



# Survey of the Construction Industry Relative to the Use of CPM Scheduling for Construction Projects

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**Abstract:** While critical-path method (CPM) scheduling has been around since the 1950s, its application in the construction industry has still not received 100% acceptance or consistency in how it is used. Project controls, and CPM scheduling in particular, have gone unchanged in the standards arena with little focus for a common understanding and recognition of what is required for CPM schedule development, implementation, and use. In recent years, little research has been conducted relative to the use of CPM and its benefits. In order to determine how the industry views its applicability and usage, a survey was developed for the stakeholders in the construction industry. This paper summarizes extensive research that was performed of the construction industry relative to the use of CPM scheduling, its applicability and its acceptance in the execution of today's constructed projects. The research obtained the stakeholders' views on the use and effectiveness of CPM scheduling; the necessary qualifications of scheduling personnel; and opinions relative to whether standards and/or best practices are necessary. The paper discusses the different views of the stakeholders and recommendations as to how consistency can be obtained in the use of CPM scheduling in order to improve the construction industry.

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## Introduction

While critical-path method (CPM) scheduling has been around since the 1950s, its application in the construction industry has still not received 100% acceptance or consistency in how it is used. In recent years, little research has been conducted relative to the use of CPM and its benefits. In order to determine how the industry views its applicability and usage, a survey was developed for the stakeholders in the construction industry. This paper summarizes extensive research that was performed of the construction industry relative to the use of CPM scheduling; its applicability and acceptance in the execution of today's constructed project. Project controls, and CPM scheduling, in particular, have gone unchanged in the standard arena with little focus for a common understanding and recognition of what is required for CPM schedule development, implementation, and use. Project Management Institute (PMI) has recently added a college of scheduling as part of its organization. PMI, the world's professional organization on project management, is internationally recognized as the leading institution setting standards on Project Management. With nearly 180,000 members and nearly 120,000 certified project management professionals (PMPs), of which the writer is a PMP, PMI strives to provide consistency in all areas of project management. The writer sits as a board director on PMI's college of

scheduling (PMICOS). One of the PMI objectives over the next 1–2 years is to develop a set of standards for CPM scheduling and its use. This standard is currently in draft form for review and is expected to be released in early 2006. PMICOS, through its scheduling excellence initiative (SEI), is also undertaking the development of best practices guidelines which can be used by the stakeholders in the construction industry. Portions of the best practices guidelines are anticipated to be released in May 2006.

The research for this paper is aimed at addressing the following key areas:

1. Establish the views from both owners and contractors as to the use of CPM scheduling and its applicability in today's constructed projects;
2. Determine what is required of individuals who perform CPM scheduling;
3. Determine whether standards, certifications and/or best practice guidelines are being sought by the industry;
4. Determine whether CPM scheduling can assist in the risk management assessment process; and
5. The research then sets a minimum requirement of what is needed in the construction industry along with proposed recommendations on how this could be accomplished.

The research presented in this paper is being proposed at a key critical time at which its results can be used by this internationally recognized professional institution as well as practitioners in the construction industry who are users of CPM scheduling.

## Research Methodology

Results for this research were based on an on-line questionnaire survey. The survey is one of the most cost effective ways to involve a large number of people in the process in order to achieve better results. By focusing on the fact that different users

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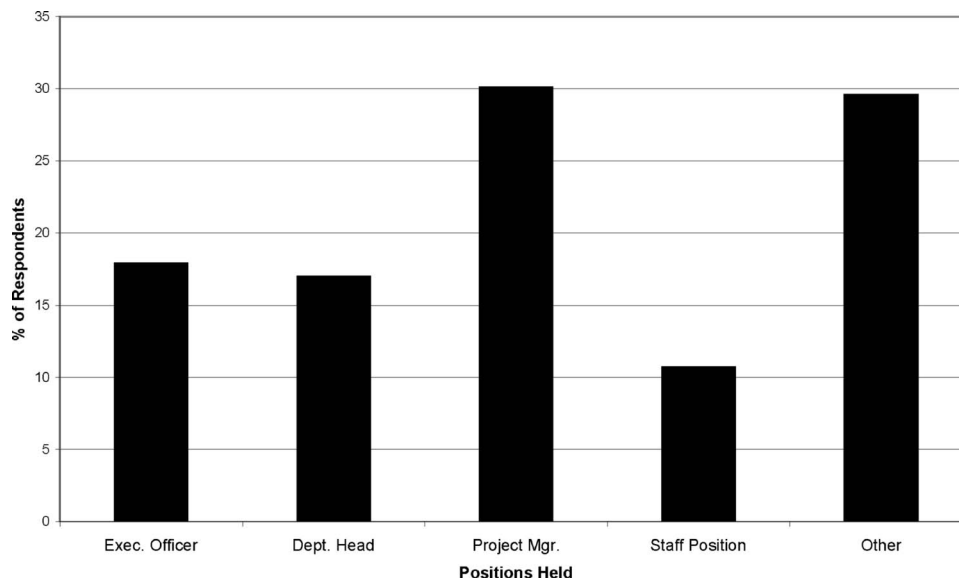


Fig. 1. Positions held

of CPM scheduling will both use and perceive its benefits differently, in addition to the overall general questions, specific questions applicable to both owners and contractors were developed.

While the construction industry remains one of the largest industries in the United States, statistics on the number of individuals performing CPM scheduling has not been tracked. The U.S. Department of Labor, Bureau of Labor Statistics (BLS) records information on the construction industry for top management, construction managers, management professionals, and related occupations and cost estimators. However, the BLS does not distinguish schedulers. Thus, in order to survey the most likely users of CPM scheduling, the writer called the Construction Management Association of America (CMAA), the American General Contractors (AGC), Engineering News Record (ENR), PMICOS, Construction Users Roundtable (CURT), the Association for the Advancement of Cost Engineering International's (AACEI), National Planning and Scheduling Committee, and the Construction Institute (CI) of the American Society of Civil Engineers (ASCE) to request assistance in having their members respond to the survey. All organizations agreed to participate. ENR indicated that they would sell a list of the top 400 international contractors, which the writer purchased.

It was determined by the writer that the largest response would be received if those taking the survey could do so via an on-line based survey. An agreement was secured with the leading professional societies serving the construction industry noted above to send an e-mail to its members notifying its members of the on-line survey. As the professional societies would not make their respective membership lists available, the total number of potential respondents is not known. Personal calls were made to the ENR companies to gain the information regarding the name and address of the corporate project controls manager for the company. A hard copy of the survey was sent to the project controls manager of these contractors.

