6.6 Free Float

6.6a Just-in-Time Activity Start and Finish Times and Just-in-Time Float

The originators of the critical path method defined a variety of floats, including total float, free float, and independent float. In 2003, author James O’Brien discussed the development of free float by James Kelley, and Mr. Kelley’s disappointment with the concept, seeking a better solution for bringing useful information from his basic algorithms for CPM. The recording of this discussion may be viewed at: <http://www.fplotnick.com/rdcpm/jjob3.mp4>.

One of the advantages of free float is that it can provide the number of working days (or other time units) from the completion of an activity until it pushes or impacts the start of an immediately subsequent activity. If that immediately subsequent activity is critical, i.e. having zero total float, the free float will be equal to the total float for this preceding activity. If the immediate subsequent activity should not be critical and has total float, the free float attribute will inform the scheduler and entire project team how many days may this preceding activity may slip before impacting the early start of the immediate successor.

This may be very useful where the prime contractor desires a material supplier or subcontractor to support that early start and allow the prime contractor to utilize all, some or none of the total float for such immediate subsequent activity. A printout of the free float of all activities titled “Delivery” will consequently provide the number of days of the total float for the delivery, and all prerequisites to delivery including fabrication and even back to shop drawings, which may be utilized by that supplier from the posted total float of the activity without using any of the total float of the prime contractor.

But this information, as noted by Jim O'Brien's recital of Jim Kelley's displeasure, is of limited use to the project team as such. It does not provide the drop dead date for starting delivery, nor any information for the predecessors of delivery back to preparation of shop drawings. While that information may be calculated from the free float of the delivery activity then to be added to the relevant Early Start or Finish of an activity, such a process is cumbersome at best.

The additional information recorded by RDM to the restraint between the delivery and installation activities allows solution of this problem. By declaring the restraint as a "Just-in-Time" restraint, the RDM algorithm will then calculate a second backward pass to indicate for each activity not only its Early and Late Start and Finish, but now also a Just-in-Time Start and Finish. Similarly the calculation will provide not only for each activity its total, free and independent floats, but now also a Just-in-Time Float. Printing of this information as a separate tabular column, rather than Free Float, will provide both prime contractor, subcontractors and suppliers with the latest date to start and complete activities to support the Early Start schedule of the prime contractor (or next highest tier of the entity to perform said activity.)

Keeping in mind that in RDM the j-node is the start of the restraint to a successor activity and not the activity itself, and that "Just-in-Time" attributes are calculated in a second backward pass:

"Just-in-Time finish" is defined as the latest date that will not delay the early start of a succeeding activity, and as equal to the Early Start of the successor of the restraint from this activity to the next which is declared a "Just-in-Time restraint."

"Just-in-Time start" is defined as the latest date that will not delay the early start of a succeeding activity, and as equal to the Just-in-Time finish minus the duration of the activity.

"Just-in-Time float" is defined as that which, if used, will not delay the early start of a succeeding activity.

6.6b Development of Just-in-Time Attributes

In 2008 to assist Fred in making a presentation on RDM for the Project Management College of Scheduling, Jim O'Brien recorded a brief introduction on the development of these Just-in-Time attributes extending the power of CPM: (See <http://www.fplotnick.com/rdcpm/jjob3.mp4>)

Good afternoon it is 5:00 on the East on the 24th of September and I'm introducing my friend and co-author Fred Plotnick who's going to cover an approach he's developed called RDM Relationship Diagramming Method. And I wanted to say a few words because I worked back in the day, about 1962, with the developer of critical path method, Jim Kelley. And Jim in the years I knew him continually looked for better way for more information to be wrung out of critical path method. He tried two concepts, one known as free float and the other as independent float. These in practice didn't work out and users of CPM ignored them and Jim never readdressed his concept to try to get more out of his schedules.

I think Fred Plotnick has found a way. When Fred and I did our Fifth Edition of CPM in Construction Management, RDM had not come into Fred's mind yet, but over the next few years he developed in great detail Relationship Diagramming Method, and I think he's found what Jim was looking for. In the words of another friend of mine, Fred has shown an amazing grasp of the obvious, and today he's going to tell us about his obvious and very in-depth approach.

6.7 Independent Float

6.8 Time Scale Network

6.9 Computation Time

6.10 Writing Your Own CPM Software

6.11 Manual and Computer Solution for PDM with Durations between Activities

6.12 Summary

This chapter discussed the use of event times to compute activity times, specifically early start, early finish, late start, and late finish. The three rules for identifying a critical activity were started, and float time was defined.

Chapter 7

Adding Complexity

Abstract of 9th and Comment to 8th Edition for Chapter 7

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The basic ADM model of 1956 requires only three data fields: an *i* node, a *j* node, and a duration. We have added quite a bit of complexity since. To appreciate the multitude of possible misunderstandings that can be created, this Chapter examines some of the enhancements to the basic model.

7.0 Introduction to Chapter

The basic ADM model requires only three data fields: an *i* node, a *j* node, and a duration. As we saw in previous chapters, preparation of a computer program to perform the calculations of activity attributes for such a simple model is an easy exercise. To appreciate the multitude of possible misunderstandings that can be created, we examine some of the enhancements to the basic model.

- 7.1 Enhancements to the Basic System
- 7.2 Original versus Remaining Durations
- 7.3 Percent Complete
- 7.4 Defined Subtasks and Check-Off Updating
- 7.5 Calendar versus Work Period Conventions
- 7.6 Multiple Calendars
- 7.7 Multiple Starting and Ending Activities
- 7.8 Artificial Constraints to Dates
- 7.9 Artificial Constraints to Algorithms
- 7.10 Negative Float
- 7.11 Definition of Criticality
- 7.12 Continuous versus Interruptible Performance
- 7.13 Actual Start and Finish Dates
- 7.14 Retained Logic versus Progress Overrides
- 7.15 Events and Milestones
- 7.16 Hammocks and Summary Network Logic
- 7.17 Summary Activity Bars
- 7.18 User-Defined Code Fields
- 7.19 Adding Resources to Activities
- 7.20 Adding Costs and Cost Codes to Activities
- 7.21 Resource-Driven Scheduling
- 7.22 Master Schedules: Local versus System-Wide Updating
- 7.23 Activity Types
- 7.24 Hierarchical Codes

7.25 Summary

As we have seen, the basic Critical Path Methodology, while bringing logic to the planning and scheduling process and being a vast improvement over simple bar charts, has limitations inherent in any model of the real world. The good news is that the methodology is flexible enough to permit numerous enhancements while still maintaining the basic concept, that each activity must await completion of its predecessors before starting and, in turn, must be complete before its successors may start. Each of the enhancements noted brings additional usefulness to the users of the Critical Path Methodology, but at the cost of requiring both the CPM preparer and CPM reviewer to address the ambiguities of non-standard terminology and algorithms, and requiring both to verify that the enhancements have not been used to accidentally or purposefully obfuscate this model of reality

Chapter 8

PERT, SPERT, and GERT

Abstract of 9th and Comment to 8th Edition for Chapter 8

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The quality of a CPM network and schedule derived depend on the care taken in choosing appropriate restraints (or predecessors and successors) and in estimating the duration of individual tasks. Typically, the level of detail for individual activities is such that the project manager or scheduler is comfortable estimating a duration with some degree of accuracy. Sometimes, however, the scope of work to be performed for the individual task is fuzzy or outside factors do not permit a reasonable degree of comfort in specifying a set duration. If the researchers were very lucky, they might locate the right alloy in an optimistic period of time. If they were unlucky, they might take a pessimistic period of time. Based on the law of averages and the experience of the research team, they could specify a most likely period of time required.

Now what? Do we take a weighted average of optimistic, most likely and pessimistic durations? Once upon a time even that that was more than the simple computers of the day could do and practitioners found a fudge to approximate, or simply guessed at a number and let those reading the “calculated” results believe such were mathematically derived. Today we can do much better.

8.0 Introduction to Chapter

As previously noted, the quality of a CPM network and schedule derived depend on the care taken in choosing appropriate restraints. These three estimates, the Optimistic, Most-Likely, and Pessimistic durations, created the basis for statistically determining the range of durations that could be experienced. Unfortunately, in 1958, computers were not fast enough and had insufficient memory to perform the true statistical analysis that represented the mathematical model for which these estimates were collected. Instead, a rough average was made using the formula $(O+4M+P)/6$ to reduce the information to a level similar to that used for CPM analysis and subsequent calculations. As computers became more powerful, various programs were developed, mostly in academia, for demonstrating the power of full implementation of a Statistical or multiple Simulation PERT under various acronyms, such as SPERT.

8.1 PERT

8.2 SPERT

8.3 GERT

8.4 Computers Add Power

8.5 Summary

Just as the introduction of the first computers led to the introduction of CPM modeling and analysis, the more powerful computers of today will permit the more powerful schedule analysis tools of SPERT and GERT to augment the basic strength of CPM.

Chapter 9

PDM and Precedence Networks

Abstract of 9th and Comment to 8th Edition for Chapter 9

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter.

9.0 Introduction to Chapter

In the early 1960s, Professor John W. Fondahl of Stanford University, an established expert on noncomputerized solutions to CPM and PERT networks, was one of the early supporters of the precedence diagramming method, or PDM. He called it the Circle-and-Connecting-Arrow Technique. His study for the Navy's Bureau of Yards and Docks included descriptive materials and gave the technique early impetus, particularly to Navy projects.

The motivation for a noncomputerized solution was based upon a number of limitations of the 1956 method imposed by the limits of digital computers of the 1950s. At that time, what we now call random access memory (RAM) had not been developed, and both programs and data resided on (at best) reel-to-reel magnetic tape. The computers also suffered a severe limit of central processor unit (CPU) memory and could hold only a few commands (lines of code) or items of data at a time. Thus once a command or set of data was read and set to the limited number of "data registers," and then supplanted by new code or data, the only means to refresh was to rewind the magnetic tape and reread.

The genius of Dr. Kelly in creating what we now call the ADM (arrow diagramming method) format, thus reducing the needed data for calculation to a simple *i* node, *j* node, and duration, created rules for recording the logic between events including activities as well as the pure logic restraints commonly called "dummy [activities]." These had several unintended benefits such as the general rule that "each activity must be 100 percent complete before the next can start" but were bothersome when such unforgiving rules impeded recording a process. An example is highway work where multiple activities of excavate, stone, and placement of several courses of bitumen are typically connected and overlap.

And so Professor Fondahl and others developed an alternate logic format that could record overlaps between two activities as well as the standard Finish-to-Start restraint. Since these could only be performed by hand calculation and presumably by humans who understood the processes recorded by the logic, careful recording of nuances of how two activities may overlap were not recorded or necessarily even discussed. This initial reliance upon the "human computers" who would perform calculations to know or intuit various options has led to many of the issues that continue to plague users of modern PDM software.

An IBM brochure credited the H. B. Zachry Company of San Antonio with the development of the precedence form of CPM. In cooperation with IBM, Zachry developed computer programs that could handle precedence network computations on the IBM 1130 and IBM 360. This was particularly significant because, in 1964, C. R. Phillips and J. J. Moder indicated the availability of only one computerized approach to precedence networks versus 60 for CPM and PERT.¹

The form for precedence networks was originally termed "activity on node," or "AON." The activity description is shown in a box or oval, with the sequence or flow shown with interconnecting lines. In some cases, arrowheads are not used, although this leaves greater opportunity for ambiguous network situations.

Figure 9.0.1 shows the John Doe network in precedence form. Seventeen precedence activities are shown, the same number as the regular activity-oriented CPM network. Simplicity of form is purported to be one of the advantages of precedence networks. When activities have to be subdivided to show phased progress, the precedence network can result in a lower number of notations—in some cases, more than a 50 percent reduction. Consequently, the precedence network has the advantage of a simple appearance, and to those who use it continually, interpreting it can be straightforward.

9.1 Precedence Logic

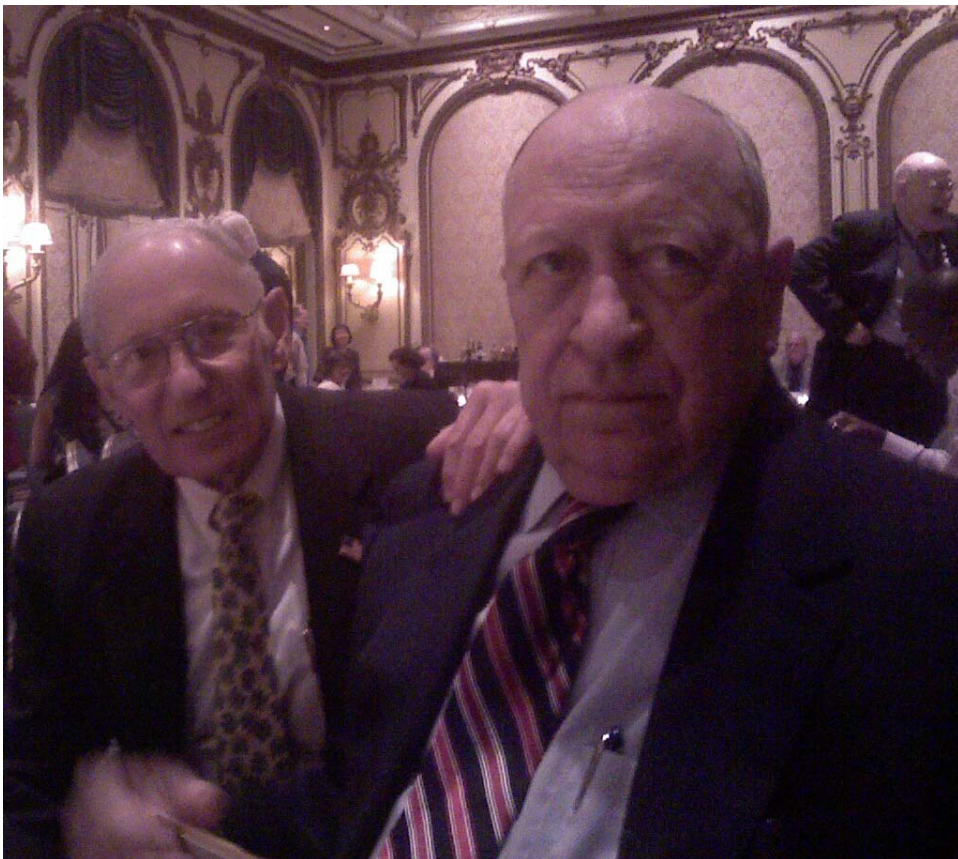
9.2 Work Package Calculations

9.3 Computer Calculation

9.4 Project Example

9.5 Summary

Both PERT and ADM formats have virtually disappeared from the construction scheduling scene, with various forms of PDM becoming dominant. However, the promise envisioned by Professor Fondahl of a system to more readily mimic a human scheduling design has largely eluded modern PDM format software. The types of relationships and restraints provided in Professor Fondahl's notes, as epitomized in Figures 9.1.2 (start B when A is 50 percent complete), 9.1.3 (continue with final 30 percent of B when A is complete), and 9.1.5 (start drainage when first ¼ mi of excavate is complete, continue with finish last ½ mi of excavate when excavate is 100 percent complete), are typically not supported by prevalent software selections. Other information expected to be known to the team players preparing the logic and performing the calculations by hand is not typically recorded (or capable of being recorded by commercially available software products). However, this is the system currently most in use, and the serious student of CPM in construction management or other time-centric usage must be familiar with the use of PDM, its strengths and its weaknesses.



John Fondahl and Jim O'Brien at the PMICOS Conference of 2011

Chapter 10

Respecting the Power of PDM

Abstract of 9th and Comment to 8th Edition for Chapter 10

A discussion between authors Jim and Fred in 2019 suggested only minor changes to this chapter relating to multiple calendars and the weather calendar. These are perhaps better addressed in our additions to Chapter 17.

10.0 Introduction to Chapter

We have all heard stories of how the modern computer is like the mythical genie, that is, it does exactly what you tell it rather than what you actually want it to do. One of the advantages of the ADM (Arrow Diagramming Method) methodology is that its stark simplicity forces the user to say exactly what he or she wants. The simple rule of ADM, that each activity may start only after its predecessors are finished, is easily understood. Moreover, although differing practitioners and writers of computer software may try to “add” features to ADM, the basic precepts of the methodology are difficult to abuse.

