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国外大学优秀教材——建设管理系列（影印版）

建筑施工计划与进度控制
（第3版）

Construction Planning and Scheduling
(Third Edition)

Jimmie W. Hinze

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北京市版权局著作权合同登记号　图字：01-2009-2618

图书在版编目(CIP)数据

建筑施工计划与进度控制 = Construction Planning and Scheduling：3rd edition: 英文 /（美）欣泽（Hinze, J. W.）著. —影印本. —北京：清华大学出版社，2009.5
（国外大学优秀教材. 建设管理系列）
ISBN 978-7-302-20217-2

Ⅰ. 建… Ⅱ. 欣… Ⅲ. ①建筑工程－施工计划－高等学校－教材－英文②建筑工程－施工进度计划－控制－高等学校－教材－英文 Ⅳ. TU722

中国版本图书馆 CIP 数据核字（2009）第 075629 号

责任编辑：徐晓飞
封面设计：刘艳芝
责任印制：孟凡玉

出版发行：清华大学出版社　　**地　　址**：北京清华大学学研大厦 A 座
http://www.tup.com.cn　　**邮　　编**：100084
社　总　机：010-62770175　　**邮　购**：010-62786544
投稿与读者服务：010-62776969，c-service@tup.tsinghua.edu.cn
质 量 反 馈：010-62772015，zhiliang@tup.tsinghua.edu.cn
印 刷 者：北京四季青印刷厂
装 订 者：三河市溧源装订厂
经　　销：全国新华书店
开　　本：185×230　　**印　张**：24.25
版　　次：2009 年 5 月第 1 版　　**印　　次**：2009 年 5 月第 1 次印刷
印　　数：1~2000
定　　价：42.00 元

本书如存在文字不清、漏印、缺页、倒页、脱页等印装质量问题，请与清华大学出版社出版部联系调换。联系电话：010-62770177 转 3103　产品编号：027780-01

国外大学优秀教材——建设管理系列（影印版）

序　言

建设管理原是我国土木工程专业中重要的方向，许多土木类院系设有该专业，近年不少综合性大学也设置了该专业。随着我国加入WTO、中国企业角逐国际工程、国外建筑企业挤入中国市场，使得建设管理专业教育必须提供从内容到语言上能够与国际建筑业接轨的课程。

鉴于这种趋势，清华大学出版社凭借在引进国外原版教材方面的领先地位，与全球高等教育出版巨擘——美国培生教育出版集团——合作，经过清华大学建设管理系专家评审，率先推出这套“国外大学优秀教材——建设管理系列（影印版）”教材。

“国外大学优秀教材——建设管理系列（影印版）”适合作为建设管理专业、相关经济类专业和土木工程专业的英文版教材，也适合具有较好英文基础和专业背景、渴望了解国外相关领域知识的企业界人士作为参考书。

“国外大学优秀教材——建设管理系列（影印版）”包括：《房屋设计与施工案例分析》（Case Studies in Building Design and Construction, 1st ed）、《建筑工程合同》（Construction Contracts, 3rt ed）、《建筑工程估价》（Estimating in Building Construction, 5th ed）、《建筑工程项目管理（专业版）》（Construction Project Management-Professional Edition, professional）和《建筑施工计划与进度控制》（Construction Planning and Scheduling, 3rd ed）。

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Preface

Many textbooks have been published on construction scheduling. Many provide excellent information on a variety of scheduling subjects. Unfortunately, they are often limited in their scope, often omitting scheduling subjects that might be of particular interest to the reader. This text is written to provide broad coverage on all major scheduling subjects.

My first employment with a construction contractor was a summer job in the 1960s. Although I was given many different assignments, I have vivid memories of the arrow diagram network that I was asked to draw by hand. Fortunately, I had recently taken a class on the fundamentals of arrow diagramming, so the scheduling assignment was reasonably easy for me. A few years later while working for a different firm, my primary responsibility was scheduling. The scheduling effort was largely focused on the coordination of subcontractors on several different projects for which I used the precedence diagramming method. It was during this period that I developed a strong appreciation for the value of effective scheduling and the use of precedence diagrams.

There are many approaches to providing scheduling information. Some of these are described briefly in Chapter 1. This textbook is written with a major emphasis on precedence diagramming, with only the last chapter addressing arrow diagramming. Although most scheduling is done with precedence diagrams, I also believe that an introduction to arrow diagramming is appropriate. In academic settings, I have found that students can grasp arrow diagramming more easily if they have not already been exposed to precedence diagrams. For this reason, instructors who plan to lecture on arrow diagrams should consider jumping to Chapter 16 after the first two chapters are covered. Chapter 3 explains the fundamentals of precedence diagrams. Regardless of the scheduling technique used, successfully using scheduling information begins with accurate time estimates for activity durations as discussed in Chapter 4.