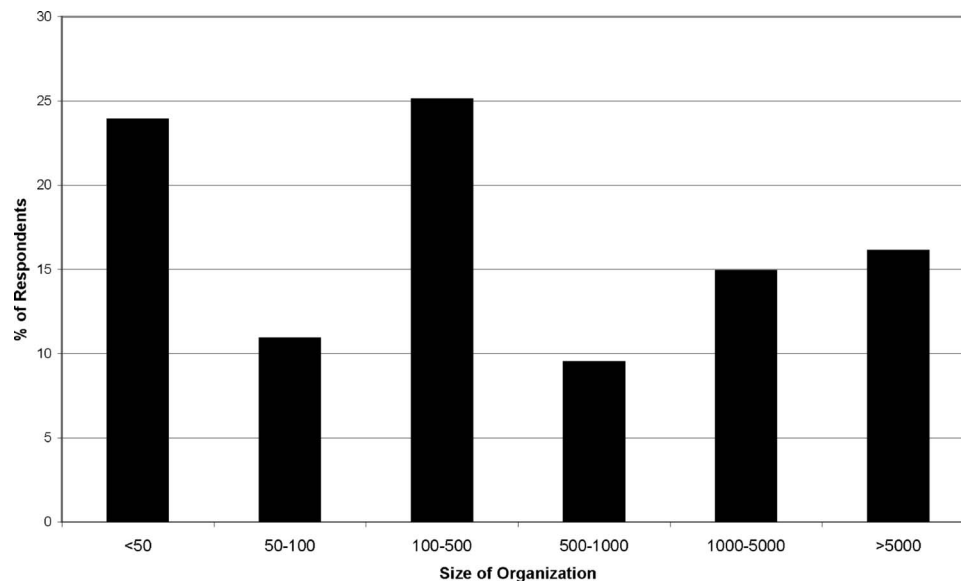
In searching for prior studies on the use of CPM scheduling, the writer obtained a prior study performed by Andrew Kelleher as part of his Masters of Science in Civil Engineering at Virginia Polytechnic Institute presented to the department in 2004 (Kelleher 2004). In addition to Kelleher's study, only two previous studies of ENR top 400 contractors' use of CPM have been per-

formed, one by Edward Davis in 1974 and the other by Amir Tavakoli and Roger Riachi in 1990. Kelleher discussed other studies regarding CPM that have been undertaken, however, most of these studies were done in the 1960s and 1970s (Kelleher 2004). Little research has been done in recent years. Kelleher noted that he limited his own study to the ENR 400 top contractors since "...the top 400 contractors are more likely to be users of CPM than a sole proprietor or other small company" (Kelleher 2004). Out of 400 contractors surveyed, Kelleher received responses from 65 companies.

Recognizing the need for the survey to be representative of the construction industry, the writer monitored the responses being received weekly and determined that the majority of ENR's top 20 international contractors had responded, as well as major owner companies, government agencies, and construction managers, thus reflecting largest users of CPM scheduling in the construction industry.

The on-line survey was open for a period of 6 months. A total of 430 responses were received composed of approximately 41% owners (private and government), 31% contractors, 19% engineers, and 19% construction managers. The remaining respondents were from universities and consultants serving the construction industry. Fig. 1 shows the positions held of those responding to the survey. The industry survey centered on the following subjects:

- Contract requirements for CPM scheduling;
- Requirements for schedule updates versus schedule revisions;
- Resource and cost loading requirements and usage;
- Computerized software required and used;
- Scheduling techniques employed;
- Applications and primary use of CPM scheduling;
- Management decision making based on CPM schedules;
- Advantages and disadvantages of CPM scheduling;
- Success of CPM scheduling usage;
- Personnel qualifications for schedulers;
- Knowledge regarding professional organizations supporting CPM scheduling;
- Opinions relative to CPM scheduling standards and best practices;



**Fig. 2.** Size of organization

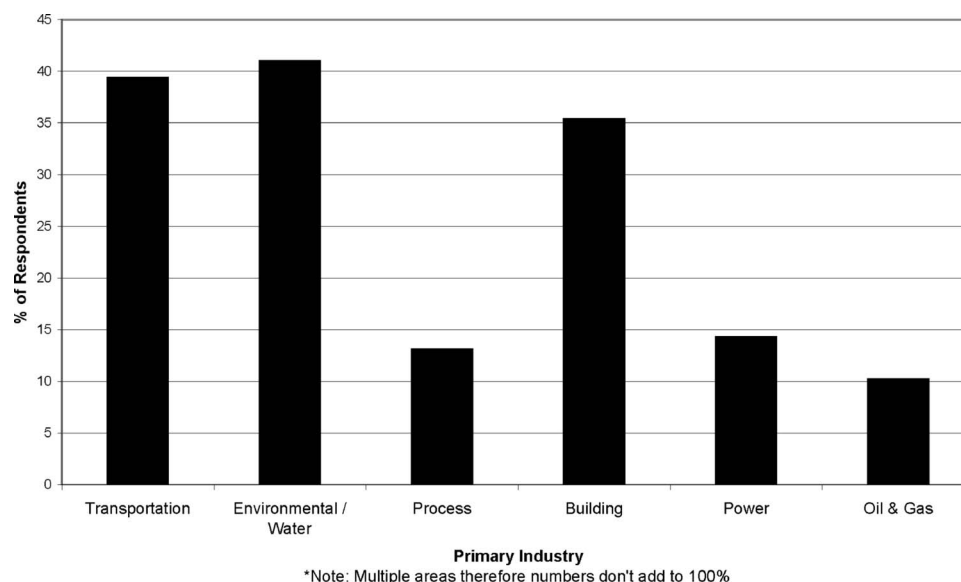
- Opinions relative to university curriculums for the study of CPM scheduling;
- Use of CPM scheduling in risk management; and
- Use of CPM schedules in claims avoidance and claims preparation.

The data analysis for the results included calculating the overall percentage of each question of the responding companies. A statistical analysis of the respondents was not possible as the survey was voluntary. Since the survey was voluntary, it was not possible to say the results represented the entire construction industry with a certain confidence level. 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. Since a confidence level could not be obtained, the writer did request information on company size (Fig. 2), type of construction (Fig. 3), and annual construction budget/revenue (Fig. 4) for

assurance that there was a wide representation throughout the construction industry.

### Industry Survey

While CPM scheduling has been around since the 1950s and is assumed to be a basic project control tool that is commonly used on all construction projects, the results of the industry survey demonstrate that CPM scheduling is still not a mandatory requirement nor is it a project control tool which has gained the trust of the industry. Based upon the results of the prior research performed on the course curriculums of the universities, it was not surprising to see some of the responses from industry relative to CPM scheduling.



**Fig. 3.** Primary industry

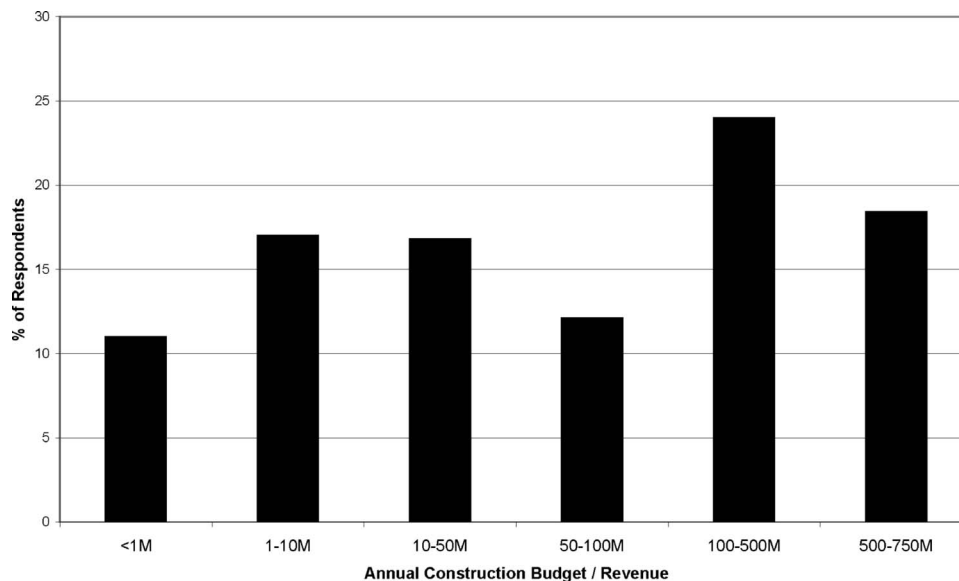


Fig. 4. Annual budget

### Owner Specification Requirements for CPM

Of the owners that responded, only 47.6% indicated that CPM scheduling is always required on their projects. Of those requiring CPM scheduling, 72.5% do specify CPM scheduling in their contracts, but only 55.9% require a baseline schedule. Owners were split on whether the CPM specification in their contracts was a standard specification or was customized for a particular project. Over 64% of the owners indicated that they used Primavera as their specified software with only just over 20% requiring MS Project. Other software mentioned included:

- OPLAN;
- MS Excel;
- Government Proprietary software;
- CBCM; and
- CA Super Project.