PDM (Precedence Diagramming Method) is the much more powerful system, so powerful that its inner workings are rarely understood by the user. One of the most oft-cited advantages of PDM is its use of lead and lag factors, or more succinctly, duration between activities or portions thereof, to supplement the information given by the duration of an activity. Unfortunately, there does not exist a universally agreed set of definitions relating to what is meant by lead and lag factors. One result of this lack is that various software vendors may each use a differing definition without even realizing the problem.

10.1 Durations between Activities: Percent Lead/Lag Relationships

10.2 Defining Overlapping Activities: Durations between Activities

10.3 Negative Durations between Activities

10.4 Remaining Durations between Activities

10.5 Impact of Percent Complete upon Durations between Activities

10.6 PDM and Hammocks

10.7 Continuous versus Interruptible Progress

10.8 Undefined Subtasks and Relationships to Other Activities

10.9 Multiple Calendars

10.10 Retained Logic versus Progress Override

10.11 Total Float Calculation

10.12 Erroneous Loop Errors

10.13 Summary

As we have seen, the Precedence Diagramming Method variant of the Critical Path Method of schedule analysis brings a great deal of additional power to the project control team in creating a model of the real world of scheduling. However, it also brings the capability of ignoring the basic regimen required of the planning professional in preparing a proper logic network, and depicting possible schedules based upon guesswork rather than logic. This new power is there for experienced schedulers to be properly used and not abused.

Chapter 11

RDM Networks Restore the Promise

Abstract of 9th and Comment to 8th Edition for Chapter 11

The story of how the Relationship Diagramming Method (RDM) was developed has been presented in the preface and elsewhere in this text. One of the goals of this text is to report on the development of RDM and to present details of this new methodology. It shall be left to the marketplace to determine whether RDM supplants PDM as PDM has supplanted ADM and PERT. However, considering that the concept was developed along with the preparation of and first announced in the 6th edition of this text in 2004–2005, and that the format was then first implemented in Primavera Pertmaster commercial software in 2008, it then boded well. Despite abandonment since acquisition of Primavera (and thus Pertmaster) by Oracle in 2008, recent events suggest there may yet be resurgence of interest in the RDM format and implementation. In any case, the mathematics behind RDM deserve review and study by the student of CPM.

11.1 Relationship Logic

11.2 Design of the Methodology for Calculation

11.3 Additional Attributes of RDM—TJ, JLF, JLS, and JTF

11.4 The Backward Pass—TJ, JLF, JLS, and JTF

11.5 Implementation by Oracle Primavera Pertmaster Risk Analysis

This section 11.5, Implementation by Oracle Primavera Pertmaster Risk Analysis, may be augmented by the following. The Pertmaster 8.0 HELP section upon RDCPM[®] provides a glimpse of many of the benefits of this partial implementation of RDM, as repeated below in Figure 11.5.12. The implementation in this version by Primavera Pertmaster (now renamed Oracle Primavera Risk Analysis) allows the User to categorize and encode a restraint (or “link” in Pertmaster terminology) as being either Physical Resource or Just-in-Time, or other category as defined by the User. Up to 256 Link Categories may be defined. A suggested more complete implementation of RDCPM’s double code of Reason/Why, thus Resource and then choice of resource such as Carpenter. Link Category 2 is reserved for coding for a Just-in-Time restraint as discussed in Chapter 6 of this Addendum.

The Just-in-Time link category attributes are next touted, followed by the ability to provide a written description about this restraint or link. Unfortunately, Oracle/Primavera/Pertmaster does not provide a means to easily access or print this description, which must instead be accessed by the dialog box or pivoted to an Excel file. Up to four additional User defined text fields are available to provide other User selected information relating to the restraint or link.

Next view Figure 11.5.13 to see how this was all implemented in the Bridge Casino example project provided on the 8th Edition text website, and previously on the CD-rom of the 7th Edition. (See <http://www.fplotnick.com/CPMinConstructionManagement/mhhe8th-1.htm>.)



Importance to include Physical restraint of Wall Required for Roof and not just a Roofer

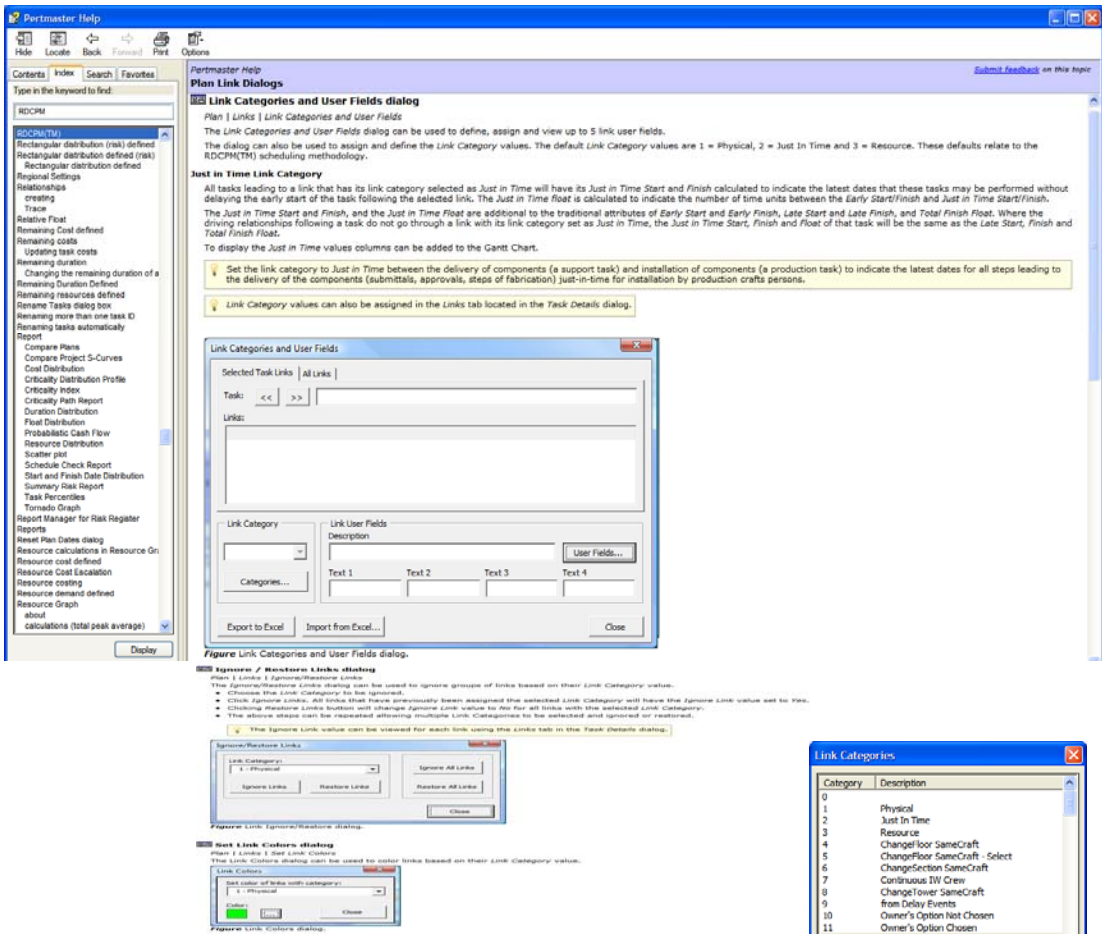


Figure 11.5.12 HELP screen from Pertmaster 8.0

and some possible link descriptions

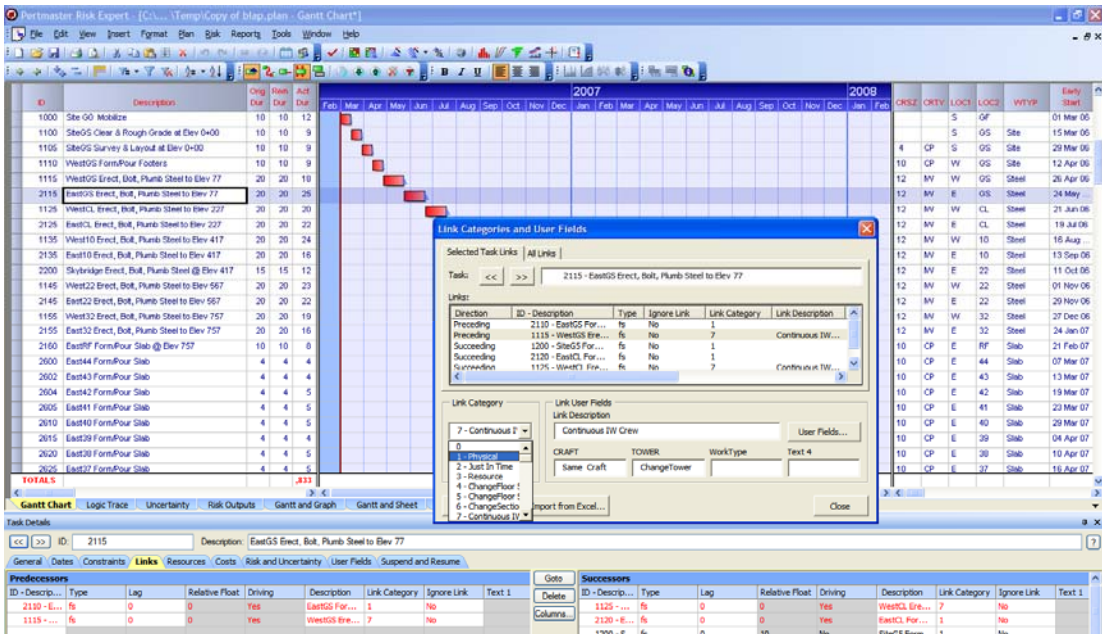


Figure 11.5.13 View using Pertmaster 8.0 from the Bridge Casino project files associated with the 8th Edition

11.6 The Road Ahead for RDM

This section 11.6, The Road Ahead for RDM, must also be augmented. The acquisition of Primavera and by definition also Pertmaster by Oracle in 2008, and differing focus by Oracle towards Pertmaster from being a high end alternate to the P6 flagship to merely a high end attachment or add-on dealing strictly in risk (including renaming as Primavera Risk Analysis or PRA,) has led to a downgrading of support for RDCPM®. While other software developers have spoken to us relating to an implementation of RDCPM®, none have yet taken the step of engaging their software team to provide code.

And yet some good news may be brewing. The latest release of P6 (for the desktop rather than in-the-Cloud) has added a new field to the file storing data upon the restraint. See Figure 11.5.14 below. This new “Comment” field proves that the software team can now add this and thus presumably other fields to this file. It is only a matter of some additional coding to restore the other features of Pertmaster 8.0 or even beyond to a more robust RDCPM®.

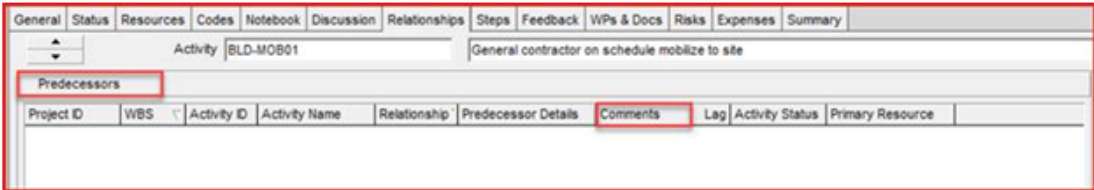


Figure 11.5.14 P6 (version 20.12) file format for Relationships now has added a “Comment” field

11.7 Summary

The new methodology of RDM provides the additional power of PDM while retaining the rigor of the original ADM system. It also adds the ability to record information on restraints and use that information for further calculations and functionality. An example of new functionality is a diagnostic to check that each activity is preceded by physical infrastructure rather than merely that resources are available to perform the work. Another example is the Just-in-Time date and float attributes which determine the latest dates that activities must be performed, not merely to avoid delaying the total project, but to delay (or disrupt) the smooth flow of work. A third example is restoration of the difference between counting the days since an activity started and measuring the progress of work performed on an activity. Other new functionalities are discussed. The implementation by Pertmaster is discussed.



Pertmaster Risk Expert v8

FRED
EnProMaC
8.5.0030
4400-1019-1118-1022-9292



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Chapter 12

Overview of Prevalent Software Products

Abstract of 9th and Comment to 8th Edition for Chapter 12

A discussion between authors Jim and Fred in 2019 suggested changes to this chapter may be too transitory and short-lived to warrant an Edition Update. But events and news releases by these product developers in 2020 (before the passing of Jim December 31st 2020) and even accelerating in the past months of 2021 suggest prevalent softwares are morphing beyond or away from CPM and back to other forms of scheduling.

Planning and Scheduling of the 2020s appears to Jim and Fred to have regressed to simply Scheduling with little consideration of planning. Let us be clear that software that calculates a “forward pass” but does not calculate a “backward pass” may be scheduling but is not CPM scheduling. The general concept promoted by software product sales staff is that a contractor should bring together each week (or month or quarter) a group of their forepersons or subcontractors to discuss what they should (or perhaps would like to) work upon this week. We may start with the assumption each entity desires to work upon something billable and with the minimum of interference with other entities.

Scope with higher markup will be promoted over that with lower markup. Any scope missed in the bid will be deferred as long as possible. Certainly scope which may utilize equipment currently placed onsite will be promoted with little concern for which scope best advances completion of the project. Some thought may be considered for what work need be done this week or period to allow work in the next period, but this is secondary to each entity being able to show maximum earned revenue for this period. Welcome to principles of lean construction, obtaining for this time period maximum earned revenue for minimal expense. Will the project be completed on time? With the knowledge that some changed or extra work or other intervening event are likely to delay completion, such considerations are easily put off to tomorrow. And yet the pyramids did get built, usually in time to house the deceased pharaoh.

Perhaps a brief reiteration of history is here warranted. Planning and Scheduling prior to 1910 was any form to invite and record a list of activities and then suggest a sequence, order or possible timing.

Following the development of the Gantt Chart or bar-chart by Henry Gantt in 1910, many contractors and others working upon time sensitive projects morphed to this new graphical depiction providing a list of activities and current schedule of timing. Note such schedule of timing does NOT by itself note required sequence, so two steps forward and one back.

The development of mechanical and then digital electronic computers during and after WWII and desire to provide commercial application by Dr. Mauchly led to the marriage between the mathematics of Dr. Kelley and computer with creation of CPM in 1956 and with PERT in 1958. This period, just following the stress and urgency of the Manhattan Project (development of the atomic bomb) and surprise by launching of Sputnik by USSR, was impelled with a need for speed and earliest possible completion of projects ranging from the Polaris Missile system to NASA's program to reach the moon.

The period continuing from the mid-1950s to the 1980s continued the frenzy for speed beyond military and now to the commercial sector due to the twin economic drawbacks caused by the rapidly increasing economy, Inflation and Escalation. Commercial interest rates topped 30% while escalation pushed 20%. Thus funds to support a budget for even a one year project may be

whittled down by 15% just to pay interest, and the budget for labor may need to anticipate an average 10% to 20% increase after the date of renewal of the labor contract. A regular issue for a contractor was to perform as much scope as possible before that date. The value of those providing advice on planning and scheduling rose accordingly. Software developers vied to support and sell to this market.

