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A Continuously Changing As-Planned Baseline?

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Virtually all forensic schedule analysis methodologies require an as-planned schedule. The issues associated with identifying and as-planned schedule and perhaps modifying this schedule are familiar to forensic schedule experts. But what if, the planned schedule is created with built-in changes from the contract as bid, and is then modified virtually continuously over a period of years as conditions continue to change? How does a contractor or an owner evaluate impact on the contractor's performance? For that matter, how does a forensic scheduling expert identify and quantify delays, impacts and accelerations?

OVERVIEW OF PROBLEM

The issues discussed in this article are real. They were faced by the two authors when working on opposite sides of one of the largest disputes associated with the Central Artery/Tunnel (CA/T) in Boston: The Big Dig.

The Central Artery/Tunnel Program is the largest, most complex and technologically challenging highway program ever attempted in American history. It is the largest federally-funded public work project in history, noted as "bigger than the Panama Canal or the Hoover Dam," consisting of 161 lane-miles (the majority of which is underground at depths up to 120 feet), and requiring excavation of 18 million cubic meters of earth and placement of 4 million cubic yards of concrete (enough to build a foot path three feet wide from Boston to San Francisco and back three times). The casting basis, built on site for construction of the submersed tunnel sections at the Fort Point Channel, was large enough to hold three Titanics. The program will dramatically reduce traffic congestion and improve mobility in one of America's oldest and most congested major cities, improve the environment, and lay the groundwork for continued economic growth for millions of New Englanders in the coming new century. While planning commenced in the mid 1980s, actual construction did not start until 1992.

As 2005 commenced, the construction is over 90 percent complete and dozens of major construction contracts have been awarded, with untold engineering and management contracts. The current program is scheduled to be completed in 2005 with an overall program cost in excess of $14 billion.

The complex program was divided into hundreds of individual construction contracts, such that the largest, with one or two exceptions, was limited to approximately $90 million. The CA/T and its consultants managed the scheduling of the Big Dig through a master program scheduling system that required each construction schedule to match up to a master schedule, known as a construction schedule update, or CSU. This would allow the overall decision makers to review program and individual project progress at a relatively high level. Thus, while the summary master schedule had between 1,500 to 2,000 activities, the overall program was run using schedules that had a total activity count of over 50,000.

Not surprisingly, the CA/T maintained a large and sophisticated scheduling staff to oversee the development, integration and updating of the decade-long scheduling program. As previously discussed, each contractor performing a portion of the work was required to prepare its own detailed construction schedule to be integrated by the program manager (Bechtel/Parsons Brinkerhoffer, or B/PB) within the master schedule. Because of the complex construction, differing site conditions and design changes initiated by the CA/T, it was common for individual construction packages to be delayed—some very seriously. These delays have been widely reported in the press. Because of the cumulative, if overlapping effect of each of these delays on the various component contracts, the overall construction duration went from an original program duration of approximately nine years to a current projected duration of fifteen years. These delays created many disputes between the CA/T and the contractors.

Of interest for this article however, is that there was only one construction contract that covered the entire 161 lane-mile of tunnels, bridges and buildings. This was the contract for the smart highway system that integrated traffic control, signage, ventilation control, fire and security, and video monitoring. The CA/T recognized that this contractor would have both a construction component, installation of electrical conduit, pulling of wires and installation in control rooms, as well as a computer installation of both hardware and software, servers, routers and integrative programs. Further, complicating the situation was the phased completion. Major portions of the program would be completed five years earlier than others.

Because of this complexity and the timing of the Big Dig, the CA/T reasonably decided to issue two contracts for the work: a contract for a first part that covered the initial roadway opening, the Ted Williams Tunnel between downtown Boston and Logan Airport, and a second contract that integrated the first part into the remainder of the system. This second contract was substantially larger and more complicated. The first part became partially operational in 2000.

Bidding on the second part of the system, C22A2—integrated project control system (IPCS) commenced in November 1998, and an award of approximately $103 million was made May 26, 1999. NTP was issued on June 10, 1999 with contract completion established for February 18, 2005—2,080 calendar days later. The specific tasks required of the IPCS included:

- Gathering data from sensors throughout the CA/T Program.
- The processing and display of that data at a central location.
- The provision of control for equipment dispersed throughout the CA/T Program.
- The provision of security and traffic control.
- The provision of information for users of the CA/T Program's highway bridge and tunnel system.

