Lost in the CPM Details?

By: Dr. Gui Ponce de Leon, PE
John M. Zann, PE

Preface

It is not uncommon for construction CPM schedules for projects exceeding $50M+ in construction costs to encompass over 3,000 activities. Along with the 3,000+ activities, a schedule of this sort could easily contain 6,000+ logical ties, many of which may include leads/ lags. Even with all the advanced sorting, grouping, and filtering capabilities of today's CPM software, a schedule this large can be cumbersome at best; at worst it is a useless time-sink that requires valuable resource hours each month to update and is truly understood by no one.

Further compounding the issue, in today's construction industry, the scheduler is often not really a planner, but rather a 'software jockey', for lack of a better term. He or she is likely quite proficient in the scheduling software of choice, but often times a junior-level person with limited field experience to draw from. Likewise, it is common that the planners on the project (typically the project manager and superintendents) are not fluent in the protocols of the CPM software package of choice. Therefore, the disconnect may be set from the start, with each party fluent in their own expertise, but with only a basic understanding of their counterpart's. As a result, the scheduler frequently acts as a scribe or surrogate planner endeavoring to portray through the CPM software the plan as envisioned by the project manager (PM) and superintendents, however, sometimes subtle details are lost in the translation from project manager/superintendents to scheduler to CPM software. Following the initial input of the schedule, the iterative review process begins. Typically this consists of the scheduler passing a hardcopy of the CPM output along for comments. Due partially to time constraints as well as potential lack of understanding of the CPM software details, this review does not typically include any detailed review of logic ties and constraints and includes perhaps only a cursory review of such basic elements as durations. The more likely focus of the review is the projected finish dates for key project milestones. The obvious problem of this scenario is the scheduler knows the software and the PM/superintendents know the project, but neither knows enough of the other to ensure a tight project schedule. Once the baseline is set in this manner, there is distinct potential that the newly anointed baseline schedule is wrought with pitfalls. Likely, updates of the schedule proceed in this similar iterative process, and the pitfalls of the baseline are unearthed (and not necessarily corrected) as the updates continue, only compounding the problems.

The above situation is certainly not meant as an indictment of the scheduling profession, but the pattern, as lived by one of the authors, is rather well established. In this case, the co-author spent much of the first five years of his career as a self-proclaimed (in hindsight) 'software jockey', understanding in great detail how to make a schedule show exactly the dates the PM/superintendents wanted to see. Dates were sometimes accomplished with a series of negative lags, questionable SS and FF logic ties, and a liberal use of constraints. As the author became more self-aware of the big-picture, he realized these schedules frequently lacked relevance due to the manner in which they were built and updated and he became increasingly disenchanted with this lack of relevance. The only real relevance some of the schedules had was as a response to a requirement of the contract documents. Well-intended to be sure, these requirements were often times so rigorous and restrictive as to further render the schedule pointless as an actual planning and/or communication tool.

The disconnect between a schedule and reality was even more manifest when developing CPM schedules for subcontractors, who merely wanted a schedule they could 'throw over the fence' to the owner's team (through the prime contractor) to satisfy the aforementioned restrictive contract requirements. In any one case, the project manager for the subcontractors always kept a working schedule 'off-line' that was the actual work plan to be performed. This working schedule could take many shapes, depending upon the specific project, ranging from a detailed Microsoft Project schedule to a 'to do' list written in a field book. Rarely did the working schedule align with the contract schedule, except for perhaps the project end date. In some extreme situations, the subcontractor's project manager looked favorably on unnecessary complexity in the contract schedule so as to potentially confuse/confound the prospective owner's reviewers of the schedule. As a response, often times, the reviews of these schedules would become reams of computer output, focusing on things such as negative lags and a few open-ended activities, instead of more relevant items such as out-of-sequence work and planned vs. actual progress. The review of a massive CPM schedule often takes weeks for the owner's representative to complete, and then incorporation and response to comments and questions by the prime contractor can take several more weeks. This type of timing can certainly further jeopardize the legitimacy of the schedule, as it becomes out of phase with the work often times by a month or worse. In these cases, the only people to really know the details of the schedule were the author and the reviewer - not the subcontractor, not the contractor, and certainly not the owner's representative professionals.

