

## CDR.07

# CPM Scheduling and How the Industry Views Its Use

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**D**elivering a project on time does not just mean signing a contract and hoping that the required completion date will be met. More often than not, the majority of today's construction projects encounter events and or changes that affect the original plan for executing a project. Further, resources such as labor and material/equipment may be scarce and in high demand and as a result may hamper project execution. Attempting to solve these unforeseen issues during a project without a plan in place to determine the immediate impact is a major risk which can often lead to delay, disruption and disputes between the parties. Experience over the past 20 years has demonstrated that a well developed, updated and consistently used critical path method (CPM) schedule during a project can increase the probability of a project finishing on time and/or assisting in party-agreed extensions of time. Tracking critical activities with a CPM schedule throughout the project allows a contractor to know when the critical path is changing, what activities are being delayed and the flexibility to resequence and/or develop work around plans for various project activities to avoid project delay. In addition, an accurate, consistently used and updated CPM schedule allows either party to demonstrate the history of how the project was executed and if delays occurred to the project, when, where and what activities were specifically impacted by these delays. Demonstrating how a project was executed and what was critical at the time can be especially useful when resolving disputes that may arise as the project progresses, not just at project completion. Both during the project and at project completion, the negotiation of changes and claims are facilitated through the implementation of a CPM schedule. This process is more cost effective than other dispute resolution alternatives. The net result is improved commercial results.

However, based on personal experience and experience gained over the last 25 years with particular projects around the world, the methods and techniques of CPM scheduling vary widely on any construction site. CPM methodologies in delay analyses also vary widely amongst experts testifying on delays after the fact. In light of these differences, a crying need has emerged for standards for CPM scheduling and delay analyses; a common ground from which terms, definitions and applications can be universally understood. In determining what recommendations might be reasonable in the area of scheduling standards, one area to be examined is how CPM scheduling is being taught in universities, how

CPM scheduling is being described and discussed in the professional arena, and how CPM scheduling is being applied in reality in the field.

This paper summarizes extensive research that was performed of universities in the US, Europe and Asia and of stakeholders involved in a construction project including the owner, engineer, construction manager and contractor, relative to the industry's views of CPM scheduling applicability and usefulness in planning and executing projects. A total of 108 universities were researched, including 71 in the US, comprising over 50 percent of those schools indicating that they have a construction management program and nearly 80 percent of those who are a member of the Associated Schools of Construction, Canada and Trinidad, 17 in Europe and 20 in Asia. The university research included a review of the following specific areas:

- Whether the course was a dedicated course to CPM scheduling or whether it was part of a more general course on project management;
- The course syllabus relative to the specifics that are being taught;
- The textbooks used in the course;
- The reference material, in addition to the textbook, used in the classroom;
- The software, if any, that is used in the computer applications of CPM scheduling.

Relative to the construction industry survey, surveys were sent to members of: the construction institute (CI) of the American Society of Civil Engineers (ASCE); the Construction Management Association of America (CMAA); The American General Contractors (AGC); Project Management Institute College of Scheduling (PMICOS); and AACEI's National Planning and Scheduling Committee. A total of 429 responses were received composed of approximately 41 percent owners ,private and government, 31 percent contractors, 19 percent engineers and 19 percent construction managers. The remaining respondents were from universities and consultants serving the construction industry. 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 disadvantage of CPM scheduling.
- Success of CPM scheduling usage.
- Personnel qualifications for schedulers.
- Opinions relative to CPM scheduling standards and best practices.
- Opinions relative to university curriculums for the study of CPM scheduling.
- Use of CPM schedules in claims avoidance and claims preparation.

### 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 amongst all stakeholders relative to the following points:

- CPM scheduling has become a standard project control tool and both owners and contractors use the tool whether it is or isn't required by contract.
- While all parties generally felt that CPM scheduling was a good project control tool for monitoring, planning and executing a project, CPM scheduling has become so sophisticated that specialists in CPM scheduling are now required to develop and understand CPM schedules. While Primavera software is the number one choice amongst the stakeholders, it is believed to be complex and difficult to understand thus increasing the cost to the project.
- CPM schedules are easily manipulated, especially with respect to logic abuse.
- The majority of those responding indicated that they believed certification of schedulers would improve the industry.
- 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.
- Over 92 percent 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.
- Most participants agreed that there should be consistency in university curriculums. However, as noted in the university survey below, there is no consistency in the universities as to

how CPM scheduling is taught. By the answers to the 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 non-standard development, usage and interpretation of results from CPM schedules.

### UNIVERSITY COMPARATIVE STUDY

Of the 71 schools that responded to the request for course curriculum regarding the teaching of CPM scheduling, almost a third of the courses were part of a general course on construction management and were not a separate and specific course teaching solely critical path method scheduling. These schools did not generally indicate whether specific software was used or not and from the material received, it was unclear as to whether computerized scheduling was even part of the class curriculum.