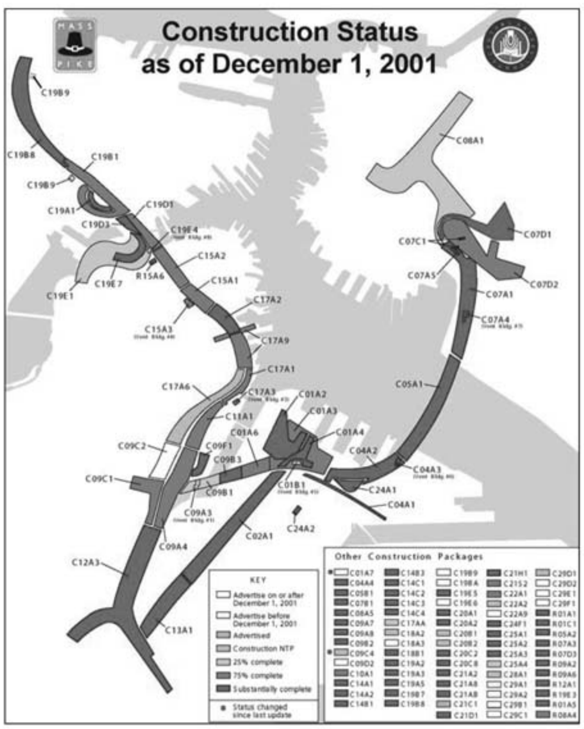

Figure 1—Big Dig Construction Status Map.

The contract had 60 milestones and 254 access restraints. A milestone was a mandatory partial completion date, and an access restraint was a restriction on the commencement of some particular portion of the work, usually because the area was not available—it had no access and was outside the contractor's control. Some of the milestones and access restraints were related to the provision of data and software by CA/T, but most concerned physical and operational limitations. Since many of the milestones and access restraint dates were predicated on construction activities that were ongoing during the time of bidding and construction, it was recognized by the CA/T that there would be revisions to most, if not all the milestone and restraint dates through no fault or responsibility of the C22A2 contractor. In fact, hundreds of milestone and restraint dates were modified by addendum during the bidding process.

A further complication not fully appreciated by either party to the contract, was that the cable routing shown on all the design documents, consisting of approximately 160,000 linear feet of fiber copper cable and over 1/2 million miles of copper cable was predicated on the final as-built condition. This meant that conduit location was shown on the construction drawings in its anticipated final position, even if the tunnel portion that the conduit was to traverse was not completed in time to accomplish a particular milestone. As an example, there were instances where the contractor was expected to make certain safety functions operational in a particular section of the roadway, by installing equipment and connecting the cabling back to the control center, yet the intermediate sections of the roadway, and pathway for the conduit were not yet complete, making it impossible to complete the cabling to the control center. The CA/T tried to accommodate these problems by changing the Milestone date that certain functionalities were required. In the example above, the CA/T would release the functionality milestone from the original date, to one that was after the completion of the intermediate sections of roadway.

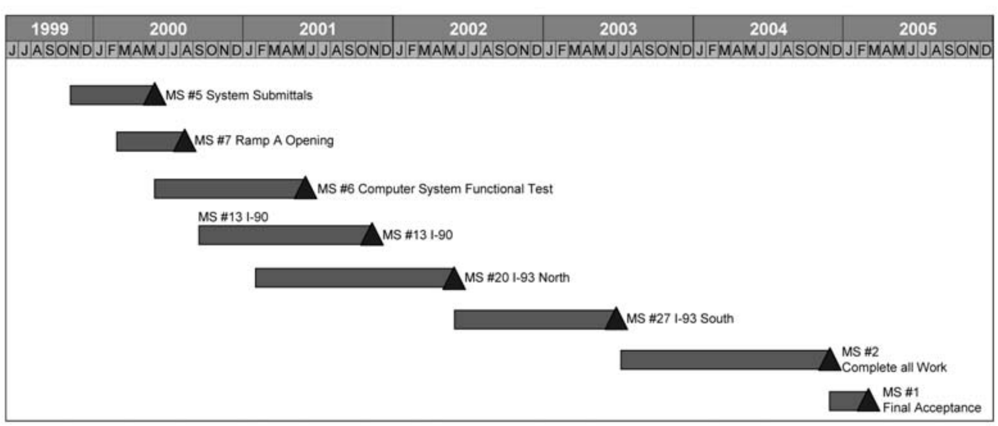

Figure 2—Summary Level Barchart of Contractor's Work.