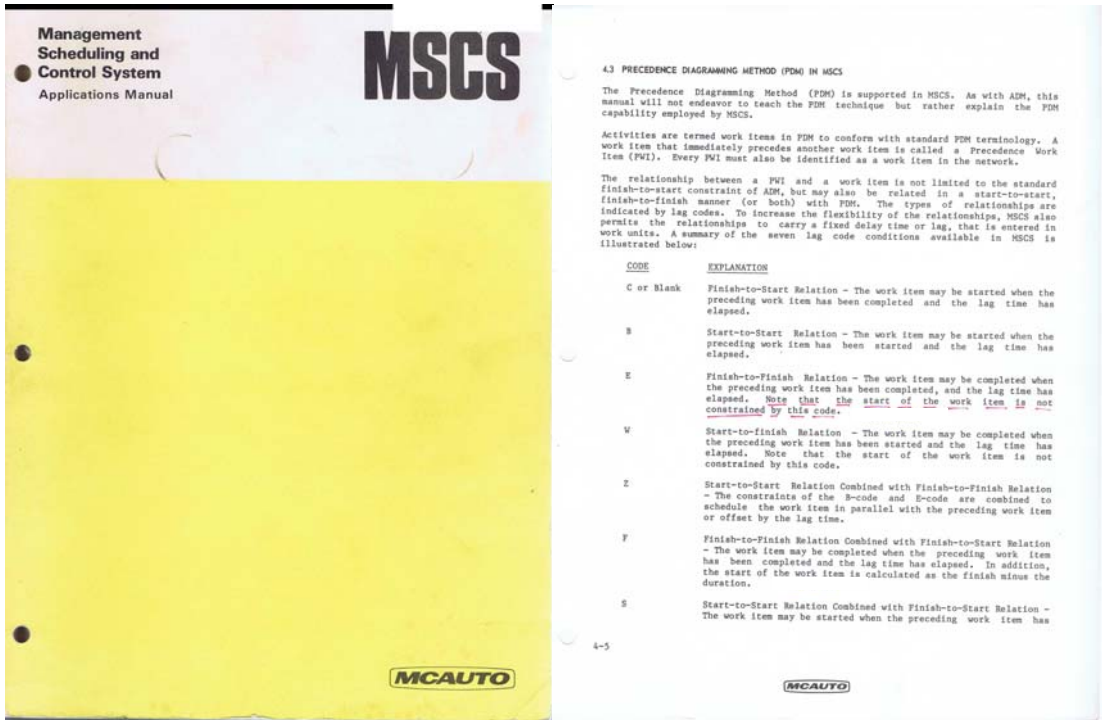


Figure 12.0.1 Cover of MSCS Manual and Page 4-3 on Relationships supported by software

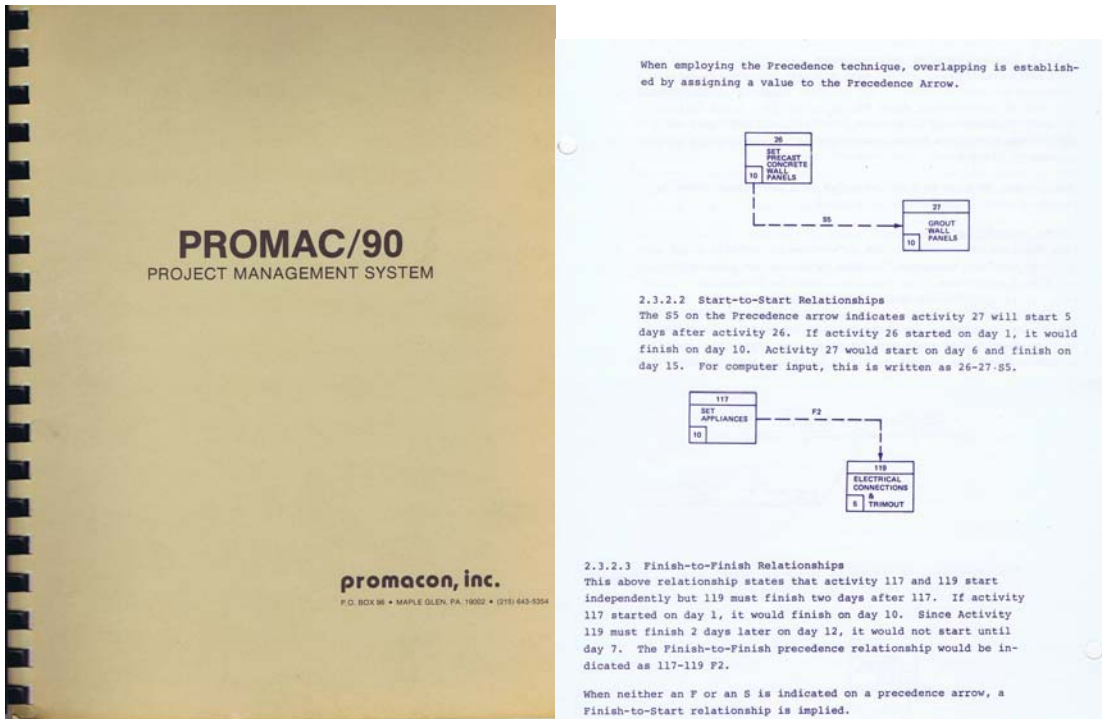


Figure 12.0.2 Cover of Promac90 Manual and Pages 2-9 and -10 on Relationships supported by software

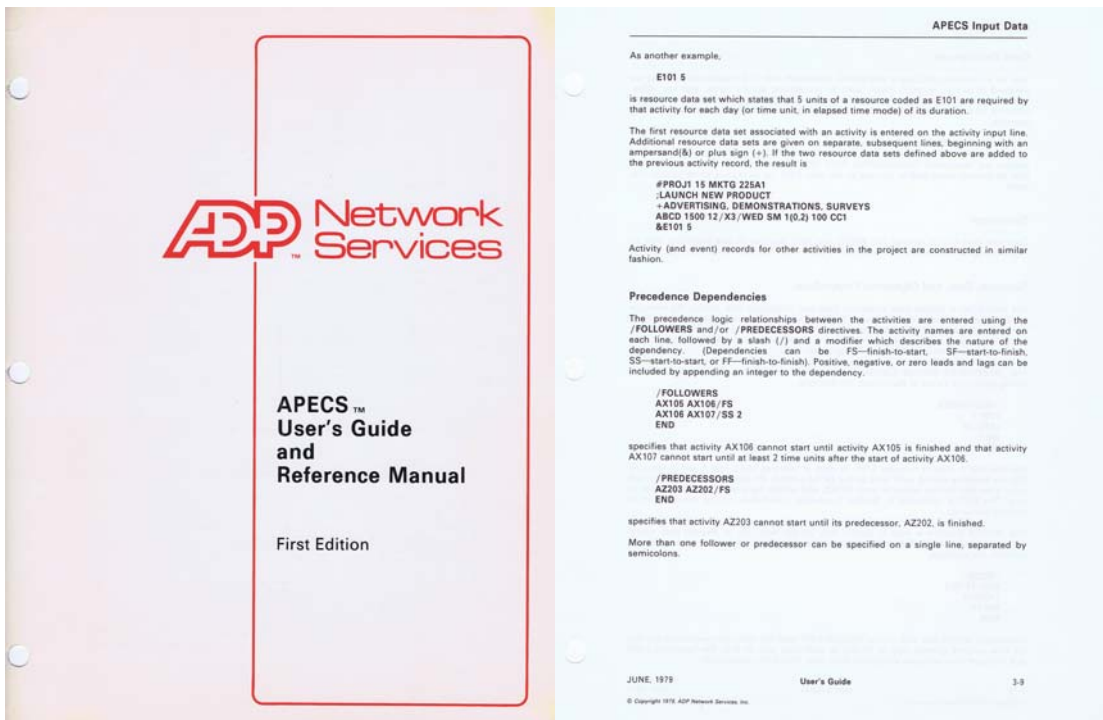


Figure 12.0.3 Cover of ADP Network Services APECS and Page 3-9 on Relationships supported by software

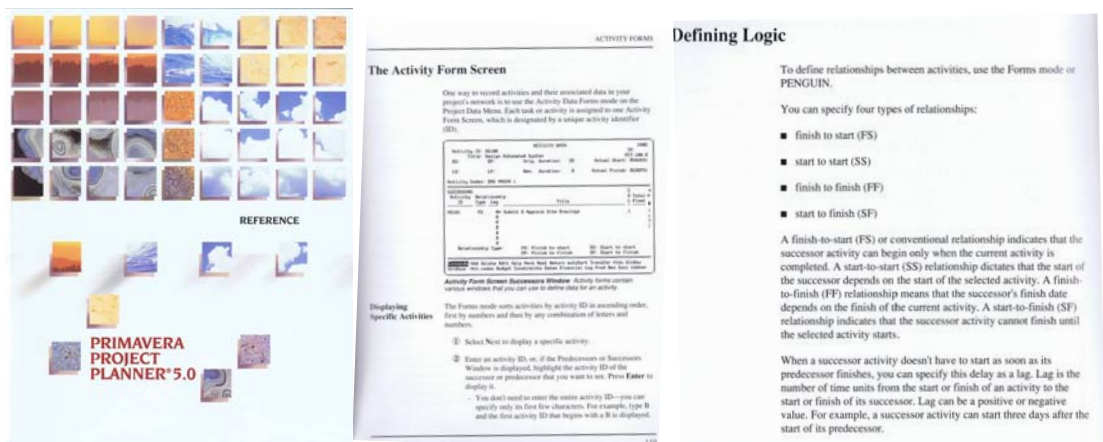
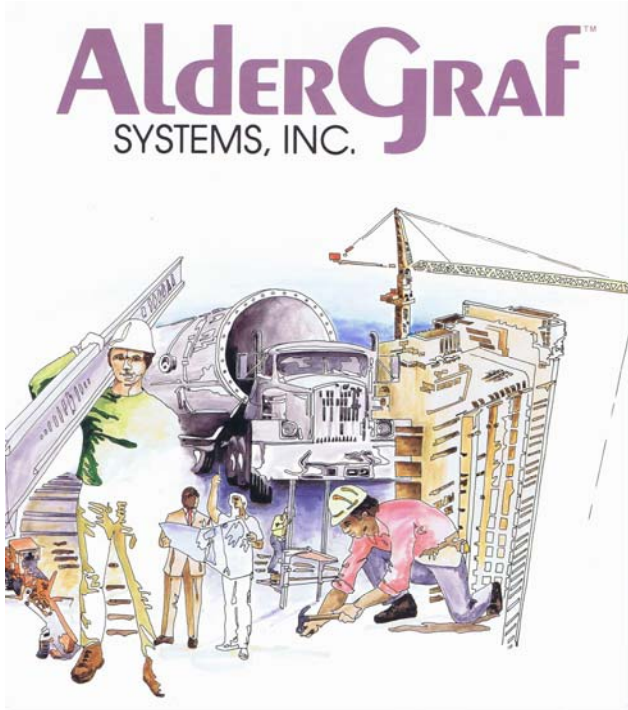


Figure 12.0.4 Cover of Primavera (for MS-DOS) and Pages 119 and 256 on Relationships supported by software

A plethora of software solutions were offered first on giant mainframe computers (and thus as a SaaS or Software as a Service) and later on the untethered desktops of the 1980s. Chief amongst these mainframe solutions were McAuto MSCS and Project/2 although many others (including PROMAC90, the mainframe precursor of Primavera P3) proliferated. Chief amongst the PC offerings were Primavera (P3,) Pertmaster (by Westminster Software, and unrelated to the Pertmaster product of Primavera,) AlderGraf, MicroPlanner, and Microsoft Project.

But inflation and escalation were largely tamed by the end of the 1980s and so the value of planning and scheduling declined. And a second and third mega-trend also influenced software development. That WWII had been fought and won by new technologies and engineering has been widely written of elsewhere. This to some extent created an aura around Engineers as King, as perhaps written in the science fiction book Player Piano by Kurt Vonnegut in 1952. However the punishing economic impacts of increasing inflation and escalation led to university and college business schools in the late 1950s and 1960s to upgrade their curriculum to teach new post graduate program to then award a MBA or Masters of Business Administration. As graduates of these programs rose to lead major companies and positions in government, the Engineer as King was supplanted by the MBA as Emperor. And the courses these MBAs studied as students focused upon a differing form of scheduling designed to achieve best productivity and utilization of resources rather than earliest completion.

The third mega-trend was consolidation as an offshoot of management of, by and for MBAs. Synergies across vast conglomerates of only loosely related entities were sought. The key effort again shifted from the earliest completion of any one project to the allocation of resources and combined economic impact of the enterprise. And so, the software developers of the 1990s and beyond have focused more upon the dictates of the C-Suite MBAs rather than those of project oriented engineers.



AlderGraf Scheduling System

EDITOR WITH RELATIONSHIP WINDOW

Activity ID	Activity Description	Act 1	Act 1 Fin	Z	Exp	Emp
17	FOUND. EXCAV.	01/25/93	02/04/93	100		
15	UNDERSLAB STORM DRAIN	02/24/93	02/11/93	100		
27	FORM & REINFORC. SLAB	02/25/93		40	45	03/25/93
11	FOUNDING TOUSETTE	02/19/93		100		
23	FORM REINFORC. SLAB	02/25/93		90	4	03/11/93
24	COMPLETE REINFORC. SLAB					
20	STEEL WINDWAY				4	13

Predecessor	Actv ID	Typ	Lag	Successor	Actv ID	Typ	Lag
UNDERSLAB STORM	15	FS	0	FORM REINFORC. SLAB	27	FS	0
FORM REINFORC. SLAB	27	FS	0	COMPLETE REINFORC. SLAB	24	FS	0

RelatF9 calls up a relationship window which displays predecessors on the left and successors on the right. The **Alt F9** key works as a rotary switch changing the window from both Predecessors and Successors, to Predecessors only, then to Successors only. After a relationship window is on screen, **RelatF9** moves the cursor back and forth between the **EDITOR** screen and the relationship window.

- The items required to enter a relationship are:
- Actv ID** to identify the activity which has the relationship.
 - Typ** (Type) of relationship which could be FS, SS, FF, or SF.
 - Lag** which is the number of workdays between the two points.

When in **Add** mode, a selection pop-up window will appear on the screen for both **Actv ID** and **Typ** when entering the first relationships. Move the cursor to the selection and press **Enter**. To manually key in the selection, press **Esc** and the selection pop-up window will disappear.

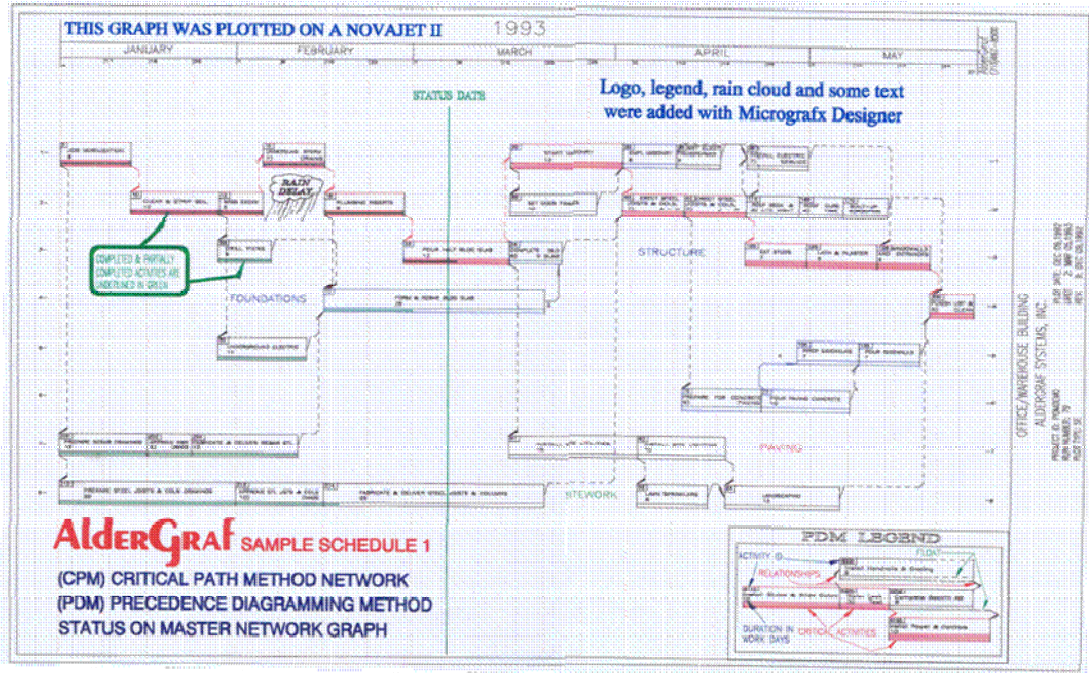


Figure 12.0.5 Cover of AlderGraf Manual and Page 90 on Relationships supported by software, Graphics by AlderGraf