While almost 46% of the owners indicated that they require precedence diagramming methods, 14% indicated that they still require arrow diagramming CPM scheduling. In addition, owners indicated the preference for using other scheduling techniques including: almost 50% indicated their preference for bar charts or some form thereof; 27% indicating that they use PERT; 4% indicated requirements for 4D Planning; and another 20% required either Line of Balance (LOB) or Linear Balance Charts (vertical production methods) in their specifications.

Relative to the CPM specification requirements, nearly all respondents indicated that schedule updates were required and over 84% required schedule revisions; however, only 68% indicated that they distinguished between an update and a revision. Updates were deemed to be necessary on a monthly basis submitted in electronic format in over 2/3 of those responding. Almost 50% also indicated that they limited activity durations and nearly 65% indicated that they required activity coding. While the majority of the owners responding indicated that activity durations and coding was important, the owners were split as to whether resource loading was a specification requirement. Over 70% were primarily concerned with manpower loading on activity, while only 50% of the owners required cost loading or trade breakdown. A few owners also noted that they required resource loading for

major equipment only, critical items, quantities or that "...resource loading is not defined, it is just required."

### Owner's Viewpoints on CPM Scheduling

#### Schedule Revisions

Owners have a variety of reasons that they specify revisions in their specifications. The largest response as to why a schedule revision was required was equally shared (72%) between:

- Project behind schedule; and
- Change orders.

The next major reason cited was critical path changes (56%). Other reasons noted by owners for requiring schedule revisions included:

- Resource changes for either manpower or equipment;
- Logic changes/duration changes/or contractor sequence changes;
- When requested by the owner; and
- When time extensions are approved.

#### Advantages

The owner respondents were vocal as to specific applications and why they liked or disliked specific scheduling techniques and why CPM may not be the most appropriate application for the type of project being constructed. Owners that preferred merely bar charts explained their response in that they were easy to understand, they can provide near-term look aheads, and are more appropriate on smaller projects as budgets do not allow the cost of CPM scheduling and/or the managers do not have the necessary training in order to review and monitor CPM schedules. Those owners indicating the use of linear scheduling and LOB indicated that CPM scheduling was not appropriate as the projects were linear in nature (highway and/or pipeline projects in particular) and linear scheduling was more accurate relative to measuring progress and specifically, production rates. Four-dimensional (4D) modeling was discussed as primarily being used before the

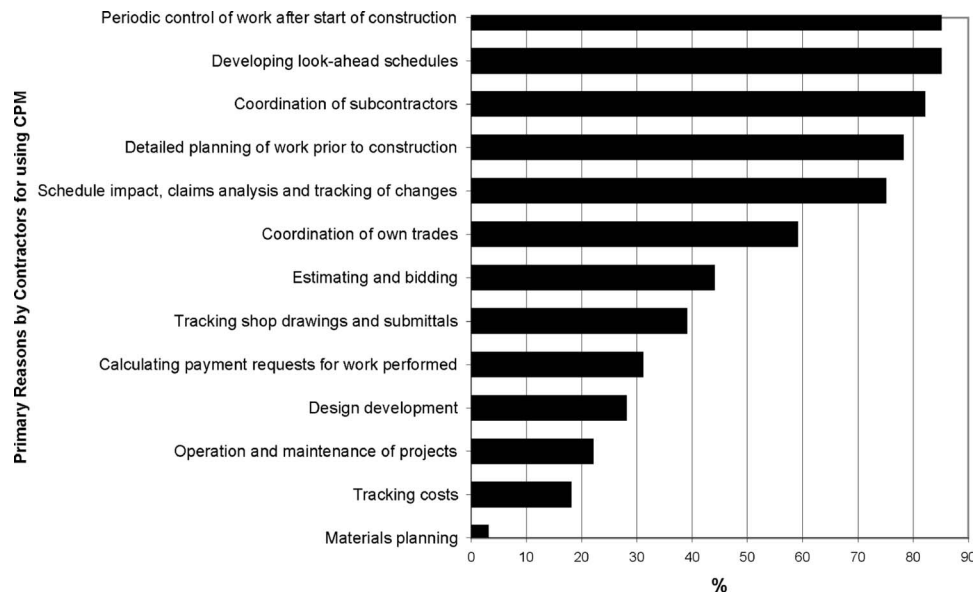


Fig. 5. Primary reasons by contractors for using CPM

project was executed in determining the best schedule alternatives for a specific project before it starts as well as optimizing communication, planning, and visualizing the project. CPM scheduling was indicated as being advantageous in that “what if” scenarios could be performed when submitted in electronic format to determine impacts on changes and delays to the project. CPM also allowed summarization into a bar chart format for ease of understanding by management.

### Disadvantages

The two main disadvantages noted by owners in the use of CPM scheduling were:

1. The construction managers and project managers do not use the software enough to be knowledgeable in its use and what it is portraying; and
2. The contractor is more informed about CPM and can more easily manipulate the schedule and use it for claims.

Owners felt that CPM was overkill for small projects with little cost justification. Owners were also concerned as while their preference was to use Primavera as the required software specified, that their experience was that many contractors still use MS Project which has limitations and does not allow the owner to perform the monitoring that it desires throughout project execution. For those owners using linear scheduling techniques, their primary concern was that few contractors understood this scheduling technique and that it was not well known in the industry.

## Contractor's Viewpoints on CPM Scheduling

### Contract Specifications

Over 50% of the contractors responding noted that they now find that their contracts require CPM scheduling. If CPM scheduling is not required, nearly 67% indicate that they still prepare a CPM for purposes of planning and monitoring their work. While the results did not determine whether Primavera was primarily used as a result of being a contract requirement, despite the responses received from the owners on the perception of software usage by

contractors, nearly 65% indicated that they prefer to use Primavera software, with only 22% indicating they prefer MS Project. With respect to resource loading requirements, the contractor respondents were split relative to whether they found resource loading useful. Forty percent of those responding did not believe either manpower or cost loading was useful while 30% did believe resource loading was useful and 15% did not have an opinion one way or another. The remaining respondents commented that it was considered “extra work,” or depended on the specific project. Other comments made centered around lump sum contracting where it was noted it was not necessary in the respondent's opinion to track manpower or costs per activity.

### Use of CPM

The primary reasons noted by contractors for using CPM scheduling (Fig. 5) included the following:

- Periodic control of work after start of construction (85%);
- Developing look-ahead schedules (85%);
- Coordination of subcontractors (82.1%);
- Detailed planning of work prior to construction (78.1%);
- Schedule impact, claims analysis and tracking of changes (75%);
- Coordination of own trades (59%);
- Estimating and bidding (44%);
- Tracking shop drawings and submittals (39%);
- Calculating payment requests for work performed (31%);
- Design development (28%);
- Operation and maintenance of projects (22%);
- Tracking costs (18%); and
- Materials planning (less than 3%).

Over 80% of those contractors responding indicated that they rely on their CPM schedules for making decisions on the project execution. In response to a question on whether the contractor maintains a separate schedule to monitor the work in addition to the contract specified schedule, 28% indicated that they did and 52% indicated that they did not. The remaining respondents indicated that they would prepare a separate schedule based on the following:





**Fig. 6.** Contractor noted advantages of using CPM scheduling

1. The need to prepare 4-week rolling for their own forces;
2. The specific project;
3. The need for a target schedule to provide better control;
4. When they are a subcontractor and the general contractor's schedule is not representative of the subcontractor's work;
5. Whether the owner is refusing to recognize delay and grant time extensions;
6. The need to review fragments and provide an indication of change impacts; and
7. The need to have a more summary level schedule for presentation to management.