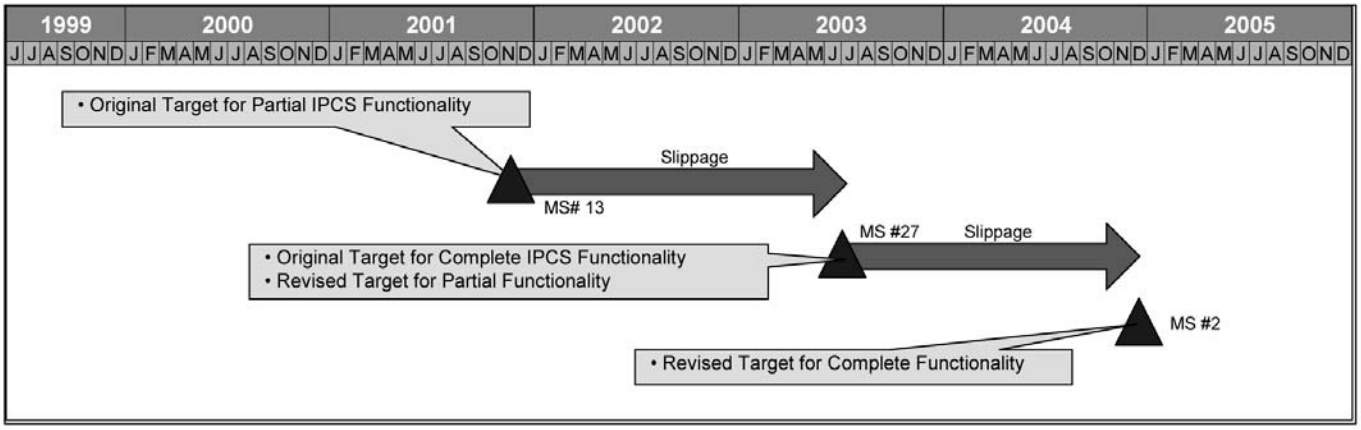

Figure 3—Milestone Release Model.

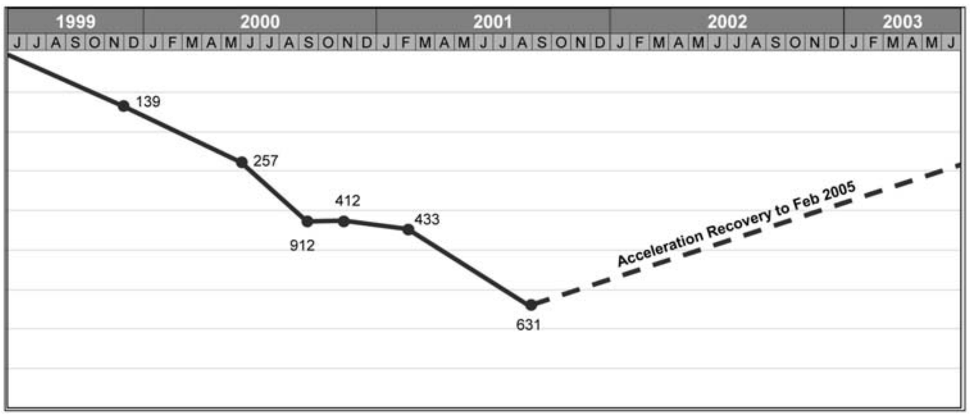

Figure 4—Delay Trend Chart.

Because the delayed progress of many of the approximately 50 ongoing construction contracts, the milestones and access restraint dates in effect on the date of award were inaccurate. They became more inaccurate as time progressed, and while the CA/T issued numerous change orders to accommodate these shifts, the COs were often out of date by the time they became effective. So, the contractor was faced with planning and coordinating a $103 million project against a contractually mandated schedule that changed frequently and was always effectively incorrect. This would have been a challenge for the most scheduling-sophisticated contractor. In total, only six percent of the site accesses were granted on time, with over 80 percent of the accesses granted more than nine months late. Further, approximately 40 percent of the fiber routes were changed during construction to implement work-arounds for late access, adding over 25 percent more fiber cable.

CONTEMPORANEOUS SCHEDULING BY THE PARTIES

The CA/T had a large and sophisticated scheduling department that managed the master schedule and also monitored the individual construction contractors' schedules. However, as with many large programs, many of the decisions were not driven by demand as opposed to reasoned construction sensibilities. From a production perspective there were also significant disputes between the parties on the timeliness and quality of the exchange of schedule submissions made between the CA/T and the contractor. The preliminary schedule was submitted in the summer of 1999, approximately two months late. This preliminary schedule, a necessary antecedent to the creation of a baseline schedule was eventually accepted in January 2000, approximately six months late. The baseline schedule followed a similar pattern and eventually became the Accepted Baseline Schedule by the CA/T at the end of March 2001, approximately 21 months after NTP. The contractor submitted monthly updates of this schedule through November 2001. Following a major revision in the milestones and access restraint dates in the fall of 2001 and in recognition that the contractor was approximately two years behind schedule in mid-November 2001, a revised baseline, known as the February 2002 Accepted Baseline Schedule, complete with a time extension was created, and effectively accepted by the CA/T in February 2002. The contractor continued updating this schedule for payment purposes through its termination for convenience in the summer of 2004. After October 2002, the contractor used a series of "completion schedules" to progress its work, consistent with agreements reached between the contractor and the owner to accelerate the completion of the project, although these schedules were never recognized by the CA/T as the official Schedule of Record under the contract.

