

**AN INVESTIGATION OF THE EXPANDING ROLE OF THE CRITICAL PATH  
METHOD BY ENR'S TOP 400 CONTRACTORS**

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## **ABSTRACT**

The Critical Path Method (CPM) is a widely used tool throughout the construction industry. Since its creation, the use and application of the Critical Path Method has grown tremendously. Up to date, three studies have been performed on how Engineering News Record's (ENR) Top 400 Contractor use CPM. The first study was performed by Edward Davis in 1974 and the second was performed by Amir Tavakoli and Roger Riachi in 1990. This paper is a summary of the third survey, which took place in 2003. The results from the three studies indicate that CPM use by the Top 400 Contractors is growing and the areas of use are expanding. The number one use of CPM throughout the years is detailed planning before the start of construction. Periodic control during construction is another large area of CPM use and has been a large area of growth due to the advances in technology, which make updating a schedule during construction easier and faster than was possible with a mainframe computer in the past. Another area of CPM growth is estimating and bidding for several reasons: use in this area has jumped from 19% to 54% in the past 30 years. An area of concern lately in CPM is the use of precedence diagramming instead of arrow diagramming. Despite the debate, the responding companies found precedence diagrams easier to read, provide more flexibility, and allow for easier use of "smart" relationships (i.e. start-start).

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# TABLE OF CONTENTS

<u>SECTION</u>	<u>TITLE</u>	<u>PAGE</u>
I.	EXECUTIVE SUMMARY.....	1
II.	OVERVIEW AND INTRODUCTION .....	4
III.	LITERATURE REVIEW.....	5
IV.	OBJECTIVES, PURPOSE & SCOPE.....	16
V.	METHODOLOGY .....	18
VI.	RESPONSE RATE AND STATISTICS USED.....	20
	Survey Response .....	20
VII.	GROWTH OF CPM.....	24
	CPM Usage .....	24
	Discussion .....	25
VIII.	TYPES OF COMPANIES USING CPM.....	27
	Overview of Companies .....	27
	Discussion .....	27
IX.	USAGE OF CPM IN DIFFERENT LIFE CYCLE PHASES OF A PROJECT .....	28
	Major Areas of CPM Application .....	28
	CPM’s Role in Claims and Litigation .....	30
	Time Impact Analysis.....	31
	Discussion .....	32
X.	INDUSTRY FEELINGS TOWARD CPM.....	34
	Reasons for CPM Usage.....	34
	Frequency of CPM Use.....	35
	Logic Network.....	35
	Benefits of CPM Application.....	36
	Disadvantages of CPM .....	38
	Use of a Consultant vs. In-House Staff .....	39
	Degree of Success in Achieving Advantages of CPM .....	40
	CPM’s Usage at Different Management Levels .....	41
	Importance of CPM to Present Success of Company.....	42
	Importance of CPM to Future Success of Company .....	43
	Decisions Based on CPM.....	43
	Updating the Schedule .....	44
	Discussion .....	45
XI.	TECHNOLOGY’S ROLE IN CPM APPLICATION.....	48

Degree of Success in Achieving Advantages of CPM .....	48
New Hardware.....	48
Software Used .....	49
Discussion .....	49
<b>XII. COST OF CPM APPLICATION.....</b>	<b>51</b>
Cost of CPM Application.....	51
Discussion .....	51
<b>XIII. CONCLUSIONS AND DISCUSSION .....</b>	<b>53</b>
CPM Usage by Large Companies .....	53
Usage by Small Companies .....	55
Technology’s Role in CPM Development.....	56
More Knowledgeable Construction Professionals .....	56
Project Management Institute – College of Scheduling .....	57
Association of Advancement of Cost Engineering International.....	58
Concluding Remarks .....	58
<b>XIV. REFERENCES .....</b>	<b>59</b>
<b>XV. APPENDIX A – LESSONS LEARNED .....</b>	<b>61</b>
<b>XVI. APPENDIX B - SURVEY.....</b>	<b>62</b>
<b>XVII. APPENDIX C – QUESTION 14 RESPONSES .....</b>	<b>72</b>
<b>XVIII. APPENDIX D – QUESTION 36 RESPONSES .....</b>	<b>77</b>
<b>XIX. APPENDIX E – QUESTION 42 RESPONSES .....</b>	<b>82</b>
<b>XX. APPENDIX F – QUESTION RESULTS COMPARED WITH PAST DATA .....</b>	<b>86</b>

## TABLE OF CONTENTS (Continued)

### LIST OF TABLES

<b><u>TABLE</u></b>	<b><u>TITLE</u></b>	<b><u>PAGE</u></b>
Table 3.1	Literature Review Summary.....	15
Table 4.1	Key Issues.....	17
Table 7.1	Scheduling Methods Used Based on Company Size .....	25
Table 7.2	Scheduling Methods Used Based on Industry Sector .....	25
Table 8.1	Industry Breakdown.....	27
Table 9.1	Areas of CPM Application based on Company Size .....	28
Table 9.2	Areas of CPM Application Based on Type of Construction .....	29
Table 9.3	Comparison of CPM Application Areas between the Different Studies.....	29
Table 9.4	CPM Use for Periodic Control of Work During Construction.....	30
Table 9.5	Use of CPM in Claims Analysis Based on Company Size .....	30
Table 9.6	Growth of CPM in Claims Analysis since 1990.....	30
Table 9.7	Percent of Claims CPM is Used On.....	31
Table 9.8	CPM's Use in Litigation .....	31
Table 9.9	Type of Time Impact Analysis Used .....	32
Table 10.1	Reasons for CPM Use Based on Company Size .....	34
Table 10.2	Reasons for CPM Use based on Type of Construction.....	34
Table 10.3	Frequency of CPM Use based on Company Size .....	35
Table 10.4	Frequency of CPM Use based on Type of Construction.....	35
Table 10.5	Diagramming Methods Used.....	36
Table 10.6	Benefits Obtained by the Entire Group and by Company Size .....	37
Table 10.7	Benefits Obtained Based on Construction Type.....	37
Table 10.8	Disadvantages of CPM over Time .....	38
Table 10.9	Disadvantages of CPM Based on Company Size .....	39
Table 10.10	Disadvantages of CPM Based on Type of Construction.....	39
Table 10.11	Consultant v. In-House Staff based on Company Size .....	39
Table 10.12	Consultant v. In-House Staff based on Type of Construction.....	40
Table 10.13	Degree of Success based on Company Size .....	40
Table 10.14	Reasons for Being Successful When Using CPM .....	41
Table 10.15	Levels of Management based on Company Size .....	41
Table 10.16	Levels of Management based on Type of Construction.....	41
Table 10.17	Levels of Management Using CPM over Time .....	42
Table 10.18	Importance of CPM to Present Success based on Company Size .....	42
Table 10.19	Importance of CPM to Present Success based on Type of Construction.....	42
Table 10.20	Importance to Present Success over Time.....	42
Table 10.21	Importance of CPM to Future Success based on Company Size .....	43
Table 10.22	Importance of CPM to Future Success based on Company Size .....	43
Table 10.23	Importance to Future Success over Time.....	43
Table 10.24	Frequency of Decisions based on CPM (Company Size) .....	44
Table 10.25	Frequency of Decisions based on CPM (Type of Construction).....	44

Table 10.26	Comparison of Frequency of Decisions based on CPM over Time .....	44
Table 10.27	Frequency of Updating based on Company Size.....	45
Table 10.28	Frequency of Updating based on Company Type .....	45
Table 11.1	Reasons for Being Successful When Using CPM .....	48
Table 11.2	Use of New Hardware by Respondents .....	48
Table 11.3	Software Used.....	49
Table 11.4	Opinions on Flexibility in Scheduling Software .....	49
Table 12. 1	Cost of CPM Application Based on Company Size .....	51
Table 12. 2	Cost of CPM Application Based on Type of Construction.....	51

## TABLE OF CONTENTS (Continued)

### LIST OF FIGURES

<b><u>FIGURE</u></b>	<b><u>TITLE</u></b>	<b><u>PAGE</u></b>
Figure 6.1	Responding Company Distribution.....	20
Figure 6.2	Position within Company of Respondents .....	21
Figure 6.3	Chi-Square Test Results .....	22
Figure 7.1	Increase in CPM Usage .....	24
Figure 9.1	CPM Applications over Time.....	29
Figure 10.1	Disadvantages of CPM.....	38

## **I. EXECUTIVE SUMMARY**

Since its creation, the use and application of the Critical Path Method has grown tremendously. Up to date, three studies have been performed on how Engineering News Record's (ENR) Top 400 Contractor use CPM. The first study was performed by Edward Davis in 1974 and the second was performed by Amir Tavakoli and Roger Riachi in 1990. The following is a summary of the third survey, which took place in 2003. The results from the three studies indicates that CPM use by the Top 400 Contractors is growing with 98% currently using it compared with 90% in 1974. While this growth is not extraordinary, the frequency with which companies use CPM has grown in addition to the application areas of CPM expanding.

The number one use of CPM throughout the years is detailed planning prior to the start of construction. This is expected because CPM's main purpose is as a planning tool. The nature of the method forces companies to sit down and think about the logic and relationship of activities before construction begins. Although detailed planning is the main area of CPM application, there has not been much growth in the last 30 years. This lack of growth is probably because CPM use in this area was already high in 1974 and computers are not necessary if CPM is used solely for detailed planning. A computer's main benefit in CPM application is its ability to update a schedule with minimal work and redrawing of the network diagram. The advances in technology are one of the main factors of CPM's growth in the area of periodic control during construction. Personal computers make updating a schedule during construction easier and faster than was possible with a mainframe back in the 1970's. Another area of CPM growth is estimating and bidding, which use in this area has jumped from 19% to 54% in the past 30 years. The increased use for estimating and bidding could be a result of many factors. One big reason could be that 94% of companies feel that CPM improves understanding of the project. By performing a CPM for estimating and bidding, a more reliable estimate can be made because understanding of the project is improved. Other factors could be owner requirements at the time of bid or the fact contractors are beginning to compete on the basis of time in addition to cost.

Another surprising finding of this third study is companies rely on specialists for CPM just as much now as they did in 1974 even though fewer companies find it requires excessive work to implement. This dependency on specialists may be for different

reasons in now than in 1974. In the last 30 years, technology has greatly improved along with knowledge about CPM. Specialists were initially needed because of the lack of knowledge of CPM and because application at the time was such a labor-intensive process. In 2003, more people are aware of CPM and software has made application much easier. CPM has also developed more uses and applications over the years. A new use of CPM since 1974 is claims analysis and litigation. Specialists are often hired to review and “pick apart” the schedule as companies prepare for claims and litigation. This may be the reason why specialists are needed just as much now as they were in 1974.

An area of concern lately in CPM is the use of precedence diagramming instead of arrow diagramming (Korman and Daniels 2003). It is almost impossible to find scheduling software that support the use of arrow diagrams. Primavera stopped supporting arrow diagrams in 1994 when it switch to a windows version of their program. Some schedulers claim precedence diagramming is detrimental to scheduling because it can easily be manipulated and the logic of the schedule is not as apparent as it is with arrow diagramming. Others believe precedence diagramming is actually a clearer representation of the logic and work flow because there are no “dummy” activities. Overall, the responding companies found precedence diagrams easier to read, provide more flexibility, and allow for easier use of “smart” relationships (i.e. start-start). Most companies relate better to precedence diagramming because of their use in programs like Primavera Project Planner and Microsoft Project. Some disadvantages listed by the respondents about precedence diagramming are: precedence diagrams do not always simulate actual conditions; they allow users to use different relationships in order to fix a date (logic abuses); and the logic can be harder to follow and explain because of the different relationships. Not many positive comments were given about arrow diagramming. Many companies feel that arrow diagrams are outdated and difficult to use because of the i-j notation and the use of dummies. Many companies do not see the need for arrow diagramming anymore, especially since scheduling software relies on precedence diagramming.

The future of CPM application appears hopeful. The development of new uses and applications of CPM since its inception in the late 1950’s has been overwhelming. Technology has been one of the greatest enablers of these new functions and as technology continues to improve, it is almost certain CPM will find new uses and

features. One such possible growth is integration. Integration of scheduling software with other software applications holds a number of opportunities for contractors. One possibility includes integration with accounting software in which a cost loaded schedule can automatically transfer information about work in place and money spent to accounting software. Another possibility is the ability to integrate with procurement systems so materials are ordered automatically when they are needed. Other possibilities of growth include enhanced features for CPM's use as a forensic tool. Such enhanced features could include the ability to tag activities with notes regarding why a delay occurred, or why the activity finished earlier than expected. Also, being able to link any letters, memos, change orders, or requests for information related to activities could be extremely beneficial and time saving when analyzing claims. Photographs linked to activities can also have a strong impact in litigation since a picture is worth a thousand words.

Overall, the results from this study indicate the top 400 contractors are pleased with CPM. Of those that use CPM, 98% feel it is a valid management tool and 80% claim it improves communication among the workforce. CPM is not just the current trend in scheduling as demonstrated by the fact that 95% of companies feel CPM ranges from moderately to very important to the present and future success of the company. The reason these companies have had such success with CPM is good support from project management. The study indicates companies will encounter more benefits from CPM application the more project and top management believe in its usefulness.

## II. OVERVIEW AND INTRODUCTION

The Critical Path Method (CPM) of scheduling is a widely used tool throughout the construction industry. Critical path scheduling emerged as a legitimate form of scheduling in the late 1950's. CPM differs from the traditional Gantt chart because it has an underlying logic network. Only by doing forward and backward passes through the logic network can the critical path be found, along with the float for each activity. Before the wide availability of scheduling software, performing a CPM analysis was often a time consuming and tedious task. When CPM first emerged, personal computers were non-existent and performance of a schedule analysis occurred by hand or on a mainframe computer. The difficulty of performing a CPM analysis often outweighed any benefits obtained from it. By 1990, personal computers were becoming widespread and there was an increase in the use of CPM. Even in 1990 with personal computers starting to saturate the market, medium sized firms were still lagging behind larger companies in CPM use (Tavakoli 1990). With personal computers becoming industry standard, mainframes were soon obsolete, rendering CPM easier and cheaper to implement.

There have been two previous studies on the use of CPM by *Engineering News Record's* (ENR) top 400 contractors. Edward Davis (Davis 1974), and Amir Tavakoli and Roger Riachi (Tavakoli and Riachi 1990) performed studies on the use of CPM by the top 400 contractors as listed in ENR. These two surveys provide insight into utilization of critical path scheduling during two unique points in time.

This paper discusses the results of a third survey, compares how different size and different types of companies use CPM, and compares the results with past data. Comparisons are made between how different size companies and companies involved in different types of construction use CPM. The results of the Davis study (Davis 1974) show that large firms used CPM more often and for more uses than smaller companies. By 1990, CPM was being used more by smaller companies, shrinking the gap of CPM utilization among large and small construction companies. The purpose of this study is to evaluate the differences in CPM use in small, medium, and large companies.

### III. LITERATURE REVIEW

Edward Davis studied the usage of CPM among the 400 contractors listed in the April 8, 1971 issue of ENR. Davis' results are published in the *Journal of the Construction Division* in "CPM use in the Top 400 Construction Firms" (Davis 1974). Before Davis' study, a study in 1965 by M.R. Robinson questioned small general contractors about their use of CPM. The 1965 study showed that companies were generally not using CPM. Davis' research shows the primary users of CPM during the 1970's were large construction companies. Davis' research also shows 45% of the survey group used CPM seldom or never. While Davis' study showed 45% of companies used CPM seldom or never, only 19% of the study group thought CPM was unimportant to their firm's future success. According to Davis, a large majority of firms were using CPM for detailed planning before the start of construction and for periodic control of the work during construction. These firms employed CPM less frequently in tasks related to estimating, bidding, and maintenance of projects. The most frequently reported benefits of CPM analysis were improved planning before work starts and improved project control. Davis' study questioned top management's major concerns regarding CPM. Top management's three major concerns were low rates of CPM use among construction personnel, amount of work required to implement CPM, and the need for specialists to conduct CPM analysis.

In 1990, Amir Tavakoli and Roger Riachi performed a second study of ENR's top 400 contractors and their use of CPM (Tavakoli and Riachi 1990). Tavakoli and Riachi used questions from Davis' study to facilitate an analysis of developing trends in addition to preparing a more detailed questionnaire. Tavakoli and Riachi divided the study sample into two groups based on annual volume as follows: large companies (annual volumes more than \$200,000,000) and small companies (annual volumes less than \$200,000,000). They then analyzed CPM usage among the categories. By 1990, about 93% of the firms were utilizing CPM. Only 14% in 1990 were seldom or non-users compared with 45% in 1974. About 80% of the responding firms also reported using CPM for claims analysis, which may be a reason for increased use. Detailed planning before construction and periodic control during construction were still the major uses as in 1974, but CPM usage jumped in areas of preconstruction, estimating, and project maintenance. Along with the benefits seen in 1974, Tavakoli and Riachi determined CPM provided faster response to

problems and improved communication among the workforce. The 1990 study concluded the availability of good software, improvements of hardware, and better educated personnel led to increased and more effective use of CPM.