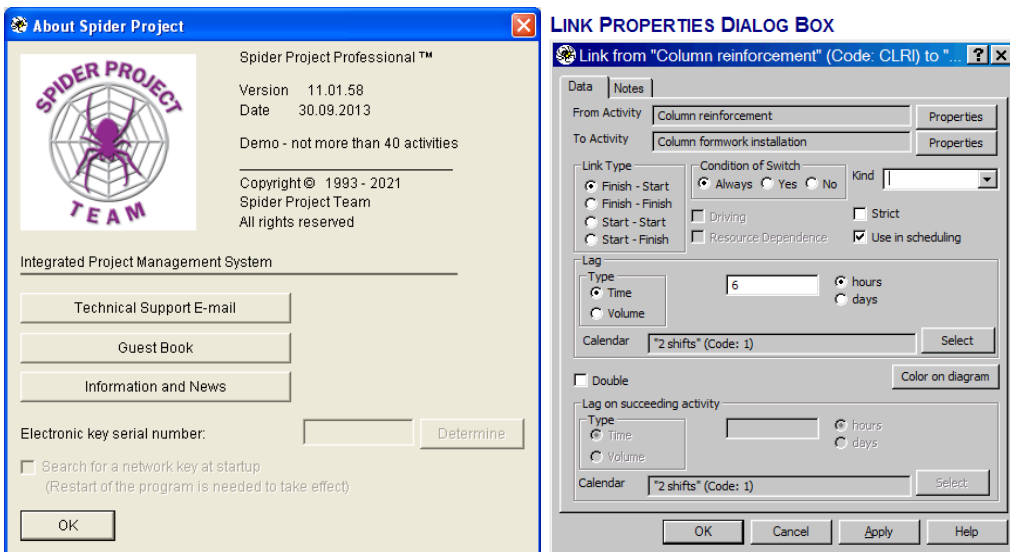


Figure 12.0.6 Spider Project Professional supports the MSCS full six restraints (C S B F E W) with Lag Type **Begin** and **End** are supported with the **Time** type of lag simply measuring time from commencement or to completion **Start** and **Finish** are supported by **Volume** type of lag measuring days (hours) of work performed to release next activity



Lag

For each relationship between activities, you can define a lag. This specifies a time delay associated with the relationship. Lags can be either positive (to indicate a delay between two events) or negative (to indicate an overlap or lead time between two events). Lag is used to specify the number of periods that must elapse between events such as the finish of one activity and the start of the next activity.

For start-to-start relationships, it is also possible to define a lag as a percentage of the predecessor activity's duration. To enter a percentage-driven lag, enter a value followed by a percent sign (%). For example, to define a lag equal to one half of the predecessor's duration, enter 50%.

Figure 12.0.7 Deltek Open Plan provided with the 8th Edition Supports the MSCS **Start** restraint if lag entered as a percent (This is not well documented nor even understood by Deltek personnel, but the % lag does trigger the alternate algorithm)

- 12.1 Overview of Primavera Project Planner P3
- 12.2 Overview of SureTrak Project Planner
- 12.3 Overview of Primavera P6
- 12.4 P6 Navigation
- 12.5 P6 Reflection Change Maintenance Feature
- 12.6 P6 Multiple Float Paths
- 12.7 Overview of Primavera Pertmaster aka Oracle Primavera Risk Analysis
- 12.8 Overview of Deltek Open Plan Enterprise Project Management Software
- 12.9 Overview of Microsoft Project Professional 2007
- 12.10 Other Software Products

12.11 Summary of Overviews

The Summary of the Eighth Edition still is valid and applicable. As can be seen from even a cursory review of only a few software products, the implementations of various options with regard to each of the extensions of the traditional, simple ADM model are fraught with the danger of accidental or intentional misuse. The marketplace has demanded of high-end systems a level of power that requires study, care, and integrity in their use. Conversely, the marketplace requires simplicity in application of powerful and often only partly understood tools. The software products available today struggle to provide what is desired by the marketplace, often being of greater complexity than understood by the user.

Chapter 13

Measure Twice—Cut Once

Abstract of 9th and Comment to 8th Edition for Chapter 13

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. A common complaint of the construction industries has been a perceived lack of increased productivity even as more and better equipment and management practices have been provided. Many studies suggest the construction industries have moved backward with lower productivity, citing perhaps parasitic safety and other mandates as causes.

But perhaps it is simply the hidden costs of better and more expensive equipment and management tools, and mindset to utilize these expensive tools, that have more than offset better training, materials and equipment. The old time worker had no problem putting down a shovel to rush to work on a time critical task. The modern highly trained on equipment worker does not want to stop using the expensive equipment to allow that time critical activity to intervene. After all, despite lip service to team effort, each worker is tied to an app that reports her or his personal productivity to upper management.

Imagine that mindset on a basketball or baseball team. When my personal scoring history is more important than team wins, and when it is more important that my personal scoring history is better than that of a teammate and who cares if we win, the team suffers. Rubrics such as cubic yards of earth moved by the machine and its person (and no longer person and his machine) do not count RBIs (runs batted in) or sacrifice bunts.

- 13.1 **Preparing to Collect the Input**
- 13.2 **The Pure Logic Diagram**
- 13.3 **A Team Effort . . . on the Blackboard or Sketch pad**
- 13.4 **Format for Ease of Data Collection versus for Ease of Data Entry to Chosen Software**
- 13.5 **Bar Chart: May Be Based upon Logic, but Is Not a Logic Network**
- 13.6 **Logic-Restrained Bar Chart**
- 13.7 **Freehand**
- 13.8 **PERT, GERT, PDM, and RDM**

13.9 Summary

The collection of data for the CPM logic network must be a team effort led by the experienced scheduler. Advance preparation of lists of activities or bar chart schedules may be counterproductive as the team member performing such work may then be reluctant to repeat such drudgery as part of the team effort. The exact format used by the scheduler to record the information acquired is not so important as the need for consistency and ability for this (or another) scheduler to transcribe these notes to the selected software product.

Chapter 14

Choosing Codes

Abstract of 9th and Comment to 8th Edition for Chapter 14

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The need to do so before collecting data on activities is often forgotten in the mad rush to produce a submittal report. However, the review of needed codes reflects the needed effort to consider an overview of intended audiences. However, the practitioner of planning and scheduling must always remember that the codes augment data for the activity, and that activities must be chosen to reflect the work to be done by or under a directly immediate supervisor of such (be that foreperson or other line manager.)

- 14.1 Calendar
- 14.2 Deliverable and Responsible Entity: SHT1, SHT2, RESP, and SUBC
- 14.3 Key Resources: CRTY, CRSZ, MHRS, SUPV, and EQUIP
- 14.4 Overtime, Night Work, Special Supervision, and Inspection
- 14.5 Quantities and Rates of Productivity
- 14.6 Location, Location, Location
- 14.7 Budget Codes for Cost: Labor, Equipment, and Materials
- 14.8 A Word about Codes Tied to the Activity ID
- 14.9 A Word about Aliases

14.10 Codes versus Tags

The increased power of modern computers, operating systems and software to attach “objects” or “links” or “tags” to an activity creates an entirely new dimension for organizing activities to enhance the data stream both to and from the CPM data collection and reporting efforts. Rather than merely noting an activity is best depicted on a drawing plan and section, we may now tie directly to the BIM (Building Implementation Model) objects of the design documents. Perhaps with a robust BI (Business Intelligence) or AI (Artificial Intelligence) subsystem of the software, we can have coding, and then even possibly sequence derived from the design documents.

14.11 Summary

Choosing the codes to be assigned to each activity is the first step in data acquisition for preparing the CPM. The proper choice of codes is important and will greatly impact the usefulness of the CPM. Some codes, such as activity type, calendar, and responsible entity, must be coordinated with the activity scope, description, and duration. Others, such as key resources, overtime, and productivity, may be used to validate the durations chosen. Still others, such as location and cost, may be used to enhance the data stream from the CPM effort, but must yield accuracy to the “set of instructions given to a competent foreman” that may transcend the sharp boundaries of such codes.

Chapter 15

Acquiring Information for Initial Schedule

Abstract of 9th and Comment to 8th Edition for Chapter 15

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. It is important that while a practitioner of planning and scheduling must lead this effort, the information acquired (and most but not necessarily all to be entered to software) must be elicited from the team members having experience in this type of project.

15.1 The Activity Description—A Gross Abbreviation

15.2 Activity ID, Activity Codes, and Logs

15.3 The Activity Further Defined by Resources Assigned

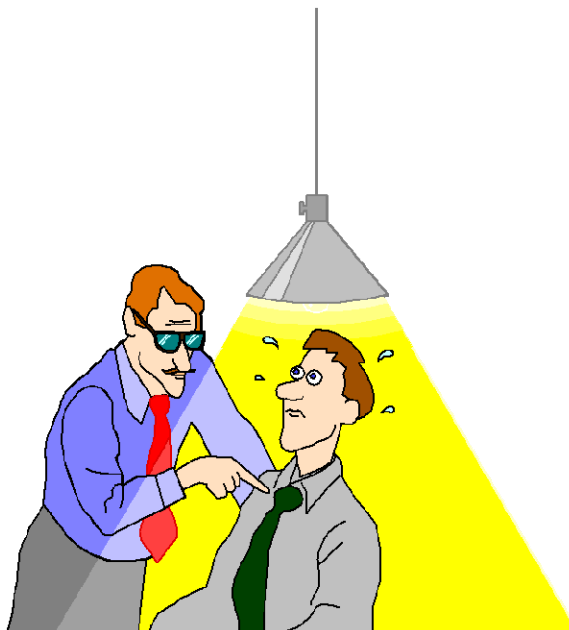
15.4 The Activity Further Defined by Predecessors and Successors

15.5 The Checklist of Subtasks

15.6 The Checklist of Subdeliverables (Events)

15.7 Summary

Acquiring activity information for a CPM logic network is more than just compiling a list of activities. The first step is always to determine who may be using the CPM and to choose appropriate codes to permit easy dissemination of the activity information collected. The resources assigned to the activity as well as by the predecessors and successor to that activity will also define the scope of the activity. If an activity consists of a number of discrete tasks, these may be listed in a log or note to the activity or as Steps in P6. However, it is important to list as such tasks or subtasks only those of such scope as is within the original set of instructions to be given the foreman or other line-level responsible party.



Chapter 16

Specifying Restraints

Abstract of 9th and Comment to 8th Edition for Chapter 16

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. Every professional planner and scheduler should be aware that the predominant softwares of today still do not support those supported by the initial softwares run on mainframe computer in the 1960s. (See Chapter 12 infra on MSCS versus Promac90 versus P3 for a history of this devolution.) But perhaps such simply underscores the importance that, whatever is used to promote ease of use and viewability of output, each activity must follow a physical predecessor and be followed by a physical successor. All others restraints must be able of explanation.

- 16.1 Mandatory and Discretionary Physical Restraints
- 16.2 Mandatory and Discretionary Resource Restraints
- 16.3 Mandatory and Discretionary Timing Constraints
- 16.4 The Misuse of Restraints and Constraints: “Nailing the Bar Down Where It Belongs”
- 16.5 The Need to Document the Basis of Each Restraint and Constraint
- 16.6 Choosing the Type of Relationship between Activities
- 16.7 The Case for Restricting Relationships to Traditional “FS” without Lag
- 16.8 The Need for Nontraditional Relationships
- 16.9 The Desire for Nontraditional Relationship and Resulting Misuse
- 16.10 Nontraditional Relationships Supported by Popular Software
- 16.11 Minimum Restrictions for Proper Usage of PDM
- 16.12 Review the Strengths of ADM: Expand the Definitions
- 16.13 Start of Each Activity Must Have Predecessor
- 16.14 Finish of Each Activity Must Have Successor
- 16.15 Real World Relationships between Activities
- 16.16 The Final Forward Pass
- 16.17 The Final Backward Pass
- 16.18 Choosing the Algorithm for the Initial Schedule

16.19 Summary

Setting and recording the relationships between activities is the step that distinguishes CPM from a “ToDo” list or a Gantt chart. It is important that the start of each activity (other than the first) be preceded by a relationship from another activity representing a physical dependency.

Similarly, it is important that the finish of each activity (other than the last) be succeeded by a relationship to another activity representing a physical dependency. Assuming unlimited resources would be enough; to account for less than unlimited resources, additional relationships may be placed between activities to communicate the preferred flow of such resources. Constraints, or locked-in dates, should be used sparingly and should be properly documented for need.

It is recommended that the use of nontraditional relationships and lag durations between activities be kept to the minimum necessary to make the CPM easier to use in the field and not simply to make the preparation of the CPM easier. If used, a check must be performed to ensure that the start of each activity has a predecessor and the finish of each activity has a successor. The scheduler must work with the tools of the software being used to “fudge” what is said about relationships into what the software will accept, but then be vigilant in remembering and explaining the inaccuracies this causes.

A final walk through the project from start to end, and then from end back to start, is a good way to check that the CPM logic is correct. The scheduler must take care in choosing what algorithm will be used in calculating the CPM so as not to have his/her careful work negated.

Chapter 17

Acquiring the Durations

Abstract of 9th and Comment to 8th Edition for Chapter 17

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. One key exception discussed is to consider the use of SPERT style Monte Carlo computation to create a variable weather calendar based upon risk rather than a flatly defined number of days (or other unit of time) for this contingency. And while considering the weather contingency and impact to activity (and project) duration, to also here consider other contingencies.

- 17.1 Best Estimate with Utilization of Resources Envisioned
- 17.2 Compare with PERT Durations: Optimistic, Most Likely, Pessimistic
- 17.3 Schedule Durations versus Estimating Durations
- 17.4 Estimated Durations versus Calculated Durations
- 17.5 Do We Add Contingency Here?
- 17.6 Estimated Durations versus Expected Completion Dates: "As Good as the Promise"
- 17.7 Productivity
- 17.8 Durations and the Project Calendar or Calendars

17.8a Adjusting the Project Calendars for Weather

As professional Planner Schedulers we must plan for the worst, but also plan for the best. In construction and other time centric projects, one rarely does as well as planned. But then how should one plan? Two takes:

- One almost never does better than planned. Plan for the worst and hope for the best. But best cannot be achieved by mere hoping.
- However, it may also be said that "You need to buy a ticket to win the lottery" and "Luck Is What Happens When Preparation Meets Opportunity."

In the eliciting, analyzing and communication of the plan of execution for a project, the professional planner-scheduler will often consider issues of climate and weather. Traditionalists may simply plan for lost days with project contingency and perhaps a slight padding of durations.

The issue of the need for and use of a weather calendar often comes up between the time of Award and the Pre-Construction meeting as the planning and scheduling professionals of the owner and contractor spar over details of the CPM to be provided. Senior management of both entities, often more familiar with the set dates of a static bar chart than the range of dates provided by CPM analysis, may desire a result with promised interim performance via declared or informal milestones. As a totally non-weather impacted project is unlikely, both entities will insist upon contingency to be added within the activities of the project. This then often leads to a self fulfilling prophesy of delayed completion even when the project experiences better than average weather.

In the early days, practitioners would insert a "weather restraint" of up to some hundreds of days from NTP to a selected activity to account for "winter shutdown" or other climatic issue. Later such issues which may shut down an entire project could be partially addressed by use of a calendar with user directed non-work days. Still later the software supported constraints. Much much later the software supported multiple calendars. These were tacked onto the underlying algorithm with little thought other than producing the initial bar-chart output and have been a source of difficulty ever since.

Some practitioners (and some owners micromanaging the CPM in an effort of claims control) dictated a weather calendar which would arbitrarily cut one or more days per week during various seasons. The number (and placement) of such non-work days was often based upon past averages over the past five or ten years at a location nearby to the project site.

In some cases, an average number of non-work days would be added; in other cases the greatest number of non-work days would be added to cover the worst past year. Only if the number of non-work days exceeded this average or worst case in the aggregate (or perhaps on a month by month) basis would the owner provide an extension of time for “unanticipated conditions.” While providing some direction relating to “changed conditions” and other issues of claims management, such instruction does not help the contractor nor owner achieve the desired result of a timely completed project. This indeed is planning for mediocre or even the worst case, and often that is precisely what the parties get.