The significant and growing delay on the project, as measured in November 2001 and thereafter, belied the fact that significant work was being accomplished on tasks that were not on the critical path. As a result, in the spring of 2001 the contractor retained a forensic schedule expert to assist in discussions with the CA/T, which followed suit in December 2001.

initial analysis by the experts

Just like the project itself, the forensic experts were almost overwhelmed by the complexity of the scheduling task. One of the authors, the contractor's expert, identified eight major impacts and inserted them sequentially into the accepted baseline schedule. This effort was focused almost exclusively on the software development portion of the contact, due to the fact that in November 2001, little if any field construction work had been initiated. This TIA-like analysis resulted in a projected delay of 645 calendar days. The contractor proposed both a time extension and acceleration to recover this delay. The projected acceleration costs were significant, at that time estimated to be in excess of $75 million.

The TIA methodology was applied to the accepted baseline schedule only, which the contractor recognized was flawed as containing access restraint dates that differed from the original contract, but which had been scheduled in to the contract milestone dates so as not to show delay. The analysis was also done on a summary level and only addressed eight major impacts to the software development work up to the cut-off date of the analysis in November 2001.

The other author, representing the CA/T, calculated the delay at 671 calendar days as of mid November 2001 using an as-planned versus as-built methodology (AP/AB methodology). acceleration after November 2001 was not considered. While the delay calculation for each analysis was similar in results, the allocation of responsibility was very different.

The AP/AB methodology also ignored the changes in the milestones and access restraints. This same methodology, if applied to the February baseline schedule, would have provided a corrected calculation. The AP/AB methodology provides a more detailed and fine grain possibility for allocation of responsibility.