One topic seldom addressed in scheduling texts, especially in detail, is that of contract provisions related to scheduling. This text devotes an entire chapter to this subject (Chapter 5). Resource leveling and resource allocation are described in Chapter 6. The impact of scheduling provisions on cash flow is also addressed (Chapter 7). Manual solutions are described for solving problems related to resource utilization and cash flow. Although such problems are often solved by computer, it is helpful for schedulers to understand the process of arriving at a solution in order to fully comprehend computer solutions.

Schedules are management tools. It is through the proper use of schedules that management is able to make informed decisions about scheduling activities. This use includes updating the schedules when the schedule information ceases to be useful for making informed decisions. This process is described in Chapter 8.

Chapter 9 addresses computer applications. This chapter is not a user's manual, nor is it a proponent for any particular scheduling software. The more widely used software programs are described, but no endorsement of any particular product is made. The purpose of the chapter is to familiarize the reader with some of the basic scheduling concepts that are addressed by computer software.

Chapter 10 describes earned value concepts. Project schedules are generally adversely impacted by changes in the project. Chapter 11 provides information for quantifying such impacts. Such information is often required when a claim is prepared. Chapter 12 presents a brief discussion of the value of schedules in litigation.

The treatment of short-interval schedules in Chapter 13 is far more extensive than any known writings on the subject. The use of short-interval schedules is vital to the successful completion of many construction projects. Although concepts of their use and application are simple, the subject warrants a discussion in any serious text on scheduling.

Linear scheduling (discussed in Chapter 14) is a relatively new scheduling technique used in the construction industry. Linear scheduling is a viable method for projects that would otherwise be difficult to schedule. Schedulers should consider using linear scheduling on projects that lend themselves to this technique. The use of probabilistic duration estimates is described in Chapter 15. Although the use of PERT is perhaps minimal in the construction industry, the basic concepts should be understood.

SUPPLEMENTS

To access the online Instructor's Manual, instructors need to request an access code. Go to www.prenhall.com, click the Instructor Resource Center link, and then click Register Today for an instructor access code. Within 48 hours after registering you will receive a confirming e-mail including an instructor access code. Once you have received your code, go to the site and log on for full instructions on downloading the materials.

ACKNOWLEDGMENTS

It is perhaps rare for a text to be written entirely by one person. I certainly can make no such claim. Others have provided valuable assistance in helping me compile all of the information for this text. Dr. Ian Flood also offered valuable comments as the initial text was being finalized. The efforts of Bruce Jamieson were instrumental in compiling the information on short-interval scheduling, and Rory McCarty contributed to the chapter on litigation. A considerable amount of the material on linear scheduling was developed by Greg Hanby, Phil Nelson, Brendan Kennedy, and H. C. Phillips. Dr. Robert Shawcroft contributed significantly by providing me with some scheduling class notes that eventually became part of this text. Most of all, I must thank my good friend John Gambatese, who offered suggestions for the third edition. He made many suggestions for changes and improvements in the third edition. This version of the text is a true credit to him. Of course, as in the first edition, Chapter 9 is wholly his contribution. Helpful suggestions were also provided by Dr. Phillip Dunston, Dr. Douglas Lucas, and Dr. Richard Smailes.

Contents

1

Introduction

It's about time.

Planning can be thought of as determining "what" is going to be done, "how," "where," and by "whom." In scheduling, this information is needed in order to determine "when." In construction projects the "plans" (blueprints) and specifications for the project generally define both the end product and, often, the general time frame in which to complete the project. However, they normally do not specifically identify the individual steps, their order, and the timing followed to achieve the end product. Thus, when we discuss planning and scheduling in the construction process, we must address the "how" and, therefore, the "what," "who," "where," and "when."

When we discuss scheduling, we are usually interested in some aspect of the time element of the plan. In essence, a schedule is a timetable of activities, such as of "what" will be done or "who" will be working. Such a timetable can be looked at in two ways: the first is focusing on an activity, such as determining "when" a certain task will be performed relative to other activities. The second is concentrating on a specified time frame and then ascertaining "who" will be working (or needed) or "what" should be occurring at a particular time. All of us are involved in planning and scheduling on an ongoing basis. The degree to which we carry it out and the techniques we use vary depending upon the complexity of our situations and our needs and objectives. In summary, planning relates to developing the logic of how a project will be constructed, while scheduling consists of integrating that plan with a calendar or a specific time frame.