In a normal project, some activities are finished later than estimated and some may be finished in less than estimated duration. That is the definition of “estimate” with each having some degree of tolerance. Physical dimensions are neither exact nor even to the nearest angstrom. Durations may account for varying levels of productivity and for rain this week or next week. But while such an approach addresses some, it does not address all of the ramifications of this issue. Much of the insight provided is noted even in the first edition of this text in 1964. The key point is to properly consider weather as a contingency and not *fait accompli* for most activities.

Of course, if in a location where all asphalt plants shut down from November 15th to March 15th in anticipation of cold weather, a proper weather calendar may exclude placement of asphalt during this period. But the truth is that many road building contractors have their own plants and will determine when to shut down or restart based upon actual conditions known only days or weeks in advance. To deliberately delay fabrication of steel, perhaps allowing an extended period for shop drawing preparation and review, because roughly 50% of the time we may experience unacceptable temperatures in a specific year, yields a great loss of opportunity for both the contractor and owner.

However, the weather calendar is but one form of resource that dictates whether an activity may be performed. Other resources may include availability of not only acceptable weather but also of craft labor, equipment, inspectors and perhaps other resources. It is perhaps because softwares historically added the “multiple calendars” including the “weather calendar” and only later considered these other resources that most now have two separate resource systems and even two separate “weather” calendars: one for the activity and one for the resource. At least one software developer has merged these two “weather” systems to create one which simply lists all resources (be such clear weather or availability of crafts.) While this may seem obvious, one must always remember with software development that “add to” is favored over “rethink and re-write.”

What has not here been explored is the impact upon our considerations of the use of risk software. Bad weather is a risk. Seasonal weather variations provide both an opportunity and threat to timely or earlier completion. And so this text now suggests considering the use of a Weather Risk Calendar compared to the traditional use of a static Weather Calendar.

The developers of PERT explicitly stated that also understood by the Kelly-Walker team: activity duration is only an estimate, subject to a range or tolerance, and the estimate given is usually the “Most-Likely” after consideration of worst case (Pessimistic) and best case (Optimistic) estimates. The text, dating back to the computer hardware and software capabilities of the 1960s, suggests using with this “most-likely” estimate of extended duration for non-production down time caused by weather, or perhaps even a few days less to achieve the likely “earliest date on which the activity may first be performed.”

And thus a proper approach may be to treat weather as a contingency. Instead of aiming for the average weather of the past five or ten years, and then a complex contractual formula to determine if an extension of time may be granted for “unanticipated poor weather,” we suggest to aim for the best while defining project contingency for the worst. The project team should order material to be delivered and subcontractors to be ready to perform based upon a best-case scenario which should be better than actually achieved in the past five years.

How much better may be a matter for discussion by the contractor team. We may suggest one to two standard deviations from the period (five to ten year) average. While it is unlikely the contractor will experience such good luck, the contractor should be ready (and definitely should be permitted) to capitalize if such occurs.

The flip side may be a matter for discussion by the owner team in preparing the contract specification. The owner does not want to pay the contractor to accept too much risk. (An owner should remember that a contractor still in business after many years probably charges more to cover risk than the owner could pay an insurance company for similar coverage.) We suggest weather more severe than that experienced in one to two standard deviations for the period.

As noted elsewhere in the text, the place for such a contingency is at the end of the project.

17.9 Durations between Activities

17.10 Summary

Durations for individual activities should be estimated as the activity scope is determined along with the recording of crew size and other assigned resources. Durations should not be based upon information in the bid estimate. The project manager should be encouraged to give ranges of duration concluding with a “most likely” duration. Contingencies for foreseeable, but not expected, situations should not be factored into the duration, but should be noted and recorded separately. Once all activities and durations have been provided and recorded, the durations can be crosschecked against the bid estimate and against the durations of similarly scoped activities for the purpose of validation.



Record snowfall 06FEB10 at Fred's house

In the ten year period 2010 to 2020, maximum one day snowfall in Philadelphia was 21.9 inches (shown,) lowest was 2.3 inches, average was 9.8 inches. In four of these eleven years one day snowfall exceeded 12 inches. How much snow should entitle contractor to an extension of time?

Chapter 18

Evolution of the Project Schedule

Abstract of 9th and Comment to 8th Edition for Chapter 18

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The initial and to be submitted plan should be prepared within a rather short period after the project team is assembled and provided authority to act. A little more time should then be allotted to conversion to a schedule or possibly schedules for differing audiences.

As the project evolves, and almost all projects experience change of scope or conditions from that initially anticipated, a proper project plan should hold up with minimal revisions. Revisions (or reBaselining in modern parlance) should be discouraged and only prepared or accepted as a last resort. Parties should always demand a full Update to show performance-to-date prior to introduction of a Revision.

A proper CPM provides at least two possible sets of performance, including as calculated by the forward pass to contribute an Early Start and Finish, and then the backward pass to contribute a Late Start and Finish. Care should be taken to not permit the parties to prejudice the onsite team by premature allocation of float. The Early Dates should indeed be the earliest that the activity may occur.

But now the second stage of thought kicks in with the team to hone the calendar and availability of other resources, level and smooth allocation of resources, and consider other schedule manipulation in preparation of the continuously reviewed and modified short term working schedule. And this process of going back to the end of the first stage will need to be reviewed and reconsidered with each Update.

18.1 Preliminary Schedule

18.2 Preconstruction Analysis

18.3 Contractor Preconstruction Analysis

18.4 Milestones

18.5 The John Doe Schedule

18.6 Resources

18.7 Fast Track

18.8 Responsibility

18.9 Schedule versus Calendar

18.10 Contingency

18.11 Schedule Manipulation

18.12 Working Schedule

18.13 Summary

The first CPM computation is a plan, not a schedule. After adjusting the project completion date by changing sequences and time estimates, an end date is determined. The date should precede the desired completion with a suitable contingency. The intermediate dates should be reviewed with the realities of seasonal weather. Seasonal factors can be accounted for if necessary. The schedule at this point can still be rather loose. Lead and lag arrows can adjust float to position activities within the range of their CPM dates. Schedule sequence arrows can be used to provide a schedule using fewer crews. Scheduling arrows can add to the effectiveness of the CPM results, but one error in their use can far outweigh their benefits.

The owner sets the overall schedule dates, often on the basis of uninformed intuition. Preconstruction schedule analysis by a construction manager can yield important results. Milestones help in controlling the schedule. The basic schedule can be expedited, but a major time reduction requires either changes in basic policy or major efforts, such as fast tracking.

Chapter 19

Equipment and Workforce Planning

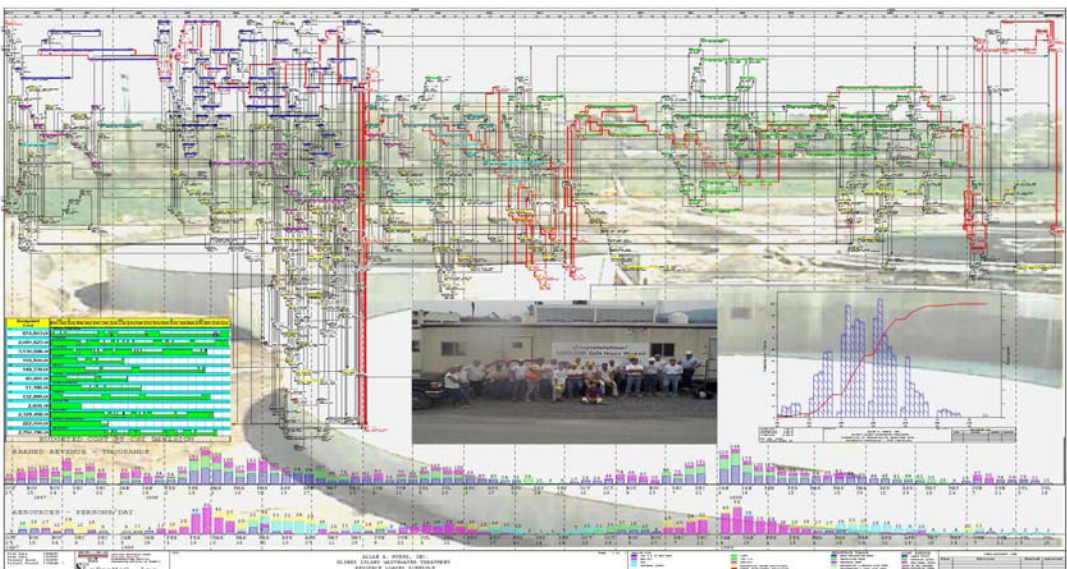
Abstract of 9th and Comment to 8th Edition for Chapter 19

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter at this time. New softwares and the mindsets behind such may warrant a rethink on this for a future Addendum or new Edition.

- 19.1 Workforce Leveling
- 19.2 Computerized Resources Planning
- 19.3 Resource Leveling and Smoothing
- 19.4 Limitations of Algorithms
- 19.5 Driving Resources
- 19.6 Resource Calendars
- 19.7 Practical Solutions
- 19.8 Summary of Resource Leveling
- 19.9 Turnaround Application
- 19.10 Examples of Resource Loading on John Doe Project
- 19.11 Resource Leveling Significance

19.12 Summary

Resources such as workforce, equipment, and money, can be assigned to CPM activities. For a simple network, maximum workforce requirements can be forecast and leveled by two manual techniques. When resource limits are set in, the project duration can be lengthened. Manual techniques are limited and cannot handle large networks. Large networks are an excellent area for computer application. When a schedule is resource-constrained (i.e., certain resources are not available to support critical activities), the network float concept no longer controls identification of controlling activities. In multiproject systems, such as turnarounds, the identification of the critical path is often less important than the cataloging of all the work to be done.



Workforce Planning depicted in [Award Winning Graphic](#) Primavera Conference 1997

Chapter 20

Procurement and Preconstruction

Abstract of 9th and Comment to 8th Edition for Chapter 20

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. As this Interim 9th / Addendum to 8th Edition is published, issues with procurement and logistics of timely delivery are all the news. Our Section 20.2 on RDM Just-in-Time to the Rescue has perhaps become even more important to suggest that Procurement may have float, but only that degree of float to not impact the best allocation of resources in field towards not only timely but economic completion. And if your software does not support this calculation, the practitioner of planning and scheduling must do so by use of other tools or even if necessary by hand.

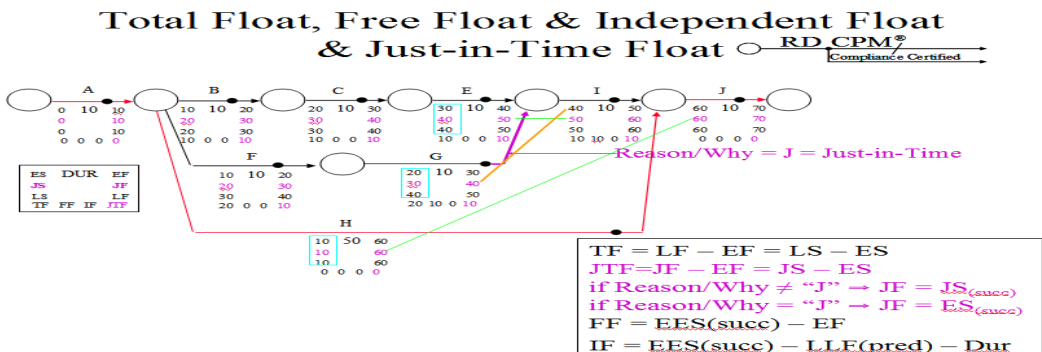
- 20.1 Scheduling Materials Procurement
- 20.2 RDM Just-in-Time to the Rescue
- 20.3 John Doe Example
- 20.4 Preconstruction
- 20.5 Predesign Phase
- 20.6 Design

20.7 Summary

If procurement is ignored in the scheduling process, materials and equipment deliveries can become the controlling factors by default. In most major projects, there is enough non-materials-oriented front-end work to allow time to order materials through the contractor. However, in special situations (renovations, overseas projects, and/or fast-track projects) it might be necessary for the owner to preorder equipment or materials.

To achieve the real benefits of logic and control through network analysis, project management should be instituted as early as practicable, preferably about the time a project is identified in a budget. Installation and implementation of CPM in the actual construction phase are of great importance, but many opportunities to save time and money will be missed if this control is instituted too late.

It is important that early and non-construction-related activities be scheduled to support the early-start dates of the construction, erection, and installation activities of the field. It is important not to use the contingency of float for tasks in this more easily controlled environment. Therefore, it may take some effort to note the free float of the last activity in, for example, a procurement string, such as delivery, to determine Just-in-Time late dates for which such activities must be performed to best support the field effort. This may be a tedious task, but it is well worth the effort. This task was automated by the RDM functionality of Pertmaster versions 8.2 through 8.6 but is not now supported by current software.



Chapter 21

CPM and Cost Control

Abstract of 9th and Comment to 8th Edition for Chapter 20

A discussion between authors Jim and Fred in 2019 suggested the need to consider two additions to this Chapter relating to Earned Value Management and the Work Breakdown Structure often employed by home office (or owner) management and then dictated down. These are discussed below in a revised Section 21.6 and new Section 21.6a.

Chapter 21.CPM and Cost Control

- 21.1 CPM Cost Estimate
- 21.2 Progress Payments
- 21.3 Cost Forecasting
- 21.4 Network Time Expediting
- 21.5 Minimum Cost Expediting

21.6 Earned Value Management

A full discussion of earned value management (EVM) is well beyond the scope of this text. However, a robust EVM system may well build upon cost control components of a proper CPM logic network plan and then calculate the schedule. It is most important to understand that CPM and EVM often use different tolerances and rounding models, with the same words have differing meanings to practitioners of each, and while the CPM represents a plan around a team effort, implementation of EVM is always specific to each party of that team.

Traditional use of EVM evolved around the work breakdown structure (WBS), organizational breakdown structure (OBS), and enterprise project structure (EPS) of one master entity. But while the instant project may be only one part of a program of an owner, the inspector only one staff member of a department of the engineering office, and the component being installed being further defined by a hierarchy based upon function, location, or other attribute, all such categorizations may be entirely different for the prime contractor, for a subcontractor, for a vendor, and for a third-party member of the project team.

Depending upon union jurisdictions and other factors, a small concrete structure such as a storm sewer inlet may be formed, rebarred, and poured by one crew and all within 1 day. To break this one activity into three or more activities to meet a WBS or EVM system desiring to track rebar productivity will degrade the usefulness of the CPM, and eventually the validity of the EVM data tracked. Similarly, to combine or merge several activities to support an EVM protocol will reduce the usefulness and validity of the CPM and ultimately may create difficulties in implementation in the field. Moreover, while a proper WBS will indeed include all scope of the contract for cost considerations, it will include other elements not required of a CPM schedule designed to expedite the project, such as weekly cleaning of the office assigned to the owner or engineer's representative, and not include important and required scope to actually built the project, such as falsework. All too often a CPM is modified for the benefit of home office EVM staff, and then it is totally abandoned as a working tool by the field. Yes, the field will have a low-level body faithfully report what *has* happened, but the tool is no longer valid for planning ahead.

And so, beyond the scope of this text should be a discussion about software to take data from the CPM, to be massaged and modified as necessary for use in a robust EVM system. The approach to using the cost data associated with a CPM for purposes of progress payments as suggested in Chapter 30 may be a first draft toward a proper solution.

21.6a Creation and Use of a Work Breakdown Structure

As we compare the differing mindsets of the Planner/Scheduler and Accountant, we should look first at the smallest unit of work as defined by each profession. We have previously stated that to a Planner/Scheduler in the construction industry, an activity is “a proper activity is a set of instructions, given to a competent foreperson, who is then expected to complete such activity without further supervision or interaction with other than his or her own subordinates.” In the construction industry, typically a Planner/Scheduler does not micromanage and therefore the “activity” is the smallest component of work within a CPM plan.

But in the world of Accountants and others who utilize a WBS, or Work Breakdown Structure, for organizing, executing and reporting performance of scope, the smallest unit of scope is the Work Package, possibly defined as a group of related tasks leading to a defined deliverable and appearing similar to a small but defined project. These then must be accumulated in a hierarchical manner with others of some “similar” appearance to a higher level, and such group with other groups of this level to yet a higher level. But as in any system of items being accumulated within a hierarchical structure, the question arises as to what is at the top.