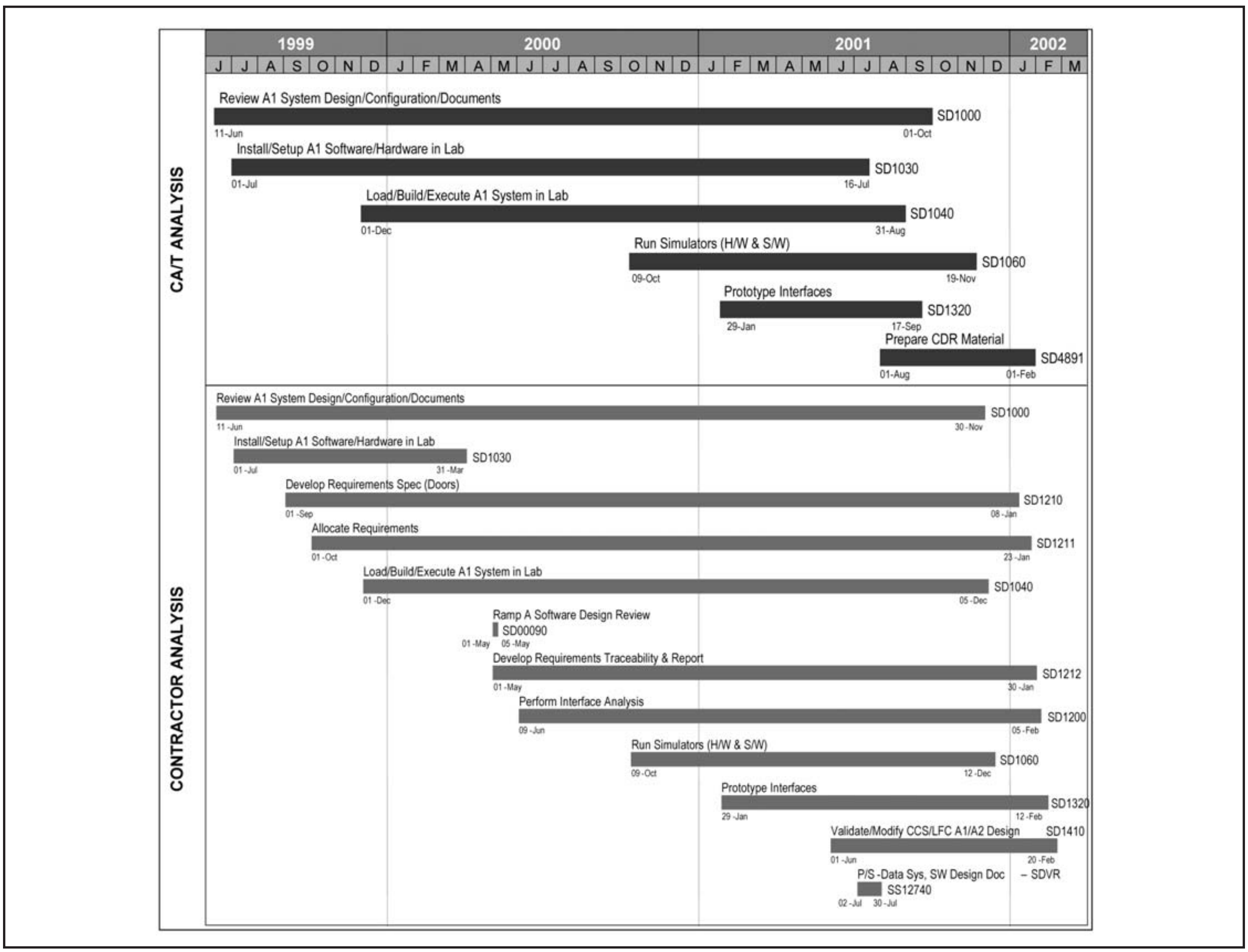

Figure 5—Comparison of Contractor and CA/T Critical Paths.

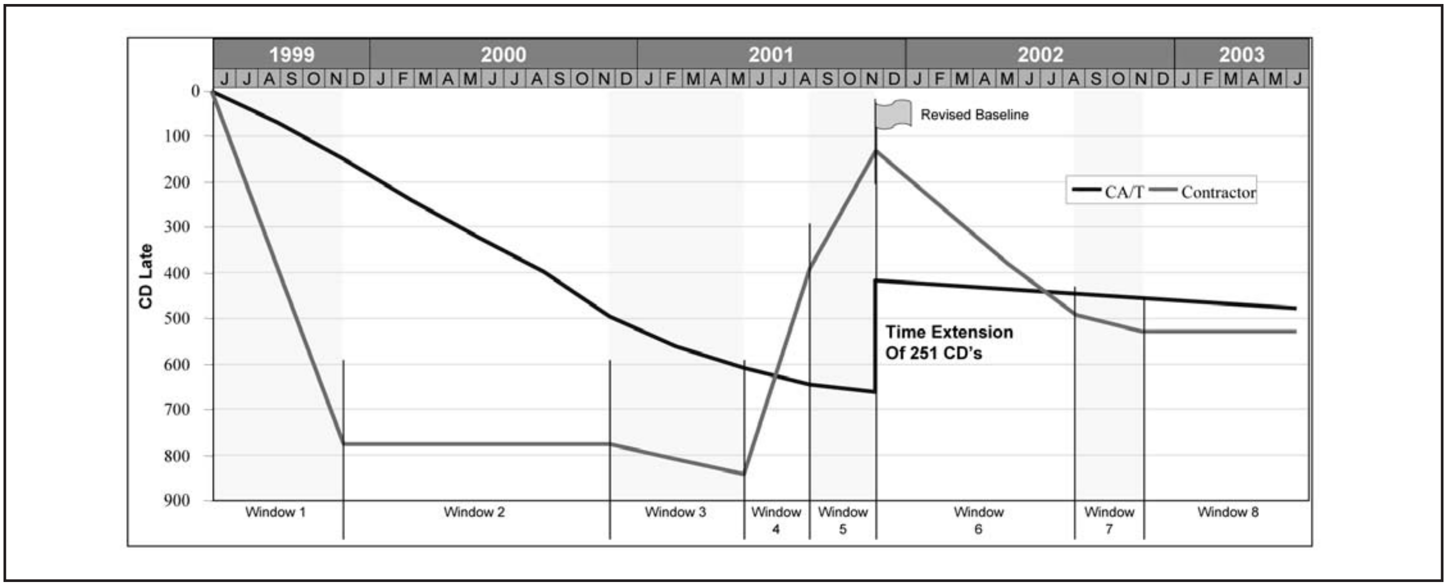

Figure 6—Comparison of Contractor and CA/T Critical Paths.

FINAL ANALYSIS OF THE EXPERTS

The initial contractor's delay analysis was presented in January 2002, while the initial CA/T's analysis was presented in September 2002, although it was prepared in May 2002. By the time this first round of analyses and discussions were completed in the fall of 2002, a significant amount of continuing construction work and delay had occurred, and the status of the project was substantially different than when first analyzed. The final analysis of the experts was presented in the late part of 2003.

The contractor's analytical methodology changed significantly for its second submission in September 2003. For this submission, the contractor presented nine-window analyses that incorporated the initial analysis through November 2001 in the first five windows and added an additional four-window analysis for the period after November 2001. However, the major change in the contractor's analysis was the abandonment of the accepted baseline schedule. As indicated in the contractor's first submission, the accepted baseline schedule included changes in access restraint dates that were known up to the date of acceptance of the baseline schedule. The contractor's revised analysis adjusted the accepted baseline schedule to reflect the access restraint dates reflected in the contract. Not surprisingly, the adjusted baseline schedule substantially changed the contractor's analysis and also not surprisingly, the CA/T objected to using anything other than the agreed upon, accepted baseline schedule. The analysis also used other contemporaneous acceleration schedules developed and agreed to between the parties, but not recognized under the contract as the schedule of record.