In the December issue of *Building Construction* in 1965, three articles featured the Critical Path Method. The first of these was “CPM Studied: Conceptions and Misconceptions of a New Tool,” by Herbert M. Priluck, president of Construction Planning Management (Priluck 1965). Priluck discusses CPM utilization at the time since it was still relatively new. At the time, proponents of CPM were claiming benefits such as complete project control when in actuality it is only a powerful tool in the hands of a competent construction manager. CPM is unique from other scheduling methods because of the separation of planning and scheduling. Priluck defines planning as “the study of activities comprising a project and their interrelationship, presented in a systematic manner.” In other words, planning is the development of the logic network. Scheduling occurs after the planning and involves assigning durations to the activities developed in the plan. After estimating the activity times, determination of the early and late start times occurs using the forward and backward pass. Priluck continues to discuss the control aspect of CPM but suggests “monitor” might be a better term. CPM is not able to control a project; control is up to the judgment of management. Another benefit proposed by CPM proponents was “management by exception,” which involved focusing only on critical activities and believing other activities would take care of themselves. But completion of a project will not be successful if efforts are concentrated almost exclusively on critical activities, which are only a small fraction of the total number of activities. CPM use at the time could be considered extensive. However, if only analyzing times it was used as “the true plan for construction” CPM had “barely gained a foothold.” Even in 1965, contractors used CPM as a tool to determine fault for delays. In addition to using CPM as a delay analysis tool, contractors also used CPM as a sales gimmick. Contractors would claim to use CPM in order to win negotiated work while not being fully knowledgeable or experienced with it.

The next article in the same edition of *Building Construction* was “CPM Surveyed: Definitely a Shortcut to Building Efficiency” by Morris R. Robinson (Robinson 1965). Robinson summarizes the results of a survey conducted by the Bureau of Building Marketing Research (BBMR) on a random sample of 500 firms including architects,

engineers, contractors, and sub-contractors. The study found time savings occurring from CPM usage ranged from 5-40% with an average of about 30%. The results also show CPM tends to work best on complicated projects. At the time, CPM and bar graphs were the two methods used most by the firms surveyed. Of the “turnkey” firms (architects, engineers and contractors), 75% used CPM to plan, schedule and control projects. While half the firms contacted had access to a computer to perform CPM analysis, the study showed a computer was not necessary for successful implementation. Through this study, the BMMR concluded that CPM barely had a grip in the industry mainly due to a reluctance to change. Another factor slowing the spread of CPM was the lack of education about CPM use of those implementing it. Most of the respondents to the study claimed they based their knowledge of CPM on articles in professional magazines.

The third article in the December issue of *Building Construction* (1965) was more of a discussion about CPM (CPM Discussed 1965). Comments collected from various firms were compiled in “CPM Discussed: Clout Needed for Control and Savings” from the study completed by the BBMR. Here are a select few of the comments made by various sectors in the industry:

“Excellent in owner, architect, contractor teamwork to produce a finished product. CPM can be abused by any one of the three by either lack of understanding or superior ability in use of the method.” - A/E Firms (CPM Discussed, 1965, pp. 45)

“Only as effective as the accuracy and knowledge of the project manager; checklists, standards, programs would simplify the system.” – Architectural Firms (CPM Discussed, 1965, pp. 45)

“The possible interpretation of CPM charts by owners gives rise to certain very serious legal questions, which have not been tested in court. The risk of misinterpretation of contractors in another contingency factor to be included in a bid.” - Engineers with General Contractors (CPM Discussed, 1965, pp. 46)

“CPM helps during pre-project planning, awarding of sub-contracts, placing material orders; but, it requires too much time to keep up to date

on the chart as the job changes due to change orders and schedule changes.” – Subcontracting Firms (CPM Discussed, 1965, pp. 46)

During the mid to late 1960's, proponents claimed CPM as a complete project management tool. Burl Howard illustrates this notion in his article “CPM-As Complete Project Management” published in the *Journal of the Construction Division*, in 1965 (Howard 1965). The use of CPM in time/cost trade-offs, resource leveling, and scheduling across multiple projects was becoming more popular. With the development of these extensions on CPM, contractors needed a computer to fully experience the benefits of CPM. Using CPM in a time/cost analysis is beneficial because if a project needs expediting, knowing which activities control the project duration is helpful. The use of CPM also helps with this analysis because as “crashing” of the activities occur the critical path may change. Howard also discusses the benefits of resource analysis as a tool to best use the means at the contractor's disposal. Howard gives evidence of cost savings when using CPM as a tool to schedule across multiple projects/buildings. A housing developer was able to save \$1,400 per house using CPM versus the cost of \$130 per house of implementing CPM. The use of CPM started to blossom in the 1960's as more ways to utilize it developed.

Peter Schoderbek performed a study on the use of CPM and PERT on 200 companies randomly selected from a list of the 500 largest industrial concerns in the United States published in *Fortune Directory* (Schoderbek 1965). *The Academy of Management Journal* published Schoderbek's results in 1965 in an article titled “The Study of the Applications of PERT.” Schoderbek combined CPM and PERT in his study because he considered PERT “a refinement and extension of the Critical Path Method.” The purpose of the study was to determine the percentage of companies using PERT/CPM as a management tool, the type of projects where use of PERT/CPM occurs, and the characteristics of the users and non-users among others. Of the respondents to the survey, only 44 percent were using CPM/PERT. The study showed similar results to the study performed by Davis in 1974 when comparing advantages and disadvantages. A few of the advantages included time and cost savings, better control of projects, improved communications, and improved planning and scheduling. The disadvantages

included an excessive amount of work to implement, the special training required for personnel, and cost of application.

In the May 1971 issue of *The Constructor*, four presidents and vice presidents of various sized companies held a discussion titled “CPM-Solution or Problem” (CPM-Solution or Problem 1971). The discussion involved topics such as the size and type of project CPM is effective on, current use of CPM, how effective CPM is, and the future of critical path scheduling. The consensus of the group was CPM was not necessarily more effective on large projects as much as on complicated projects with many activities. The group also used CPM reluctantly and hardly used it past the preplanning stages of a project. One of the discussion members said using CPM during the preplanning stages helped plan the project and give a better understanding of the work. The main reasons given for not keeping the CPM updated when using it, or the reasons for not using it at all, were the amount of time, effort, and money involved with implementing the system. Although the use between the four companies differed, all agreed planning is the key to keeping a project on schedule.

Calin Popescu and John D. Borcharding discuss computer usage concerning CPM and PERT in the *Journal of the Construction Division* in a paper titled “Developments in CPM, PERT, and Network Analysis” published in December 1975 (Popescu and Borcharding 1975). During the late 1960’s, developments in CPM analysis took place regarding resource leveling, resource scheduling, and time-cost curves. By making CPM and PERT techniques more complicated, network programs tended to increasingly need electronic data processing, causing a decline in CPM usage during the 1970’s compared with the 1960’s. Computer usage to analyze networks usually was done on shared computers not owned by contractors. Often, the duration between the data submission and time the analysis finished was unacceptable. In addition to this lag time, if a mistake was present on the input data, discovery of this mistake usually happened after completion of the analysis. Another drawback to using computers in CPM application was the availability of computer programs. Not all computers were equipped with a CPM analysis program. Contractors would have to write their own programs and pay to store them in the computer. In addition, separate programs were often needed for resources scheduling and time-cost curves. An alternate to this system was time sharing on

computers. Data would be directly input into the computer from a keyboard console. The results would be available almost immediately.

In 1980, Steven Pinnell, principal of Pinnell Engineering, wrote “Critical Path Scheduling: an Overview and a Practical Alternative” in *Civil Engineering* (Pinnell 1980). Pinnell discusses the reasons for CPM’s and PERT’s limited use and failures. Pinnell states the major reason for failures in using CPM results from the limitations of computers during the time. Either a computer was unavailable, or a contractor was unable to sort through the copious amounts of paper produced. Pinnell presents the idea of a time scaled arrow diagram as an alternative to computerization. Pinnell states it is often more time and cost effective to manually compute the critical path rather than using a computer. Being difficult to draw, difficult to update, time consuming to draw, and not providing enough information are all “alleged” criticisms of time-scaled arrow diagrams. Pinnell counters these points and states arrow diagrams have greater flexibility, provide better communication and visualization, are faster and cheaper to prepare than a computer schedule, and are also more powerful.

Elise McGough (McGough 1982) in “Scheduling: Effective Methods and Techniques,” briefly traces the origination of scientific consideration of work scheduling to the early 1900’s, when Gantt and Taylor popularized the graphical representation of work versus time. Network-based schedules developed in 1957 and 1958 when the Sperry Rand Corporation developed the Critical Path Method for Dupont Corporation. Network-based schedules provide advantages over the traditional bar chart. Some of the advantages of network-based schedules include the ability to see the overall plan and the relationships between activities. Network-based schedules prevent unrealistic planning and allows for consideration of resource and time constraints before evaluation. Network-based schedules increase the accuracy of target dates and allow cost considerations to be included in a schedule.

Several studies conducted during the 1980’s demonstrated the need for proper planning and effective scheduling. Fleishman Hillard, Inc. prepared two of these studies (one in 1983, the other in 1985) for Wagner-Hohns-Inglis, Inc. Both studies are titled “Opinions of Building Owners on the Construction Industry” and Callahan, Wackenbush, and Rowings summarize the results in the textbook Construction Project Scheduling (Callahan et. all 1992). The surveys focused on owners involved in building construction

and each showed similar results. The results showed owners feel contractors that use critical path scheduling are less susceptible to delays than are other contractors. This is important because the 1983 study showed that delayed projects are closely related to disputes. The majority of owners also felt that a significant cause of cost overruns was due to poor scheduling on the part of the contractor. "Construction schedules can reduce delays, cost overruns, and disputes" (Callahan et al. 1992).

Ali Shash and Abdullatif Al-Abdullatif discuss scheduling techniques used in Saudi Arabia in "A Survey of Planning and Controlling Techniques Used by Construction Contractors in Saudi Arabia," published in February 1993 in *Cost Engineering* (Shash and Al-Abdullatif 1993). A decline in the mid to late 1980's in the Saudi Arabian construction industry prompted the government "to establish policies to improve the quality of construction." One of these new policies was to improve planning, scheduling, and analysis of construction operations. Shash and Al-Abdullatif performed a study on 200 Saudi Arabian contractors based on the survey developed by Davis (Davis 1974). Of the 200 contractors, 61 responded. The results of the study show the critical path method and the Gantt Bar Chart as the two most popular planning techniques. Use of precedence network diagrams and Project Evaluation and Review Techniques (PERT) was rare and the results indicated the Graphical Evaluation and Review Technique (GERT) was never used in Saudi Arabia. The companies implemented these techniques mainly at the project management level rather than at the superintendent level. The study also showed the most often obtained benefit from using the various planning and scheduling techniques was improved planning before construction.

In 1993, George Navarrette and Irtishad Ahmad in "Computer Scheduling and Construction Specs," published in the *Journal of Construction Engineering and Management*, discuss the effect microcomputers had on CPM utilization (Navarrette and Ahmad 1993). The article analyzes two rapid-transit projects, one from 1979-1985, and the other from 1991-1994. The 1979 project used a mainframe computer to process the schedule data, while the 1991 project utilized a microcomputer with Primavera. The results showed scheduling performed with microcomputers was less costly and required minimal training while mainframes were inefficient and costly. Also noted, were software features of Primavera such as cost loading, activity coding, manpower loading, target projects, and earned value reports.

CPM analysis allows for the quantification and apportionment of delays on construction projects. Lee Schumacher discusses the different evaluation techniques using CPM in “Quantifying and Apportioning Delay on Construction Projects,” published in *Cost Engineering* in February of 1995 (Schumacher 1995). The article briefly describes the different delay types, assigning responsibility of delays, and the special case of concurrent delays. Schumacher describes three types of delay analysis: “what-if” evaluations, “but-for” evaluations, and Contemporaneous Period Analysis (CPA). The “what-if” method bases the analysis on the as-planned schedule. The use of this method is declining because the industry is becoming more sophisticated and realizes project schedules are dynamic. Because actual progress usually differs from the as-planned schedule, delay analysis is difficult using a fixed as-planned schedule. The “but-for” technique uses an as-built schedule rather than the as-planned but is still a retrospective approach. The drawback of this approach is the difficulty in determining the critical path. In an as-built schedule, the dates are actual start and finish times so the activities have no float. Care must be taken when determining the critical path in this case. The third method is a contemporaneous approach. Analysis of delays occurs as the delay happens. The use of any of these approaches should be used with good judgment and knowledge of the fact that the courts and arbitrators are becoming more sophisticated and knowledgeable about delay analysis using CPM.

CPM analysis has gained prominence because it is the most accurate tool available for delay analysis. Project owners frequently require a CPM analysis on change orders and time extension requests. Robert McCullough (McCullough 1999) discusses delay analysis in “CPM Schedules in Construction Claims from the Contractor’s Perspective”. Contemporaneous analysis of delays is effective because the best time to evaluate a delay is at the time it occurs. The article also discusses several retrospective analyses such as the impacted as-planned analysis, total delay analysis, but-for analysis, and the collapsed as-built analysis. The impacted as-planned analysis uses the original as-planned schedule and only applies delays caused by the owner. The impacted as-planned analysis fails to account for delays that are caused by the contractor or delays that are neither party’s fault. The total delay analysis is rejected by courts because it assumes all delays are the fault of one party and this is rarely the case in construction. The but-for analysis relies on the as-built schedule. Delays are inserted into the as-built schedule and are assigned

responsibility (owner caused delay, contractor caused delay, or excusable delay). The but-for method then looks at the schedule “but-for” the actions of the other party. The collapsed as-built analysis is very similar to the but-for in that both rely on the as-built schedule. The collapsed as-built method removes delays from the schedule and an “unimpacted” schedule is the result. The use of retrospective methods depends on the existence of a reliable baseline schedule. Poorly conceived and maintained schedules hinder the analysis. For an effective analysis to be possible, contractors must have good documentation and record keeping. In addition, evaluation of delaying events should occur as soon as possible to strengthen a contractor’s claim.

A study performed on the use of project management software in 1998 included members of the Project Management Institute (PMI). The study group consisted of both construction and non-construction professionals. “Project Management in Construction: Software Use and Research Directions,” published in the *Journal of Construction Engineering and Management* by Liberatore, Pollack-Johnson, and Smith, contains the results of this study pertaining to construction project management (Liberatore et. al 2001). The results of this study showed construction personnel use project management software more often than non-construction personnel and have been using it longer. The main software packages used by the construction industry are Primavera and Microsoft Project. The findings from this study also showed that of the construction respondents, 89% used CPM for planning and 72% for control during construction. Other uses of CPM cited were resource scheduling and earned value control. One third of the construction respondents also used techniques such as multi-project scheduling, time/cost tradeoff, and probability analysis. An important finding of the study is that complexity of the project is the most important factor in deciding when to use project management software.

Richard Korman’s “Critics Can’t Find the Logic in Many of Today’s CPM Schedules,” published in ENR May 26, 2003, discusses problems with today’s CPM schedules (Korman and Daniels 2003). Scheduling experts discuss how software is making scheduling more susceptible to abuse. Flexibility in software is taking scheduling out of the hands of specialists and putting it into the hands of “P3 mechanics” who are not as familiar with the concepts behind CPM application. Also discussed in the article is scarcity of activity on the arrow networks. Primavera and other software rely on precedence diagramming

rather than arrow networks. Companies now focus on precedence diagramming rather than arrow diagramming because of software companies' exclusive use of precedence diagrams. Some schedulers claim precedence diagramming is detrimental to scheduling because it can easily be manipulated and the logic of the schedule is not as apparent as it is with arrow diagramming. Others believe precedence diagramming is actually a clearer representation of the logic and work flow because there are no "dummy" activities.

**Table 3.1 Literature Review Summary**

Author	Date	Title	Subject/Topics
Editorial	1965	CPM Discussed: 'Clout' Needed for Control and Savings	Industry Opinions of CPM
Howard	1965	CPM-As Complete Project Management	Complete Project Manageme, Time & Cost Savings, Computers necessary for advanced features
Priluck	1965	CPM Studied: Conceptions and Misconceptions of a New Tool	Basic Elements of CPM, Management by Exception
Robinson	1965	CPM Surveyed: Definitely a Shortcut to Building Efficiency	Benefits of CPM - Time Savings
Schoderbeck	1965	A Study of the Applications of PERT	PERT as an extension of CPM, Advantages and disadvantages of PERT
Editorial	1971	CPM-Solution or Problem	CPM application, used primarily for planning because of time and money needed to implement during construction
Davis	1974	CPM Use in Top 400 Construction Firms	Survey of the Top 400 Contractors
Popescu and Borcherdig	1975	Developments in CPM, Pert, and Network Analysis	Technology and CPM, New uses required computers and computer usage was scarce
Pinnell	1980	Critical Path Scheduling: an Overview and a Practical Alternative	Time scaled arrow diagrams as an alternative to computerization
McGough	1982	Scheduling: Effective Methods and Techniques	Evolution of CPM
Tavakoli and Riachi	1990	CPM Use in ENR Top 400 Contractors	Survey of the Top 400 Contractors
Callahan et. al	1992	Construction Project Scheduling	Survey of owners regarding CPM, found contractors less susceptible to delay with CPM use
Navarrete and Ahmad	1993	Comparison of Delay Analysis Methodologies	Case study of CPM application with a personal computer v. without
Shash and Al-Abdullatif	1993	A Survey of Planning and Controlling Techniques Used by Construction Contractors in Saudi Arabia	Study of Contractors in Saudi Arabia, found most frequent use was detailed planning prior to construction.
Schumacher	1995	Quantifying and Apportioning Delay on Construction Projects	Time impact analysis, contemporaneous methods used more often because critical path is dynamic
McCullough	1999	CPM Schedules in Construction Claims From the Contractor's Perspective	Time impact analysis methods, contemporaneous method more effective than retrospective
Liberatore et. Al	2001	Project Management in Construction Software Use and Research Directions	Use of project management software
Korman and Daniels	2003	Critics Can't Find the Logic in Many of Today's CPM Schedules	Logic abuses in schedules due to flexibility in software

#### **IV. OBJECTIVES, PURPOSE & SCOPE**

This research quantifies the degree to which the construction industry uses CPM. The research looks at the differences between large, medium, and small companies' utilization of CPM. The research also looks at how companies involved in various types of construction use CPM. This study also looks at the life cycle phases of a project in which CPM can be used, such as design development, estimating and bidding, detailed planning prior to notice to proceed, control during construction, and operation and maintenance of a facility. In addition to a comparison of the different sized companies' usage, a comparison is made in some cases to past years using the data from the 1974 and 1990 studies. This research shows how CPM usage has changed over the years and how the respondents of the survey are currently using it. Attitudes of the construction industry toward CPM are questioned in the survey, such as the benefits obtained from CPM analysis and any reasons for success or lack of success in implementing it. The study provides insight into how technology has affected, and will continue to affect the industry in regards to implementation of CPM.