We all do planning and scheduling on a regular, albeit informal basis. For whatever undertaking, we mentally determine a plan and schedule, such as what we will do in the next half-hour or how and when we will accomplish that task, such as a homework assignment. Often it is necessary for us to go a step beyond this level by creating a "to-do list." None of us can retain the organization of all the tasks we have to do on a daily basis, so we document what needs doing by writing down the information. This is also helpful if we are coordinating with other parties. By writing down the list of items, and perhaps copying and distributing it, we have documented a basis of agreement. We may also prioritize this list by writing the items in the order in which they will be done.

As the number of items increases and/or the time frame expands, we find we have to put our to-do list in the context of time. Normally, we do this using an appointment book or calendar. The driving forces typically are to avoid scheduling multiple things at the same time, to ensure that we allow sufficient time to prepare for an event, and/or to provide a record of what activities we undertook and when and how long we spent on them.

BAR CHARTS

In 1917 Henry Gantt developed a method of relating a list of activities to a time scale in a very effective manner, by drawing a bar (or Gantt) chart such as those shown in Figures 1.1 and 1.2. Activities are represented as bars on the chart, while across the top or bottom of the chart is a time line. For each activity, a bar is drawn from the activity's starting time until its ending time. The Gantt chart has been widely used in depicting schedules for construction projects and has some very useful characteristics. Its primary advantage is that its simple graphic representation allows one to grasp schedule information quickly and easily.

Bar charts are simple presentations that show how major work activities are scheduled. A major advantage is that they are easily prepared as time-scaled presentations. Bar charts are the most commonly employed and readily recognized scheduling models in use today. In recognition of their creator, the terms *bar chart* and *Gantt chart* are used interchangeably by many schedulers.

The widespread use of bar charts can best be attributed to the ease with which they can be understood with only a cursory examination. The bar chart in Figure 1.1 is a good example: the activity sequencing is apparent, and one can surmise easily when