Here as with the EPS or Enterprise Project Structure, that will be defined differently by the different members of the project “team.” Keep in mind that the deliverable of a specific work package represents a tangible outcome that gives satisfaction to one or more project stakeholders. The owner may certainly desire to build towards project completion, but accumulating at intermediate levels based upon the accounting structures or breakdown of items of other projects. The same may be said for the contractor and again for each of the subcontractors and other providers to the project. But whether rebar used on the project is to be installed by the prime contractor or one of several subcontractors, or supplied by one or several material vendors is of differing importance to that owner, prime contractor or other team member.

The absolute size of a deliverable (of related tasks) versus of an activity (of set of instructions to one foreperson) also creates issues with assigning a WBS to each activity. Perhaps such is backward with one activity creating measured performance to two or more work packages, in turn to accumulate to divergent areas of the one work breakdown structure. A comment or instruction of the draft GAO (Government Accountability Office) Guideline Specification for a CPM highlights the issue by demanding that an “activity” of the CPM may need to be split into two activities or two activities combined to one to fit the more important WBS nomenclature.

As software to more fully support RDCPM® is developed, some more thought may be given to this issue and the situation where PART of an activity is required to advance one WBS work package, while another PART is required for a differing WBS work package.

21.7 Summary

A cost breakdown of the CPM network is best done by activity and best carried out immediately after the award of the contract. The cost breakdown should be within the framework of the bid, and it must be realistic. An important use of the activity cost breakdown has been in making progress payments. However, it is important to remember the primary purpose of the CPM is for forward planning and not the recording of the past, even for purposes of payment. Where the selection and definitions of activities diverge for use for schedule or cost consideration, it is better to keep to the CPM definition with a footnote to the cost department than to degrade the usefulness and validity of the CPM.

Cash requirements of the project can be forecast on a time basis by computer with the use of the CPM cost estimates. The forecasts can guide owners in investing the construction funds to realize the highest yield and contractors in determining their financial needs and methods.

The cost of expediting a project can be accurately estimated by using a CPM-based cost system. There are even cases in which a project can be completed early at a lower cost through carefully directed expediting. The promise of cost expediting has not been fully realized, principally because existing cost collection and accounting systems do not relate directly to construction activities.

Chapter 22

Enterprise Scheduling

Abstract of 9th and Comment to 8th Edition for Chapter 22

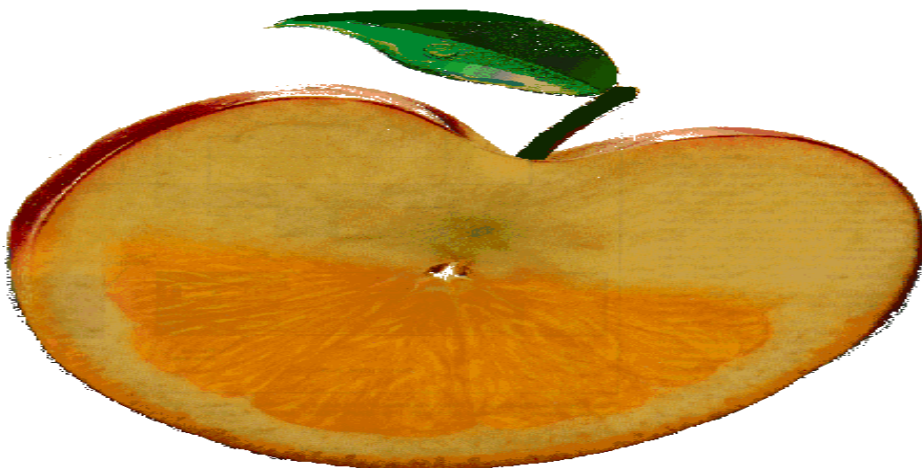
A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. We again stress the CPM Planning and Scheduling relate to timely completion of one defined project and that rarely will all parties to a contract or team members of differing organizations agree on disrupting or delaying that one project for the cited enterprise of other members.

- 22.1 Multiproject Scheduling
- 22.2 Multiproject Leveling
- 22.3 Summarization by Enterprise Organization
- 22.4 The Dashboard
- 22.5 Program and Portfolio Management
- 22.6 Enterprise Software

22.7 Summary

Enterprise program and portfolio scheduling systems may add additional enterprise-wide benefits to those attained by individual projects from the proper use of CPM. However, it must always be remembered that the primary purpose of the CPM is to promote an individual project, and that any diminution of the quality of the CPM model to accommodate enterprise scheduling needs may well overwhelm those benefits. True multiproject scheduling is rare as the director of a program or enterprise rarely has sufficient control over execution of the various program projects. Where such control exists, the ability to move limited resources from one project to another may be of significant benefit to the enterprise.

Dashboards and other high-level reporting tools may provide information to upper management but must be viewed in context. Program and portfolio management systems may also be used to choose which projects are to be nourished and which are to be suspended. The vendors of CPM scheduling software are all devoting a major portion of their R&D efforts toward servicing the program, portfolio, and enterprise needs of upper management, in some cases at the expense of ease of use of such software by personnel on the front lines who are more concerned with their own projects.



Chapter 23

Converting the Team Plan to the Calculated Schedule

Abstract of 9th and Comment to 8th Edition for Chapter 23

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The practitioner of planning and scheduling may be the person most knowledgeable of the process of planning and the softwares for scheduling, but the real input both of data and of the usage of output belongs to the project team leader and her team.

The focus of many recently released software products is to assist the project team to “develop” and “display” this week’s version of the Project Schedule. We do not need the mathematics nor software code of CPM to collect the opinions of members of the team and spit back what was suggested. What we have been emphasizing in this text is to collect data – not opinions – and upon which to perform mathematical calculations to suggest a possible schedule.

But at the same time, it is important that the end product be directly usable by the team and not require an on-site “priest” to interpret.

23.1 Data Entry Made Easy

23.2 Check and Set Schedule Algorithm Options

23.3 First Run and Debugging the Logic

23.4 Loop Detection and Correction

23.5 Technical Review: The Primavera Diagnostic Report

23.6 Beyond the Primavera Diagnostic

23.7 First Review of Calculated Output: Reality Check

23.8 Detail Views of Output of Schedule Calculations

23.9 Timescaled Logic Diagram

23.10 Tailoring Initial Output to the Chosen Audiences

23.11 Whatever Owner Wants, Owner Gets

23.12 “You Can’t Always Get What You Want, But . . . You Get What You Need”

23.13 Reports and Views for the Foreman Performing the Work

23.14 Reports and Views for the Contractor’s Superintendent

23.15 Reports and Views for the Contractor’s Upper Management

23.16 The Narrative Report for Each Audience

23.17 Summary

Going from the step of data acquisition for a logic network to the publication of the contractor’s schedule involves a number of steps, from data entry to validation of the plan to validation of the schedule to preparation of reports tailored to the intended audience. An important point to keep in mind is that the quality of the product must be kept in the forefront and not be subject to dilution by the desires of the project manager, the owner’s engineer, or third parties.

Chapter 24

Engineer's Review of the Submitted Initial CPM

Abstract of 9th and Comment to 8th Edition for Chapter 24

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter.

24.1 Legal Aspects of a Review

24.2 Reviewing the Plan

24.3 Technical Review

24.4 Reschedule and Review the Diagnostic Report

24.5 But Is the Logic Realistic? The Smell Test

24.6 Metrics

24.7 Project Calendar or Calendars

24.8 Summary

The engineer cannot and should not attempt to verify that the contractor can perform the contract work according to the “plan of execution” provided by the initial CPM submittal. However, the engineer can and should verify that the submittal is technically correct and that the logic and durations of the submittal appear “reasonable.” Finally, the engineer should “walk through the CPM” and determine if everything “smells right,” which may lead to additional scrutiny. But the review of the initial submittal of the CPM must be handled in as professional a manner as any other submittal to the engineer.



**The Legal Obligations of Reviewing
the CPM Submittal and Updates**

Chapter 25

Updating the Schedule

Abstract of 9th and Comment to 8th Edition for Chapter 25

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The whole purpose of the development of CPM as improvement over the previous Gantt or bar-chart method was to rapidly facilitate the Update. And so the practitioner of planning and scheduling must always focus the project team on this goal while building the plan.

We repeat that a proper Update may include only information from the past (preferably immediate prior past period) and never consider new anticipation of the future.

25.1 Why Update the Schedule?

25.2 Acquiring the Data for an Update

25.3 Distinguishing Updates from Revisions

25.4 Purpose of an Update

25.5 The Purpose of a Revision

25.6 Who Should Collect Data for an Update?

25.7 Who Should Prepare Data for a Revision?

25.8 Information Required for Schedule Control: AS, RD, AF

25.9 Determination of Actual Start and Actual Finish Dates

25.10 Determination of Remaining Duration of Activities: Repeat the Steps of the Master

25.11 Expected Completion and Renewing Promises

25.12 Automatic Updates

25.13 The Forgotten Step: Determination of Remaining Duration between Activities

25.14 Save and Rename: Naming Strategies

25.15 Reports and Views to Assist Acquiring Data for an Update

25.16 Electronic Tools to Assist Acquiring Data for an Update

25.17 Choosing the Correct Algorithm for Updates

25.18 Scheduling the Update: Interpreting the Results

25.19 Technical Review: The Primavera Diagnostic Report

25.20 What to Look for When Reviewing the Update

25.21 Tailoring Update Output to the Chosen Audiences

25.22 The Narrative Report for Each Audience

25.23 Summary

The creation of a process of updating the schedule from the initial plan was the initial impetus of the Kelley-Walker group at DuPont in developing CPM. It is still the major difference from static processes, such as a Gantt chart. The effort and care by the top members of the project team in preparing the initial CPM plan will enable less-experienced personnel to collect update data. It is important to distinguish between an update and a revision. An update will only add the date an activity actually started and finished, or if not finished, will add a new assessment of the remaining duration of an activity. An update will never modify logic or allow changes to the original duration of activities not yet started. In updating activities connected to others by nontraditional relationships, it is important to manually review the lag durations between such activities. Update information should never be applied to an existing file; the file should be saved and copied to another file to which the update data may be applied. Review of the update should focus upon the critical and near-critical paths and upon variance from the initial "plan of execution," as may be determined by review of the work performed out-of-sequence diagnostic. Tabular, graphic, and narrative reports should be prepared taking into consideration their intended audiences.

Chapter 26

Revising the Logic Network

Abstract of 9th and Comment to 8th Edition for Chapter 26

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. We repeat that Revising the Plan should be a last resort and only if the team understands they have no chance of returning to that plan. We repeat it is imperative to Update the Schedule before Revising the Plan so to allow the team and others to see where continuing on the prior plan will go. And preparation of a Revision should be reviewed with the same degree of care as that Original or current plan.

26.1 “What If” versus Committed Changes

26.2 Changes: Approved, Constructive, and at Contractor’s Cost

26.3 Revised Baseline

26.4 Update Then Revise

26.5 Summary

Revisions to the network are required whenever the assumptions of the original “plan of execution” are no longer accurate. Revisions to the network are neither required nor appropriate so long as the team has any desire to return to that original “plan of execution.” Once revisions are made it may not be possible to measure performance against the original plan. The first step of a revision is to copy the last update to a new file. At this point that last update may be the only file that may be used to measure performance since the inception of the project (or previous revision.) To the copy of last update new and additional activities must be placed based upon “physical” logic restraints—leading from work that must be complete before the new activity may start and leading to work that cannot start until the new activity is complete. Serious consideration must be given to the provision of resources to perform the extra work and from where such resources may be diverted. It is important to always update before revising a network.



Chapter 27

Engineer's Review of the Submitted Update or Revision

Abstract of 9th and Comment to 8th Edition for Chapter 27

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. We repeat that review of a Revision should be considered with the same degree of care as that given the Original or current plan.

27.1 Is This an Update or a Revision?

27.2 The Technical Review

27.3 The Critical Path

27.4 What to Accept and What to Reject

27.5 Metrics for Updates

27.6 Revisions Are Not Updates

27.7 Minor Revision

27.8 Major Revision

27.9 Recovery Schedule

27.10 Summary

The submitted update of the CPM allows the engineer to determine whether the project is continuing on course or is falling behind. It also may be used to determine if the contractor is having difficulties that may result in a proper or improper claim against the owner. The first check by the engineer should be to ensure that the submittal is strictly for an update and does not improperly mix an update with a revision. Next, the engineer should verify that the input to the update (the actual start and finish dates and remaining durations for work-in-progress) is correct and matches what exists in the field. The engineer should run the update file on his or her own computer to remove the temptation of cheating from the contractor. The engineer should carefully review the diagnostics to determine if and where the contractor is deviating from its plan of execution and the reasons why. The engineer should review the near-term for the critical and near-critical paths to ensure that the engineer will be ready to assist so that this work is performed in a timely manner. The engineer should also check for signs of understaffing or lack of progress on noncritical but soon-to-be-critical work. The engineer's acceptance of the update should be limited to agreement to the input and to the form of submittal. Opinions of the contractor as to the cause of delay or disruption should be noted as heard, reserving the right to respond to a more proper forum. Nonetheless, the engineer should be watching for contractor problems before they are brought as claims.

The engineer's review of a submitted revision to the CPM requires care in preventing the contractor from cooking the books while professionally avoiding pressure by the owner to do the same for the owner. The first step of any revision is to have a full and complete update of the status of the project prior to modifying the approved baseline plan. Minor revisions involving the addition of various changes and unanticipated events to the last update to determine their impact should be done on a contemporaneous basis. Major revisions to the contractor's plan of execution should be preceded by a full audit and documentation of the current status of the project. A recovery schedule or acceleration schedule should be reviewed with responsibility-neutral bias.

Abstract of 9th and Comment to 8th Edition for Chapter 28

A discussion between authors Jim and Fred in 2019 suggested we add one or more new Case Histories. Ultimately only one was deemed to be of sufficient interest to be included, involving nuances of the CPM logic that draw attention to differing calculated results for the same data by differing software, and the importance of the interruptible or discontinuous algorithm supported by many but not all software products.

28.1 Chicago Courthouse

28.2 Times Tower

28.3 Airport Construction

28.4 High-Rise Construction

28.5 NASA

28.6 Housing

28.7 Manufacturing Facilities

28.8 SEPTA Rail Works

28.9 New Jersey Turnpike Authority 1990–1995 Widening Program

28.10 JFK Redevelopment

28.11 Toronto Transit's "Let's Move" Program

28.12 Phoenixville-Mont Clare Bridge

28.13 Graduate Hospital Diagnostic Building

28.14 Interstate 76, 202, and 422 Interchange

28.15 Port Authority of New York and New Jersey

28.16 Maricopa County Jail Design and Construction Program

28.17 TXDOT SH45 Highway with Five High Bridge

28.18 J.J. Pickle Federal Building – A Comparison of P3 v P6 Software

Renovation of the J.J. Pickle Federal Building in Austin Texas presented an almost insurmountable challenge to remove potentially hazardous material from an operating government building while continuing to actively serve the general public, and all within a very limited timeframe. Wikipedia states that "The J.J. Pickle Federal Building is one of the largest mid-century modern buildings in Texas and has a rich political history ... [and] is known for its famous [former] occupants, including Congressman J. J. Pickle and President Lyndon B. Johnson," and the current office for Senator Ted Cruz.

Briefly, the plan of execution developed by the team was to vacate one floor then to be sealed and renovated, another floor of operating offices then moved over a weekend, and the process repeated until the building was restored to full service. This required a careful CPM plan involving coordination of stacking of several trades in a very tight space during the limited period allocated for renovation of each floor. Trades would be expected to work quickly, then stop to allow another trade to come in, and then return to complete work in each area. Efforts were made to send "stopped" crews to perform non-critical work in adjacent corridors or other common areas of the building while waiting to be recalled to their critical mission scope.