The net effect of this change in the analytical baseline was that the contractor showed significantly more delay at the outset of the job - delay that was recovered through acceleration in the latter part of the job, or through continuous work-arounds and design changes to cable routing.

In addition, the windows covering the period until November 2001 were different from the original windows. They showed a huge delay, and effectively a different critical path than presented in the first contractor's analysis. The windows applying to the period after November 2001, showed both delay and acceleration depending on the window. At the end of the last window, the contractor showed that it had been delayed a total of 528 calendar days.

The CA/T's final analysis took a very different tact from the contractors. The portion associated with the AP/AB methodology that applied to the work through November 2001 remained largely unchanged, and the CA/T simply rejected the initial portion of the contractor's revised analysis since it was based on a schedule that had never been accepted or used to administer the project. A separate new analysis was undertaken by the CA/T for the period after November 2001 that used an impacted as-planned analysis. Using the revised February baseline schedule, the CA/T consultant developed an analysis that was effectively an impacted as-planned methodology. The forensic schedule experts estimated increased durations associated with each of the identified and "accepted impacts" and inserted these as new activities into the revised February baseline. Using this methodology, the CA/T identified the time extension it believed was due the contractor - any delay beyond the analysis was deemed to be the contractor's responsibility.

DEFECTS IN THE FORENSIC ANALYSIS

Taken together here were four different analysis performed by three different forensic experts as indicated in the chart below. All four analyses had significant problems. The CA/T forensic AP/AB analysis, completed in the fall of 2002, provided a valid methodology for analyzing what had happened, but provided no insight into the accelerations that would be necessary if the contractor was to recover. In addition, it did not reflect the ongoing changes to the original accepted baseline schedule. Finally, due to the

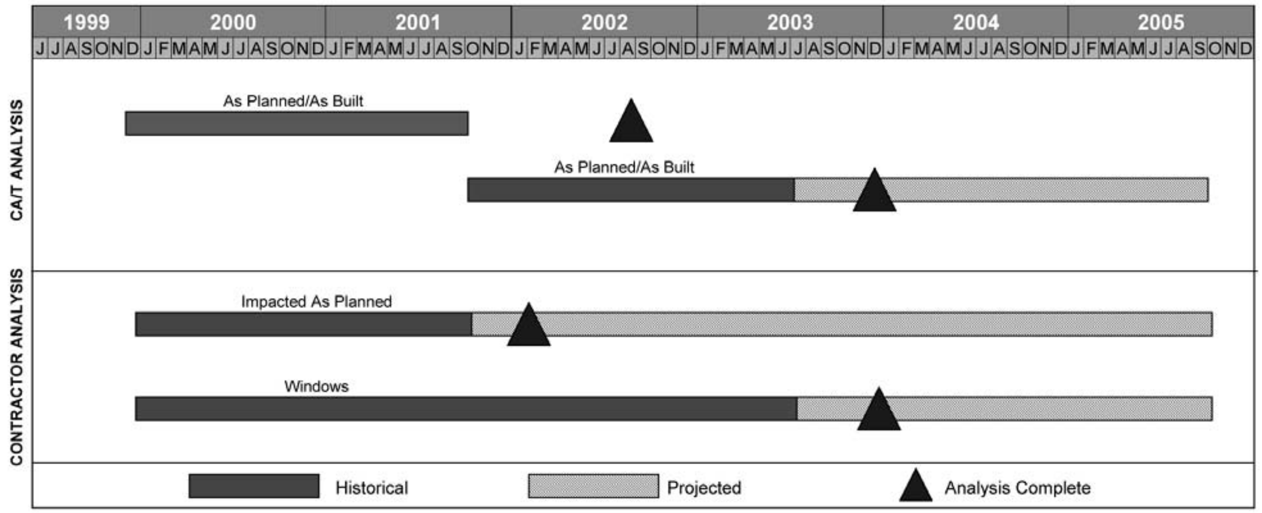

Figure 7—Comparison of Forensic Analysis Periods.

complexity of the issues, the analysis took almost ten months to complete and present to the contractor —too long to be of particular value in an ongoing construction/settlement environment. No prospective recovery analysis was performed.

The CA/T forensic, projected impacted as-planned analysis, completed in January 2004, and using the revised February baseline schedule provided a projection of completion, and partial consideration of CA/T caused impacts, but failed to adequately address the CA/T's own responsibilities. Further, it simply failed to identify the full impact of the contractor's acceleration efforts. The contractor's initial impacted as-planned analysis, completed in January 2002, accurately depicted the delay through 2001, but failed to consider the necessary accelerations that would be required. Further, it too provided no consideration of the contractor's own mistakes. This analysis's greatest virtue was that it was reasonable contemporaneous and provided a platform to discuss future accelerations. The contractor's windows analysis, completed in the summer of 2003, provided the most complete and accurate portrayal of actual events, and used a sufficient number of windows to capture actual progress, delays and accelerations on a simulated real-time basis. However, its use of an adjusted baseline schedule rather than the accepted baseline schedule and the use of acceleration schedules other than the schedule of record could not be accepted by the CA/T as contrary to the contract.