Schedule Detail Continuum

Consider a $100M high-rise hotel project with a 2-year construction duration. Taken to the extremes of the schedule detail continuum, construction for this project could be scheduled using either of two extremes:

Option 1 - The schedule consists of one 2-year activity labeled ‘construction’.

Option 2 - The schedule is broken down into minute detail, consisting of detailed activities for all procurement, submittals, approvals, re-submittals, deliveries, installation, commissioning, FF&E install, etc. As an example of the detail in this option, no single activity has a duration exceeding one week. Total activities: 10,000. Total logic ties: 20,000.

Both options have significant and obvious shortfalls and positive attributes, chiefly amongst them:

Negative Attributes	
Option 1	Option 2
No ability to track progress vs. plan	Regular updates take excessively long
No ability to predict finish date	No individual can understar the entire schedule

Positive Attributes	
Option 1	Option 2
Extremely quick to update (i.e., 1 minute)	Each day can be scheduled
Easy for stakeholders to understand (but useless)	Can tie payment to schedule successfully

Clearly, the optimum location on the continuum falls somewhere between Options 1 and 2. The industry frequently tends to veer too near Option 2 and the negative attributes of Option 2 shown above are prevalent.

Prime and Crucial Milestones Protocol

The protocol provided will work with almost any type of project, *providing there is sufficient historical benchmarking milestone data from similar projects*. This point is of utmost importance and worth repeating – the thinking is to use lessons learned followed by judgment. For firms that have managed or built similar projects over the years, this data should be available to harvest and add to as additional projects are completed.

The specific steps are as follows:

1. **Identify project parameters/metrics** - Compile basic information on the project, including items such as total GSF, type of foundations, frame type…. This identification of project parameters helps in the selection of similar projects from which to pull the schedule data.
2. **Define Prime Milestone 1** - This Milestone will be referred to as M1 and should be a milestone that is typically scheduled for somewhere near the middle of the project duration, which in a building would constitute the turn-over from core & shell to interior work. In this light, the most typical M1 (Prime) Milestone would be Building Enclosure.
3. **Define Prime Milestone 2 –** This Milestone will be referred to as M2 and should occur at or near the end of the project and will likely be either Substantial Completion, Certificate of Occupancy, or Final Completion.
4. **Determine Crucial Milestones** - Select Crucial Milestones for each Prime Milestone (for two Prime Milestones, depending on phases, phase duration and project complexity, seven to fourteen may make sense for a two to three year construction phase). As the process is implemented on more and more projects, the Crucial Milestone selection (and for that matter Prime Milestone choice) will likely become repetitive and quick. Assign each Crucial Milestone to the more pertinent Prime Milestone - it will be obvious which of the two Prime Milestones each Crucial Milestone is associated with. For example, Complete Structural Steel Erection would be linked to M1 – Building Enclosure. Number each Crucial Milestone in order, using the Prime Milestone it is associated with as the prefix. For example, Complete Structural Steel Erection may be M1-1. Note that M1 needs to also be a crucial milestone to M2.
5. **Normalize Comparable Schedule Data, Calculate Dates** - Examine and normalize actual schedule data from similar project types for these Milestones. Based on the normalized data, select the number of calendar days between each Crucial Milestone and pertinent Prime Milestone. Calculate the dates for the Milestones. An example is shown in the paragraphs that follow. Obtain consensus from project management and supervision that the intervals are accurate for the project to a 2% to 5% tolerance
6. **Milestone Display for Monitoring–** Put the schedule into a format for tracking. Two suggestions are either a CPM format or a milestone table.

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Example Project

To better convey the principals described above, we will now walk through an example.