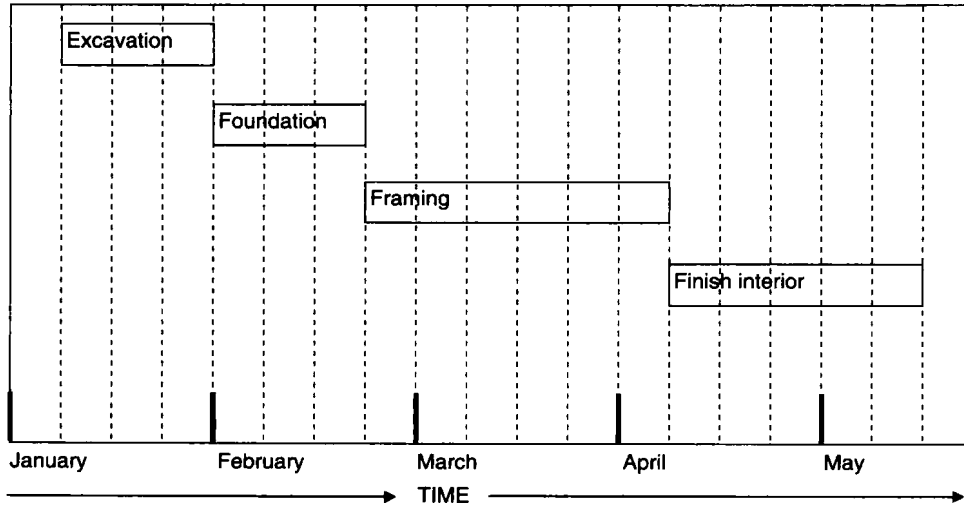

Figure 1.1 Bar Chart Showing General Construction Work Tasks

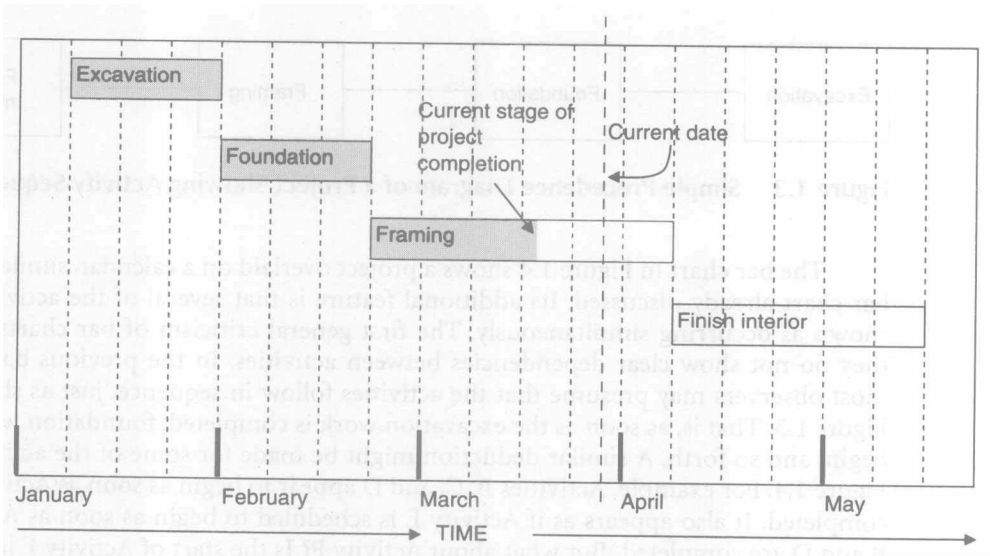

Figure 1.2 Bar Chart Showing Scheduled Versus Actual Performance

each activity is to begin and when it is to be completed. This simple example shows at a glance how the different activities relate to each other. Note that the activities are time-scaled and that they have been superimposed over a calendar.

With the time-scale presentation, a bar chart shows operations and the time consumed by each operation. In addition, it can show the scheduled versus actual progress. This is demonstrated in Figure 1.2. The heavy dashed vertical line represents the current date, and the shaded portions of the activities indicate the amount of work that has been completed by the current date. It is obvious that the project is slightly behind schedule. The progress on the framing activity has not met expectations. Adjustments to the schedule may be warranted if the delay in project completion (about one week) is not acceptable. In this simple depiction, it is evident that the project can be completed on time by accelerating the work effort on framing, finishing interiors, or both. This information is easy to grasp from this bar chart, and there is little chance of misinterpretation.

Shortcomings of Bar Charts

Despite the wide usage and appeal of bar charts, they do possess some features that make them difficult to use in certain settings. It is particularly when projects become more complex that bar charts begin to fail to provide the type of information that is often so valuable for planning and scheduling. An example with a bar chart will illustrate some of these shortcomings. First, consider the simple schedule shown in Figure 1.1. It can easily be shown in network form; see Figure 1.3.

It is simple to see the relationship between the bar chart shown earlier and the same information presented in network form, in this case as a precedence diagram. This diagram is not time-scaled in that the lengths of the activities do not correspond to the durations.

Figure 1.3 Simple Precedence Diagram of a Project Showing Activity Sequences

The bar chart in Figure 1.4 shows a project overlaid on a calendar, similar to the bar chart already discussed. Its additional feature is that several of the activities are shown as occurring simultaneously. The first general criticism of bar charts is that they do not show clear dependencies between activities. In the previous bar chart, most observers may presume that the activities follow in sequence, just as shown in Figure 1.3. That is, as soon as the excavation work is completed, foundation work can begin, and so forth. A similar deduction might be made for some of the activities in Figure 1.4. For example, Activities B, C, and D appear to begin as soon as Activity A is completed. It also appears as if Activity E is scheduled to begin as soon as Activities B and D are completed. But what about Activity F? Is the start of Activity F linked to the completion of Activity B, Activity D, or both? The start of Activity F could also be linked to Activity C. This cannot be ascertained from the bar chart. Similar dilemmas exist for Activities G, H, and I. The failure to show the interrelationships between activities is a major shortcoming of bar charts, mandating that more sophisticated scheduling techniques be utilized on complex projects.

The bar chart shown in Figure 1.4 shows the relative status of completion. Note that Activity G is ahead of schedule and Activity F is on schedule, but Activity E is behind schedule by about a week. While the relative schedule status of each activity