See Figure 28.18.1 and note the degree of overlapping activities and “stacked” crews. HVAC Distribution must complete 4 of 13 days scope before starting (and finish 2 days before finishing) Water Supply. Water Supply must overlap 2 days with Electrical Distribution. Electrical Distribution must overlap 2 days with Fire/Security Alarms and Datacom scope. These then all overlap to Ceiling Installation and then to Flooring. Limited space and the need for all crafts to wear hazmat protective clothing meant a constant need to move people out and in. This is a team effort of separate crafts and multiple subcontractors who must work together each yielding continuous productivity for team speed of the project.

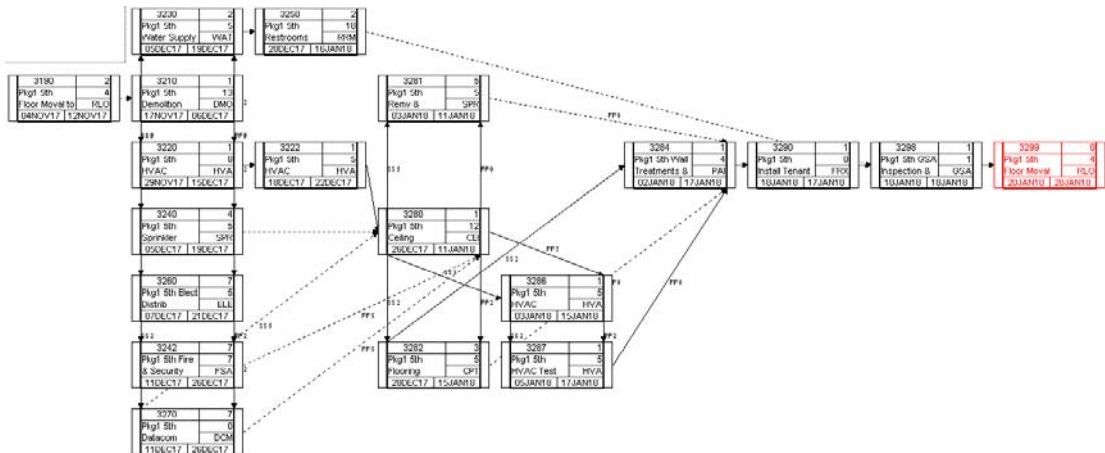


Figure 28.18.1 Logic of renovation of the fifth floor of the J.J. Pickle Building illustrating the close coordination required

An interesting element was that the GSA specification required the use of the “latest version of P3 software” for scheduling. This was initially thought to be by design with the understanding that P3 supports this form of scheduling algorithm, but was later determined to be merely a poorly written specification where the GSA misunderstood “latest version of P3” to be P6. Well who cares?

The issue came to a head when running the same logic used with P3 on P6 resulted in the project requiring an additional nine weeks to perform, pushing completion beyond the contractual deadline. This as noted in elsewhere in this text is because P3 is designed to an algorithm to finish the project as quickly as possible even if increasing the cost of crews required to deal with multiple mini-mobilizations, while P6 is designed to an algorithm to maximize the efficiency of each crew even if such delays completion of the project.

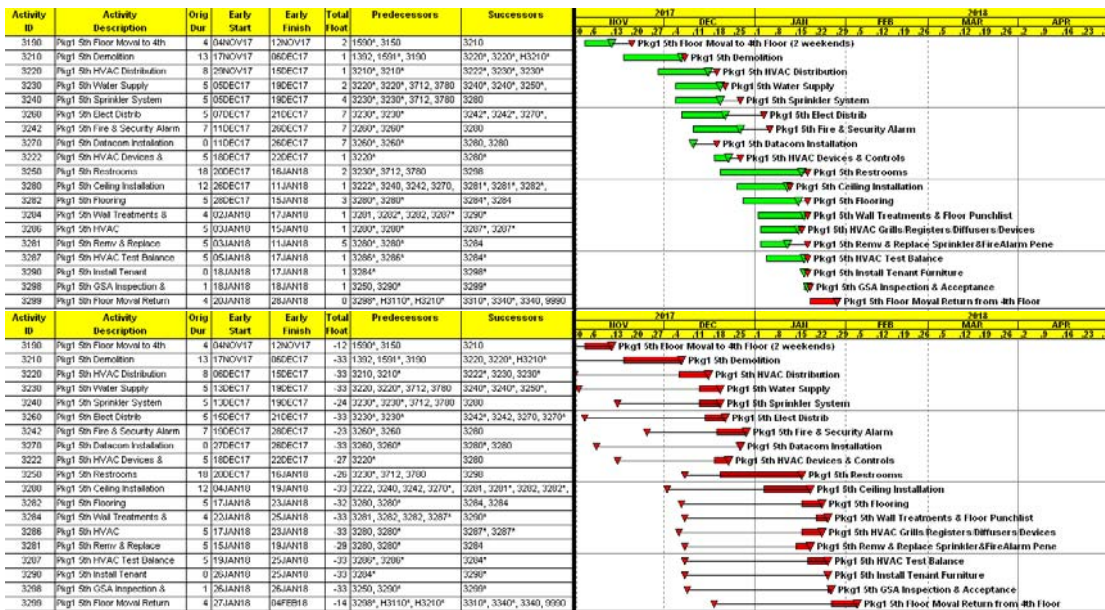


Figure 28.18.2 Calculation with Interruptible Algorithm (P3) versus Continuous Algorithm (P6)

This is illustrated in Figure 28.18.2 and 28.18.3 which demonstrates the importance of use of the Interruptible (or Discontinuous) algorithm for calculation of a schedule when working with such a complex and coordinated logic. Repeat the one week difference for each of the nine floors to be renovated and the scope of the issue becomes significant. The interruptible algorithm is supported by Primavera P3, Deltek OpenPlan, Elecosoft Powerproject, Phoenix Project Manager, Spider Team and many others, but not by Oracle Primavera P6 nor by Microsoft Project.

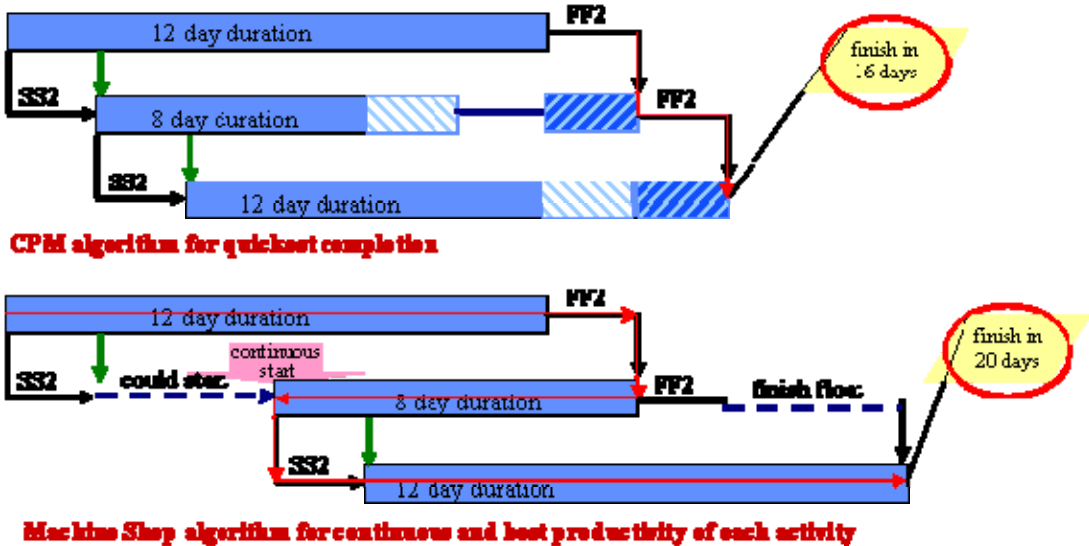


Figure 28.18.3 Illustration of Interruptible versus Continuous algorithms

After careful explanation in performing calculations by hand and other persuasion the GSA consented to allowing the calculations to be performed using P3 with the results then to be reported in P6 and the project was able to be completed in the time allotted. While the performance of work encountered additional issues, these were resolved by the teaming of the contractor, Robins & Morton, and the GSA to bring the project to fruition in a timely and cost efficient manner.

28.19 Summary

The size of a useful network is almost unlimited. Network analysis is usually a must in projects valued over \$5 million, but it can also be used in less expensive projects. CPM often exposes undefined planning factors. The trend is to apply CPM after the award of contract, but this is not a hard and fast rule. Network analysis done prior to award of contract can provide better construction schedule requirements, and CPM can also be applied profitably after construction work has started. Phase 1 of the network preparation is collecting information and the concurrent preparation of a rough diagram. The information collection can be made by any of four approaches: conference, executive, consultant, or staff planning. The second phase of the network preparation is the rearrangement and redrawing of the rough version into a smooth form. In any approach, it is vital that the plan reflect the real plans of the contractor. Subcontractors perform many critical work functions. Their information must also be incorporated in the network. It is difficult to set definite time requirements for the preparation of a network. Familiar projects can be diagrammed more quickly than unfamiliar ones and noncomplex projects more quickly than complex ones. CPM seems to require more time than traditional planning but only because, with CPM techniques, planning is done in greater depth.

Chapter 29

Specifying the CPM

Abstract of 9th and Comment to 8th Edition for Chapter 29

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter.

29.1 Attorney's Viewpoint on Writing a CPM Specification

29.2 Pure Logic Drawing

29.3 Content of the Logic Network

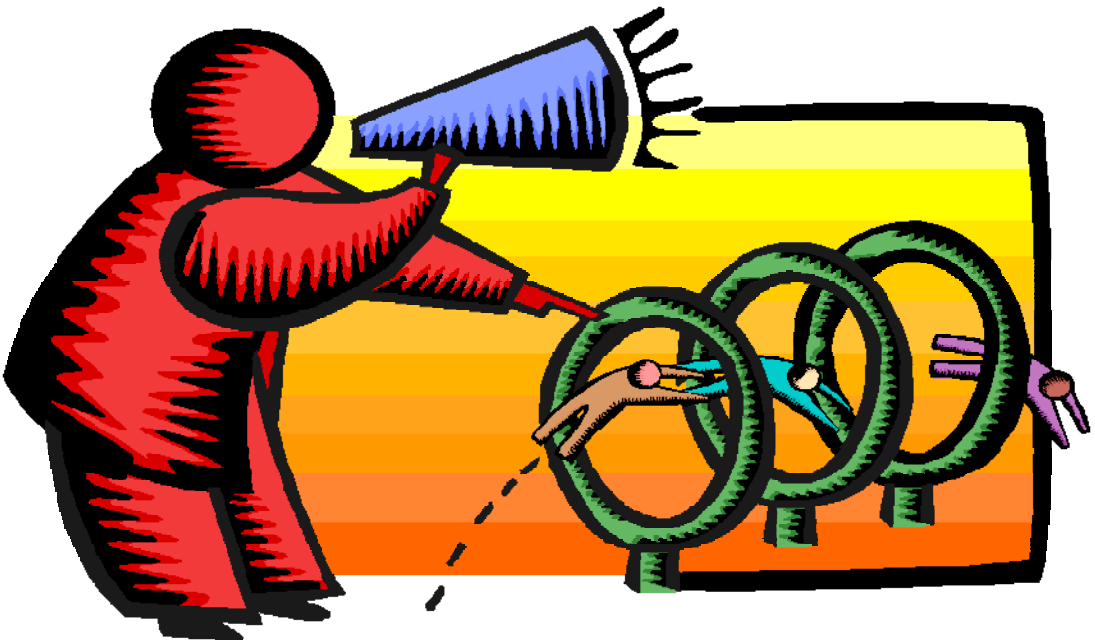
29.4 Updates and Revisions

29.5 Standard References

29.6 Sample CPM Specification

29.7 Summary

CPM as a theory needs a specification to bring it into contractual reality. The availability of an acceptable reference standard can make this easier. Currently, there are no ANSI or ASTM standard references to fill this role. The 1965 AGC book can fill the role even-handedly, but the 1976 AGC effort does so less even-handedly. The remaining chapters provide examples of various modes of scheduling specifications that could be used with minimal changes to a project.



Chapter 30

Sample CPM Specification: A Guideline for Preparing Your Own Specification

Abstract of 9th and Comment to 8th Edition for Chapter 30

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter.

30.1 Project CPM Logic Plans, Schedules, and Reports

30.2 Project Preliminary Schedule

30.3 Project Management and Coordination

30.4 Payment Procedures

30.5 Contract Modification Procedures

30.6 Summary

A possible Guideline Specification is provided. As such will be hopefully be construed as a legally enforceable document, care must be taken to format and layout as well as language. It is to be desired the CPM specification to relate to preparation and submittal of the CPM submittal and not to dabble in additional instructions best included in the section on payments, coordination, or change management. These sections of the specification instruct the contractor “how to” perform. The CPM specification then is thus to be limited to preparation of the initial CPM logic plan and calculated schedule, updates, and revisions, all of which may be used in other sections of the specification to support payment, coordination, and change management.

The format and layout should preferably be structured for reference by the parties to the contract, and others who may be impacted thereby. Layout is therefore provided in a format similar to other sections of a guideline specification in three Parts: General, Products and Execution. Subsections within are designed to “provide an instruction” only once, and to roll-up to the Section, Part and then entire specification and contract.

The Sample Guideline is not in a “cut and paste” format but is freely annotated with comments by the authors. Such comments are interspersed in italics as to the reasons why specific language has been suggested. But, once again all are reminded that since a Specification is hopefully be construed as a legally enforceable document, and such “construction of language” may differ from one country, state or other locale to another, the team preparing the Specification is advised to have such reviewed by legal counsel.

Effort has been made in this Sample Guideline to consider the current state of computer hardware and software and upgrade the methods used by the industry to utilize the additional power not available in the 1950s or even in the 2000s. Too often antiquated specifications saddle parties with unintended liabilities for consequences not foreseeable many years ago but now capable of control due to improvements to technology. And thus this Guideline may already be antiquated and in need of legal review as software considering risk has become more available.

Chapter 31

Unified Facilities Guide Specification

Abstract of 9th and Comment to 8th Edition for Chapter 31

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The authors of this text initially collaborated on the writing of the Unified Facilities Guide Specification in 1987. This was in fact the first project on which Fred was invited to collaborate with Jim, and thus perhaps the basis for Jim’s later invitation to Fred to join in updating this text CPM in Construction Management from a Fourth to Fifth Edition.

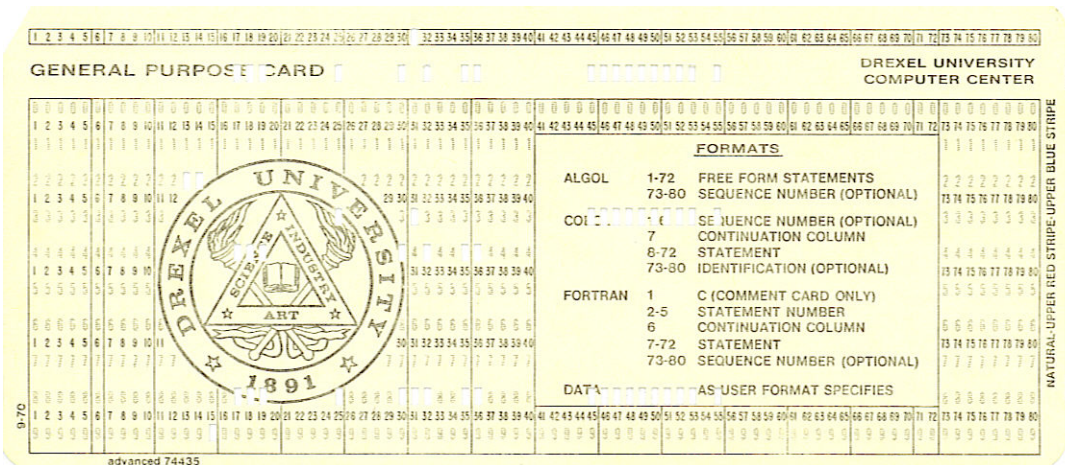
An interesting point of the 1987 effort was that while the Navy desired to request contractors to use P3, the authors were not permitted to specify the use of a named sole source software. A great deal of effort was therefore required to write our specification to require the contractor to provide computer readable files that could then be “read” by P3 in its “batch” mode. While a footnote provided that P3 would do this automatically, contractors were invited to use other softwares, some quite less expensive, to fully meet this UFGS Specification.