1. Identify project parameters - The example project consists of a new, high-rise 4-star hotel project. Project specifics:

Item	Detail
Keys	300
Stories	20
Total GSF	350,000
Foundation	H-Piles
Frame	CIP Concrete
Slabs	CIP Concrete
Skin	Glass curtainwall
Finishes	High-end, stone, millwork
Site	Minimal demo

2. Prime Milestone 1 – M1 = Building Enclosure
3. Prime Milestone 2 – M2 = Substantial Completion
4. Crucial Milestones – These milestones are typical of the types of milestones that would be expected for similar architectural projects. Note that Prime Milestone M1 is also a Crucial Milestone vis-à-vis M2. This is required in order to be able to calculate all the dates.

M1 – Building Enclosure

M1.1 = Start Construction
M1.2 = Start Foundations
M1.3 = Erect Tower Crane
M1.4 = Start Above Grade Frame
M1.5 = Foundations Complete
M1.6 = Erect Man/Material Hoist
M1.7 = Start Exterior Skin
M1.8 = Slab-on-Grade Complete
M1.9 = Concrete Topped-Out
M1.10 = Remove Tower Crane
M1.11 = First Elevator Operational
M1.12 =Remove Man/Material Hoist
M1.13 = Complete Exterior Skin

M2 – Substantial Completion

M2.1 = Permanent Power Available
M2.2 = Initial Floor of Guest Rooms Complete (FF&E can start)
M2.3 = Chilled Water Available
M2.4 = Building Enclosure (note, this is also a prime milestone)
M2.5 = Conditioned Air Available
M2.6 = Restaurant Millwork Delivered
M2.7 = Fire Command Center Complete

M2.8 = Elevators Operational

M2.9 = MEP Systems Ready for Startup

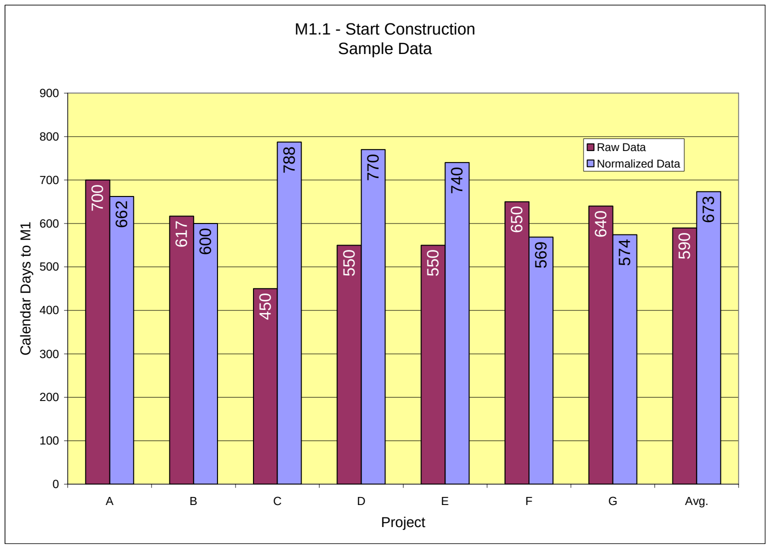
M2.10 = Back of House Areas Complete

M2.11 = Top Floor of Guest Rooms Complete

M2.12 = TCO Issued

M2.13 = Lobby Complete

5. Normalize comparable schedule data – The graph below shows typical schedule data for one Crucial Milestone, M1.1 – Start Construction. All values represent the number of calendar days between M1.1 and M1. There are seven projects of data as well as an average of the seven projects shown. The red bars represent the raw data for each project and the blue bars represent the normalized data, based on project SF.