The scope of this study was limited to the top 400 contractors, as listed by ENR in the May 19, 2003 issue. The reason for this study's limited focus is the size of the companies because the top 400 contractors are more likely to be users of CPM than a sole proprietorship or other small companies because of the size of the projects they handle. CPM analysis may not be necessary on jobs with only 10-20 activities. The size of the projects a company handles is a good indicator of whether they are users of CPM or not. Another reason for using the top 400 contractors is their use in the 1974 and 1990 studies.

This paper makes references to small, medium, and large firms. These labels are relative to the group studied, not to the entire spectrum of contractors. A small company in the top 400 Contractor list is by no means a small contractor. This nomenclature helps distinguish between different size companies in the list. The large companies are those with an annual volume greater than \$600 million. Small companies are those companies with an annual volume less than \$160 million. Medium sized companies are those in between. This demarcation is arbitrary but helps distinguish how different size companies use CPM.

This study was conducted using an online survey (located in Appendix A). The survey is located in the appendix of this paper. Table 4.1 is a list of key issues addressed in this study and the questions in the survey addressing each issue:

**Table 4.1 Key Issues**

<b>Key Issues</b>	<b>Questions to Address Issue</b>
1. Types of companies utilizing CPM	3, 4
2. If the overall use of CPM has increased	6, 8
3. Life cycle phases of a project CPM is used on	15, 16
4. The different applications for CPM	15, 16, 28, 29, 30
5. How technology has and will affect CPM utilization	22, 23, 34, 35, 36, 37
6. Overall industry feelings toward CPM	6, 7, 9, 11, 13, 14, 17, 18, 21, 22, 23, 24, 25, 26, 27, 33, 37
7. Cost associated with CPM application	19, 20
8. Benefits of CPM and reasons for success in CPM utilization	17, 21, 23 – Part of Key Issue #6
9. Disadvantages of CPM and reasons for unsuccessful utilization	18, 21, 22 – Part of Key Issue #6

Questions not listed above but in the survey (e.g., question 10 asks when firms first started using CPM, and question 5 asks how much work is self performed) serve as supporting and background information. Other questions in the survey address items such as the level of detail in the data used, the type of time impact analysis method used, other planning techniques used, etc.

## V. METHODOLOGY

The study was performed using a web-based survey that was made available to ENR's list of the Top 400 Contractors. The web tool used to collect data is located at [www.survey.vt.edu](http://www.survey.vt.edu). This tool is available only to faculty and students of Virginia Tech. A web-based tool provided by Virginia Tech was chosen to help add credibility to the study. The survey used in this study is based on the two studies done in 1974 and 1990. The questions used in this survey that were used previously will help study the trends of CPM usage in the construction industry. There are some additional questions, which will provide more insight into the industry's use of CPM.

The list of the Top 400 Contractors was supplied by ENR in an Excel format. The Excel file contained information about each company such as the president's name, the street address, and the website. No email addresses were provided. Email addresses were found by visiting each company's website and looking up contact information. In most cases, an email address was provided for a general company mailbox. In other cases, individual email addresses were given for officers of the company. Where possible, emails were sent directly to officers of the company, such as operations managers or chief schedulers. Most emails were sent to the company's general mailbox. Most websites that did not provide email addresses provided a form for general inquiries. The form was completed and asked for the company's participation and provided the link to the survey. A week before the survey deadline, a reminder email was sent to each company that had not responded and the deadline was extended another two weeks to encourage more responses. By sending emails rather than directly calling companies, response to the survey was voluntary.

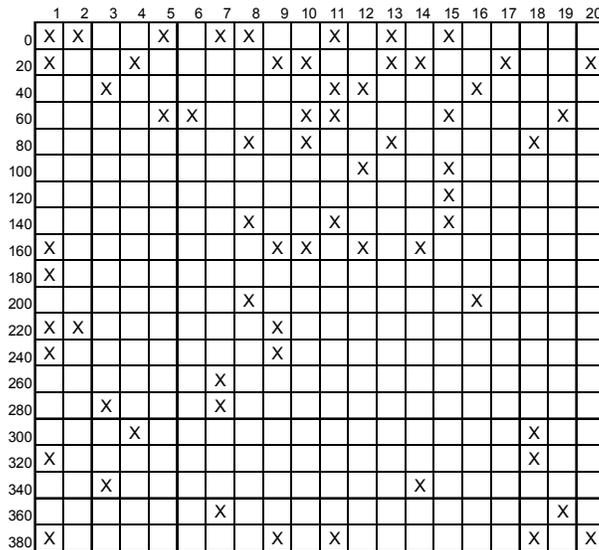
The data analysis for the results included calculating the overall percentage of each question response by the responding companies. The responses were then analyzed based on company size and the type of construction the company is involved in. Statistical analysis of the responses was not possible for a couple reasons. The first reason is because the survey is voluntary. Some underlying factor could exist as to why certain companies responded and others did not. The survey being voluntary prevented the determination of a confidence level that would be possible with a random sample selected from a population. The second reason is the low response rate to the survey

and the number of responses to each question, which prevented the use of a chi-squared test to analyze differences between respondents. In order to use the chi-squared test, a matrix needs to be created for each question with the type of company (based on size or type of construction) on one axis and the responses to the question on the other. The number of responses for each type of company would be entered in next to the corresponding response. The chi-squared test would not work for the majority of the questions because the number of responses for each choice in a question was too small to make the test valid. Chi square tests are used to determine if seemingly small differences are statistically significant. This study looks at large differences; so not being able to use a chi square test was not a significant problem. The large differences between responses can be observed using simple percentages for the different types of companies responding.

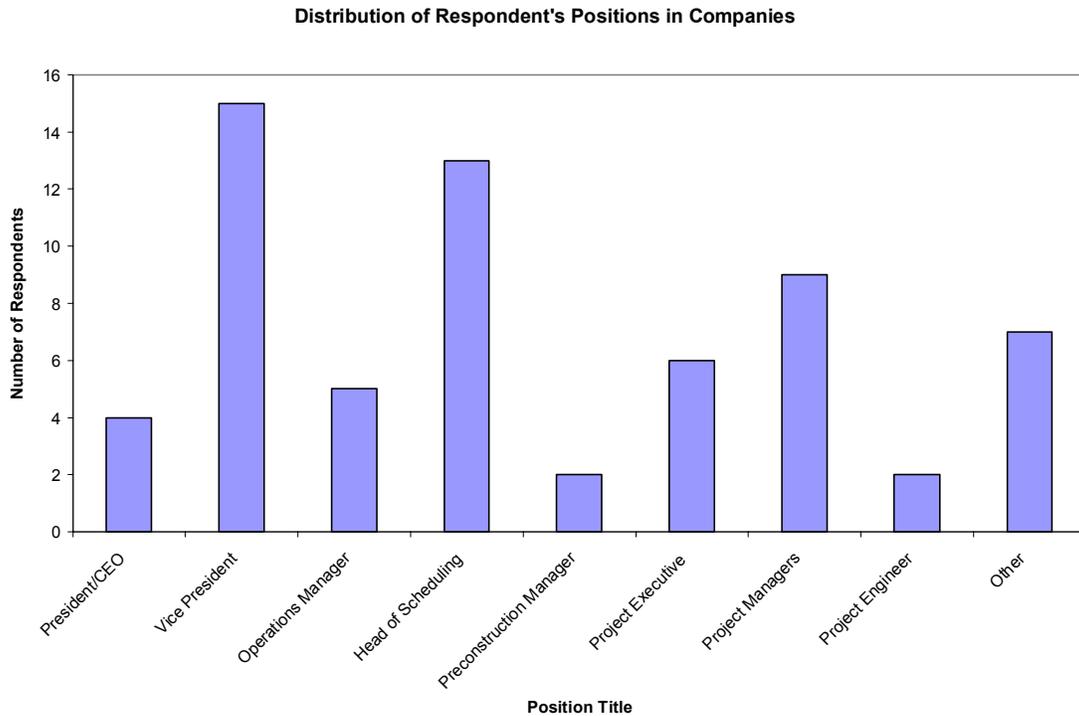
## VI. RESPONSE RATE AND STATISTICS USED

### Survey Response

Out of the 400 companies emailed, 67 responded. Two companies responded to the survey twice. In this situation, the position of the respondent in the company was used to decide which set of responses to keep. In total, 65 responses were used to evaluate the results of this study. The response rate to the survey was 16%. Although only 65 companies responded, the respondents spanned the entire spectrum of the 400 contractors. Both the number one and the number 400 company responded. Figure 6.1 below shows the graphical distribution of the responding companies. The numbers listed vertically added to the numbers listed horizontally give the ranking of the responding company in the Top 400 list. Also shown below for information purposes is the distribution of the respondent's position in their company (Figure 6.2). Some positions, such as "Senior Field Coordinator" and "Customer Service Operations Manager" did not fit into any of the categories and were assigned a value of "other."



**Figure 6.1      Responding Company Distribution**



**Figure 6.2 Position within Company of Respondents**

**Statistics Used for Results**

Because response to the survey was voluntary, its not possible to say the results represent the entire 400 Contractors with a certain confidence level. Confidence levels are reserved to surveys where a random sample is selected from a population. A confidence level calculation is not valid for a voluntary survey because underlying factors could exist as to why these companies chose to respond and others did not. Because a confidence level cannot be obtained, the number of large, medium, and small companies responding to the survey was compared to the total number of large, medium, and small companies in the top 400 Contractors. A chi-square test was performed to compare the actual percentage of small, medium, and large companies to the responding company composition. The result of the chi-square test is not significant which shows that different company sizes are not over or under represented by the responding companies. This means the breakdown of responding company sizes is representative of the group of 400 contractors. The number of small, medium, and large companies in the Top 400 compared to the number of respondents is shown in Figure 6.3 below along with the results of the chi-square test. .

**CHI-SQUARE TEST OF HOMOGENEITY FOR COMPANY SIZE**

Table of Observed Counts						
No. of Companies	Actual Respondents	Company Size				
		Small	Medium	Large		
		116	216	68	400	
		15	33	17	65	
		131	249	85	465	

Table of Expected Proportions under Homogeneity						
No. of Companies	Actual Respondents	Company Size				
		Small	Medium	Large		
		0.24234	0.460631	0.157244	0.860215	
		0.03938	0.074853	0.025552	0.139785	
		0.28172	0.535484	0.182796	1	

Table of Expected Counts under Homogeneity						
No. of Companies	Actual Respondents	Company Size				
		Small	Medium	Large		
		112.6882	214.1935	73.11828	400	
		18.31183	34.80645	11.88172	65	
		131	249	85	465	

Calculation of Chi-Square Test Statistic						
Chi-Square =	$\sum_{AllCells}$	$\frac{(ObservedCount - ExpectedCount)^2}{ExpectedCount}$				
		Terms: 0.097332	0.015235	0.35828		
		0.598968	0.093755	2.204797		
		Sum of Terms: 3.368367				
		Chi-Square = 3.368367				
		df = 3				
		p-value = 0.33824	(NOT SIGNIFICANT)			

**Result:** Basically this test is comparing the actual percentages of small, medium, and large companies to the percentage of these companies that responded. The Chi-Square test is not significant which indicates that the percentage of companies who responded from each size category is close to the actual percentage. Therefore, different company sizes are not over- or under-represented in the sample.

**Figure 6.3 Chi-Square Test Results**

Comparisons are made throughout the results of how different size companies or companies involved in different types of construction answer certain questions. Initially, it was desired to compare the results of different types of companies and different size companies using chi-squared tests. After the data was collected and analyzed, it was determined the chi square test was not applicable. The chi-squared test would not work for the majority of the questions because the number of responses for each choice in a question was too small to make the test valid. Chi square tests are used to determine if seemingly small differences are statistically significant. This study looks at large

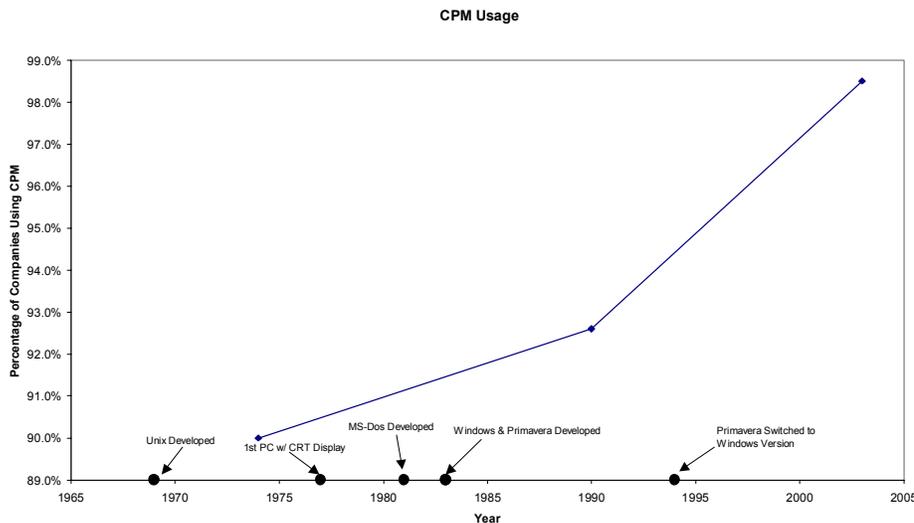
differences; so not being able to use a chi square test was not a significant problem. The large differences between responses can be observed using simple percentages for the different types of companies responding.

Some questions permitted more than one answer from a company. For this reason, the sum of the percentages of the responses is more than 100% in many cases. The percentages of respondents for questions requiring a response (questions that pertain to everyone or questions with a not applicable option) were based on the number of respondents to that question. In certain cases, some companies would omit a question so the total number of respondents for that question was not the same as the total number of respondents in the survey. The number of responses for each question is shown in each table in parenthesis next to the type of company.

## VII. GROWTH OF CPM

### CPM Usage

Of the 65 companies responding, 64 used CPM, which means only 1.5% of the responding companies did not use CPM. Comparatively, 92.6% of the respondents in the 1990 survey used CPM and 90.0% used CPM in the 1974 survey. The results of this study indicate that the use of CPM has grown, shown in Figure 7.1, although not definitively because of the low response rate. Also shown in Figure 7.1 are some dates of the development of certain technologies that have facilitated the use of CPM. The company that does not use CPM indicated the reason for non-use was CPM was not useful.



**Figure 7.1 Increase in CPM Usage**

Question 8 in the survey asks if any other scheduling techniques are used, either in addition to or in place of CPM. Table 7.1 shows the results of this question. The most frequently used scheduling technique other than CPM are free hand bar charts (not based on a logic diagram) with 41.5% of the respondents using this method. The next most frequently used method is Program Evaluation and Review Techniques (PERT) at 23.1%. About 10% use in-house scheduling systems, Microsoft Project Gantt charts, or Excel as an alternative to CPM. The techniques used least by the respondents are Line of Balance, Linear Balance Charts, and 4-D planning. Small companies are almost twice as likely to use free hand bar charts compared to medium and large companies. Medium and large

companies are more likely than smaller companies to use PERT. Larger companies are the most likely to use in-house scheduling techniques.

**Table 7.1 Scheduling Methods Used Based on Company Size**

Method	65 Responses		Large (17)		Medium (33)		Small (13)	
	No. of Responses	Percent						
PERT	15	23%	6	35%	8	24%	1	7%
4D-Planning	2	3%	1	6%	1	3%	0	0%
Line of Balance (LOB)	2	3%	1	6%	1	3%	0	0%
Linear Balance Charts	2	3%	1	6%	1	3%	0	0%
Free Hand Bar Chart	27	42%	6	35%	12	36%	9	60%
Other	7	11%	4	24%	2	6%	1	7%

A comparison was also made of the scheduling techniques used based on the industry sector of the respondents. Table 7.2 shows how alternative scheduling techniques are used based on industry sector. One observation that can be made is companies involved in residential construction are least likely to use free hand bar charts compared with building, heavy, and industrial construction companies.

**Table 7.2 Scheduling Methods Used Based on Industry Sector**

Method	Residential (14)		Building (50)		Heavy Construction (29)		Industrial (33)	
	No. of Responses	Percent	No. of Responses	Percent	No. of Responses	Percent	No. of Responses	Percent
PERT	2	14%	9	18%	8	28%	8	24%
4D-Planning	0	0%	2	4%	1	3%	2	6%
Line of Balance (LOB)	0	0%	1	2%	2	7%	1	3%
Linear Balance Charts	0	0%	1	2%	1	3%	2	6%
Free Hand Bar Chart	2	14%	21	42%	15	52%	13	39%
Other	0	0%	6	12%	3	10%	2	6%

Comparing the data from this study with that collected in 1990, use of the free hand bar chart has decreased by almost 50%. The use of PERT has grown from 17% to 23% while the use of the remaining methods has not grown a significant amount.