Of the 50 schools that did have a specific course on CPM scheduling, the vast majority used the Primavera software in the teaching of computerized scheduling. Only four schools indicated that Microsoft Project (MS Project) was the software that was used in the classroom, though seven schools did indicate that in addition to Primavera, an introduction to MS Project was also taught as part of the curriculum.

With respect to the general courses, there was no consistency in the topic areas that were included other than the definition of CPM scheduling, its use and the basic calculation of how to develop and use a network diagram. There were a handful of schools that discussed its use in delay applications, risk allocation, life cycle analysis, critical chain theory and Monte Carlo simulations. The general courses focused more on the application of project management and the use of scheduling as a control tool.

With respect to the schools that had specific courses on CPM scheduling, almost every school curriculum noted the instruction of resource leveling, resource allocation and crashing of a schedule to meet compressed time schedules. While it is assumed that the schools instruct in both arrow and precedence diagramming methods, only approximately 25 noted arrow diagramming and approximately 37 noted only precedence diagramming. Approximately 25 indicated the instruction of PERT and approximately 20 indicated instruction in linear scheduling.

However, the real surprise came when researching what textbooks were used in the classroom. In this research, it became clear that the textbook selected was a choice of the professor and clearly the choices of the professor were independent of what was being used in the industry or in other universities or colleges. Over 39 different textbooks are used in North America in the instruction of CPM scheduling. Only a few textbooks were used in more than a couple universities. These textbooks included:

- *Construction Planning and Scheduling*—American General Contractors.
- *Construction Planning and Scheduling-Special Edition Using Microsoft Project*—J.W. Hinze.
- *Construction Scheduling With Primavera Project Planner*—D. Marchman.

- *Construction Project Scheduling*—Callahan, Quankenbush, and Rowings.
- *Construction Scheduling With Primavera Project Planner*—L. Feigenbaum.
- *Construction Scheduling with Sure Trak*—D. Marchman
- *Construction Project Administration*—E. Fisk.
- *Managing the Construction Project; Estimating, Scheduling, and Project Control*—F. Gould.

Universities also had no common base in the reference books that they suggested as reading and guides for the classroom. Over 40 different reference books were noted in the schools that responded to the request for information.

## 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 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.

### Owner Specification Requirements for CPM

Of the owners that responded, only 47.6 percent indicated that CPM scheduling is always required on their projects. Of those requiring CPM scheduling, 72.5 percent do specify CPM scheduling in their contracts, but only 55.9 percent 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 percent of the owners indicated that they used Primavera as their specified software with only just over 20 percent requiring MS Project. Other software mentioned included:

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

Interestingly, while almost 46 percent of the owners indicated that they require precedence diagramming methods, 14 percent indicated that they still require arrow diagramming CPM scheduling. This then correlates to why there was a corresponding percentage of owners that require MS Project as the specified software as Primavera software does not support arrow diagramming. In addition, owners indicated the preference for using of other scheduling techniques including: almost 50 percent indicated their preference for bar charts or some form thereof; 27 percent indicating that they use PERT; 4 percent indicated requirements for 4D planning; and another 20 percent 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 percent required schedule revisions. However, only 68 percent 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 two thirds of those responding. Almost 50 percent also indicated that they limited activity durations and nearly 65 percent 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 percent were primarily concerned with manpower loading on activity, while only 50 percent 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 percent between:

- Project behind schedule,
- Change orders.

The next major reason cited was critical path changes, 56 percent. 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.
- 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 line of balance 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. 4D modeling was discussed as primarily being used before the 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:

- The construction managers and project managers do not use the software enough to be knowledgeable in its use and what it is portraying;
- 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 percent of the contractors responding noted that they now find that their contracts require CPM scheduling. If CPM scheduling is not required, nearly 67 percent 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 percent indicated that they prefer to use Primavera software, with only 22 percent 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 percent did believe resource loading was useful, and 15 percent 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 included:

- Periodic control of work after start of construction, 85 percent;
- Developing look-ahead schedules, 85 percent;

- Coordination of subcontractors—82.1 percent;
- Detailed planning of work prior to construction—78.1 percent;
- Schedule impact, claims analysis and tracking of changes—75 percent;
- Coordination of own trades—59 percent;
- Estimating and bidding—44 percent;
- Tracking shop drawings and submittals—39 percent;
- Calculating payment requests for work performed—31 percent;
- Design development—28 percent;
- Operation and maintenance of projects—22 percent;
- Tracking costs—18 percent;
- Materials planning—less than 3 percent.

Over 80 percent 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 percent indicated that they did and 52 percent indicated that they did not. The remaining respondents indicated that they would prepare a separate schedule based on:

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

**Advantages**—Over 96 percent of the contractor responding indicated that they believed that there was an economic benefit to using CPM, and over 89 percent 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 included:

- Improved planning before work starts—92 percent;
- Improved scheduling—84 percent;
- Improved understanding of the project—83 percent;
- Improved project control after work starts—80 percent;
- Improved communications among the workforce—54 percent;
- Increased control over risk and uncertainty—53 percent;
- Reduced delays—50 percent;
- Minimization of disputes between the contractor and owner—46 percent;
- Time savings—39 percent;
- Faster response to problems—34 percent;
- Cost savings—30 percent;
- Improved estimating/bidding—28 percent;

- Helps train future project managers—26 percent;
- Positive psychological effect on employees—22 percent.