Shown in tabular form for all Milestones, the data looks like this, with Column 12 showing the normalized days for each Milestone:

M1 Normalized Data

1		2	3	4	5	6	7	8	9	10	11	12	13
		A	B	C	D	E	F	G	Min.	Max.	Avg.	Sample	Sample
GSF (x000)		370	360	200	250	260	400	390	200	400	314	350	Dates
M1-1. Start Construction	Actual Days to M1	700	617	450	550	550	650	640	450	700	590		
	Normalized Days to M1	662	600	788	770	740	569	574	569	788	673	673	3/1/08
M1-2 Start Foundations	Actual Days to M1	679	526	500	454	322	567	432	322	679	498		
	Normalized Days to M1	642	511	875	636	433	496	388	388	875	583	583	5/30/08
M1-3 Erect Tower Crane	Actual Days to M1	563	359	200	246	275	388	376	200	563	352		
	Normalized Days to M1	533	349	350	344	370	340	337	337	533	388	388	12/11/08
M1-4 Start Above Grade Concrete/Steel	Actual Days to M1	552	245	201	255	202	405	380	201	552	333		
	Normalized Days to M1	522	238	352	357	272	354	341	238	522	355	355	1/13/09
M1-5 Foundations Complete	Actual Days to M1	451	434	230	270	240	410	380	230	451	344		
	Normalized Days to M1	427	422	403	378	323	359	341	323	427	378	378	12/21/08
M1-6 Erect Man/Material Hoist	Actual Days to M1	448	427	300	330	340	380	350	300	448	369		
	Normalized Days to M1	424	415	525	462	458	333	314	314	525	419	419	11/10/08
M1-7 Start Exterior Skin	Actual Days to M1	385	189	180	220	248	405	384	180	405	288		
	Normalized Days to M1	364	184	315	308	334	354	345	184	364	306	306	3/3/09
M1-8 SOG Complete	Actual Days to M1	353	291	190	220	235	388	364	190	388	291		
	Normalized Days to M1	334	283	333	308	316	340	327	283	340	318	318	2/19/09
M1-9 Concrete/Steel Topped Out	Actual Days to M1	325	284	160	184	203	374	344	160	374	268		
	Normalized Days to M1	307	276	280	258	273	327	309	258	327	291	291	3/18/09
M1-10 Remove Tower Crane	Actual Days to M1	227	37	24	32	38	39	35	24	227	76		
	Normalized Days to M1	215	36	42	45	51	34	31	31	215	78	78	10/17/09
M1-11 First Elevator Operational	Actual Days to M1	50	104	50	43	47	38	55	38	104	59		
	Normalized Days to M1	47	101	88	60	63	33	49	33	101	64	64	10/31/09
M1-12 Remove Man/Material Hoist	Actual Days to M1	45	67	35	22	32	42	35	22	67	41		
	Normalized Days to M1	43	65	61	31	43	37	31	31	65	45	45	11/19/09
M1-13 Complete Exterior Skin	Actual Days to M1	4	64	50	20	30	40	55	4	64	37		
	Normalized Days to M1	4	62	88	28	40	35	49	4	88	44	44	11/20/09
M1 Building Enclosed													1/3/10