## **Discussion**

While statistically it is difficult to compare the data from this study and past studies, some generalizations can be made with the results of this survey. Using the data from this study, CPM use has grown 6% since 1990 and 8.5% since 1974. There are many

possible reasons why CPM usage has increased throughout the years. Different companies will have different reasons for using CPM and will use CPM in different ways. The rest of this paper will discuss how companies are using CPM and why they are using it.

## VIII. TYPES OF COMPANIES USING CPM

### Overview of Companies

The third question in the survey categorized the responding companies by size according to annual construction revenue. Seventeen companies (26%) fall into the category of being a large company with over \$600,00,000 of annual construction revenue. Thirty-three companies (51%) are mid-sized companies with annual construction revenue between \$160,000,000 and \$600,000,000. The number of small firms responding to the survey is fifteen (23%) with less than \$160,000,000 in annual construction revenue.

The fourth question addresses the types of construction in which companies may be involved. Several companies partake in more than one type of construction. Table 8.1 shows the breakdown of what industry sectors the responding companies are involved. The total percentage for the industry breakdown is greater than 100% because many companies are involved in more than one type of construction. Eight companies responded as being involved in other types of construction. Other types of construction included retail, site work, pipeline construction, stadiums, marine construction, and golf courses.

**Table 8.1 Industry Breakdown**

Industry Sector	No.	Percent
Residential	14	22%
Building	50	77%
Heavy	29	45%
Industrial	33	51%
Other	8	12%

### Discussion

All different types of construction companies are using CPM. CPM usage is not limited to any particular type of construction or size of company. As stated previously, the responding companies were representative of the companies in the top 400 contractors list according to size. The most represented type of construction is building construction with 77% of the respondents. Next, industrial construction is well represented with over 50% of the companies. Forty five percent of the companies are active in heavy construction and 21% are active in residential construction.

## IX. USAGE OF CPM IN DIFFERENT LIFE CYCLE PHASES OF A PROJECT

### **Major Areas of CPM Application**

CPM can be used for many different applications through the life cycle of a construction project. CPM is used in all phases of construction from design development through operation and maintenance of projects. Table 9.1 gives details on the areas CPM is used by the respondents along with details about how different size firms apply CPM. Detailed planning before the start of construction (98%) and periodic control of work after the start of construction (97%) are the two main areas of CPM application. CPM use in design development and during the estimating and bidding phase is a little over 50%. CPM is used least in operation and maintenance of projects at 41%. Other areas of CPM application include sales presentations, proposals, and forensic use. The results of the survey show application is fairly independent of the size of the company except for its use in design development. CPM is more likely to be used by large firms (65%) than smaller firms (38%) in design development.

**Table 9.1 Areas of CPM Application based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Design Development	33	52%	11	65%	17	52%	5	38%
Estimating and Bidding	34	54%	9	53%	18	55%	7	54%
Detailed Planning	62	98%	17	100%	32	97%	13	100%
Periodic Control	61	97%	16	94%	32	97%	13	100%
Operation and Maintenance	26	41%	8	47%	13	39%	5	38%
Other	4	6%	1	6%	2	6%	1	8%

The different areas of CPM application were then analyzed based on industry sector. Table 9.2 shows the breakdown of the areas of application by companies based on the type of construction. Companies involved in building construction and industrial construction are more likely to use CPM for design development than those companies involved in residential and heavy construction. The remaining areas of CPM application do not seem to be dependent on the type of construction.

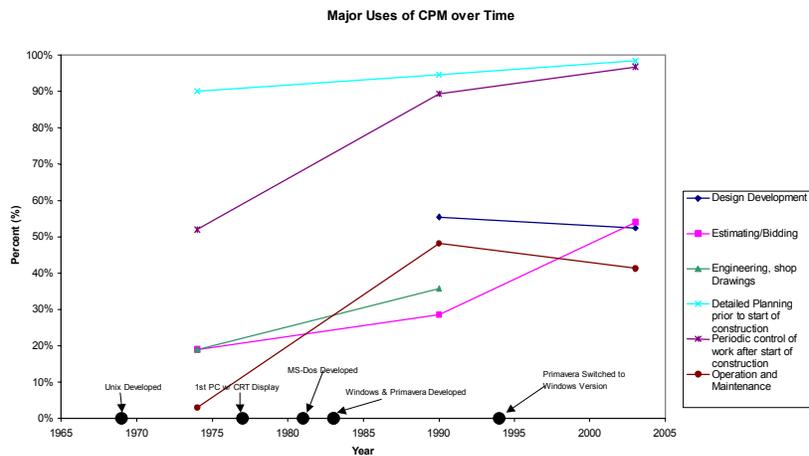
**Table 9.2 Areas of CPM Application Based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Design Development	6	43%	31	63%	13	45%	21	66%
Estimating and Bidding	8	57%	27	55%	14	48%	18	56%
Detailed Planning	14	100%	49	100%	28	97%	32	100%
Periodic Control	14	100%	49	100%	28	97%	31	97%
Operation and Maintenance	6	43%	19	39%	11	38%	15	47%
Other	0	0%	4	8%	1	3%	2	6%

Areas of CPM application have remained the same over the years although some areas have seen increased usage (Table 9.3 and Figure 9.1). Also shown in Figure 9.1 are the dates of the development of certain technologies that have facilitated the use of CPM. Use of CPM in estimating and bidding has doubled since 1990 and almost tripled since 1974. Use of CPM has also increased in the use of periodic control of work after the start of construction. This study indicates CPM is used for control of work about 97% of the time compared with 52% in 1974 and 89% in 1990.

**Table 9.3 Comparison of CPM Application Areas between the Different Studies**

	1974	1990	2003
Design Development	X	55%	52%
Estimating/Bidding	19%	29%	54%
Engineering, shop Drawings	19%	36%	X
Detailed Planning prior to start of construction	90%	95%	98%
Periodic control of work after start of construction	52%	89%	97%
Operation and Maintenance	3%	48%	41%
Other	X	10%	6%



**Figure 9.1 CPM Applications over Time**

CPM has many uses in the periodic control of construction. Question 16 in the survey addressed these uses and the results are shown in Table 9.4. The most frequent uses are coordination of subcontractors and developing look-ahead schedules. Other popular uses include schedule impact analysis and tracking changes, tracking shop drawings and submittals, and coordination of own trades. The tasks utilizing CPM the least are tracking costs and calculating payment requests.

**Table 9.4 CPM Use for Periodic Control of Work During Construction**

	63 Responses	
Coordination of Subs	61	97%
Coordination of Own Trades	43	68%
Schedule Impact Analysis and Tracking Changes	53	84%
Tracking Shop Drawings and Submittals	41	65%
Tracking Costs	12	19%
Calculating Payment Requests	23	37%
Developing a Look Ahead Schedule	58	92%
Other	3	5%

### CPM's Role in Claims and Litigation

The results from this study show that 85% of the respondents use CPM in claims analysis (Table 9.5). All of the large companies use CPM for claims analysis while about 70% of small companies do. CPM's role in claims analysis has grown since 1990 (Table 9.6). The results from this study indicate that 15% more companies are now using CPM for claims than in 1990.

**Table 9.5 Use of CPM in Claims Analysis Based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Uses CPM in Claims Analysis	54	86%	17	100%	28	85%	9	69%
Does not use CPM in Claims Analysis	9	14%	0	0%	5	15%	4	31%

**Table 9.6 Growth of CPM in Claims Analysis since 1990**

	1990	2003
Uses CPM in Claims Analysis	71%	86%
Does not use CPM in Claims Analysis	30%	14%

After determining how many companies use CPM in claims analysis, this study asked what percent of claims CPM is used on. The results from this question are based only on those responding yes to using CPM in claims analysis. Table 9.7 shows the results to question 29 and how different sized companies responded. Surprisingly, small companies that use CPM for claims analysis seem to be using CPM in claims analysis more frequently than medium size companies. Medium size companies are using CPM the least frequently in claims.

**Table 9.7 Percent of Claims CPM is Used On**

	53 Responses		Large (17)		Medium (28)		Small (8)	
0-25%	18	34%	4	24%	12	43%	2	25%
25-50%	7	13%	3	18%	3	11%	1	13%
50-75%	10	19%	3	18%	5	18%	2	25%
75-100%	18	34%	7	41%	8	29%	3	38%

Not every claim escalates to litigation. For those that do, CPM seems to be a tool used frequently either for one side or the other. Question 30 asked if the responding companies have been involved in litigation where CPM was used to either prove or disprove a claim. Two thirds responded they have been involved in litigation where CPM was used (Table 9.8). A larger percentage of large companies have been involved in litigation with CPM than medium or small companies.

**Table 9.8 CPM's Use in Litigation**

	60 Responses		Large (16)		Medium (31)		Small (13)	
Yes	40	67%	15	94%	18	58%	7	54%
No	20	33%	1	6%	13	42%	6	46%

### **Time Impact Analysis**

Several different types of time impact analysis exist, many with different names for the same method. The different types of time impact analysis are variations of two main methods, contemporaneous and retrospective. Question 31 asked what type of time impact analysis method is used to quantify the effect of a delaying event. Table 9.9 shows the results of this question. Almost half of the respondents say that the time impact analysis used is contract dependent. Contemporaneous is used more often than the retrospective method except in the case of medium size companies.

**Table 9.9 Type of Time Impact Analysis Used**

	59 Responses		Large (16)		Medium (31)		Small (12)	
Contemporaneous	18	31%	9	56%	4	13%	5	42%
Retrospective	7	12%	1	6%	5	16%	1	8%
Contract Dependent	29	49%	5	31%	19	61%	5	42%
No TIA Used	5	8%	1	6%	3	10%	1	8%

**Discussion**

CPM is not only used during the construction phase of a project. CPM is used by companies for design development, estimating and bidding, detailed planning of work prior to start of construction, periodic control of work after start of construction and operation and maintenance of projects. Tables 9.1 and 9.2 show what phases of a project CPM is used for by the respondents. Use of CPM for estimating and bidding and control of work during construction has increased since 1990. Use in other phases of a project has not changed much.

The increased use of CPM during bidding and estimating could be the result from contractors competing not only the basis of cost, but also on time to complete a project. Another reason may be owner bid requirements ask for a CPM as owners become more knowledgeable about CPM. The increased use of CPM for estimating and bidding could also be because 93% of the respondents feel that CPM can improve understanding of a project. Similarly, the reason more companies use CPM for periodic control of work after the start of construction could be due to the fact that 97% of the respondents found CPM improves project control after work starts.

In addition to CPM’s use throughout the life cycle phases of a project, it is also used as a forensic tool. CPM is often used in analyzing claims and the effects of delaying events. Thirty three percent of the respondents use CPM because of its increased use in litigation. An even more impressive figure is 86% use CPM for claims analysis. Only 70% of the respondents in the 1990 survey used CPM for claims analysis. All the large companies responding used CPM in claims analysis while only 70% of the small companies did. Of those who did use CPM for claims, around 60% of both large and small companies used CPM on 50% or more of claims.

A result of CPM being used in claims analysis is its presence in litigation. Two thirds of the respondents have been involved in litigation where CPM was used to prove or disprove a claim. Over 90% of large companies have been involved in litigation involving CPM while only 50-60% of medium and small companies have. This could be due to the size or type of projects large companies work on. Large companies might also just end up being involved in more litigation than small or medium size companies.

Using CPM to quantify a delaying event's impact requires time impact analysis. Over 90% of the respondents use some kind of time impact analysis to quantify the effect of a delay. Almost 50% of the companies say the time impact analysis used is contract dependent. By dictating a certain type of time impact analysis method into the contract, owners show they are aware of time impact analysis and the use of CPM as a claims tool. When the time impact analysis method is not stipulated in the contract, the bulk of the companies (30%) use a contemporaneous approach. This may be due to the opinion that the best time to analyze a delay is when it occurs, especially if a contractor wants to strengthen his case (McCullough 1999). A contemporaneous approach is also useful because the critical path is dynamic and changes throughout the life of a project. A retrospective analysis is not always a true representation of a delaying event's effect.

## X. INDUSTRY FEELINGS TOWARD CPM

### Reasons for CPM Usage

Question 9's purpose was to identify the reason why contractors use CPM. This question looks at whether CPM is being used because companies believe in its value, because it is forced on them as a contract requirement, or for other reasons. A comparison of responses was then made based on both company size (Table 10.1) and industry sector (Table 10.2). Almost all respondents indicated they feel CPM is a valid management tool. The next most cited reasons for using CPM is it is a contract requirement and it improves communication. CPM's increased use in litigation was cited the least as a reason for use other than individual responses.

Large companies are more likely than small or medium sized companies to use CPM because of its increased use in litigation. Large companies use CPM 30% more than small companies because of its use in dispute resolution. Small companies unanimously responded they use CPM because it is a contract requirement. This does not mean CPM is used only because it is a contract requirement, but all agreed it is one of the reasons it is used. Companies involved in building construction are least likely to use CPM because it is a contract requirement. Heavy and industrial construction companies are more likely than building and residential construction companies to use CPM for its use in dispute resolution.

**Table 10.1 Reasons for CPM Use Based on Company Size**

	63 responses		Large (17)		Medium (33)		Small (13)	
Valid Management Tool	62	98%	17	100%	32	97%	13	100%
Dispute Resolution	42	67%	14	82%	21	64%	7	54%
Contract Requirement	50	79%	14	82%	23	70%	13	100%
Improves communication	50	79%	14	82%	24	73%	12	92%
Increased use in litigation	21	33%	7	41%	11	33%	3	23%
Other	3	5%	0	0%	3	9%	0	0%

**Table 10.2 Reasons for CPM Use based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Valid Management Tool	14	100%	49	100%	28	97%	32	100%
Dispute Resolution	10	71%	30	61%	23	79%	25	78%
Contract Requirement	13	93%	36	73%	26	90%	28	88%
Improves communication	12	86%	39	80%	24	83%	25	78%
Increased use in litigation	7	50%	16	33%	10	34%	11	34%
Other	1	7%	3	6%	0	0%	1	3%

## **Frequency of CPM Use**

After determining how many companies use CPM and why they use it, the frequency of use was asked in question 11. Once again, the responses are broken down by size of company and industry sector and the results are shown in Tables 10.3 and 10.4. Overall, 87% of the responding companies use CPM 75% of the time or more. This has increased since 1990 when only 60% of contractors used CPM 75% of the time or more. No significant differences are noticed in frequency of use by different sized companies.

**Table 10.3 Frequency of CPM Use based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
All Contracts	23	37%	6	35%	13	39%	4	31%
75-100% of the Time	32	51%	10	59%	16	48%	6	46%
50-75% of the Time	5	8%	0	0%	3	9%	2	15%
25-50% of the Time	1	2%	1	6%	0	0%	0	0%
0-25% of the Time	1	2%	0	0%	0	0%	1	8%
Only When Required	1	2%	0	0%	1	3%	0	0%

**Table 10.4 Frequency of CPM Use based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
All Contracts	7	50%	20	41%	9	31%	10	31%
75-100% of the Time	6	43%	24	49%	16	55%	19	59%
50-75% of the Time	1	7%	4	8%	2	7%	1	3%
25-50% of the Time	0	0%	1	2%	1	3%	1	3%
0-25% of the Time	0	0%	0	0%	0	0%	1	3%
Only When Required	0	0%	0	0%	1	3%	0	0%

## **Logic Network**

When using CPM, the logic network can either be an arrow or precedence diagram. Question 13 in the survey asks companies which diagramming method their company uses for CPM application; arrow, precedence, or both. The precedence diagramming method is used most frequently with 62% of the respondents using it exclusively (Table 10.5). Only 3% of the respondents use arrow diagramming exclusively. This leaves 35% of the respondents who use both diagramming methods. The overwhelming number of respondents that use precedence diagrams exclusively is probably due to software only supporting this type of diagramming method (Korman and Daniels 2003).

**Table 10.5 Diagramming Methods Used**

	63 Responses	
Arrow	2	3%
Precedence	39	62%
Both	22	35%

**Benefits of CPM Application**

In addition to discovering how companies are using CPM, the survey also tried to address the benefits obtained from CPM application. The first study in 1974 gave six different options for benefits including improved estimating/bidding, improved planning before work starts, improved project control after work starts, faster response to problems, improved communication among the work force, and cost savings. In 1990, more benefits were added to the survey such as improved scheduling, helps train future project managers, positive psychological effects on employees, and time savings. This study added a few more benefits including improved understanding of the project, reduces cost overruns, minimizes disputes, and more control over risk and uncertainty.

Table 10.6 shows the benefits obtained by the responding companies as a whole group and by company size. Table 10.7 shows how companies in the different areas of construction viewed the benefits obtained from CPM application. Large companies were more likely to obtain the listed benefits than medium and small companies except for a few cases such as positive psychological effects on employees, time savings, and cost savings. CPM is more likely to have positive psychological effects on employees in small companies than medium or large companies. Time savings and cost savings were obtained almost the same by large and small companies with medium companies lagging behind.