### Advantages

Over 96% of the contractors responding indicated that they believed that there was an economic benefit to using CPM and over 89% indicated that they have had moderate to high success in achieving various benefits using CPM. The advantages of using CPM scheduling as noted by the contractors (Fig. 6) included:

- Improved planning before work starts (92%);
- Improved scheduling (84%);
- Improved understanding of the project (83%);
- Improved project control after work starts (80%);
- Improved communications among the workforce (54%);
- Increased control over risk and uncertainty (53%);
- Reduced delays (50%);
- Minimization of disputes between the contractor and owner (46%);
- Time savings (39%);
- Faster response to problems (34%);
- Cost savings (30%);
- Improved estimating/bidding (28%);
- Helps train future project managers (26%); and
- Positive psychological effect on employees (22%).

Other comments that were specifically noted by those responding as to the benefits of CPM scheduling included:

- Imparts a sense of control for the management team enabling them to accurately plan ahead;
- Useful tool to discuss issues that could be clearer;
- Gets owners to react more quickly;

- Basis for earn value cost preplanning, cost reporting and time job cost control;
- If owner approved, easier to show delays;
- Easily flags adverse trends against the baseline schedule; and
- Allows ability to do "what if" scenarios.

### Disadvantages

Nearly 40% of the contractors indicated that the primary disadvantage to CPM scheduling was logic abuse. As noted previously, this was also a concern of the owners and leads into comments that will follow relative to the need to scheduling standards, best practices, and certification. The other major common areas of concerns relative to CPM scheduling (Fig. 7) included:

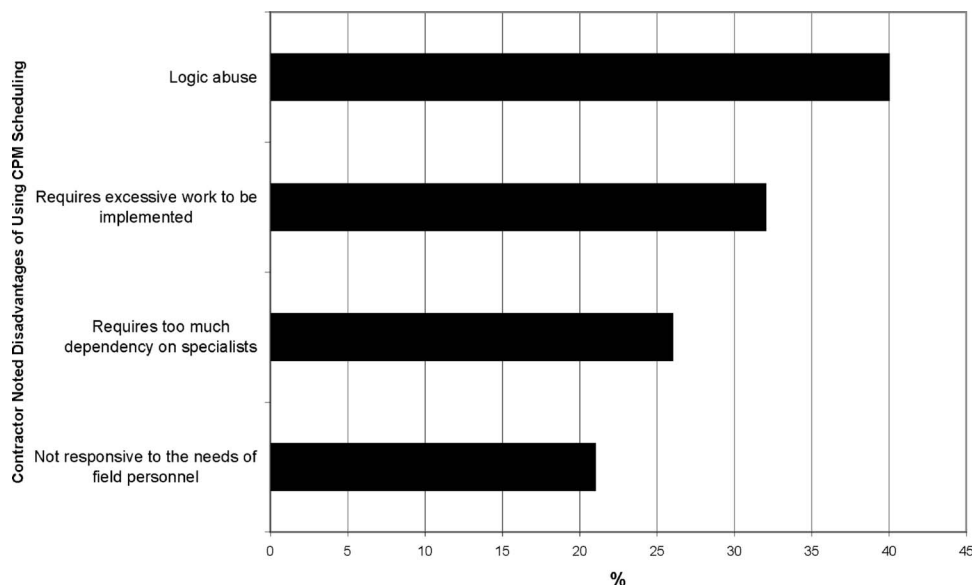
- Requires excessive work to be implemented (32%);
- Requires too much dependency on specialists (26%); and
- Not responsive to the needs of field personnel (21%).

Other comments noted by contractors relative to the disadvantages of CPM scheduling included:

1. Must be kept up to date if it is to be relied upon;
2. No one knows how to use it properly;
3. Too much interpretation which leads to owner mistrust and misuse;
4. Owners attempt to use the CPM schedule against the contractor instead of working with the contractor to resolve delays and impacts;
5. Not understood by laborers or superintendents;
6. Requires users trained in CPM scheduling;
7. P3 graphics are difficult to read; and
8. P3 software has become so sophisticated it requires skilled specialists to use the program.

### CPM Scheduling Personnel

The industry surveyed all the stakeholders relative to the skills and qualifications of their respective personnel that develop and use CPM scheduling on construction projects. The industry is almost equally divided on whether the organization employs an



**Fig. 7.** Contractor noted disadvantages of using CPM scheduling

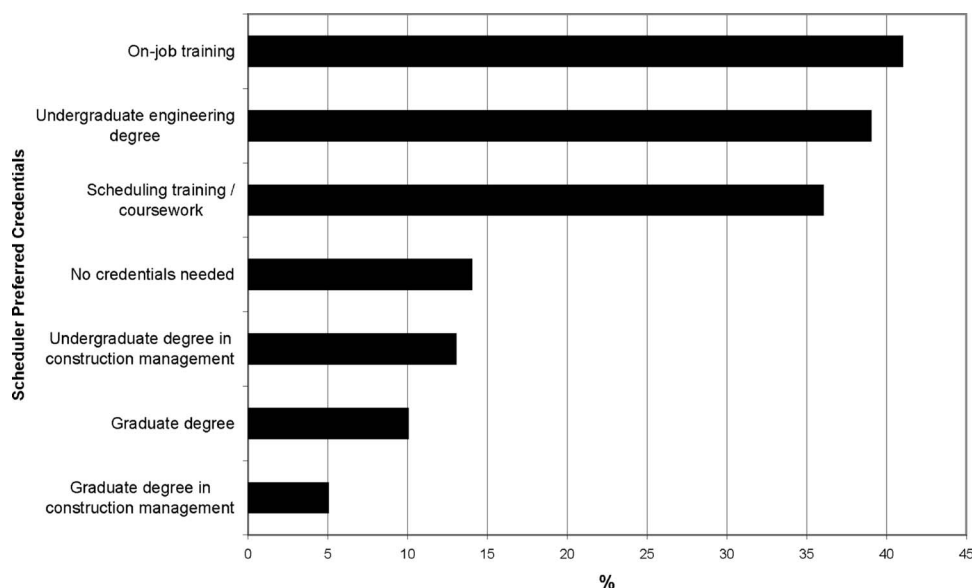
overall manager for planning and scheduling with 59% indicating that they did not and the other 41% indicating that they did. However, this percentage switched slightly with respect to specific projects, with 57% of the respondents indicating that they did employ a person solely dedicated to this effort, while 43% indicated that they did not. Of those employing a dedicated scheduler, 84% responded that this individual is expected to perform other tasks in addition to CPM scheduling. 67% indicated that their scheduling is performed by in-house personnel, while only 7% indicated that they used outside consultants solely and the remainder indicated a combination of in-house and consultants. Most interestingly, when it came to the desired background of the personnel performing planning and scheduling, nearly 56% indicated that they preferred someone with an engineering background and 44% indicated that they desired someone with project management background. Some respondents also commented that

it may vary project to project and that site experience and/or a certification might be preferred in addition to the backgrounds noted above. Relative to the specific credentials of the scheduler, the following credentials were noted as preferred for someone performing CPM scheduling (Fig. 8):

- On-job training (41%);
- Undergraduate engineering degree (39%);
- Scheduling training/coursework (36%);
- No credentials needed (14%);
- Undergraduate degree in construction management (13%);
- Graduate degree (10%); and
- Graduate degree in construction management (5%).