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M2 Normalized Data

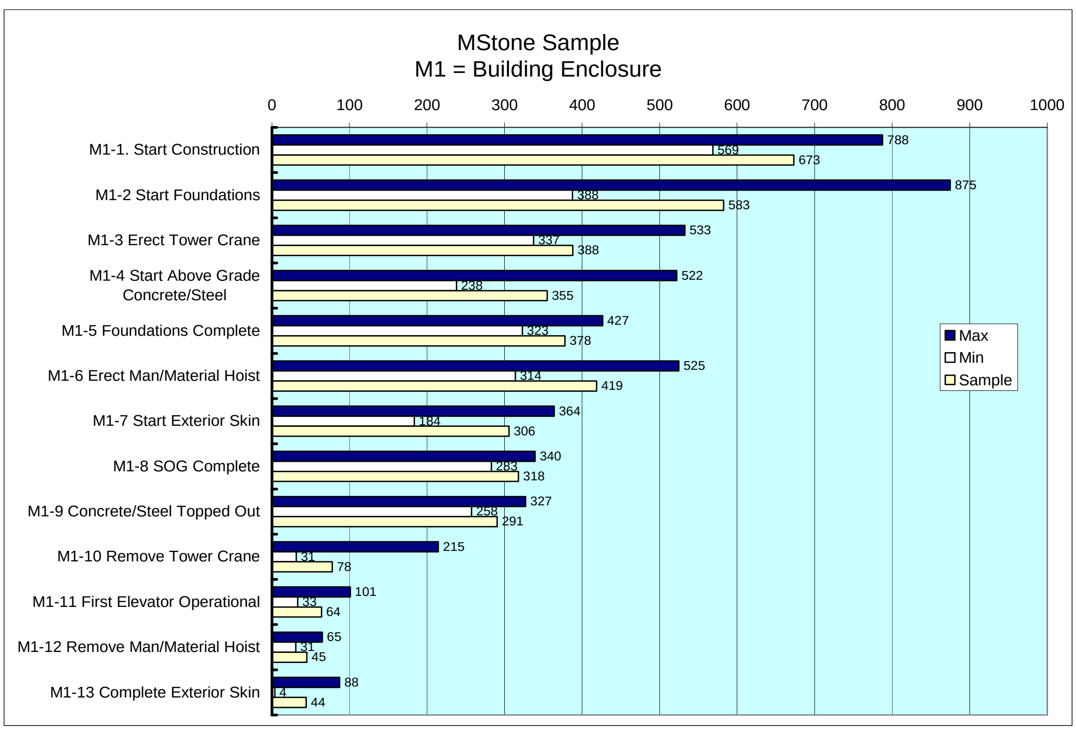
1		2	3	4	5	6	7	8	9	10	11	12	13
		A	B	C	D	E	F	G	Min.	Max.	Avg.	Sample	Sample
GSF (x000)		370	360	200	250	260	400	390	200	400	314	350	Dates
M2-1. Permanent Power Available	Actual Days to M2	137	167	100	105	110	130	140	100	167	128		
	Normalized Days to M2	130	162	175	147	148	114	126	114	175	143	143	11/14/09
M2-2 Initial Floor of Guest Rooms Complete (FF&E Start)	Actual Days to M2	130	99	85	90	95	105	110	85	130	103		
	Normalized Days to M2	123	96	149	126	128	92	99	92	149	117	117	12/10/09
M2-3 Chilled Water Available	Actual Days to M2	123	61	70	80	84	76	91	61	123	85		
	Normalized Days to M2	116	59	123	112	113	67	82	59	123	95	95	1/1/10
M2-4 Building Enclosed	Actual Days to M2	109	82	50	75	89	78	99	50	109	82		
	Normalized Days to M2	103	80	88	105	120	68	89	68	120	93	93	1/3/10
M2-5 Conditioned Air Available	Actual Days to M2	109	47	60	70	75	84	68	47	109	74		
	Normalized Days to M2	103	46	105	98	101	74	61	46	105	82	82	1/14/10
M2-6 Restaurant Millwork Delivered	Actual Days to M2	95	44	50	55	57	61	48	44	95	61		
	Normalized Days to M2	90	43	88	77	77	53	43	43	90	67	67	1/29/10
M2-7 Fire Command Center Complete	Actual Days to M2	74	80	40	55	78	94	52	40	94	67		
	Normalized Days to M2	70	78	70	77	105	82	47	47	105	76	76	1/21/10
M2-8 Elevators Operational	Actual Days to M2	67	34	40	45	63	28	52	28	67	47		
	Normalized Days to M2	63	33	70	63	85	25	47	25	85	55	55	2/10/10
M2-9 MEP Systems Ready for Start-up	Actual Days to M2	53	31	40	45	57	60	61	31	61	49		
	Normalized Days to M2	50	30	70	63	77	53	55	30	77	56	56	2/9/10
M2-10 Back of House Areas Complete	Actual Days to M2	39	30	31	35	38	41	29	29	41	35		
	Normalized Days to M2	37	29	54	49	51	36	26	26	54	40	40	2/25/10
M2-11 Top Flr Guest Rooms Complete	Actual Days to M2	39	23	22	27	28	35	21	21	39	28		
	Normalized Days to M2	37	22	39	38	38	31	19	19	39	31	31	3/6/10
M2-12 TCO Issued	Actual Days to M2	25	30	23	25	21	22	28	21	30	25		
	Normalized Days to M2	24	29	40	35	28	19	25	19	40	29	29	3/8/10
M2-13 Lobby Complete	Actual Days to M2	14	5	6	10	20	25	14	5	25	14		
	Normalized Days to M2	13	5	11	14	27	22	13	5	27	15	15	3/22/10
M2 Substantial Completion													4/6/10