**Table 10.6 Benefits Obtained by the Entire Group and by Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Improved Estimating/Bidding	23	37%	9	53%	11	33%	3	23%
Improved Planning before Work Starts	61	97%	17	100%	32	97%	12	92%
Improved Scheduling	57	90%	17	100%	28	85%	12	92%
Improved Project Control after Work Starts	61	97%	17	100%	31	94%	13	100%
Faster Response to Problems	34	54%	10	59%	18	55%	6	46%
Improved Understanding of the Project	59	94%	16	94%	30	91%	13	100%
Improved Communication among Work Force	51	81%	15	88%	26	79%	10	77%
Helps Train Future Project Managers	30	48%	11	65%	16	48%	3	23%
Positive Psychological Effects on Employees	15	24%	3	18%	8	24%	4	31%
Cost Savings	32	51%	11	65%	13	39%	8	62%
Time Savings	43	68%	14	82%	18	55%	11	85%
Reduces Delays	45	71%	14	82%	19	58%	12	92%
Reduces Cost Overruns	27	43%	12	71%	11	33%	4	31%
Minimizes Disputes between Contractor and Owner	43	68%	13	76%	22	67%	8	62%
More Control over Risk and Uncertainty	46	73%	13	76%	24	73%	9	69%

**Table 10.7 Benefits Obtained Based on Construction Type**

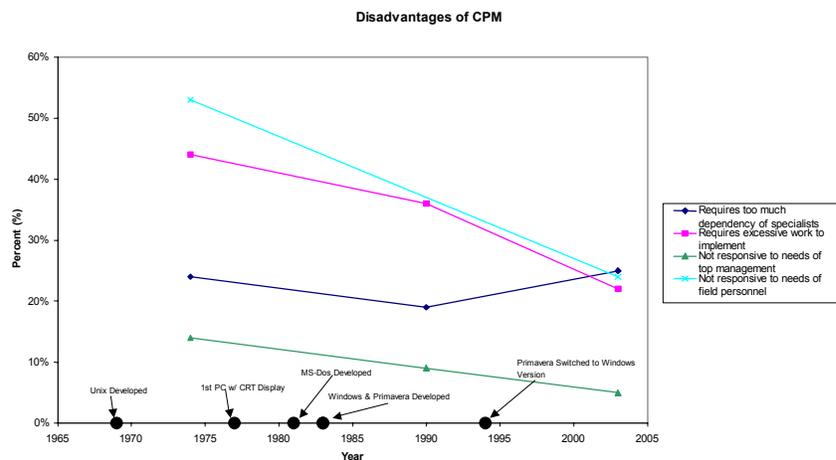
	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Improved Estimating/Bidding	4	29%	16	33%	15	52%	14	44%
Improved Planning before Work Starts	12	86%	48	98%	28	97%	30	94%
Improved Scheduling	14	100%	44	90%	27	93%	29	91%
Improved Project Control after Work Starts	14	100%	48	98%	28	97%	31	97%
Faster Response to Problems	7	50%	28	57%	15	52%	18	56%
Improved Understanding of the Project	14	100%	46	94%	28	97%	29	91%
Improved Communication among Work Force	13	93%	43	88%	23	79%	26	81%
Helps Train Future Project Managers	6	43%	24	49%	16	55%	17	53%
Positive Psychological Effects on Employees	4	29%	14	29%	5	17%	5	16%
Cost Savings	5	36%	25	51%	16	55%	19	59%
Time Savings	10	71%	35	71%	20	69%	25	78%
Reduces Delays	11	79%	36	73%	20	69%	23	72%
Reduces Cost Overruns	6	43%	23	47%	16	55%	17	53%
Minimizes Disputes between Contractor and Owner	10	71%	32	65%	22	76%	23	72%
More Control over Risk and Uncertainty	10	71%	37	76%	20	69%	22	69%

## Disadvantages of CPM

The survey also tried to address some of the disadvantages of CPM. All the disadvantages listed in this survey were used in the past two studies except for logic abuses and the addition of a “no major disadvantages” option. Table 10.8 and Figure 10.1 shows how the results of this survey compare with the past two studies. Also shown in Figure 10.1 are the dates of the development of certain technologies that have facilitated the use of CPM. As the years progressed, fewer companies find CPM requires excessive work to implement. Fewer companies are also finding CPM is not responsive to the needs of top management and field personnel. Forty nine percent of the respondents feel logic abuses are a disadvantage of CPM. Over a quarter of the respondents did not feel there were any major disadvantages to CPM. The results broken down by company size and type of construction are shown in Table 10.9 and Table 10.10.

**Table 10.8 Disadvantages of CPM over Time**

	1974	1990	2003
Requires too much dependency of specialists	24%	19%	25%
Requires excessive work to implement	44%	36%	22%
Not responsive to needs of top management	14%	9%	5%
Not responsive to needs of field personnel	53%	X	24%
Logic abuses	X	X	49%
No Major Disadvantages	X	X	27%
Other	21%	13%	13%



**Figure 10.1 Disadvantages of CPM**

**Table 10.9 Disadvantages of CPM Based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Requires too Much Dependency of Specialists	16	25%	6	35%	8	24%	2	15%
Requires Excessive Work to Implement	14	22%	3	18%	7	21%	4	31%
Not Responsive to Needs of Top Management	3	5%	1	6%	1	3%	1	8%
Not Responsive to Needs of Field Personnel	15	24%	4	24%	7	21%	4	31%
Logic Abuses	31	49%	8	47%	14	42%	9	69%
No Major Disadvantages	17	27%	2	12%	13	39%	2	15%
Other:	8	13%	4	24%	2	6%	2	15%

**Table 10.10 Disadvantages of CPM Based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Requires too Much Dependency of Specialists	5	36%	11	22%	5	17%	8	25%
Requires Excessive Work to Implement	5	36%	12	24%	3	10%	6	19%
Not Responsive to Needs of Top Management	0	0%	1	2%	3	10%	1	3%
Not Responsive to Needs of Field Personnel	3	21%	8	16%	7	24%	8	25%
Logic Abuses	8	57%	24	49%	12	41%	18	56%
No Major Disadvantages	5	36%	13	27%	11	38%	7	22%
Other:	1	7%	8	16%	4	14%	5	16%

**Use of a Consultant vs. In-House Staff**

Question 12 addresses how companies handle CPM application, whether it is done using a consultant, in-house staff, or both. This relates to the disadvantage of requiring too much dependency on specialists. In 1990, 15% of responding companies used a consultant while 90% used in-house staff. This means there was overlap between the two of 2.5% using both. The responding companies in this study indicated that only 2% use a consultant while 54% use in-house staff. This means 44% of the companies use both a consultant and in-house staff. Table 10.11 and 10.12 show the responses to question 12. No significant differences based on company size or industry sector are noticed.

**Table 10.11 Consultant v. In-House Staff based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Consultant	1	2%	0	0%	0	0%	1	8%
Staff	34	54%	10	59%	17	52%	7	54%
Both	28	44%	7	41%	16	48%	5	38%

**Table 10.12 Consultant v. In-House Staff based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Consultant	0	0%	1	2%	1	3%	1	3%
Staff	8	57%	26	53%	15	52%	18	56%
Both	6	43%	22	45%	13	45%	13	41%

**Degree of Success in Achieving Advantages of CPM**

Question 17 asked what benefits are obtained from CPM application. Questions 21, 22, and 23 serve as a follow up to this trying to determine the degree of success and the reasons for being either successful or unsuccessful. This question was asked in the previous two studies. Companies that responded to being very successful or moderately successful were asked for the reasons of their success (question 23). Companies responding that they were unsuccessful were asked for the reasons for being unsuccessful (question 24). Table 10.13 shows how successful the respondents were to achieving the advantages of CPM. Only one company felt they were unsuccessful in achieving CPM’s advantages and one company was undecided on the issue. Only 27% felt they were very successful in achieving the benefits of CPM compared with the 70% that responded as being moderately successful. The degree of success seems to be independent on the company’s size.

**Table 10.13 Degree of Success based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Very Successful	17	27%	4	24%	10	30%	3	23%
Moderately Successful	44	70%	13	76%	21	64%	10	77%
Unsuccessful	1	2%	0	0%	1	3%	0	0%
Undecided	1	2%	0	0%	1	3%	0	0%

The one company responding as being unsuccessful cites lack of top management support, project management support, and support from field people as the reasons for being unsuccessful. Although 61 companies responded to being either very or moderately successful, only 60 gave reasons for being successful. These responses are shown in Table 10.14. The most cited reasons for being successful are good computer programs and good support from project management. Good training of personnel, good support from top management, and good support from field people received about the same amount of responses. Only four companies thought the development of new hardware helped in being successful when using CPM.

**Table 10.14 Reasons for Being Successful When Using CPM**

	60 Responses	
Good Computer Programs	44	73%
Good Training of Personnel	33	55%
Good Top Management Support	33	55%
Good Support from Project Management	50	83%
Good Support from Field People	30	50%
Development of New Hardware	4	7%

**CPM's Usage at Different Management Levels**

Question 24 in the survey asked what levels of management in the company use CPM. Tables 10.15 and 10.16 show the results to this question based on company size and type of construction. All companies use CPM at the project management level. Small contractors are more likely to use CPM at the superintendent level than medium and large companies. Similarly, companies involved in residential and building construction are more likely to use CPM at the superintendent level than companies doing industrial and heavy construction. Residential companies were also the most likely to use CPM at top management levels.

**Table 10.15 Levels of Management based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Top Management	30	48%	6	35%	18	55%	6	46%
Project Management	63	100%	17	100%	33	100%	13	100%
Superintendents	49	78%	13	76%	25	76%	11	85%
Foreman	8	13%	3	18%	5	15%	0	0%

**Table 10.16 Levels of Management based on Type of Construction**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Top Management	10	71%	26	53%	16	55%	15	47%
Project Management	14	100%	49	100%	29	100%	32	100%
Superintendents	12	86%	42	86%	22	76%	23	72%
Foreman	1	7%	6	12%	6	21%	3	9%

There is not much difference in the levels of management using CPM today compared with the data from 1990 (Table 10.17). The use at each level of management is within 5% of those from 1990. Use of CPM today at the superintendent positions is still well above that in 1974.

**Table 10.17 Levels of Management Using CPM over Time**

	1974	1990	2003
Top Management	40%	52%	48%
Project Management	89%	98%	100%
Superintendents	26%	73%	78%
Foremen	--	14%	13%

**Importance of CPM to Present Success of Company**

Question 25 addressed how companies view CPM in relation to the present success of the company. Tables 10.18 and 10.19 show the responses to this question. Large companies find CPM is very important to their present success more often than medium and small companies. Companies involved in residential construction were the most likely to find CPM very important to their present success.

**Table 10.18 Importance of CPM to Present Success based on Company Size**

	62 Responses		Large (17)		Medium (33)		Small (12)	
Very Important	21	34%	7	41%	11	33%	3	25%
Moderately Important	38	61%	10	59%	20	61%	8	67%
Unimportant	3	5%	0	0%	2	6%	1	8%
Uncertain	0	0%	0	0%	0	0%	0	0%

**Table 10.19 Importance of CPM to Present Success based on Type of Construction**

	Residential (13)		Building (48)		Heavy Construction (29)		Industrial (31)	
Very Important	8	62%	19	40%	11	38%	13	42%
Moderately Important	5	38%	27	56%	17	59%	17	55%
Unimportant	0	0%	2	4%	1	3%	1	3%
Uncertain	0	0%	0	0%	0	0%	0	0%

Over the years, according to the data from the three studies, the importance of CPM to the present success of the company has changed (Table 10.20). Fewer companies now view CPM as being unimportant to their firm's present success.

**Table 10.20 Importance to Present Success over Time**

	1974	1990	2003
Very Important	22%	38%	34%
Moderately Important	46%	48%	61%
Unimportant	27%	14%	5%
Uncertain	X	X	0%

**Importance of CPM to Future Success of Company**

Question 26 is very similar to question 25, however, it asks about CPM’s importance to the future success of the company rather than the present success. The results are shown in Table 10.21 and 10.22. Small companies are less likely to view CPM as being very important to future success than large or medium size firms are. Companies involved in residential construction are most likely to view CPM as very important to future success. Companies are more likely now to see CPM as very important to their future success than they were in 1990 or 1974 (Table 10.23).

**Table 10.21 Importance of CPM to Future Success based on Company Size**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Very Important	32	51%	10	59%	18	55%	4	31%
Moderately Important	29	46%	7	41%	13	39%	9	69%
Unimportant	2	3%	0	0%	2	6%	0	0%
Uncertain	0	0%	0	0%	0	0%	0	0%

**Table 10.22 Importance of CPM to Future Success based on Company Size**

	Residential (13)		Building (49)		Heavy Construction (29)		Industrial (32)	
Very Important	10	77%	25	51%	17	59%	20	63%
Moderately Important	4	31%	23	47%	11	38%	11	34%
Unimportant	0	0%	1	2%	1	3%	1	3%
Uncertain	0	0%	0	0%	0	0%	0	0%

**Table 10.23 Importance to Future Success over Time**

	1974	1990	2003
Very Important	32%	44%	51%
Moderately Important	43%	52%	46%
Unimportant	19%	5%	3%
Uncertain	X	X	0%

**Decisions Based on CPM**

This study also tried to determine how frequently companies make decisions based on CPM information. Table 10.24 and 10.25 show the results to question 27. Size seems to play a role in how frequently decisions are made based on CPM information. Large companies are the most likely to make decisions frequently based on CPM while small companies are least likely. Companies involved in residential construction are more

likely to frequently make decisions based on CPM than companies involved in other types of construction. Table 10.26 only shows the differences between 1990 and 2003 because the question was not asked in the 1974 survey. It appears CPM information is being used more often to make decisions.

**Table 10.24 Frequency of Decisions based on CPM (Company Size)**

	63 Responses		Large (17)		Medium (33)		Small (13)	
Frequently	30	48%	11	65%	16	48%	3	23%
Moderate Frequency	27	43%	6	35%	12	36%	9	69%
Infrequently	5	8%	0	0%	4	12%	1	8%
Never	1	2%	0	0%	1	3%	0	0%

**Table 10.25 Frequency of Decisions based on CPM (Type of Construction)**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Frequently	9	64%	26	53%	14	48%	16	50%
Moderate Frequency	5	36%	19	39%	13	45%	15	47%
Infrequently	0	0%	4	8%	1	3%	1	3%
Never	0	0%	0	0%	1	3%	0	0%

**Table 10.26 Comparison of Frequency of Decisions based on CPM over Time**

	1990	2003
Frequently	30%	48%
Moderate frequency	51%	43%
Infrequently	19%	8%
Never	1%	2%

### **Updating the Schedule**

CPM schedules are made to be updated but how often they should be updated is always a question. Some contracts dictate the frequency in which schedules should be updated. Often it is up to the company's discretion. Tables 10.27 and 10.28 show how often companies update their schedules. Almost 50% of the companies update their schedule monthly. Small companies and building construction companies are more likely to update their schedules monthly than others are. None of the respondents update their schedule daily. Thirty percent of the large companies update their schedules weekly compared with 20% of medium sized companies and none of the smaller companies.

**Table 10.27 Frequency of Updating based on Company Size**

	63 Responses		Large (16)		Medium (33)		Small (13)	
Monthly	30	48%	6	35%	14	42%	10	77%
Biweekly	12	19%	3	18%	8	24%	1	8%
Weekly	11	17%	5	29%	6	18%	0	0%
Daily	0	0%	0	0%	0	0%	0	0%
When Required by Contract	5	8%	1	6%	4	12%	0	0%
Never	0	0%	0	0%	0	0%	0	0%
Other	5	8%	2	12%	1	3%	2	15%

**Table 10.28 Frequency of Updating based on Company Type**

	Residential (14)		Building (49)		Heavy Construction (29)		Industrial (32)	
Monthly	6	43%	27	55%	11	38%	11	34%
Biweekly	5	36%	11	22%	5	17%	8	25%
Weekly	3	21%	6	12%	6	21%	8	25%
Daily	0	0%	0	0%	0	0%	0	0%
When Required by Contract	0	0%	2	4%	5	17%	1	3%
Never	0	0%	0	0%	0	0%	0	0%
Other	0	0%	3	6%	2	7%	4	13%

**Discussion**

Based on the results from this study, the top 400 contractors appear to be pleased with CPM. Almost every company that responded to this survey used CPM. Of those who use CPM, 98% feel it is a valid management tool and 80% feel that it improves communication among parties involved in a project. Another sign that companies are buying into the power of CPM is over 85% of respondents use CPM on 75% or more of contracts.

Every respondent that uses CPM uses it at the project management level. Seventy five percent are using it at the superintendent level and 47% are using it at top management levels. Encouraging is the fact that some companies are putting the schedule in the hands of their foremen (12%). CPM is and can be used by all levels of management. The more people that have access to scheduling information, the more likely problems can be caught early.

CPM is not just the current trend in scheduling. Overall, companies view CPM in a positive light. Ninety five percent of companies feel CPM is either moderately to very important to the present success of the company. Similarly, 96% feel CPM will be moderately to very important in the future success of the company. Comparing benefits to disadvantages of CPM application also gives a good indication of how companies view CPM, because the respondents encountered more benefits than disadvantages. The

number one reason for the success in achieving the advantages of CPM is good project management support. This seems to show that if project managers believe in the usefulness of CPM, companies will encounter more benefits. The fact that lack of support from project management, lack of support from top management, and lack of support from field people are the main reasons for not achieving the advantages of CPM, shows support is needed from management in order to be successful.

An interesting finding in Table 10.8, which discusses disadvantages of CPM, is the percentage of firms that feel CPM requires too much dependency on specialists has remained almost constant while less companies feel it requires excessive work to implement. So even though companies feel CPM is easier to implement, they depend just as much on specialists as they did in 1974 and 1990. This dependency on specialists may be for different reasons over the years. In 1974, CPM application was done by hand or on mainframe computers. Not many people were experienced in the ways of CPM so CPM was mainly handled by scheduling experts and specialists. In 2003, more people are aware of CPM and software has made it so anyone is able to do scheduling on a PC. CPM over the years has also developed more uses and applications. Also during this timeframe, our society has become more litigious. So with more people using CPM as it becomes more complicated, more companies are using CPM for claims analysis and disputes. Often times, specialists and CPM experts are needed to review and “pick apart” the schedule for claims and litigation. This may be the reason why specialists are needed just as much now as they were in 1974.