Respondents also commented that the following credentials would also be desirable:

- Masters degrees;
- Professional engineering license;



**Fig. 8.** Scheduler preferred credentials

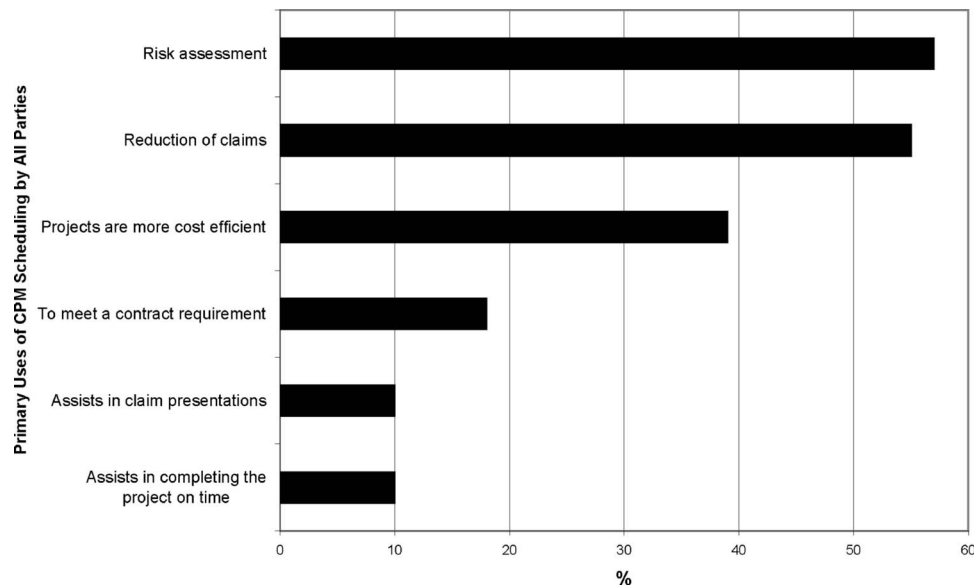


Fig. 9. Primary uses of CPM scheduling by all parties

- 5 years experience on comparable projects;
- Prior experience;
- Certification such as PMP, certified cost engineer (CCE), ICEC certification, or AACEI schedule certification (PSP); and
- Field experience.

## CPM and CPM Standards

When asked for the reasons why CPM scheduling was used, over 82% indicated that it was a beneficial planning tool that makes projects more efficient and cost effective. In response to the question that was asked (to check all answers that applied), relative to the reasons why they used CPM scheduling, the following were noted:

1. Contract requirement (63%);
2. Claims, after the fact (53%);
3. Change management (47%); and
4. Other (so noted)
  - a. Anticipated shifts in funding needs;
  - b. Understanding true delay;
  - c. Earned value management;
  - d. Bid evaluation;
  - e. Coordination of multiple construction projects;
  - f. Identification of delay issues;
  - g. Bases for 3-week look-aheads; and
  - h. Assists in getting buy-in from subcontractors.

The primary uses of CPM scheduling were noted by all parties (Fig. 9) to be:

- Risk Assessment (57%);
- Reduction of claims (55%);
- Projects are more cost efficient (39%);
- To meet a contract requirement (18%);
- Assists in claim presentations (10%); and
- Assists in completing the project on time (10%).

Those responding also indicated that 66% of their senior management used and relied upon the CPM schedules in making decisions while 25% indicated senior management did not use the schedules and 9% indicated that they did not know.

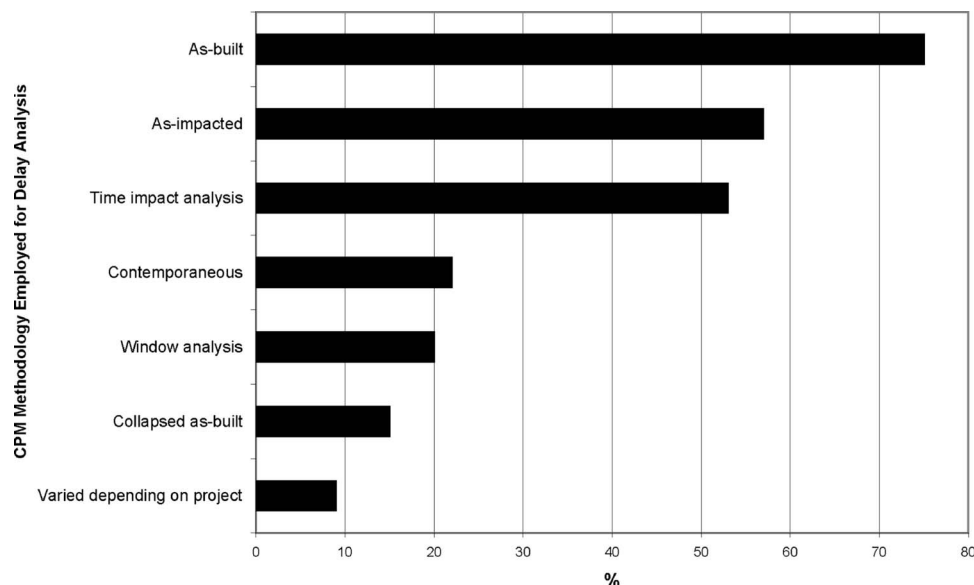
One of the crying needs cited in the survey was with respect to the need for standards in CPM scheduling. Seventy nine percent indicated that standards should be defined in the area of CPM scheduling. However, there was no consensus as to who should develop these standards with multiple organizations cited and 50% of those responding indicating that they simply did not know. Of the two primary organizations focused on the improvement of the CPM scheduling industry, PMICOS and AACEI, 70% were not familiar with PMICOS and 77% were not familiar with AACEI. However, over 53% indicated that they were familiar with PMI's body of knowledge (PMBOK) although over 89% indicated that they did not train their personnel in the use of PMBOK time management and 92% indicated that they did not attempt to assure that their CPM schedules and processes conformed to the PMBOK time management guidelines. However, while the majority of respondents were not familiar with the time management module of the PMBOK, over 58% indicated that certification of schedulers would improve the industry and a surprising 92% of those responding indicated that best practices guidelines should be developed that could be made available to owners and contractors.

While 78% of those responding indicated that they believed it was important to have a consistent university curriculum for CPM scheduling, only 17% had indicated that they had ever reviewed a university curriculum to see what was being taught at the university level. However, over 55% indicated that the university curriculums should use the PMBOK as a guide to what should be taught with respect to CPM scheduling.

## Claims Avoidance and Usage of CPM Scheduling

Over 67% of the survey respondents indicated that the use of CPM scheduling minimized claims on their projects. Over 82% indicated that they used CPM scheduling in claims resolution, and of those responding that they used CPM schedules in their claim resolution, over 85% indicated that they used the existing schedules that were used during the project. Further, over 84% indicated that they believed the use of CPM scheduling was essential





**Fig. 10.** CPM methodology employed for delay analysis

in delay claim resolution. However, the methodologies for CPM delay analyses varied greatly with the following noted as being methods that have been used by respondents (Fig. 10):

- As-built (75%);
- As-impacted (57%);
- Time impact analysis (53%);
- Contemporaneous (22%);
- Window analyses (20%);
- Collapsed as-built (15%); and
- Varied depending on project (9%).