Column 13 shows the calculated dates for each Milestone. These dates are calculated in either of the following two ways, depending on whether the start date or the finish date is known:

a. Project Start Date is Known - start with the M1 Milestones. Set M1-1 equal to the projected start date and than calculate the M1 date as the projected start date + days shown in column 12. In this example, if the projected start date is known to be 3/1/08, then M1 becomes 3/1/08 + 673 calendar days = 1/3/10. All the other dates for the M1 Crucial Milestones are then calculated as M1 – column 12. For example, M1-2 becomes 1/3/10 – 583 = 5/30/08.

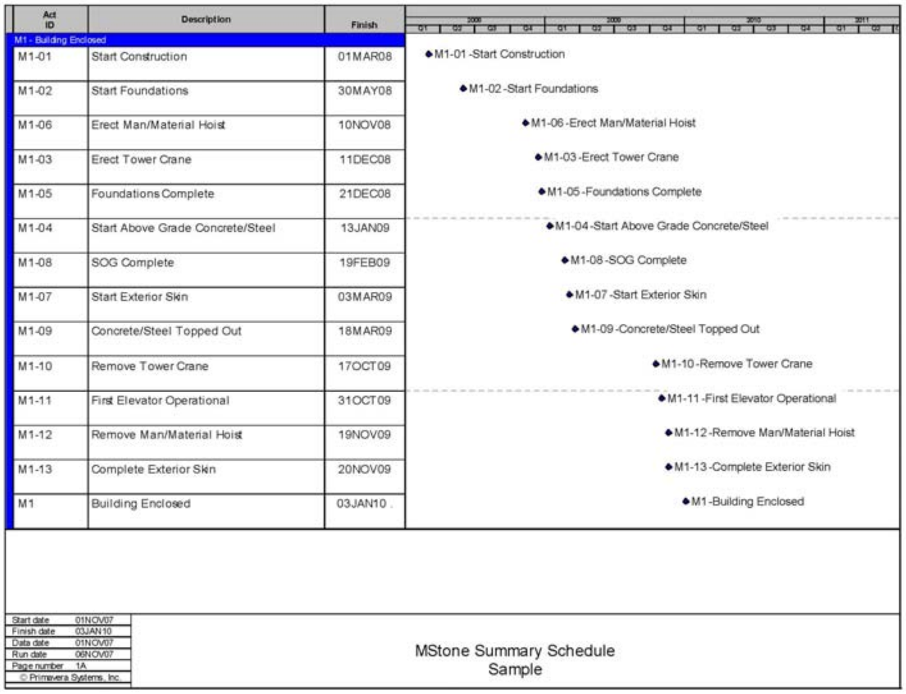
   Once dates for all Crucial Milestones relate to M1 are calculated, then calculate the M2 date based on the M1 date, where M2 becomes M1 + days shown in column 12. In this example, M2 = 1/3/10 + 93 = 4/6/10. Lastly, calculate all M2 Crucial Milestones based on the calculated M2 date.

b. Project Finish Date is Known - start with the M2 Milestones. Set M2 equal to the end date, and calculate all M2 dates as M2 – column 12. Transfer the M1 date from the M2 table to the M1 table and calculate all M1-related Crucial Milestone dates.



The graph above compiles the data for each Crucial Milestone affiliated with M1. The blue bars represent the maximum days between each Crucial Milestone and the Prime Milestone and the white bars represent the minimum. The yellow bars represent the normalized days for our sample schedule. For example, M1-1 has a max of 788, a min of 569, and an expected value of 673.