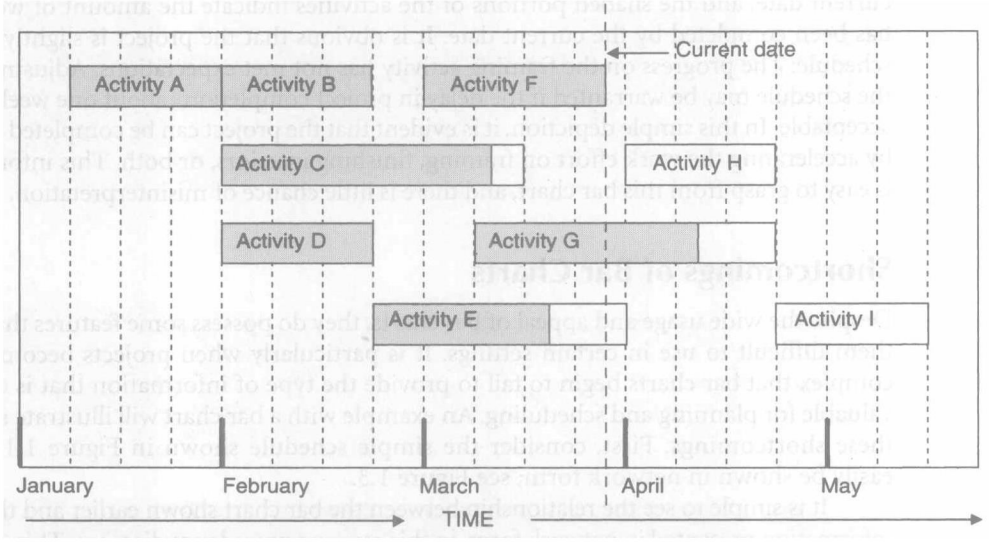

Figure 1.4 Bar Chart Showing General Construction Work Tasks

can be determined from the bar chart, the actual status of the project cannot be readily determined. The big question for the scheduler would be, "Does the behind-schedule status of Activity E or C compromise project completion?" This cannot be determined from the bar chart. Therein lies another shortcoming of bar charts: although the status of individual activities can be readily ascertained, the overall status of a project cannot be determined when some activities are not on schedule. This makes it difficult to assess the need for making scheduling adjustments, and it also makes it difficult to determine the appropriate activities to target for acceleration.

Even a change in the logical sequencing of the activities in a bar chart cannot be readily made, especially when many activities are involved. The information shown in the bar chart in Figure 1.4 is shown in the precedence diagram in Figure 1.5. Note that the relationships of the activities are consistent with the information shown in the bar chart, but the precedence diagram could not have been, with certainty, developed solely from the bar chart. The precedence diagram is not time scaled. While one can see the relationships between the information shown in the bar chart and the precedence diagram, it is not generally necessary to develop both types of schedules. Many of the computer scheduling programs available today readily enable the conversion (automatic) of network information into bar charts.

While some of the disadvantages of bar charts have been noted, the shortcomings are not overwhelming. In fact, bar charts are the most popular means by which scheduling information is communicated in the construction industry. This is even true of projects that are complex and involve many activities. Figure 1.6 shows a bar chart schedule for the construction of a metal barn. The level of detail is such that the general nature of the activities can be readily understood. Many of the interdependencies between the activities, although not specifically noted, can be surmised with relative confidence based on the logical relationships that generally exist between activities. Of course, one would need to know more about the project itself to be certain about some interpretations.

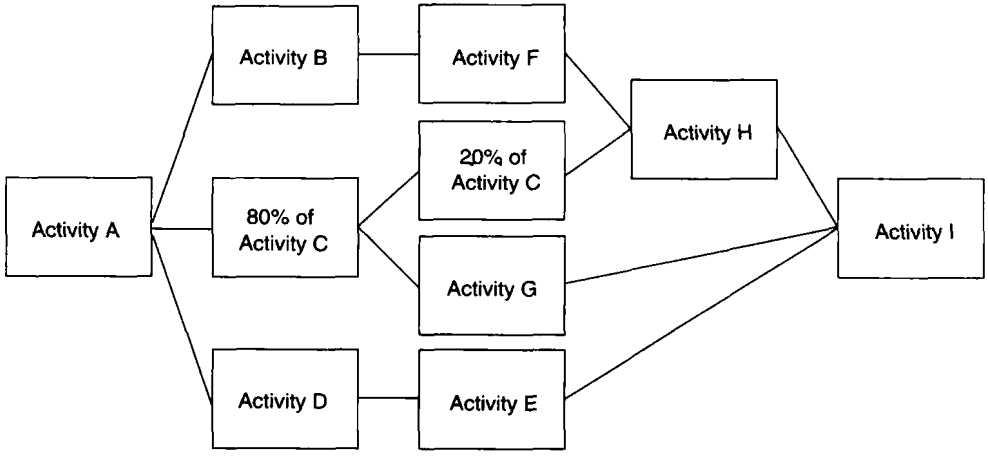

Figure 1.5 Precedence Diagram of the Project Shown Earlier in Bar Chart Form