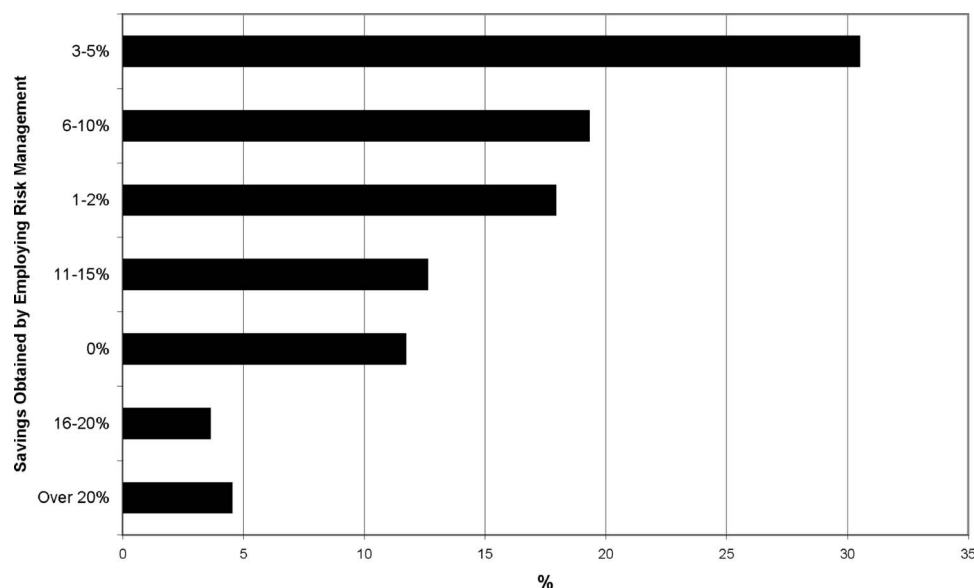
## Risk Management

The respondents were almost equally split as to whether they had a company-wide risk management program with 47% indicating

that they did and 53% indicating they did not. Surprisingly, while 41% indicated that they did have a risk management officer, 62% responded that they did not have a project risk management program for their specific projects undertaken. Despite the fact that no specific program was identified, 52% indicated that they now perform project risk assessments with over 83% indicating that they believed risk management assessments saved money on projects as follows (Fig. 11):

- 3–5% (30.5%);
- 6–10% (19.3%);
- 1–2% (17.9%);
- 11–15% (12.6%);
- 0% (11.7%);
- 16–20% (3.6%); and
- over 20% (4.5%).

Forty six percent of those responding indicated that risk assess-



**Fig. 11.** Savings obtained by employing risk management

ments were performed with in-house personnel, while 31% indicated a combination of in-house project team and other company personnel. Twenty percent indicated the use of a combination of in-house and external personnel as part of the risk management assessment team. Of those performing risk assessments, 75% indicated that they do not use simulation modeling and over 44% indicated periodic risk assessments throughout the life of the project, with quarterly being the preferred time interval (34%) and 20% indicating a preferred monthly interval.

## General Observations/Conclusions Drawn from Survey

As noted above, the survey respondents well represented the construction industry and were reasonably equally divided among owners, contractors, engineers/construction managers, all stakeholders in the project, and parties who have to live with the decisions based on the CPM scheduling information. It was interesting to note that while some differences existed between owners and contractors relative to the reasons CPM scheduling was used and/or its benefits, there were common opinions among all stakeholders relative to the following points:

1. CPM scheduling has become a standard project control tool and both owners and contractors use the tool whether it is or is not required by contract.
2. While all parties generally felt that CPM scheduling was a good project control tool for monitoring, planning, and executing a project, commonality existed relative to:
  - a. CPM scheduling has become so sophisticated that specialists in CPM scheduling are now required to develop and understand CPM schedules;
  - b. While Primavera software is the number one choice among the stakeholders, it is believed to be complex and difficult to understand, thus increasing the cost to the project; and
  - c. CPM schedules are easily manipulated, especially with respect to logic abuse.
3. Of the two organizations which primarily have CPM scheduling as a key focus: PMICOS and AACEI, more than 70% of the respondents had not heard of one of the organizations.
4. The majority of those responding indicated that they believed certification of schedulers would improve the industry.
5. The majority of those responding indicated that there was an immediate need for standards for CPM scheduling although half of those responding did not know who should develop such standards and the remainder indicated multiple organizations; noting that the organizations should come together to develop common standards.
6. Over 92% indicated that they desired to have some sort of best practices guidelines that could be issued to both owners and contractors relative to CPM scheduling.
7. The majority of the respondents felt that CPM scheduling was beneficial in risk management applications.
8. Most participants agreed that there should be consistency in the university curriculums. However, as noted in research that has been performed of the universities in the United States, Europe, and Asia (Galloway 2006), there is no consistency in the universities as to how CPM scheduling is

taught. By the answers to the industry survey questions, it is apparent that this is a major area requiring reform as CPM scheduling appears to mostly be taught and learned by on-the-job training, thus resulting in nonstandard development, usage, and interpretation of results from CPM schedules.

## Writer Recommendations Based on Survey Results

Based on review of the findings of the survey, the writer makes the following recommendations to the construction industry:

1. University programs must be reviewed to bring both consistency and relevancy (practicality) into the curriculums in order to better prepare individuals for the construction industry. While universities provide a good base understanding of CPM scheduling, unfortunately the industry still considers the programs to be too theoretical and that on-the-job training and specific courses offered by Primavera are still the only ways to bring an individual up to speed on CPM scheduling.
2. The professional organizations (such as AACEI, ASCE, CMAA, AGC, PMICOS, DBIA) need to come together in a collation to address what is required relative to standards for CPM scheduling and to move those standards to the American National Standards Institute (ANSI) standards so as to provide a more trusting atmosphere and basis from which all stakeholders in the construction project can rely with respect to CPM scheduling.
3. Certification of schedulers appears to be the wave of the future. AACEI is on the forefront in its certification examination of schedulers. Additional advanced certifications may be warranted relative to those individuals in a managerial role for the oversight and direction of the CPM schedules in either a company or a large capital project.
4. Best practice guidelines should be developed sooner than later. Organizations such as PMICOS are already far along in their work relative to best practices guidelines using expert resources from all areas of the construction industry including owners (private and public), contractors, construction managers, engineers, and consultants to the construction industry who have had to defend analyses based on CPM schedules used during the constructed project.

Until the above four reform areas are addressed and implemented, the industry will continue to have its doubts over the use of CPM scheduling and that continued misuse, abuse, and multiple interpretations of the data will continue, thus reducing the benefits so noted by the stakeholders of reducing the cost, increasing efficiency, and reducing claims of the constructed project.

## Acknowledgments

The writer would like to thank all the organizations that participated in this study and the information that they provided. The writer also wishes to thank Brook Maples for her assistance in designing the on-line survey and transmitting the results to the writer for the research and analysis of the data for development of this paper by the writer.

# Appendix I. Survey Questions and Results Thereof

## APPENDIX A: SURVEY QUESTIONS AND RESULTS THEREOF

### Critical Path Method - Industry Questionnaire

Exit this questionnaire >>

#### General Information

\* 1. Organization Name:

\* 2. What is your position within your organization?

- ☐ Project Manager  
☐ Department Head  
☐ Staff Position  
☐ Executive Officer  
☐ Other (please specify)

\* 3. What is your average annual construction budget or revenues?