Question 14 of the survey tried to gain insight into how the respondents felt about the different diagramming methods. The responses to question 14 are found in Appendix B. Overall, the responding companies found precedence diagrams easier to read, provide more flexibility, and allow for easier use of “smart” relationships (i.e. start-start). Another advantage of precedence diagrams is their use in scheduling programs. Most companies relate better to precedence diagramming because of their use in programs like Primavera Project Planner and Microsoft Project. Some disadvantages listed are the fact that precedence diagrams do not always simulate actual conditions; allow users to use different relationships in order to fix a date (logic abuses); and can be harder to follow and explain logic because of the relationships. Not many positive comments were given about arrow diagramming. One company feels arrow diagramming gives a better flow of

logic than precedence diagramming. Another company says arrow diagramming is best used for brainstorming and network analysis. Many companies feel that arrow diagrams are outdated and are difficult to use because of the i-j notation and the use of dummies. Many companies did not see the need for arrow diagramming anymore, especially since scheduling software relies on precedence diagramming.

One of the benefits observed by companies was improved estimating and bidding. Earlier, it was discussed how the use of CPM has jumped in the area of estimating and bidding. Now as companies are using CPM more often for estimating and bidding, some companies are starting to see benefits from this usage. Heavy construction contractors are seeing the most benefit from this type of usage with 52% claiming a benefit in estimating and bidding.

## XI. TECHNOLOGY'S ROLE IN CPM APPLICATION

### Degree of Success in Achieving Advantages of CPM

The degree of success in achieving the advantages of CPM was discussed in the previous section but is mentioned again because of the reasons for success and how technology plays a role in CPM application. The most cited reasons for being successful are good computer programs and good support from project management (Table 11.1). Only four companies thought the development of new hardware helped in being successful when using CPM.

**Table 11.1 Reasons for Being Successful When Using CPM**

	60 Responses	
Good Computer Programs	44	73%
Good Training of Personnel	33	55%
Good Top Management Support	33	55%
Good Support from Project Management	50	83%
Good Support from Field People	30	50%
Development of New Hardware	4	7%

### New Hardware

New technologies developed in the last decade, such as personal digital assistants (PDAs) and tablet PCs, have potential uses in CPM. Question 34 asked which of these new technologies were currently being utilized. Only one firm is using PDAs for CPM implementation and four are using tablet PCs (Table 11.2). Ten percent of the responding firms are using these new systems in addition to a PC for CPM implementation.

**Table 11.2 Use of New Hardware by Respondents**

	63 Responses	
Personal Digital Assistant (PDA)	1	2%
Tablet PC	4	6%
Other	1	2%

## **Software Used**

Several software packages are available for CPM application. Question 35 asks the names of the preferred software for scheduling purposes. Primavera Project Planner was the most popular software package with Suretrak right behind (Table 11.3). Thirty five percent of the companies responded to using Microsoft Project. Other software used is AlderGraf and P3e.

**Table 11.3 Software Used**

63 Responses		
Primavera Project Planner	49	78%
Microsoft Project	22	35%
Suretrak	37	59%
Other	3	5%

Software has become more flexible and allows more options for users. There is a debate that flexibility in scheduling software is leading to scheduling and logic abuses (Korman and Daniels 2003). When asked about this in the survey, 75% of the companies find that flexibility in software leads to easier utilization rather than scheduling abuses (Table 11.4).

**Table 11.4 Opinions on Flexibility in Scheduling Software**

63 Responses		
Easier Utilization	47	75%
Scheduling Abuses	16	25%

## **Discussion**

Technology has played a role in the use and implementation of CPM. When CPM was first developed, the only computers available were mainframes that were often shared and rented out by contractors. The development of the personal computer made CPM easier to implement and more practical to update. PCs have been the technology that has had the most influence on CPM implementation. New hardware has been developed that can possibly have a huge impact on how CPM is implemented. Personal digital assistants (PDA) and Tablet PC's enable a user to carry the CPM schedule with them out in the field and make updates and changes on the spot. This will allow users to have a schedule that is updated almost every day. As of now, these new devices are

seldom used for CPM application. Only one user responded to using a PDA and four used Tablet PCs. PDAs and Tablet PCs are getting a slow start but have the potential to change how CPM is implemented. The slow start in implementing these technologies is probably the result of the construction industry's resistance to change. Most companies will need to see a clear advantage of using these new technologies before they are implemented.

In addition to new hardware being developed, software has come a long way from the simple programs used on mainframe computers. Software manufacturers continue to add flexibility and functions to software. Primavera Systems appears to be the leader in scheduling software for the construction industry with Primavera Project Planner and Suretrak being the two most widely used software packages. Microsoft Project is trailing in third with 35% of the respondents using it.

Question 36 in the survey asked the contractors their opinion regarding new technology and its affect on the use and application of CPM. The responses to question 36 are located in Appendix C. Several contractors see technology as making CPM implementation easier, and it improves the speed and efficiency of the process. Multiple companies responded they are looking into how PDAs can help CPM application. Some feel it will be beneficial to give superintendents and foreman PDAs with CPM information. One company mentioned using digital cameras to photograph areas of critical schedule problems. Others do not see new technology in such a beneficial light. One company feels technology is taking the focus away from the primary purpose of planning and scheduling as a time control tool. Another says there is an adverse affect from the "just push the button" mentality. For more comments from the responding companies please see Appendix C.

## XII. COST OF CPM APPLICATION

### Cost of CPM Application

As with any application in a business setting, cost is a factor. In order for a company to implement any system it needs to have a cost benefit unless it is a requirement determined by an outside source. Question 19 of the survey asked the respondents the average cost of CPM application as a percentage of total project cost. Question 20 follows up asking the companies if they feel there is an economic benefit to using CPM. Table 12.1 shows how different size companies responded to both question 19 and 20. Table 12.2 shows the differences of the cost of CPM application for companies in different types of construction.

**Table 12.1 Cost of CPM Application Based on Company Size**

	62 Responses		Large (17)		Medium (33)		Small (12)	
0-0.25%	45	73%	8	47%	27	82%	10	83%
0.25-0.50%	8	13%	4	24%	3	9%	1	8%
0.50-0.75%	7	11%	4	24%	2	6%	1	8%
0.75-1.00%	1	2%	1	6%	0	0%	0	0%
Over 1%	1	2%	0	0%	1	3%	0	0%
Economic Benefit - Yes	59	95%	17	100%	31	94%	11	92%
Economic Benefit - No	3	5%	0	0%	2	6%	1	8%

**Table 12.2 Cost of CPM Application Based on Type of Construction**

	Residential (13)		Building (48)		Heavy Construction (29)		Industrial (31)	
0-0.25%	13	100%	37	77%	21	72%	17	55%
0.25-0.50%	0	0%	6	13%	4	14%	6	19%
0.50-0.75%	0	0%	5	10%	4	14%	6	19%
0.75-1.00%	0	0%	0	0%	0	0%	1	3%
Over 1%	0	0%	0	0%	0	0%	1	3%

### Discussion

Overwhelmingly, the responding companies feel that the savings obtained outweigh the costs associated with implementing CPM. In other words, 95% of the respondents felt CPM application provided an economic benefit. Large companies are more likely to spend more on CPM than smaller companies as seen by a higher proportion responding to higher costs of CPM application. Medium and small companies spend about the same amount implementing CPM. Table 12.2 shows companies involved in residential construction tend to spend the least amount. Companies involved in building and

industrial construction spend about the same amount on CPM application. Industrial companies seem to be spending the most.

### **XIII. CONCLUSIONS AND DISCUSSION**

The results of this study indicate a higher percentage of companies are now using CPM compared with past studies. Not only is CPM being used by more companies but it is also being used more often and for more reasons by companies. CPM is being used on 75% of contracts or more by 87% of the responding companies. In 1990, only 60% were using CPM on 75% of contracts or more. The increased frequency could be the result of many factors. CPM use may be required on more contracts now as it is becoming more widely used in litigation and accepted by the courts. Seventy five percent of the respondents feel flexibility in software is leading to easier utilization. This ease of use might be a factor in the increased use of CPM. Another possible reason is over 98% of the responding companies feel CPM is a valid management tool.

CPM has always been used in the different life cycle phases of a project but is now being used more often in some. CPM has more than doubled in the area of estimating and bidding. Companies are not only using CPM for more uses, or using it more frequently, but they are making decisions frequently based on CPM information. This indicates that the respondents trust the data produced by a CPM schedule.

Many factors play a role in the use of CPM all from the cost-benefit relationship, to it being forced upon contractors. It is difficult to single out any single reason why CPM use has grown because it is a combination of factors. Different companies use CPM for different reasons. Some use CPM because they feel they are better able to control a project from start to finish while others might use it only because it is the industry standard. Although companies use CPM for several reasons, the respondents overall, feel they are successful at achieving the advantages of CPM. Most also feel it is important to both their present and future success.

#### **CPM Usage by Large Companies**

Large companies appear to be the companies that get the most out of CPM application. Large companies use CPM on a higher percentage of contracts than medium and small companies. Ninety four percent of large companies use CPM on 75% or more of their projects. The reason for this heavy usage is due to many factors. All the large

companies responding to the survey claim CPM is a valid management tool. Other reasons are the fact that it is often a contract requirement, it improves communication, and CPM's wide use in dispute resolution. More large companies (41%) use CPM because of its increased use in litigation than medium or small companies. This is reflected in the fact that 100% of large companies use CPM in claims analysis compared with 70% of small companies. Not only do all large companies use CPM for claims, but it is used on a large percent of claims. The differences in CPM's use on claims between large and small companies could be do to the amount of claims involved in the projects. Larger companies usually handle larger projects, which inherently have a larger amount of claims do to change orders and other factors.

No matter the reasons for use, large companies trust CPM schedules. Sixty five percent of large companies use CPM information frequently for making decisions. The remaining 35% use CPM information with moderate frequency for making decisions. This is impressive when compared to the 21% of small companies who frequently use CPM information to make decisions. The fact that large companies use CPM more frequently, use it for more reasons, and trust the information produced by the schedule, is probably the reason why all of the companies see CPM as moderately to very important to their future and present success. An even larger portion of large companies saw CPM as very important to their future success than their present success.

Large companies also spend more on CPM application than medium or small companies. This may be due to the size projects the CPM is developed for, or because of how they view CPM. Large companies may spend more on CPM because they believe it is important to their company's success. Either that or CPM is such a value to the company because the amount they spend on its application. No matter the amount spent on its application, all large companies see an economic benefit in CPM.

Although large companies do see such a benefit to CPM application, they did express some concerns. Twenty two percent of large companies claim CPM requires too much dependency on specialists. This is compared to the 41% of large companies that use both in house staff and consultants for CPM application. At first, this number seems large for companies with the resources to handle CPM application in house. The most likely reason for using consultants for CPM is when it is used for other reasons than planning and control during construction. CPM is being used more often in litigation and

claims which may be the reason for using consultants. Specialists and expert witnesses are often needed when claims make their way to court.

### **Usage by Small Companies**

Smaller companies are experiencing many of the benefits of CPM but view it in a different light than large companies. While a large portion of large companies listed CPM as a contract requirement as a reason for CPM usage, all small companies used CPM for this reason. The fact that CPM is a contract requirement seems to be a larger influence on smaller companies use than it being a valid management tool. Evidence for this is the fact small companies update their schedules less frequently the larger companies. Fewer small companies (23%) than large (65%) or medium (48%) sized companies make decisions frequently based on CPM information. A possible reason for not needing to update the schedule more frequently and not having to make decisions based on CPM information frequently is small companies deal with smaller and less complicated projects.

Small companies do view CPM as important to their present success even though they do not use CPM information as frequently as large companies for decisions. A noticeable difference in how small companies view CPM compared with large and medium companies, is how important they see it to their future success. Only 30% of small companies see CPM as being very important to the companies future success, compared with 58% of large companies and 54% of medium companies. This might indicate small companies do not have as great a need for CPM as larger companies do.

Another reason why small contractors may not think CPM is as important to their success as larger firms is they do not use CPM as often for claims analysis. This may be a result of the types of projects small companies are involved in compared with those or larger companies. Smaller and less complicated projects probably do not have as many claims as larger projects. Even if claims do arise, the study indicates that smaller companies 40% less likely than large companies to have been involved in litigation where CPM has been used.

## **Technology's Role in CPM Development**

Technology has and will continue to play a role in the development of CPM. New technology has the opportunity to do one of two things for CPM users: make CPM utilization easier, or encourage the “just push the button” mentality. Personal computers have made CPM scheduling easier to utilize for companies, especially with the availability of a variety of software packages. The development of new hardware such as Pocket PCs and Tablet PCs will further enhance CPM application. While the development of Pocket PCs and Tablet PCs will not fundamentally change how scheduling is done, it can improve implementation. Schedule information can now be brought out of the construction trailer or the central office and brought out into the field in a format other than a computer printout. Having schedule information in the palm of the hand can also be handy for field superintendents who are usually not in or have a trailer. This will allow updating to occur on a more frequent basis than most companies do currently. Being able to update the schedule more often can lead to more reliable as-built schedules. Another benefit is the ability to perform contemporaneous delay analysis is improved because the schedule is always up to date.

Although technology has the potential to enhance the CPM efforts of companies, the old saying “garbage in garbage out” still applies. The easier CPM utilization becomes, the less those dealing with the schedule have to think about it. As updating becomes as easy as tapping the screen of a Pocket PC a few times a day, less thought will go into the actual updates and perhaps the downstream effects of the dates being entered. What technology does for CPM implementation is going to be company dependent. A company that is dedicated to producing reliable schedules and frequently makes decisions based on those schedules is likely to gain a lot of benefit out of new technological developments. Those companies that look at CPM as a contract requirement or something they do because everyone else is doing it, will not realize the full benefits of these new developments in technology.

## **More Knowledgeable Construction Professionals**

CPM has been in use for about 45 years and has become the industry standard for scheduling. Many colleges with construction programs have courses available that deal

with CPM. This means some construction professionals are entering the field with a preexisting knowledge of CPM. Others will receive training on CPM from employers. The current work force contains more construction professionals that are knowledgeable about CPM than in the past. For the most part, a more knowledgeable work force improves the quality and reliability of CPM schedules. It also allows for more people to take part in creating the schedule and maintaining it throughout construction so a dedicated scheduler is not always necessary.

A side effect of this large knowledgeable group of construction professionals is their ability to manipulate the schedule. Playing with dates and changing the critical path by changing the relationship among the activities can allow a company to manipulate the schedule to reflect what they want to show. This is possible to do by either the contractor or the owner. This ability will lead to distrust between the contractor and the owner especially when evaluating the effect of delays and change orders. This distrust may lead to unresolved claims and litigation. As schedules are manipulated and abused more often, there will be more of a need for forensic schedulers to deal with disputes and litigation.

### **Project Management Institute – College of Scheduling**

The Project Management Institute's College of Scheduling is an organization whose purpose is to advance the practice of project scheduling. The mission of the PMI College of Scheduling is to "promote excellence in scheduling through networking, sharing project experiences, providing and receiving training, providing support and encouragement for the ongoing development of the PMI Body of Knowledge in the areas of scheduling and time management" ([www.pmicos.org](http://www.pmicos.org)). This organization has the opportunity to influence construction professionals to create better schedules and curb the "push the button" mentality. This provides interested parties to discuss issues that plague scheduling such as precedence v. arrow diagramming or the standardization of scheduling practices and terms. While not much may be resolved by this organization at first, the fact that a forum exists for parties to discuss issues involved with the application of CPM is a good sign that there is an interest to improve the quality and reliability of scheduling as a whole.

## **Association of Advancement of Cost Engineering International**

The Association of Advancement of Cost Engineering International (AACCEI) has a special interest group called the Claims and Dispute Resolution Special Interest Group (CDR SIG). The purpose of the CDR SIG is to formalize definitions and methods associated with forensic schedule analysis. This is important to forensic schedulers because of the lack of standardization of the names of different delay analysis methods. Confusion often exists on the type of delay analysis method to be used because some analysis methods have several names. Similarly, a single name for a delay analysis method can have different meanings for different people. For example, a “but for” analysis can be performed several different ways depending on who is doing the analysis. By standardizing the terms and methods involved in delay analysis, more time can be spent by experts worrying about the larger issues rather than arguing over the implementation of the different analysis methods. This can also be helpful not only for forensic schedulers, but also for construction personnel. The general conditions of most construction contracts dictate the type of analysis to be performed when a delaying event occurs. Having the terms and methods associated with delay analysis standardized eliminates any disagreements that might arise between the owner and the contractor about the type of delay analysis method to be used.

## **Concluding Remarks**

CPM is proving to be a versatile scheduling tool in the construction industry. Different size companies and companies involved in various types of construction are finding uses for CPM. Overall, the respondents in this study are finding CPM beneficial and see it as important to their companies' success. CPM use has grown over the years and looks as if it will continue to grow based on companies viewing CPM as being important to their future success.

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## **xv. APPENDIX A – LESSONS LEARNED**

Several lessons were learned while working on this thesis. The first lesson learned deals with the effectiveness of a web-based survey tool and using email to solicit responses. Publicizing the survey to the top 400 contractors through email was not very successful. This is probably due to the fact that companies receive so much junk email and requests to participate in surveys they deleted the email before they even read it. On the other hand, the web-based survey tool did make data collection and analysis easier to handle than if the survey was paper-based. In the future, a method that may work better for a web-based survey is to call each company and speak to the person who is going to complete the survey. In the phone conversation, inform the person about the purpose of the study and let them know there will be a follow up email with the link to the survey. This will lengthen the data collection process and is a more labor intensive project, but may elicit a better response rate.