5. **Revise schedule format for tracking** – The last step is to take the schedule data and put it in a usable format. The data could be loaded into CPM software, as shown below:



Act ID	Description	Finish
M1 - Building Enclosed		
M1-01	Start Construction	01MAR08
M1-02	Start Foundations	30MAY08
M1-06	Erect Man/Material Hoist	10NOV08
M1-03	Erect Tower Crane	11DEC08
M1-05	Foundations Complete	21DEC08
M1-04	Start Above Grade Concrete/Steel	13JAN09
M1-08	SOG Complete	19FEB09
M1-07	Start Exterior Skin	03MAR09
M1-09	Concrete/Steel Topped Out	18MAR09
M1-10	Remove Tower Crane	17OCT09
M1-11	First Elevator Operational	31OCT09
M1-12	Remove Man/Material Hoist	19NOV09
M1-13	Complete Exterior Skin	20NOV09
M1	Building Enclosed	03JAN10

Alternatively, a simpler solution is to track the data within a table, as portrayed below for a real project. The Original Target Date is the data generated from above, and the Actual or Current Forecast Date is input and refined as the project progresses. This type of schedule visualization is easily understood by project stakeholders, even down to the color coding of actual dates (green = met target, yellow = met within 1 week of target, red = more than 1 week behind target).

Description	Original Target Date	Actual or Current Forecast Date
Hotel Open	11JAN08	11JAN08
Substantial Completion	21DEC07	21DEC07
Site Work Complete	17DEC07	17DEC07
West Wall and Canopy Complete	10DEC07	10DEC07
1st Floor Lobby Entry Complete	7DEC07	7DEC07
TCO Issued	26NOV07	26NOV07
21st Floor Guest Rooms Complete (FFE to Start)	12NOV07	12NOV07
Back of House Areas Complete	12NOV07	12NOV07
MEP Systems Ready for Start-up	29OCT07	29OCT07
Elevator Cabs 1-4, 7 & 8 Operational	15OCT07	16NOV07
Fire Command Center Complete	8OCT07	8OCT07
Bar – Back Wall Millwork Delivered	19SEP07	5NOV07
Conditioned Air Available (Common Space)	3SEP07	22OCT07
Building Enclosed	3SEP07	24SEP07 A
Chilled Water Available	23AUG07	12OCT07
6th Floor Guest Rooms Complete (FFE to Start)	17AUG07	17AUG07 A
Permanent Power Available	8AUG07	13AUG07 A

Notes: A = actual date, Green = met target, Yellow = within 1 week of target, Red = more than 1 week behind target

Concluding Remarks

Some project management teams find limited value with a massive CPM schedule that requires one (or more) FTEs to update and maintain. Others do not get any value but continue to produce these large schedules because of prescriptive contract documents, or maybe simply "because that's how we always do it". Either way, the authors challenge all project management teams to reflect on their current scheduling methods and improve on them to bring value back into planning/scheduling. For those that determine their current scheduling protocols need to be supplemented, one option is to try the above process. Certainly, it is not meant to replace traditional CPM scheduling, rather, it is intended to serve as an optional system for developing a scheduling framework that is quick, accurate, and easily understood by all project stakeholders.

Notes

1. Ponce de Leon, Gui (2008). *Graphical Planning Method (A New Network-Based Planning/Scheduling Paradigm).* PMICOS 5th Annual Conference, Chicago, IL. For a more radical departure from CPM practice, refer to this kick-off treatise on GPM and the Logic Diagramming Method. Unlike the milestone protocol described in this treatise, GPM provides all the requisite functionality for those looking for a planning technique that renders "getting lost in the CPM details" a non-issue.

2. Salem, O, Solomon, J., Genaidy, A., and Minkaraah, I. (2006). *Lean Construction: From Theory to Implementation.* Journal of Management in Engineering, ASCE. Authors discuss the transfer of lean manufacturing techniques to construction, with increased visualization cited as one of the key six lean construction techniques. "Project Milestones – the project personnel were not regularly informed of completion dates at the beginning of the study. Once designs were designed, completion dates were plotted and posted floor by floor throughout the project. At the end of the study, most workers stated that they felt more involved in the execution of the project."