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 to accurately plan ahead;
- Useful tool to discuss issues that could be clearer;
- Gets owners to react more quickly;
- Basis for earn value cost pre-planning, cost reporting and time job cost control;
- If owner approved, easier to show delays;
- Easily flags adverse trends against the baseline schedule;
- Allows ability to do "what if" scenarios.

**Disadvantages**—Nearly 40 percent 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 included:

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

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

- Must be kept up to date if it is to be relied upon;
- No one knows how to use it properly;
- Too much interpretation which leads to owner mistrust and misuse;
- Owners attempt to use the CPM schedule against the contractor instead of working with the contractor to resolve delays and impacts;
- Not understood by laborers or superintendents;
- Requires users trained in CPM scheduling;
- P3 graphics are difficult to read;
- 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 employees an overall manager for planning and scheduling with 59 percent indicating that they did not and the other 41 percent indicating that they did. However, this percentage switched slightly with respect to specific projects, with 57 percent of the respondents indicating that they did employ a person solely dedicated to this effort, while 43 percent indicated that they did not. Of those

employing a dedicated scheduler, 84 percent responded that this individual is expected to perform other tasks in addition to CPM scheduling. Sixty-seven percent indicated that their scheduling is performed by in-house personnel while only 7 percent 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 percent indicated that they preferred someone with an engineering background, and 44 percent 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:

- On-job training—41 percent;
- Undergraduate Engineering degree—39 percent;
- Scheduling Training/Coursework—36 percent;
- No credentials needed—14 percent;
- Undergraduate degree in construction management—13 percent;
- Graduate degree—10 percent;
- Graduate degree in construction management—5 percent.

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

- Masters degrees,
- Professional engineering license,
- Five years experience on comparable projects,
- Prior experience,
- Certification such as Project Management Professional (PMP), Certified Cost Engineer (CCE), ICEC certification, AACEI schedule certification, and
- Field experience.

### CPM AND CPM STANDARDS

When asked for the reasons why CPM scheduling was used, over 82 percent 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:

- Contract requirement—63 percent,
- Claims, after the fact—53 percent,
- Change Management—47 percent,
- Anticipated shifts in funding needs,
- Understanding true delay,
- Earned value management,
- Bid evaluation,
- Coordination of multiple construction projects,
- Identification of delay issues,

- Bases for 3-week look-aheads, and
- Assists in getting buy-in from subcontractors.

The primary uses of CPM scheduling were noted to be:

- risk assessment—57 percent,
- reduction of claims—55 percent,
- projects are more cost efficient—39 percent,
- to meet a contract requirement—18 percent,
- assists in claim presentations—10 percent, and
- assists in completing the project on time—10 percent.

Those responding also indicated that 66 percent of their senior management used and relied upon the CPM schedules in making decisions, while 25 percent indicated senior management did not use the schedules, and nine percent 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—79 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 percent of those responding indicating that they simply did not know. In addition, over 58 percent indicated that certification of schedulers would improve the industry, and a surprising 92 percent of those responding indicated that best practices guidelines should be developed that could be made available to owners and contractors.

While 78 percent of those responding indicated that they believed that it was important to have a consistent university curriculum for CPM scheduling, only 17 percent had indicated that they had ever reviewed a university curriculum to see what was being taught at the university level.

### CLAIMS AVOIDANCE AND THE USAGE OF CPM SCHEDULING

Over 67 percent of the survey respondents indicated that the use of CPM scheduling minimized claims on their projects. Over 82 percent indicated that they used CPM scheduling in claims resolution, and of those responding that they used CPM schedules in their claim resolution, over 85 percent indicated that they used the existing schedules that were used during the project. Further, over 84 percent indicated that they believed the use of CPM scheduling was essential in delay claim resolution. However, the methodologies for CPM delay analyses greatly varied with the following noted as being methods that have been used by respondents:

- as-built—75 percent,
- as-impacted—57 percent,
- time impact analysis—53 percent,
- contemporaneous—22 percent,
- window analyses—20 percent,
- collapsed as-built—15 percent, and
- varied depending on project—9 percent.

**H**aving been in the construction industry for nearly 26 years, and having been a hands-on scheduler on billion dollar programs, assisted contractors and owners in the preparation of schedules, used schedules in risk assessments and finally having used in CPM scheduling in the analysis of claims testifying on the results of those analysis; the results of the survey are not surprising to me. I have personally observed the findings that are presented herein and in my own opinions believe that immediate reform is needed for CPM scheduling in the following areas:

- 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.
- The professional organizations, AACEI, ASCE, CMAA, AGC, PMICOS, DBIA, etc., need to come together in a coalition to address what is required relative to standards for CPM scheduling and to move those standards to 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.
- 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.
- 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.

It is my personal opinion that 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.

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