The second lesson learned from this thesis deals with statistics and data analysis. It is easier to decide what type of statistics and data analysis will be performed before data collection begins and design the survey around the statistics than to try to design the statistics around the survey after the fact. The type of statistical analysis that is going to be used affects everything from the way the questions are worded, the type and number of responses, and how the survey is administered. It was determined after the fact that a conclusive trend analysis was not possible for this study because the survey was voluntary and was administered in a different format than the previous two studies. This is an important lesson learned as proper planning can provide for more credible results.

## **XVI. APPENDIX B - SURVEY**

# Virginia Tech's Study on the Use of CPM by ENR's Top 400 Contractors

Individual responses and identities will remain confidential. Company names and positions within the company are asked only to verify the data being collected.

## 1. What is your company's name?

## 2. What is your position within the company?

## 3. What is your annual construction revenue?

- Below \$160,000,000
- \$160,000,000-\$600,000,000
- Over \$600,000,000

## 4. What type(s) of construction are you involved in? (Choose all that apply)

- Residential Construction
- Building Construction
- Heavy Construction
- Industrial Construction

Other (please specify):

## 5. What is the percentage of work you self perform?

- 0-10%
- 10-20%
- 20-30%
- 30-40%
- 40-50%
- 50-60%
- 60-70%
- 70-80%
- 80-90%
- 90-100%

**6. Do you use the critical path method (CPM)?**

- Yes
- No

**7. If you answered NO to question 6, what are your reasons for not using CPM?**

**8. Do you use any other scheduling techniques? (choose all that apply)**

- Program Evaluation and Review Techniques (PERT)
- 4D Planning
- Line of Balance (LOB)
- Linear Balance Charts (vertical production methods)
- Free Hand Bar Chart (Not based on a logic diagram)

Other:

If you are not a CPM user, please skip ahead to question 42 and make any comments you would like.

**9. Please complete the following sentence (choose all that apply): Our company uses CPM because**

- it is a valid management tool.
- it assists in dispute resolution.
- it is a contract requirement.
- it improves communication among the parties involved in a project.
- of its increased use in litigation.

other:

**10. When did you start using CPM?**

- Before 1960
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-Present

**11. How often do you use CPM?**

- All Contracts
- 75%-100% of the time
- 50%-75% of the time
- 25%-50% of the time
- 0-25% of the time
- Only when required by contract

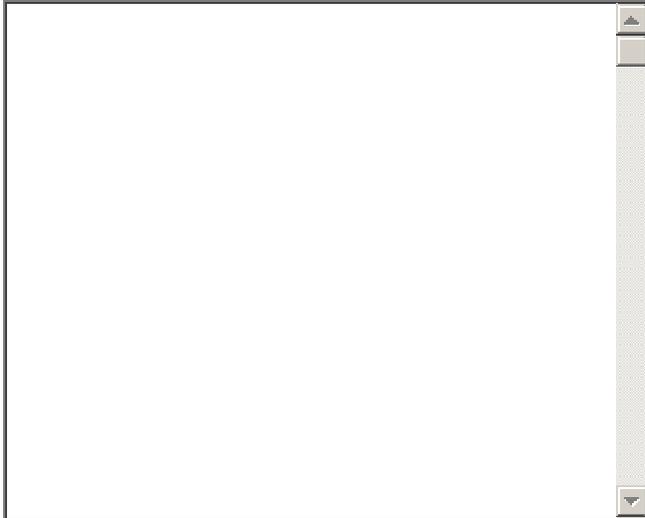
**12. Do you hire a consultant to handle CPM or does your own staff handle it?**

- Consultant
- Staff
- Both

**13. What type of logic network do you use?**

- Arrow
- Precedence
- Both

**14. List the advantages and disadvantages of the type of network you use:**



**15. What are the major areas of CPM application in your company? (Choose all that apply)**

- Design Development (conceptualization, feasibility, etc.)
- Estimating and Bidding
- Detailed planning of work prior to start of construction
- Periodic control of work after start of construction
- Operation and Maintenance of projects

Other uses:

**16. If you use CPM for periodic control of work during construction, for what tasks do you use CPM? (Choose all that apply)**

- Coordination of subcontractors
- Coordination of own trades
- Schedule impact analysis and tracking changes
- Tracking shop drawings and submittals
- Tracking costs
- Calculating payment requests for work performed
- Developing a look ahead schedule

Other:

**17. What are the benefits obtained from CPM application? (choose all that apply)**

- Improved estimating/bidding
- Improved planning before work starts
- Improved scheduling

- Improved project control after work starts
- Faster response to problems
- Improved understanding of the project
- Improved communication among work force
- Helps train future project managers
- Positive psychological effects on employees
- Cost savings
- Time savings
- Reduces delays
- Reduces cost overruns
- Minimizes disputes between contractor and owner
- More control over risk and uncertainty

other:

**18. What are some of the disadvantages of CPM? (choose all that apply)**

- Requires too much dependency of specialists
- Requires excessive work to implement
- Not responsive to needs of top management
- Not responsive to needs of field personnel
- Logic abuses
- No major disadvantages

Other:

**19. On average, what is the cost of CPM application as a percentage of total project cost?**

- 0-0.25%
- 0.25%-0.5%
- 0.5%-0.75%
- 0.75%-1%
- Over 1%

**20. Do you find that the savings obtained through CPM application outweigh the costs associated with implementation of CPM? In other words, is there an economic benefit to using CPM?**

- Yes

No

**21. What is the degree of success in achieving the advantages of CPM?**

Very successful

Moderately successful

Unsuccessful

Undecided

**22. If you have answered unsuccessful to question 21, please specify the reasons for this unsuccessfulness. (Choose all that apply)**

Poor computer programs

Poor training of personnel

Lack of top management support

Lack of support from project management

Lack of support from field people

other:

**23. If you answered very successful or moderately successful to question 21, please specify the reasons for this success. (Choose all that apply)**

Good computer programs

Good training of personnel

Good top management support

Good support from project management

Good support from field personnel

Development of new hardware (PDA's and Tablet PC's)

other:

**24. At what levels of management is CPM used? (Choose all that apply)**

Top management

Project management

Superintendents

Foremen

**25. How important is CPM to the present success of the company?**

Very important

Moderately important

- Unimportant
- Uncertain

**26. How important will CPM be to the future success of the company?**

- Very important
- Moderately important
- Unimportant
- Uncertain

**27. How often do you make decisions based on CPM information?**

- Frequently
- Moderate frequency
- Infrequently
- Never

**28. Do you use CPM analysis for assessing claims?**

- Yes
- No

**29. If you answered YES to question 28, what percentage of claims is CPM used on?**

- 0-25%
- 25%-50%
- 50%-75%
- 75%-100%

**30. Has your company been involved in litigation where CPM has been used either to prove or disprove a claim?**

- Yes
- No

**31. What type of time impact analysis method is used to quantify the effect of a delaying event?**

- Contemporaneous Method
- Retrospective Method
- Depends on what is called for in the contract
- No Time Impact Analysis Used

**32. Do you use any of the advanced techniques? (Choose all that apply)**

- Multiple Calendars
- Resource leveling
- Resource Constrained Scheduling
- Cost Control
- Integrated time and cost control
- Scheduling across multiple projects
- Not applicable

other:

**33. How often do you perform updating? (on an average project)**

- Monthly
- Biweekly
- Weekly
- Daily
- When required by contract
- Never

other:

**34. What other hardware, other than a PC, is implemented by your company for CPM application?**

- Personal Digital Assistant (PDA)
- Tablet PC

other:

**35. What are the names of the preferred software your company uses for scheduling?**

- Primavera Project Planner
- Microsoft Project
- Suretrak
- Prolog Scheduler

other:

**36. How do you see new technology affecting the use and application of CPM?**



**37. Do you find flexibility in scheduling software leads to easier utilization of CPM or scheduling abuses?**

- Easier Utilization
- Scheduling Abuses

**38. What method(s) of updating do you use?**

- Bar Chart
- S-curve
- CPM
- Dateline cutoff method

other:

**39. In your time and cost control, what are the S-curves that you use? (choose all that apply)**

- Actual Cost of Work Performed (ACWP)
- Budgeted Cost of Work Performed (Earned values, BCWP)
- Budgeted Cost of Work Scheduled (BCWS)
- Not applicable

other:

**40. Do you use a standardized work breakdown structure (WBS)?**

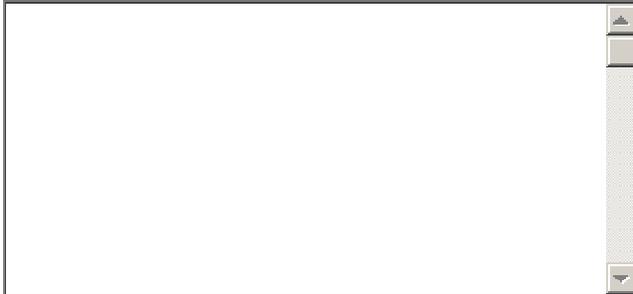
- Yes
- No

**41. What is the level of schedule detail used? For example, if the second floor of a concrete building had to be erected, what level of schedule detail would you used?**

- Summarized - 2nd Floor (1 activity)

- Moderately Detailed - 2nd Floor Columns, 2nd Floor Slab (2 activities)
- Very Detailed - Form Slab, Place Rebar, Place Concrete, Cure Concrete, Strip Forms (Crew breakdown detail)

**42. Additional comments:**



If you have any questions regarding this survey, please contact Drew Kelleher at [akellehe@vt.edu](mailto:akellehe@vt.edu).

## **XVII. APPENDIX C – QUESTION 14 RESPONSES**

#### 14. List the advantages and disadvantages of the type of network you use:

[#2: 2003-10-06 14:08:46](#)

We use two different software programs, Microsoft Project and Suretrak. Different people are proficient at different programs, and some like certain features of one better than the other.

[#6: 2003-10-06 15:02:38](#)

Advantage-Predict/Forecast outcomes

Advantage-Permits lags, trade stacking analysis

Disadvantage-Determination of the level of detail to make efficient for updates and use by office and field staff.

[#9: 2003-10-06 16:25:58](#)

Easiest to explain to the people that are dependent on it for information.

[#10: 2003-10-06 19:14:36](#)

assists in determining work flow and potential bottlenecks.also in determining opportunities and how best to take advantage of them..planning thru use of CPM can head off project pitfalls before they become fact...forecasting is more accurate and workarounds can be planned to incorporate changes without affecting the flow of the project itself...there is no downside to CPM scheduling as a primary tool in project management..properly used there are only positives and advantages.

[#13: 2003-10-07 10:05:43](#)

Precedence is more flexible so is an advantage

Arrow is now becoming out of date except to old line schedulers.

[#14: 2003-10-07 11:38:31](#)

Most of the Owners we work for specify P3 Project Planner. This is a solid scheduling tool that is the industry standard in heavy construction.

[#19: 2003-10-08 10:15:39](#)

Advantages - 1) Supports lag values 2) Appearance is simpler for users to understand

Disadvantages - 1) Doesn't always simulate actual conditions but this is not a major disadvantage

[#20: 2003-10-08 11:18:52](#)

Dis....

-difficult for older PM's to learn software

-if really tracked, it is a tremendous time drain on PM time .... it is a very small part of what we do

-owners' don't understand the dynamics and tend to use it to pin down contractors

-difficult to effectively communicate anything to subs and vendors ...they don't read what is sent Adv...

-if done correctly, lets anyone check status immediately

-" " ", is updated quickly

-not really true to life, activity overlaps are often accelerated or late which should affect final date, but can't

[#23: 2003-10-09 10:37:20](#)

Precedence provides more flexibility, is more intuitive, easier to modify logic, and is predominant in the industry. (No matter what Mr. O'Brien says.)

[#24: 2003-10-09 17:19:49](#)

On the arrow is too hard for field personnel to relate to. Also, current software does not support on the arrow. I feel you get valid results with PDM if procedures are followed.

[#25: 2003-10-10 08:43:47](#)

ease of access and distribution

[#27: 2003-10-13 08:19:06](#)

PDM is the standard I have worked with for over 10 years. In my opinion, it is the industry standard.

Downside, you have to make sure when training less experience schedulers, they don't try to use the constrained dates in lieu of good logic.

[#30: 2003-10-15 18:09:12](#)

Available Software

[#31: 2003-10-17 07:55:54](#)

Advantage: It most mirrors that way people think in the field.

Disadvantage: None

[#32: 2003-10-17 10:18:44](#)

Advantages

Start to Start relationships can help to summarize details that would have to be developed in an Arrow network.

Many times there is independence of sequence that the SS relationships allow user to summarize very detail re-occurring structure in the Arrow network system.

Disadvantages

Users tend to put relationships in to fix a date. This leads to illogical relationships and out-of-sequence progressing that tends to render the schedule usefulness. This is not a fault of the network system but the user.

Sometimes users or owners require too much detail which can't physically be managed timely or understood by anyone.

[#35: 2003-10-23 14:03:20](#)

I have worked in ADM and PDM and each has its advantages. ADM gives a better flow of the logic identifying portions of an activity, PDM can be harder to follow and explain the logic because of the start to start, finish to finish logic relationships and the use of lag durations. We use PDM because the software programs we use do not support ADM.

[#37: 2003-10-27 08:20:16](#)

Precedence seems to lend itself to construction scheduling better than Arrow. Primavera, which has become the industry standard, develops Primavera Project Planner and SureTrak, both are Precedence scheduling programs. Another program, Microsoft Project, is also precedence although we don't use it as often because it doesn't have the power or flexibility of the Primavera programs. The main reason I prefer Precedence over Arrow is it allows you to focus on the activities and their relationships to other activities rather than dummies (ties w/I,J designations). This way, activities can be managed more easily including critical path and float adjustments, resource loading and cost loading, to name a few.

[#40: 2003-10-27 09:37:03](#)

Has good integration of different levels so we can break out subcontractors/suppliers responsibility from main schedule; design/fab/deliver sections, etc.  
Sometimes too cumbersome to convey exactly what we want to convey;

[#42: 2003-10-27 10:43:37](#)

One stresses activities, the other sequencing. Selection depends on nature of project.

[#44: 2003-10-27 11:26:37](#)

Its advantage is it conforms to the vast majority of specification we encounter. It's easy to train on just one method.

[#46: 2003-10-27 14:23:13](#)

Arrow networks are outdated, should not even be used in classroom other than to should for one or two classes how CPM was developed. Everything we do is based on Precedence.

[#49: 2003-10-27 15:13:34](#)

Advantage of PDM is that it takes into account the real world of construction as oppsed to ADM.

[#52: 2003-10-28 14:06:33](#)

Fewer activities required using precedence diagramming method. Precedence is more flexible.

[#54: 2003-10-28 18:02:33](#)

We like them

[#57: 2003-10-29 12:38:23](#)

Easy to train new employees & simple for owners to understand

[#58: 2003-10-30 09:47:03](#)

Arrow, for all its problems, is not even considered. Even with minimal activities the implied

logic will lead to errors. Its not a worthy scheme.

[#59: 2003-10-30 20:14:48](#)

Arrow is best for network analysis and brainstorming logic.  
Precedence is the only option in Primavera.

[#63: 2003-10-31 19:39:51](#)

Precedence allows for more flexibility than an I-J network

[#64: 2003-11-07 14:54:46](#)

Senseless mandates by DOT's as to number of activities adds only busy work and no value. Too many constant changes with highway work make perpetual need to "redraw the diagram".

[#65: 2003-11-13 09:14:59](#)

Allows us to reflect the true nature of the construction process where lots of activities overlap.  
Changes in field and deviations from baseline often take long time to reflect on the schedule

[#66: 2003-11-16 10:20:50](#)

Advantages:

Sorts by phases and responsibilities

Monitor critical and near criticalwork activities

Disadvantages:

Cannot easily trace network logic graphically

[#67: 2003-11-17 08:40:29](#)

Its an industry standard and thus supported and requested by many owners.

## **XVIII. APPENDIX D – QUESTION 36 RESPONSES**

### **36. How do you see new technology affecting the use and application of CPM?**

[#1: 2003-10-06 14:00:40](#)

Faster and more accurate

[#6: 2003-10-06 15:02:38](#)

Shorten input times. (Possibly voice input)

Updating actuals (Possibly voice input)

[#8: 2003-10-06 15:58:47](#)

We will be research the benefits of 4D. We see a good application for 4D as a marketing tool.

[#9: 2003-10-06 16:25:58](#)

Integration into Project Estimating and Project Invoicing seem to be becoming more valuable.

Large scale jobs require a full CPM done pre bid to optimize strategy.

[#10: 2003-10-06 19:14:36](#)

I believe the Industry trend is toward a web based multi access application....providing better and quicker input regarding CPM schedules by the primaries of the projects with which they are associated and for upper management, access to all projects active within the company. This will allow more expediente solutions regarding project flow and critical path impacts and also allow management to make judgments and decisions based on that more readily obtained information. These timely decisions are ever more important in todays 'Fast Track and Flash Track' construction market.

[#12: 2003-10-07 09:18:09](#)

Automatic updating of the schedule through direct input from the field

[#17: 2003-10-07 17:19:39](#)

As computer capacities increase, amount of data will be less a burden.

[#19: 2003-10-08 10:15:39](#)

-Technology can improve the speed and efficiency of the process. But it can also take the focus away from the primary purpose of planning and scheduling as a time control tool.

[#20: 2003-10-08 11:18:52](#)

It is still GIGO

[#21: 2003-10-08 11:44:48](#)

As the technology is improved, the ease of use should increase, amount of specialized software training should decrease and we should be able to fully utilize CPM scheduling on greater project types. Technology advances will hopefully make software more user friendly and decrease the amount of time to load and format schedules.

[#22: 2003-10-08 13:55:58](#)

Our project profile is \$3M-10M. Small projects are getting more complex and small owners are

increasingly expecting scheduling.