- ☐ Under \$1 Million  
☐ \$1 - \$10 Million  
☐ \$10 - \$50 Million  
☐ \$50 - \$100 Million  
☐ \$100 - \$500 Million  
☐ Greater than \$500 Million

4. Where is the majority of your work performed? (Check all that apply)

- ☐ US - Nationwide  
☐ US - West  
☐ US - East  
☐ US - Midwest  
☐ US - south  
☐ Europe - Western and Eastern  
☐ Europe - Western  
☐ Europe - East  
☐ Europe - UK solely  
☐ Asia - throughout  
☐ Asia - China  
☐ Asia - Japan  
☐ Asia - Australia  
☐ Middle East  
☐ Africa  
☐ Latin/South/Central America  
☐ Other (please specify)

5. How large is your organization?

- ☐ Under 50  
☐ 50 - 100  
☐ 100 - 500  
☐ 500 - 1000  
☐ 1000 - 5000  
☐ over 5000

6. What is your primary industry? (check all that apply)

- ☐ Transportation  
☐ Process  
☐ Building  
☐ Power  
☐ Oil and gas  
☐ Aerospace  
☐ Other (please specify)

\* 7. What type of organization do you represent? (Note: Contractors will be forwarded to a separate page specific to contractors; Owners, construction managers, engineers, and government respondents will answer questions related to project owners.)

- ☐ Private Owner  
☐ Contractor  
☐ Government  
☐ Engineer  
☐ Construction Manager  
☐ Other (please specify)

### Critical Path Method - Industry Questionnaire

Exit this questionnaire >>

#### Use of CPM Scheduling - Owner/owner's representative

1. Do you use Critical Path Scheduling on your construction projects?

- ☐ Yes, always  
☐ On 75% or more of projects  
☐ On over 50% of projects  
☐ 25 - 50% of time  
☐ Less than 25%  
☐ No

2. If you answered "Never", please explain why:

3. Do you require a CPM baseline schedule in your contracts?

- ☐ Yes, Always  
☐ Only on projects greater than \$5M  
☐ Only on projects greater than \$10M  
☐ Only on projects greater than \$20M  
☐ Only on projects greater than \$50M  
☐ Only on projects greater than \$100M  
☐ No, Never  
☐ Other (please specify)

4. Do you use a CPM specification in your contract?

- ☐ Yes  
☐ No

5. Is the specification a standard CPM specification or is it customized for each project?

- ☐ standard  
☐ customized

6. Do you distinguish between an update and revision?

- ☐ Yes  
☐ No  
☐ Don't know

7. Do you require updates?

- ☐ Yes  
☐ No

8. How often do you require updates?

- ☐ Weekly  
☐ Monthly  
☐ Quarterly  
☐ Other (please specify)

9. Do you require revisions?

- ☐ Yes  
☐ No

10. If revisions are required, why are they required? (check all that apply)

- ☐ Critical path changes  
☐ Project behind schedule  
☐ Change orders  
☐ Other (please specify)

11. Do you limit the activity durations?

- ☐ Yes  
☐ No  
☐ Don't know

12. Do you require activity coding?

- ☐ Yes  
☐ No  
☐ Don't know

13. Do you require resource loading?

- ☐ Yes  
☐ No  
☐ Don't know

14. If resource loading is required, do the requirements include:

- ☐ Manpower level  
☐ Trade breakdown  
☐ Dollar per activity  
☐ Other (please specify)

**15. Do you require electronic file copies of the schedule to be submitted?**

- ☐ Yes  
☐ No  
☐ Don't know

**16. What computer software do you specify?**

- ☐ Primavera  
☐ MS Project  
☐ SureTrak  
☐ Artemis  
☐ Left up to contractor  
☐ Or equal  
☐ Other (please specify)

**17. Do you require a risk assessment to be performed on the schedules?**

- ☐ Yes  
☐ No  
☐ Don't know

**18. In what format is the CPM required?**

- ☐ Arrow Diagramming Method  
☐ Precedence Diagramming Method  
☐ PERT  
☐ GERT  
☐ Critical Chain  
☐ Don't Know  
☐ No Requirement  
☐ Other (please specify)

**19. What are the Advantages and Disadvantages of the format you use:****20. Do you use any other scheduling techniques? (Check all that apply)**

- ☐ Program Evaluation and Review Techniques  
☐ 4D Planning  
☐ Line of Balance (LOB)  
☐ Linear Balance Charts (Vertical Production Methods)  
☐ Free Hand Bar Chart (Not based on logic diagram)  
☐ Other (please specify and explain)

**21. What are the Advantages and Disadvantages of the method you use:****Critical Path Method - Industry Questionnaire** Exit this questionnaire >>**→ Use of CPM Scheduling - Owner/owner's representative****1. Do you use Critical Path Scheduling on your construction projects?**

- ☐ Yes, always  
☐ On 75% or more of projects  
☐ On over 50% of projects  
☐ 25 - 50% of time  
☐ Less than 25%  
☐ No

**2. If you answered "Never", please explain why:****3. Do you require a CPM baseline schedule in your contracts?**

- ☐ Yes, Always  
☐ Only on projects greater than \$5M  
☐ Only on projects greater than \$10M  
☐ Only on projects greater than \$20M  
☐ Only on projects greater than \$50M  
☐ Only on projects greater than \$100M  
☐ No, Never  
☐ Other (please specify)

**4. Do you use a CPM specification in your contract?**

- ☐ Yes  
☐ No

**5. Is the specification a standard CPM specification or is it customized for each project?**

- ☐ standard  
☐ customized

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire &gt;&gt;

**→ Use of CPM Scheduling - Contractors****1. Do you find that the contracts now contain a specification requiring CPM scheduling?**

- ☐ Yes, always  
☐ Yes, most of the time  
☐ Yes, Always  
☐ Only on projects greater than \$5M  
☐ Only on projects greater than \$10M  
☐ Only on projects greater than \$20M  
☐ Only on projects greater than \$50M  
☐ Only on projects greater than \$100M  
☐ No, Never  
☐ Rarely  
☐ Never  
☐ Other (please specify)

**2. If not required, do you still prepare a CPM on your project?**

- ☐ Yes, Always  
☐ Only on projects greater than \$5M  
☐ Only on projects greater than \$10M  
☐ Only on projects greater than \$20M  
☐ Only on projects greater than \$50M  
☐ Only on projects greater than \$100M  
☐ No, Never  
☐ Other (please specify)

**3. What are the major areas of CPM application in your organization?**

- ☐ 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  
☐ Change management and claims analysis  
☐ Other (please specify)

**4. If you use CPM for periodic control of the work during construction, for what tasks do you use CPM?**

- ☐ Coordination of own trades  
☐ Tracking shop drawings and submittals  
☐ Tracking costs  
☐ Schedule impact analysis and trackign changes  
☐ Calculating payment requests for work performed  
☐ Developing a look ahead schedule  
☐ Coordination of Subcontractors  
☐ Other (please specify)

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

- ☐ Frequently  
☐ Moderate Frequency  
☐ Infrequently  
☐ Never  
☐ Comments

**6. Do you maintain a separate schedule to maintain the work in addition to the contract specified schedule?**

- ☐ Yes  
☐ No

☐ Depends on situation (explain)

**7. What software do you prefer and use if given an option?**

- ☐ Primavera  
☐ SureTrak  
☐ MS Project  
☐ Artemis  
☐ Other (please specify)

**8. Do you find manpower loading useful and do you use it for CPM?**

- ☐ Yes  
☐ No  
☐ Don't know  
☐ Depends (please specify)

**9. Do you find cost loading useful and do you use it for CPM?**

- ☐ Yes  
☐ No  
☐ Don't know  
☐ Depends (please specify)

**10. What are the benefits obtained from using CPM? (Choose all that apply)**

- ☐ Improved scheduling  
☐ Improved estimating/bidding  
☐ Reduces delays  
☐ Time savings  
☐ Helps train future project managers  
☐ Minimizes disputes between contractor and owner  
☐ Positive psychological effect on employees  
☐ Increase control over risk and uncertainty  
☐ Faster response to problems  
☐ Improved communication among the workforce  
☐ Cost savings  
☐ Improved understanding of the project  
☐ Improved project control after work starts  
☐ Improved planning before work starts  
☐ Other (please specify)