31.1 Origins and Evolution of the UFGS

The authors of this text initially collaborated on the writing of the Unified Facilities Guide Specification in 1987. The current release of the specification, of February 2015, may be downloaded at <http://www.usace.army.mil/Portals/44/docs/Engineering/MasterGuideSpecs/013201.pdf> and other websites referencing “UFGS-01 32 01.00 10.” This chapter discusses the evolution, or perhaps devolution, of the specification since 1987.

31.2 Summary

While it is easy to snipe at any specification, and understanding that the new UFGS does represent a great deal of effort and a collaboration of many, we believe the current language may reduce the value of the real product desired—assurance that the contractor can complete on time—and possibly lead to unnecessary disputes and litigation.



Chapter 32

CPM in Claims and Litigation

Abstract of 9th and Comment to 8th Edition for Chapter 32

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. While the Cases discussed are all from many years ago, they are all still good law and illustrative of the concepts being taught. While it may be possible and suggested to add a few more recent Cases to further support these concepts, such may lead to the need for yearly updates unsuited for use to this general reference text.

32.1 Introduction 635

32.2 Early Legal Recognition 637

32.3 Evidentiary Use of CPM 637

32.4 Summary

An important function of scheduling in the construction industry is to evaluate claims of disruption and delay. Following proper procedure in preparing, updating, when necessary revising, and analysis of the CPM schedule may determine who was right and who was wrong. But the ultimate finder of fact is not your professor in the classroom, but rather a judge, arbiter, or member of a jury. From the outset of the development of CPM, many practitioners understood that CPM provided for the first time a scientific means to establish who should prevail in a dispute. While we now know much of this was based upon watered-down mathematics to fit the limits of computing software (as well as some theoretical considerations) presentation to the judge or other fact finder has become a big dollar industry. The earliest cases cited in this chapter hearken back to the early 1970s. Broad principles relating to the impact of CPM on the rule of law relating to construction are set forth in these selected cases. The latest ones run all the way to the mid-2000s. More recent cases are either still in the appeals courts, or there are no published written records of the outcomes because they were decided by private arbitration.



Chapter 33

Delay Analysis

Abstract of 9th and Comment to 8th Edition for Chapter 33

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. A minor but important change of the 8th Edition was Section 33.8 which recognizes the importance of at least spot checks of contemporaneous updates, rather than relying solely upon the final update for the As-Built schedule. As noted during discussions with members of the AACE subsection on Planning & Scheduling, too often that final update may include dates different than were contemporaneously reported, and lacking proper footnotes or other reference to the cause of discrepancy.

This discussion was addressed and further referenced in the 8th Edition section 33.8 Validation of the As-Built Schedule, and points to the advantages of our larger community providing input to this text. While we authors may hope the official record will have been honestly prepared and is devoid of deliberate modification for gaming an analysis, professionals must also recognize that the real world is not always so polite.

We have noted that another advantage of this interim Ninth or Addendum and Comment to Eighth format is the ability to embed web enabled links. Some years ago, as part of preparation of a mock trial presentation by author Plotnick, author O'Brien agreed to a mock deposition. This encapsulates much of what is written in this Chapter and may be viewed at:

<http://www.fplotnick.com/constructioncpm/2012Videos/DepositionJimOBrien.html> with reference to the cited plans at <http://www.constructioncpm.com/At-A-Glance/MockTrial2012PureLogicDwgs.pdf>.

- 33.1 Delay versus Disruption 645
- 33.2 Responsabilité/Types/Force Majeure 646
- 33.3 As-Planned Logic Network 648
- 33.4 As-Should-Have-Been CPM Network 649
- 33.5 As-Planned Schedule 651
- 33.6 Validation of the As-Planned Logic Network and Calculated Schedule 651
- 33.7 As-Built Schedule 653
- 33.8 Validation of the As-Built Schedule 653
- 33.9 As-Built Logic Network 654
- 33.10 Causative Factors 655
- 33.11 As-Impacted Logic Network 657
- 33.12 As-Impacted Schedule 658
- 33.13 Time Impact Evaluations 658
- 33.14 Zeroing to a Collapsed As-Impacted Logic Network 659
- 33.15 Zeroing Out to an As-Should-Have-Been CPM 660
- 33.16 Limitations of the TIE Methodology 662
- 33.17 TIE Example of John Doe Project 662
- 33.18 Windows Analysis 667
- 33.19 Zeroing Out within the Windows Analysis 670
- 33.20 Windows Example of John Doe Project 670

Disruption Analyses

Abstract of 9th and Comment to 8th Edition for Chapter 34

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The ACE Association for Advancement of Cost Engineers International Recommended Practice 25R-03 Estimating Lost Labor Productivity in Construction Claims states “One of the most contentious areas in construction claims is the calculation or estimation of lost productivity.” Due to the ongoing and widespread stop and go, labor, material delivery and other factors of the Covid-19 pandemic as this Interim 9th and Addendum to 8th Edition is prepared for publication, the issue of disruption or even more significant than in recent years.

The ACE RP goes on to state: "There are, in fact, numerous ways to calculate lost productivity. Many methods of calculation are open to challenge with respect to validity and applicability to particular cases... ." As with the issues of measurement and allocation of responsibility for delay, a solution calls out for a procedure which has a maximum of objectivity, a minimum of subjectivity, and is repeatable such that competing “experts” will arrive at the same conclusion.

The methodology of this Chapter was developed to provide a beginning to such a protocol.

- 34.1 Traditional Methodologies 674
- 34.2 The Measured Mile Methodology 674
- 34.3 CPM Out-of-Sequence Methodology 678
- 34.4 Adoption by the Industry 680

34.5 Summary

The as-planned logic represents the project manager’s plan of execution and, presumably, the most expedient and cost-effective means to perform the scope of work of the project. When the project manager is hindered from performing work according to this plan, additional costs can be expected, even if the disruptions incurred do not impact the current critical path of the project. Review of selected updates to determine which activities were performed Out-of-Sequence, and why, can be used to prepare or defend a claim of disruption.

Disruption Analysis

```
Structure for database: D:\diag1.dbf
Number of data records: 1021
Date of last update : 10/09/02
Field Field Name Type Width
1 SUCC Character 10
2 X1 Character 3
3 FREQ Character 10
4 X2 Character 3
5 REL Character 2
6 X3 Character 2
7 LAG Numeric 5
8 X4 Character 2
9 PROBLEM Character 90
-- Total -- 129
```

P3 Diagnostic may be augmented with activity data and with additional input

```
Structure for database: D:\diag2.dbf
Number of data records: 1059
Date of last update : 10/09/02
Field Field Name Type Width
1 ACT Character 10
2 WINDOW Character 4
3 FREQ Character 10
4 FTITLE Character 48
5 FOD Numeric 5
6 SAD Character 3
7 FAF Date 8
8 FAF Date 8
9 SUCC Character 10
10 FTITLE Character 48
11 SOD Numeric 5
12 SAD Character 2
13 SAB Date 8
14 SAF Date 8
15 REL Character 2
16 LAG Numeric 5
17 RELSNY Character 2
18 PROBLEM Character 90
19 PROBLEM Character 1
20 REASON Character 48
21 REASVDE Character 1
22 COSTVDE Character 10
23 COST Numeric 6
-- Total -- 243
```

- As-Plan Sequence is Optimal
- Out-of-Sequence has cost
- Some out-of-sequence expected
- “Too much” is Disruption
- Be aware before claim is made

- Reasons to work out-of-sequence
- 1 – Super’s choice
- 2 – Unresolved RFI or CIC
- 3 – Stop work order or C.O. pending
- 4 – etc. \$\$\$

```
tbl problem2 with '1' for problem=" Activity started, predecessor has not finished."
tbl problem2 with '2' for problem=" Activity started before its predecessor's lag would allow."
tbl problem2 with '3' for problem=" Activity started, predecessor has not started."
tbl problem2 with '4' for problem=" Activity started before its predecessor finished."
tbl problem2 with '5' for problem=" Activity finished, predecessor has not finished."
tbl problem2 with '6' for problem=" Activity started too early to allow it to finish on or after its predecessor's finish."
tbl problem2 with '7' for problem=" Activity started too early to allow it to finish after the expiration of its predecessor's"
tbl problem2 with '8' for problem=" Activity has an actual date that is on or after the date date."
```

Chapter 35

Other Claim Methods

Abstract of 9th and Comment to 8th Edition for Chapter 35

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. The years since 2016 have presented some but really not many nor significant changes to 29RP-03. New and “alternative to CPM” softwares have suggested alternate bases for dealing with delay, but have not (to Author’s knowledge) been yet tested in Court or other forums. Perhaps the most significant news may be emerging means to convey information to jurors, arbiters and other fact-finders such as VR (or Virtual Reality) goggles to present a close-up view of exhibits and possibly even recorded jobsite conditions.

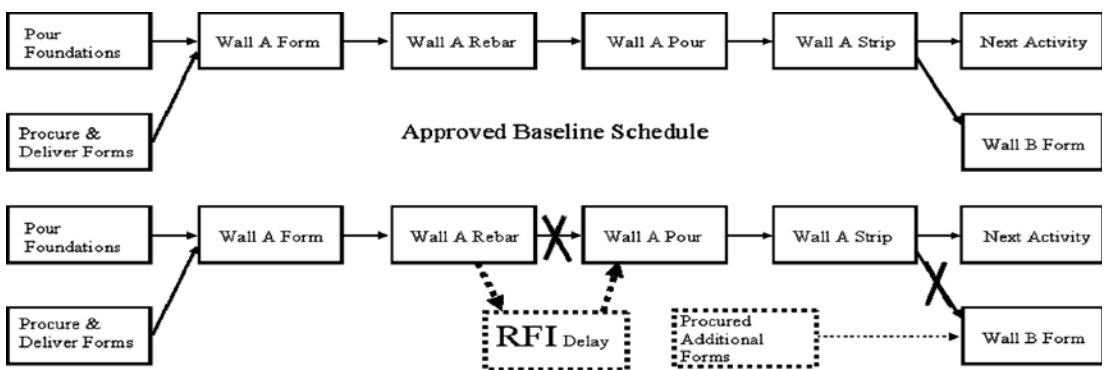
- 35.1 *Frye versus Daubert* 684
- 35.2 AACEi 29RP-03 686
- 35.3 Comparison of Three Methods for John Doe Project 694
- 35.4 Evolve or Die 697
- 35.5 The 50 Ways

35.6 Summary of Other Delay Claim Methodologies

There are numerous other methodologies for calculating or claiming responsibility for the delays to a project. A number of these predate the invention of CPM. Since the development of CPM, various methods have evolved as computers have become more powerful and capable of supporting more detailed (and we hope more accurate) analyses. A similar development has evolved in the court system which had previously favored old-but-tried methods, but now increasingly demands these old methods be tested against the newer methods. This is characterized as the evolution from the standard of *Frye* to that of *Daubert*.

The AACEi compilation 29RP-03 is deemed by the authors of this text to document a number of, but clearly not all, methodologies that have been used in one trial setting or another. 29RP-03 does provide a number of tips to practitioners on source validation and on providing the operating parameters of a number of methodologies purported to have been accepted in at least one forum. However, the authors of this text believe that none of these approaches, as provided in 29RP-03, should pass a *Daubert* review.

Moreover, the authors foresee the day when the methodologies provided in this text will similarly fail when compared to new analyses powered by more powerful analytical tools.



“When was decision to procure additional forms made and why?”

Figure 33.9.1 Fallacy of an “As-Built” Logic Network

Chapter 36

Conclusion

Abstract of 9th and Comment to 8th Edition for Chapter 36

A discussion between authors Jim and Fred in 2019 suggested no substantial changes to this chapter. We started the 8th Edition noting CPM software and practice have always been limited by the hardware and technology of the day. What more can be said now in 2021 than back in 2016?

The history of collaboration leading to our joint 5th through 8th Editions began with conversations between Jim and Fred beginning in the late 1970s. Fred would regularly attend lectures where Jim presented and ask questions, including one-on-one after the lecture. Eventually at these lectures a member of the audience would ask a question of Jim relating to a computer application and Jim would (much to Fred's embarrassment) call out from the podium "FRED, are you here? Answer the question."

In 1979 Fred was hired by Drexel University to complete the term teaching Engineering Economy for a professor who had suffered a heart attack mid-quarter. (The professor recovered and returned the following year.) But Fred was now faculty and asked to teach other courses as needed. By 1982 Fred was asked to create a brand new course on CPM Planning and Scheduling. Fred reached out to Jim and not only adopted Jim's book but discussed with Jim a proposed syllabus and content.

In 1987 Jim was approached by the US Navy to prepare a Guideline Specification. Jim was not really interested and referred the Navy to Fred. Fred's proposal to the Navy was for less than the Navy had budgeted, and the Navy then asked Jim to assist and review the work by Fred creating the first instance of collaboration of Jim and Fred.

Over the next decade, interactions continued at meetings of the American Society of Civil Engineers (where Fred was Chair of the Construction Group for the Philadelphia Chapter) and others groups, and where Fred prepared CPM submittals for contractors which were then reviewed by O'Brien-Kreitzberg on behalf of owners. But in 1997, Jim asked Fred to collaborate on the 5th Edition of this text, this substantially complete by August of 1998. It is interesting that one of the first sections written by Fred was upon the WBS, how "an activity, properly defined within a specific project, may be viewed by different entities for different scheduling purposes," and how we have now returned in this interim 9th Edition to discuss the WBS and its wrap-up to other projects within the multiple hierarchies of owner, contractor, subcontractor, material provider, and other participants of this project.

Sadly, all good things come to an end and this story ends in 2020 with the passing of James J. O'Brien. It has been an honor to collaborate with Jim for these forty-some years, and to share our conversations of these past five years on "what more can be said" with our readership.

Abstract of 9th and Comment to 8th Edition for the Appendices

Navigating the Virtual CD-ROM

Previous Fifth through Seventh editions of this text included computer readable media affixed to the back cover. Our Eighth Edition, in recognition of new hardware, software and means of computing since past editions, migrated to a link to download software promotions and additional materials. Moving forward to a Ninth Edition we shall continue this practice.

However, the provision of “free” software as from the Fifth through Eighth Editions has now become impracticable. New software, improved, and often modified for more recent browsers or operating systems, are released too frequently to warrant a hard download. Mergers and other consolidation of software providers is also problematic to this practice. Purchasers of the Eighth Edition may still be able to download a prior version of Deltek OpenPlan software, but that prior version has been supplanted by more recent (and much more powerful) versions, and support for the older downloadable version may be less than when this software was first offered in 2010 and then 2016. Therefore, those downloading the software via instruction in the Eighth Edition are invited instead to click to download a demo copy at:

<https://www.deltek.com/en/products/project-and-portfolio-management/open-plan>.

Beyond the promotional software, the old floppy diskette or CD-ROM led to additional materials and resources which now may be accessed and viewed at the website for this text by clicking to <http://www.fplotnick.com/CPMinConstructionManagement/>.

These resources include:

- [View graphics from text](#), including illustrations and screenshots as scalable PDFs
- [John Doe Project Files](#), readable by a variety of software including Deltek OpenPlan, Primavera P6, P3, Suretrak, Microsoft Project, Excel, and others
- [Additional and Legacy Files](#) including software manuals from both OpenPlan and P3

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Abstract of 9th and Comment to 8th Edition for Index

A discussion between authors Jim and Fred in 2019 suggested substantial updating of the Index. Almost immediately after publication of the 8th Edition, comments arrived from readers suggesting such updating. Unfortunately, these were collected and compiled by Jim. After Jim’s passing in 2020, an effort was made to locate this compilation, but was unsuccessful. It is therefore suggested that readers of the 8th Edition not finding a term desired to be included in the Index to please send an email to info@cpminconstruction.com. Author Plotnick will attempt (as time permits) to locate using Search of the computer readable files (and then confirmation by physical search of the print textbook) to answer the inquiry, and post to the webpage for the text, <http://www.fplotnick.com/CPMinConstructionManagement/>.