WHAT SHOULD HAVE BEEN DONE CONTEMPORANEOUSLY

The fact is that the parties had the best intentions in the contemporaneous schedule development, updating and maintenance of the project. But several failures are clearly evident:

- More clearly defined access restraints—The CA/T should have created more closely and narrowly defined restraints, exactly defining what access was granted or what deliverable from the owner was due. Many of the problems arose due to partial access or a dispute over whether the software delivered by the owner met the specific contractual requirements.
- More clearly defined milestones—The CA/T had the right idea in allowing work that was excusably delayed to receive new completion dates. However, often the methodology was to effectively redefine the scope of the milestone. Instead, it seems that each milestone should have been more clearly and narrowly defined, thus creating more milestones. These milestones could thus be more closely adjusted to reflect their individual characteristics.
- More timely baseline updates—With so many outside factors influencing the schedule, the CA/T needed a better and more timely system for approving updates to the baseline schedule. The need to conform to the master schedule slowed this activity.
- Timely modification of the contract—Both parties were at fault in not seeking and agreeing to contract modifications that captured contemporaneously the changing landscape of access restraints and milestones. As a result, neither party fully appreciated the implications of changes or could agree on the impact of these change contemporaneously.
- Better contractor planning. Early in the contract, the contractor sought to comply with the CA/T's desires to schedule around problems, as reflected in the accepted baseline schedule. However, the contractor was short-sighted in not understanding the implications of its actions in terms of schedules being interpreted by the CA/T as agreements for completion notwithstanding significant delay caused by the late accesses.
- Cost and resource loaded schedules—The contractor needed to initially develop and maintain a fully cost and resource loaded schedules that would have permitted the contractor to better recognize the effect of delays and impacts and adjust performance accordingly.
- Closer owner/contractor coordination—The CA/T needed to be more aggressive in insisting on schedule development and performance. It needed more informal methods to communicate its concerns.

The parties attempted to implement each of these ideas, or variants of each with some limited measure of success. However, the original baseline schedule required 21 months to get approved, and even then it failed to reflect the true baseline conditions at either the time it was approved, or at the outset of the project.

WHAT THE FORENSIC SCHEDULE EXPERTS SHOULD HAVE DONE ON THE RETROSPECTIVE ANALYSIS

On this project, three of the nations top forensic schedule experts used three different methodologies to model retrospective and prospective performance. Some of the work from each could be combined into a single methodology that would have resulted in better information and a more accurate picture of the past events. The retrospective forensic analysis needs to:

- Reflect the near continuous changes to the milestones and access restraints;
- Reflect the actual starts and finishes of events;
- Identify the impacted activities, regardless of criticality.

The authors propose that on projects as complicated as the Big Dig, the forensic schedule expert must use all the tools outlined below. While few projects need all of these steps, this methodology provides a blueprint for an exhaustive and expensive analysis.

- Accepted baseline schedule—The lack of an agreed upon baseline schedule during the forensic analysis made progress between the parties almost impossible;
- Many windows—The nearly constant stream of changes to the milestones and access restraints dates requires that the forensic review be conducted at a level of detail seldom required on typical projects. A monthly review in this situation would have been appropriate;
- As-Planned versus as-built for each window—If possible, it would be best to review the progress every month on a day-by-day basis, relying on the totality of daily reports, letters and similar items. Practically, this may be very difficult and costly. On this project, the poorly defined contractor software design activities made it nearly impossible to track progress against the activities. In addition, their long durations made accurate assessment of status little more than guess work;
- DDM for each window—Due to the large number of activities, and the frequency of the windows, it would have been best if the forensic experts use a relatively simple tool, the daily delay method (DDM) to quickly identify the candidates for major impact. Using this technique, an update-by-update picture of the major impacts, and likely critical path(s) could be identified for further discussion. This technique could not have resolved the factual disputes between the parties as to the responsibility for the delay/impact, but would have more narrowly focused the discussion.;
- Windows Cost and Man-Power Curves—To the extent possible, each update should be evaluated concerning historic and projected manpower and cost data. This data will assist in demonstrating the impact associated with each event.

By using this methodological approach, the forensic experts would have created a month-by-month picture of what actually happened and reflected the changes to the underlying schedule changes. The impact of each underlying change would have been more evident and discussion between the disputing parties could be more focused on responsibility rather than impact. With the input from the cost and resource loading, the parties could more readily discuss the magnitude of the impact, and what recovery would be required.