[#24: 2003-10-09 17:19:49](#)

Better communication of project status to all levels of the enterprise through the use of internet 'portals'. Enhanced ability to forecast professional labor requirements (we are a design/build firm).

[#26: 2003-10-10 14:47:15](#)

Complete integration of design, schedule, cost and project management.

[#27: 2003-10-13 08:19:06](#)

It is getting less user friendly. We must continuously sell the applications of P3 or P3e/c to our management.

For those more technologically informed, the new technology allows for less paper work and more on line information. More real time data.

[#28: 2003-10-13 22:02:13](#)

The soft ware is too user friendly. Logic errors can be allowed.

[#30: 2003-10-15 18:09:12](#)

New risk management programs to assess "duration risk" of critical activities.

[#31: 2003-10-17 07:55:54](#)

As the software becomes easier to use, CPM implementation will be more widespread. The biggest obstacle to using CPM effectively is the limited ability of field staff to use the more complicated software.

[#32: 2003-10-17 10:18:44](#)

More integration with enterprise systems  
More integration with cost systems both owner/contractor  
Closer ties to personal scheduling systems like Outlook, Lotus Notes, or PDA interfaces.

[#33: 2003-10-21 09:01:13](#)

With our Foreman being able to have the CPM schedule in their PDA the information will be available all the time.

I also believe that on question 37 its both!

[#34: 2003-10-22 09:45:10](#)

more flexibility and options to use in the software

[#35: 2003-10-23 14:03:20](#)

I see an adverse affect from the  
"Just push the button" mentality.

[#36: 2003-10-27 07:44:25](#)

UPDATING AND GENERAL APPLICATION WILL BE MUCH EASIER

[#37: 2003-10-27 08:20:16](#)

We are presently investigating the uses of PDA's in the schedule updating process. Also, the internet should improve the scheduling process, although to what extent I'm not sure.

[#40: 2003-10-27 09:37:03](#)

Making it quicker and easier to use from top management down to field superintendents

[#44: 2003-10-27 11:26:37](#)

Primavera "Windows" development made the program much easier to use. PDA use for inputting progress will be good once the proper software is developed. Anything that will make the software more user friendly will help.

[#46: 2003-10-27 14:23:13](#)

Digital cameras used to photograph areas of critical schedule problems and being able to transmit them with the information on the potential delay.

Easier to use software that makes updating an easier function.

[#49: 2003-10-27 15:13:34](#)

Will help improve the accuracy of the CPM method. Faster, more powerful computers will make assessing and developing schedules much easier. Mobile management helps by taking the schedule to the field, not the field to the schedule.

[#51: 2003-10-28 10:31:58](#)

I believe that more projects will be completed under budget and on time, if supers and pm bring new technology into the job site.

[#52: 2003-10-28 14:06:33](#)

More people/companies will be utilizing software to control their projects because the advantages outweigh the disadvantages.

[#53: 2003-10-28 14:43:18](#)

We are looking to add PDAs to implement foreman and superintendents reports. We have discussed trying to link this information to our schedules.

[#56: 2003-10-29 09:46:32](#)

Increased use of PDA's along with increased details in the project breakdown will allow more effective use by field personnel and better use of current software capabilities.

[#58: 2003-10-30 09:47:03](#)

Will increase the benefits and use.

[#59: 2003-10-30 20:14:48](#)

Linking schedules to cad models for development and statusing.

[#60: 2003-10-31 16:19:08](#)

More internet based scheduling interfaces

[#64: 2003-11-07 14:54:46](#)

No "real" effect

[#66: 2003-11-16 10:20:50](#)

Multiple input sources from various responsibilities will result in faster update turnaround time and facilitate faster managerial evaluation and decisions

[#67: 2003-11-17 08:40:29](#)

It seems that sometime the new advances in software often dictate how scheduling trends go. For example, if the software companies start saying, "this is the way scheduling will soon be done, and you need to buy our program because..." It often seems that the industry gets pushed into believing and performing the trends that the software companies initiate rather than making changes based on industry needs.

**XIX. APPENDIX E – QUESTION 42 RESPONSES**

## **42. Additional comments:**

[#3: 2003-10-06 14:15:31](#)

Find better success through Primavera/Suretrack. Using Microsoft Project has no diagnostics and typical project is left wide open. Microsoft project is better suited to MBA type of uses in lieu of construction.

[#9: 2003-10-06 16:25:58](#)

Four our type of work, we break the job down into the points of no return. i.e. concrete placements, setting beams, finishing a deck, opening to traffic, etc.

These are descriptions that mean something to the crew and the owner and allow a person to keep a global perspective on the project.

Given this level of information, we challenge the field level managers to develop short term schedules that detail rebar, curing, etc..... in a 6 week look ahead format.

The combination of the two.... Global plus detailed helps to maintain the feeling of ownership where it belongs.

[#10: 2003-10-06 19:14:36](#)

The CPM Schedule should be used as a tool to assist those involved in working together toward a mutually rewarding successful project rather than one of an adversarial nature. Having a tool that can 'predict' impacts and call out areas of concern critical to project completion, allows project management to work together with Subcontractors and be proactive in solving time concerns instead of reactive to situations. Proper planning and access to planning tools such as Scheduling software can make all the difference in leading a project to a successful conclusion. We make it a precedent to make Scheduling training available to all levels of our company....better understanding equals better communication. We teach our people how to interpret and create schedules using Primavera Scheduling Software. We make this training available from Foreman Assistant level up..these are the people that will one day be planning projects themselves from the ground up. Using a standardized form of CPM scheduling and taking the time to make sure the people who use it...understand it and can communicate with it, smoothes the way to successful projects and therefore,more profitable projects for all those involved. It is my feeling that being proactive and using the CPM in a proactive manner, minimizes the risk of schedule abuses.

[#19: 2003-10-08 10:15:39](#)

As you can observe from the answers above - the Midwest Division uses the CPM plan and schedule primarily as a time control tool, versus a cost control or billing tool. When specifications or clients require cost loading or billing per the schedule we put these systems in place, but don't feel that they enhance the time control effectiveness of CPM.

We generally use a repetitive layout format for schedules but not defined to the point to call it a standardized WBS.

[#20: 2003-10-08 11:18:52](#)

#41 - Depends on job size, contract, and PM preferences

Per above comments, Gantt Bar charts are used to give a visual review to the Owner/Arch of how the project is planned. For most projects, PMs would rather issue and forget. Updating is time consuming as is trying to revise logic or build a "recovery schedule".

[#22: 2003-10-08 13:55:58](#)

Our small project size and value limits use of scheduling to that which the Project Manager can and will implement with his own time and resources.

[#26: 2003-10-10 14:47:15](#)

Comment on #41. Depends on complexity of project, dollar value and overall time constraints. Varies between Moderately and Very Detailed.

[#28: 2003-10-13 22:02:13](#)

All of our Superintendents and Project Managers are at various levels of ability with regards to CPM & PDM scheduling and using our chosen software. With the software so easy to manipulate you can paint a picture that looks like a schedule but not build a network diagram based on logic if you don't watch or know what your doing. We provide training both in house and out-of-house periodically to improve our abilities.

[#30: 2003-10-15 18:09:12](#)

Comments concerning schedule uses and methods are based on my knowledge of the Infrastructure Business Unit.

[#33: 2003-10-21 09:01:13](#)

Like all Tools if it is not used correctly it is not helpful. We use the old saying "crap in = crap out" You have to spend the time up front with the entire team to make sure that they all buy into the schedule. If we are the only one that develops it then we are the only one that believes in it!

[#37: 2003-10-27 08:20:16](#)

In general, we require CPM on all Turner projects in the Mid-Atlantic Region. Our scheduling department (presently 8 schedulers) assist in the development and updating of the schedule for each project. Three projects at present require a full time scheduler on site. Other project schedules are managed by schedulers who travel from site to site.

Cost and resource loading is usually done only if required by contract, although occasionally we will do this even when not required. We are not big in the litigation process, although when we do have a dispute, CPM is always used to support our position.

Any questions, please give me a call at (703) 841-5257.

[#44: 2003-10-27 11:26:37](#)

The industry has come a long way since we drew arrow diagrams 33 years ago when I started to work here. The only drawback I see is that many of our young engineers hide behind their

laptops and trust the output rather than talking in more detail with the people involved with the actual work and developing common sense double checks on their work. Scheduling is a means to an end not an end in itself. It is a process and a tool, not an end product.

[#53: 2003-10-28 14:43:18](#)

I am in the Heavy Highway Division and we tend to use a more generalized schedule than our Building Division.

CPMs are becoming more and more important and we will be using the information from them in pursuing claims for additional time.

We have just been awarded a Design-Build contract and are using a CPM to tie design, construction and review from the owner into the CPM. Hopefully this will keep everyone on track.

[#58: 2003-10-30 09:47:03](#)

We need the detail to make the schedule easy to update and able to quantify impact properly and timely.

[#59: 2003-10-30 20:14:48](#)

Re 41. We use all 3 levels in our 3 level schedule hierarchy.

General: Academia tends to bombard us with impractical ideas due to lack of actual working experience; on the other hand we're reluctant - as competitive contractors always behind schedule - to entertain academics in our midst. As an overall rule - The area where CPM is weakest is in its lack of clear standard practices, and management application thereof - not new techniques or more computerized systems.

[#64: 2003-11-07 14:54:46](#)

The "planning of the work" is the most important aspect of the CPM process

**XX. APPENDIX F – QUESTION RESULTS COMPARED WITH  
PAST DATA**

No.	Question	Response	1974	1990	2003
4	What types of construction are you involved in? (Choose all that apply)	Residential	X	10%	22%
		Building	X	83%	77%
		Heavy	X	42%	45%
		Industrial	X	50%	51%
		Other	X	14%	12%
5	What is the percentage of work you self perform?	0-10	X	X	31%
		10-20	X	X	13%
		20-30	X	X	17%
		30-40	X	X	9%
		40-50	X	X	6%
		50-60	X	X	2%
		60-70	X	X	9%
		70-80	X	X	8%
		80-90	X	X	2%
90-100	X	X	3%		
6	Do you use the Critical Path Method?	Yes	90%	93%	99%
		No	10%	7%	2%
8	Do you use any other scheduling techniques (choose all that apply)	PERT	X	17%	23%
		4D-Planning	X	X	3%
		Line of Balance	X	2%	3%
		Linear Balance Charts	X	2%	3%
		Free Hand Bar Chart	X	92%	43%
		Other	X	10%	11%
9	Reasons for using CPM	Valid Management Tool	X	X	98%
		Assists in dispute resolution	X	X	67%
		contract requirement	X	X	79%
		Improves Communication	X	X	79%
		Increased use in Litigation	X	X	33%
		Other	X	X	5%
		10	When did you start using CPM?	Before 1960	X
1960-1969	X			15%	7%
1970-1979	X			39%	32%
1980-1989	X			47%	31%
1990-1999	X			X	27%
2000-Present	X			X	3%
11	How often do you use CPM?	All Contracts	--	26%	37%
		75-100%	--	34%	51%
		50-75%	--	18%	8%
		25-50%	--	10%	2%
		0-25%	--	7%	2%
		Only when required	25%	12%	2%

12	Do you hire a consultant to handle CPM of in house staff?	Consultant	X	15%	2%
		Staff	X	90%	54%
		Both	X	X	44%
13	What type of logic network do you use?	Arrow	X	38%	3%
		Precedence	X	68%	62%
		Both	X	X	35%
15	What are the major areas of CPM application in your company?	Design Development	X	55%	52%
		Estimating/Bidding	19%	29%	54%
		Engineering, shop Drawings	19%	36%	X
		Detailed Planning prior to start of construction	90%	95%	98%
		Periodic control of work after start of construction	52%	89%	97%
		Operation and Maintenance	3%	48%	41%
		Other	X	10%	6%
16	If you use CPM for periodic control, for what tasks do you use CPM?	Coordination of subs	X	X	97%
		Coordination of own trades	X	X	68%
		Schedule impact analysis and tracking changes	X	X	84%
		Tracking shop drawings and submittals	X	X	65%
		Tracking costs	X	X	19%
		Calculating payment requests for work performed	X	X	37%
		Developing a look ahead schedule	X	X	92%
		Other	X	X	5%

17	What are the benefits obtained from CPM application?	Improved estimating/bidding	15%	22%	37%
		Improved planning before work starts	79%	89%	97%
		Improved scheduling	X	90%	91%
		Improved project control after work starts	76%	85%	97%
		Faster response to problems	39%	45%	54%
		Improved understanding of the project	X	X	94%
		Improved communication among work force	36%	57%	81%
		Helps train future project managers	X	23%	48%
		Positive psychological effects on employees	X	13%	24%
		Cost savings	16%	46%	51%
		Time savings	X	57%	68%
		Reduces delays	X	X	71%
		Reduces cost overruns	X	X	43%
		Minimizes disputes between contractor and owner	X	X	68%
		More control over risk and uncertainty	X	X	73%
		Other:	15%	7%	0%
18	What are some of the disadvantages of CPM?	Requires too much dependency of specialists	24%	19%	25%
		Requires excessive work to implement	44%	36%	22%
		Not responsive to needs of top management	14%	9%	5%
		Not responsive to needs of field personnel	53%	X	24%
		Logic abuses	X	X	49%
		No Major Disadvantages	X	X	27%
		Other	21%	13%	13%

19	On average, what is the cost of CPM application as a percentage of total cost?	0-0.25%	X	X	73%
		0.25-0.5%	X	X	13%
		0.5%-0.75%	X	X	11%
		0.75-1%	X	X	2%
		over 1%	X	X	2%
20	Is there an economic benefit to using CPM?	Yes	X	X	95%
		No	X	X	5%
21	What is the degree of success in achieving the advantages of CPM?	Very Successful	15%	24%	27%
		Moderately Successful	61%	65%	70%
		Unsuccessful	17%	6%	2%
		Undecided	8%	6%	2%
22	Reasons for being unsuccessful	Poor Computer programs	17%	0%	0%
		Poor training of personnel	23%	29%	0%
		Lack of top management support	30%	29%	100%
		Lack of support from project management	X	43%	100%
		Lack of support from field people	67%	100%	100%
		Other	40%	43%	0%
23	Reasons for being successful	Good computer programs	63%	69%	73%
		Good training of personnel	67%	44%	55%
		Good top management support	82%	69%	55%
		Good support from project management	X	79%	83%
		Good support from field personnel	78%	46%	50%
		Development of new hardware	X	X	7%
		Other	22%	13%	0%
24	At what levels of management is CPM used?	Top Management	40%	52%	48%
		Project Management	89%	98%	100%
		Superintendents	26%	73%	78%
		Foremen	--	14%	13%

25	How important is CPM to present success of the company	Very Important	22%	38%	34%
		Moderately Important	46%	48%	61%
		Unimportant	27%	14%	5%
		Uncertain	X	X	0%
26	How important will CPM be to the future success of the company?	Very Important	32%	44%	51%
		Moderately Important	43%	52%	46%
		Unimportant	19%	5%	3%
		Uncertain	X	X	0%
27	How often do you make decisions based on CPM information	Frequently	X	30%	48%
		Moderate frequency	X	51%	43%
		Infrequently	X	19%	8%
		Never	X	1%	2%
28	Do you use CPM analysis for assessing claims?	Yes	X	71%	86%
		No	X	30%	14%
29	If you answered yes to question 28, what percent of claims is CPM used on?	0-25%	X	X	34%
		25-50%	X	X	13%
		50-75%	X	X	19%
		75-100%	X	X	34%
30	Has your company been involved in litigation where CPM has been used?	Yes	X	X	67%
		No	X	X	33%
31	What type of time impact analysis method is used to quantify effects?	Contemporaneous	X	X	31%
		Retrospective	X	X	12%
		Depends on the Contract	X	X	49%
		None used	X	X	9%
32	Do you use any of the advanced techniques?	Multiple Calendars	X	X	74%
		Resource Leveling	X	35%	40%
		Resource Constrained Scheduling	X	16%	35%
		Cost Control	X	8%	3510%
		Integrated time and cost control	X	16%	21%
		Scheduling across multiple projects	X	22%	23%
		Not applicable	X	X	9%
		Other	X	5%	2%

33	How often do you perform updating?	Monthly	X	69%	48%
		Biweekly	X	12%	19%
		Weekly	X	15%	18%
		Daily	X	1%	0%
		When required by contract	X	X	8%
		Never	X	X	0%
		Other	X	21%	8%
34	What other hardware is implemented by your company for CPM application?	PDA	X	X	2%
		Tablet PC	X	X	6%
		Other	X	X	2%
35	What are the names of the preferred software your company uses for scheduling?	Primavera Project Planner	X	X	78%
		Microsoft Project	X	X	35%
		Suretrak	X	X	59%
		Prolog Scheduler	X	X	0%
		Other	X	X	5%
37	Do you find flexibility in scheduling software leads to easier use or abuse?	Easier Utilization	X	X	75%
		Scheduling Abuses	X	X	25%
38	What methods of updating do you use?	Bar Chart	X	37%	56%
		S-Curve	X	9%	10%
		CPM	X	78%	75%
		Dateline cutoff method	X	20%	21%
		Other	X	3%	2%
39	In time and cost control, what are the S-curves that you use?	ACWP	X	43%	37%
		BCWP	X	35%	40%
		BCWS	X	29%	28%
		Not Applicable	X	X	44%
		Other:	X	10%	5%
40	Do you use a standardized work breakdown structure?	Yes	X	44%	37%
		No	X	46%	63%
41	What is the level of schedule detail used?	Summarized	X	X	3%
		Moderately Detailed	X	X	49%
		Very Detailed	X	X	48%