**11. What are the disadvantages of CPM? (Choose all that apply).**

- ☐ Not responsive to the needs of top management  
☐ Logic abuses  
☐ Requires excessive work to implement  
☐ Not responsive to the needs of field personnel  
☐ No major disadvantages  
☐ Costs too much  
☐ Requires too much dependency on specialists  
☐ Other (please specify)

**12. On average, what is the cost of CPM application as a percentage of total project (construction) cost?**

- ☐ 0 - 0.25%  
☐ 0.26 - 0.50%  
☐ 0.51 - 0.75%  
☐ 0.76 - 1.00%  
☐ Over 1%  
☐ Other (please specify)

**13. Do you believe there is an economic benefit to using CPM (that the benefits outweigh the costs)?**

- ☐ Yes  
☐ No

**14. What has been your degree of success in achieving the benefits of CPM?**

- ☐ Very Successful  
☐ Moderately Successful  
☐ Unsuccessful  
☐ Undecided  
☐ Comments

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire >>

**→ Personnel**

**1. Does your organization have an overall manager of planning and scheduling?**

- ☐ Yes  
☐ No

**2. Do you have a dedicated person responsible for planning and scheduling on each project?**

- ☐ Yes  
☐ No

**3. What is the background of personnel performing planning and scheduling?**

- ☐ Engineer  
☐ Technician  
☐ Project Management  
☐ Site Engineer  
☐ Dedicated Scheduler  
☐ Contractor Foreman  
☐ Other (please specify)

**4. What credentials do you require of someone performing planning and scheduling?**

- ☐ Undergraduate University Degree  
☐ Undergraduate University degree in Construction Mgt  
☐ Graduate University Degree  
☐ Graduate Degree in Construction Management  
☐ Other Scheduling Training/Coursework  
☐ On-Job training  
☐ no training/credentials required  
☐ Other (please specify)

**5. With respect to your specific project personnel responsible for CPM scheduling do they:**

- ☐ Sole duty is CPM scheduling including periodic updating  
☐ Does multiple tasks in addition to the CPM schedule

**6. Is your CPM scheduling performed by:**

- ☐ In-house personnel  
☐ Outside consultant  
☐ Combination of in-house and consultants

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire >>

**→ CPM Standards**

**1. For which reasons do you use CPM (check all that apply):**

- ☐ It is a beneficial planning tool that makes projects more efficient and cost effective  
☐ Contract Requirement  
☐ Change Management  
☐ Claims, after the fact  
☐ Other (please specify)

**2. With regard to the primary uses of CPM Scheduling (check all that apply):**

- ☐ Projects where CPM is used cost less  
☐ Projects where effective CPM has been used regularly have reduced claims  
☐ CPM schedule aids assessment of risk  
☐ CPM scheduling costs too much and is a burden on staff  
☐ CPM scheduling is only performed to meet a contract requirement  
☐ CPM schedules are only helpful in a claim presentation  
☐ Other (please specify)

**3. Does Senior Management (above project level) review and use the information provided in the CPM schedule?**

- ☐ Yes  
☐ No  
☐ Don't Know

**4. Are you familiar with the Project Management Institute (PMI) Body of Knowledge (PMBOK)?**

- ☐ Yes  
☐ No



**5. Are you familiar with the Time Management Guidelines within PMBOK?**

- ☐ Yes  
☐ No

**6. Do you train personnel in your firm to be familiar with PMBOK time management guidelines?**

- ☐ Yes  
☐ No

**7. Do you attempt to assure that your CPM schedule and process conforms to the PMBOK time management guidelines?**

- ☐ Yes  
☐ No

**8. Are you familiar with PMI's College of Scheduling?**

- ☐ Yes  
☐ No

**9. Are you familiar with AACE's National Committee on Planning and Scheduling?**

- ☐ Yes  
☐ No

**10. Do you believe standards should be defined for the area of CPM scheduling?**

- ☐ Yes  
☐ No

**11. What entity should develop these standards?**

- ☐ ANSI  
☐ AACE  
☐ PMI  
☐ Government  
☐ Don't Know  
☐ Other (please specify)

**12. Do you believe that people performing CPM scheduling should be certified?**

- ☐ Yes  
☐ No

**13. Do you believe certification would improve the industry?**

- ☐ Yes  
☐ No

**14. Do you believe Best Practices guidelines should be developed that could be made available to owners/contractors?**

- ☐ Yes  
☐ No

**15. Do you believe University Curriculum should use the PMBOK as a guide to what should be taught regarding CPM scheduling?**

- ☐ Yes  
☐ No

**16. Have you ever reviewed University Curriculum to see what is being taught regarding CPM scheduling?**

- ☐ Yes  
☐ No  
☐ Which Institution?

**17. Do you believe that it is important that CPM scheduling is consistent in the curriculum across universities?**

- ☐ Yes  
☐ No

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire &gt;&gt;

**→ Claims Avoidance and Usage of CPM****1. Does the use of CPM schedule minimize claims in your projects?**

- ☐ Yes  
☐ No

**2. Do you use CPM scheduling in claims resolution?**

- ☐ Yes  
☐ No

**3. Do you use existing CPM schedules that were used during the project or do you redevelop a schedule for the claim?**

- ☐ Existing  
☐ New Development for Claims

**4. What methods of CPM Scheduling Analysis do you use in claims (check all that apply):**

- ☐ As-Built  
☐ As-Impacted  
☐ Contemporaneous  
☐ Window Analysis  
☐ Collapsed As-Built

- ☐ Time Impact Analysis  
☐ Other (please specify)

**5. Do you believe the usage of CPM is essential in delay claims?**

- ☐ Yes  
☐ No

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire &gt;&gt;

**→ Risk Management****1. Do you have a company-wide risk management program?**

- ☐ Yes  
☐ No

**2. Do you have a Risk Management Officer?**

- ☐ Yes  
☐ No

**3. Do you have a Project Risk Management Program?**

- ☐ Yes  
☐ No

**4. Do you perform project risk management assessments?**

- ☐ Yes  
☐ No

**5. Do you believe that risk management assessments save money in overall project\_\_?**

- ☐ Yes  
☐ No

**6. How much money do you believe is saved on a project when risk assessments are performed?**

- ☐ 0%  
☐ 1 - 2%  
☐ 3 - 5%  
☐ 6 - 10%  
☐ 11 - 15%  
☐ 16 - 20%  
☐ over 20%

**7. How are risk assessments performed?**

- ☐ In-house project team personnel  
☐ In-house project team and other company personnel  
☐ Outside consultants  
☐ In-house personnel and outside consultant team  
☐ Other (please specify)

**8. Do you use simulation in risk assessment?**

- ☐ Yes  
☐ No

**9. Do you perform periodic risk assessment updates throughout the project?**

- ☐ Yes  
☐ No

**10. How often are the periodic risk assessments?**

- ☐ Monthly  
☐ Bi-monthly  
☐ Quarterly  
☐ Other (please specify)

**11. Additional Comments on Risk Management:**

**Critical Path Method - Industry Questionnaire**

Exit this questionnaire &gt;&gt;

**→ Thank You and Final Comments****1. Thank you very much for taking the time out of your busy schedule to help with this research.**

If you would like to learn the results of this research, please leave your contact information in the box below. You may also use this box to share any thoughts or comments on CPM scheduling that were not covered within the survey.

## References

- Galloway, P. (2006). "A comparative study of university courses on critical-path method scheduling." *J. Constr. Eng. Manage.*, 132 (7) 712-722.
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