WHAT SHOULD THE SCHEDULE EXPERTS HAVE DONE ON THE PROSPECTIVE ANALYSIS

The three forensic experts were asked by the CA/T and the contractor to provide both retrospective analysis and a prospective analysis. They were asked to predict what the result of the historic impacts would be and what the recovery efforts could expect to accomplish. The prospective analysis needed to address the following main issues:

- Consider future known (pending) impacts;
- Consider unknown future impacts;
- Realistically appraise unaccelerated work rate; and
- Realistically consider accelerated work rate.

To perform such an analysis the authors believe that a TIA - like analysis is the best. The time impact analysis (TIA) methodology is used to calculate the impact of the events occurring during each separate time period. The facts associated with each impact event are then examined and a portion of a critical path method (CPM) schedule network is developed for each event allowing for its specific impact on the project to be integrated into the current baseline schedule. The use of this methodology assures that the individual impact of each change is properly considered with respect to its influence upon the schedule. When all of the impacts for a particular time period have been developed and inserted into the schedule, the schedule is recalculated. The analysis is performed by taking an original schedule, modified if needed, and impacting it to reflect what would have happened "but for" the contractor's acceleration. Then, by comparing that modified schedule with the actual events as reflected in the as-built schedule, a calculation can be made that identifies the acceleration (or delay) achieved during the course of actual performance.

Two of the four schedule analysis prepared by experts on the project attempted to model what would happen to the work in the future. Neither was particularly successful. The reason was simply that the scope disputes were so significant and unresolved, that any projection was predicated on the particular expert's view of responsibility for past actions and likelihood of future productivity. The CA/T's expert believed that the slow progress to date was due to the contractor's inability to understand its scope and the resulting failure to hire appropriate or sufficient staff. Therefore, its forward projection included this continued lack of understanding or at the very least, a recognition that a substantial learning curve lay ahead. The contractor's expert generally assumed that its lower productivity was due to the owner's failure to timely provide data, and thus its projection assumes the contractor's productivity would return to the planned productivity.

Both forward looking estimates included known historic and continuing impacts. However, both analyses tended to be very optimistic in the likely resolution of delay -causing events. This was derived by the continued disagreement between the parties as to the fundamental underlying scope disputes. The authors believe that in this situation, the forensic expert would be best advised to take a conservative approach and assume that the delay/impact will continue for a time.

In addition, neither of the forward-looking time estimates made any allowances for undiscovered problems and impacts. The authors again believe that a conservative inclusive approach would best serve the forensic expert in this case and thus some allowance for future disruptions would be prudent. For example, on this Project, the scope disputes concerning software development indicates that a contingency be made for a future software dispute.

Both experts estimated the acceleration productivity that would be achieved. The contractor's expert developed detailed prospective estimates as to future productivity and manpower. Unfortunately, they also assumed that the problems encountered prior to the estimate would miraculously disappear. The estimate of productivity developed by the CA/T's expert assumed productivity similar to the impacted productivity actually experienced to date. The result was that neither of the prospective forward-looking estimates provided any reasonable basis for accurately projecting future performance.

The estimates were also, almost by necessity, heavily politicized. The CA/T experts were well aware of the difficult political situating present and recognized that using future productivities that were substantially better than the historical data potentially implied agreement with the contractor's positions on entitlement. Similarly, the contractor's expert could not reflect a productivity similar to the historical data because that might be considered an admission that the earlier problems were the fault of the contractor.

The use of a measured mile was also problematic due to the extreme positions taken by the parties and their experts on issue responsibility. Since the contractor's view was that there was no unimpacted period, there could be no supportable measured mile. The CA/T"s experts held a contrary view.

However, the problems of productivity and how to project future delay were dwarfed by a problem both parties to the dispute agreed upon: that so much time had been lost on the initial activities that the original agreed baseline schedule could not serve as a starting point for future work. It is for this reason, that the February 2002 Baseline Schedule came into existence. It was commonly accepted by the CA/T's experts that even the February baseline schedule was inapplicable after December 2002. The contractor took the added position that even the February baseline schedule could only be used for a limited time period, as other acceleration schedules became the new yard stick for measuring delay. Although these schedule had no standing under the contract as the schedule of record, matching the CA/T's master schedules.

The contemporaneous development and maintenance of a reasonable and accurate schedule on a large project with continuously changing baseline conditions creates difficult problems for both owners and contractors. Those problems continue into the forensic analysis of the schedule. The methods identified in the above pages utilize most of the best analytical techniques available to the expert today: multiple and frequent windows, detailed AP/AB comparisons, resource evaluation, measured mile, daily delay measure and TIA's for acceleration. The author's experience on this project illustrates that these tools would have made it possible to model the delays, accelerations and impacts. This superior modeling would have assisted in better understanding and addressing the underling substantive issues.

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