Development of a Construction Management System for the Southwest Freeway/HOV Lane Project

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Innovative techniques to facilitate the construction of a fast track highway project are described. The techniques include extensive construction traffic sequencing, special specifications, and a customized critical path method scheduling system. Explanations of the methodology used to implement these items and the thought behind them are provided. Their application has been difficult at times, but is proving to be exceptionally successful. The Southwest Freeway/HOV Lane Project, located in Houston, is the single largest reconstruction project ever attempted at one time in the state of Texas. Construction began in August 1989 and is scheduled to be complete in December 1992, a 40-month duration. The project encompasses 10.6 mi of the heaviest-traveled roadway in the state; average daily vehicle volume exceeds 250,000. The estimated cost for this reconstruction is $200 million. A description is given of how the system came about. It covers the original goals and how the sequencing was laid out. Also covered are the hardware and software that were selected to help accomplish these goals. Customizations that were made to the scheduling software are described in detail. Preparation of the preconstruction schedules that provided information used in the specifications is also covered. The utilization of the system is also described. The organization of the project, the staff necessary to implement this system, and the details of utilizing such a comprehensive scheduling/management tool are covered. Examples of how the system is used to manage the work and prevent time delays are included. As of October 1991, the project was approximately 70 percent complete and 3 months ahead of schedule.

The Southwest Freeway (US 59), located in Houston, is the single largest reconstruction project ever attempted at one time in the state of Texas. Construction began in August 1989 and is scheduled to conclude in December 1992—a 40-month duration. The project encompasses reconstruction 10.6 mi of the heaviest-traveled roadway in the state; average daily vehicle volumes exceed 250,000. The current estimated construction cost is $200 million.

The project is divided into four segments (I–IV). Four contractors are working side by side to accomplish this reconstruction. There are 18 main-lane bridge structures on the project.

	Length (mi)	*Number of Bridges*
Segment I	2.7	4
Segment II	2.6	3
Segment III	2.6	4
Segment IV	2.7	7
Total	10.6	18

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Of the 11 main-lane bridges in Segments I, II, and III, 9 will be demolished and constructed from the ground up. Of the remainder, one bridge will be widened and overlaid, and one new bridge will be added. All bridges in Segment IV will be widened and overlaid with a 4-in. layer of concrete. Three of the existing seven bridges were raised 1 ft to provide additional clearance underneath them.

New frontage roads were constructed, adding as much as two lanes (four lanes total) in some areas and three lanes (five lanes total) at the major street intersections. The number of main lanes will basically be doubled, from 6 to 12 lanes. In addition, a high occupancy vehicle (HOV) lane will be constructed in the center of the freeway, with three T-ramp bridges providing direct access to park & ride lot facilities.

When the project is complete, more than 1.7 million yd^2 of concrete paving/bridge slabs will have been placed. All of the frontage road paving is 9 in. thick, main-lane paving is 13 in. thick, and bridge slabs average 7 in. This yardage does not include concrete used for foundations, such as bridge structures and drilled shafts; it includes only surface area yardage.

CONSTRUCTION MANAGEMENT SYSTEM DEVELOPMENT: MANAGEMENT PHILOSOPHY

Goals of the System

The construction management system (CMS) developed for the Southwest Freeway has several goals:

- Build the project on time (in 40 months),
- Evaluate progress of contractors,
- Protect project owners from unwarranted claims, and
- Refine system for future use.

These goals are being accomplished, and additional benefits are being discovered. One such benefit derived from the system is the ability to better negotiate with the contractor. The information contained in the scheduling system, especially the resource loading, makes it difficult for contractors to get by with unrealistic demands in negotiated settlements.

Construction Sequencing

The reconstruction of US 59 is being accomplished while US 59 continues to carry its already overloaded traffic volumes;

existing capacity (number of lanes) has not been reduced during the reconstruction. Volumes have dropped some but are still above 200,000 cars per day. The foremost concern of everyone involved with the project was how to accomplish the reconstruction while continuing to keep traffic flowing. At the same time, a goal was established to minimize the construction duration and inconvenience to the traveling public while providing a safe facility.

The design consultants produced more than 1,000 sheets of traffic control drawings to plan this goal. During the planning and drawing production phase, many believed this procedure to be overkill. The criticality of this seemingly excessive planning and these drawings is now being realized. Most of the large-impact construction problems have come from traffic management issues. The traffic control philosophy is presented in Figures 1a and 1b.

Each project segment is divided into three phases. In the first phase, the frontage roads were reconstructed. The main lanes and bridges on both sides of the freeway were widened in Phase 2. During Phase 3 the middle-of-the-freeway main lanes and bridges and the HOV lane and T-ramps are constructed. Because of the phasing, four large projects were each effectively broken into three smaller, more manageable projects of about 1 year in duration.

The completion of each phase provides improved traffic flow. Noncompletion of any of these phases meant delays to the traveling public. The delays were transformed into road user costs (costs associated with delays to the traveling public due to construction) and were estimated at over $450,000 per day. The cost for these delays was translated into liquidated damages and attached to the end of each phase. The liquidated damages are large: $15,000 per day for Phases 1 and 3, and $10,000 per day for Phase 2.

Why CPM Scheduling?

The traffic control drawings and phase requirements established the work flow. The only element missing is the time frame needed to accomplish the work. This is what critical path method (CPM) scheduling adds.

CPM is a derivation of program evaluation and review technique (PERT), which has its origin in operations research. CPM scheduling is a model that allows for simulation of real-world situations without resorting to real-world experiments. Models are, in essence, an imitation of reality.

CPM modeling constructs, on paper, each of the project segments piece by piece, developing tasks/activities, calculating durations (on the basis of resources) to achieve these tasks, and logically ordering them until the project is complete.

Once the traffic control or sequencing is established, the scope of work is developed. Applying CPM methodology to the traffic control scope of work/sequencing yields a schedule, or duration to construct the project.

Selection of Scheduling Hardware/Software: What Was Considered

From inception, it was decided to use a personal computer–based local area network in a central project office. A seven-station network was set up. For our file server, we choose a 386 25-MHz computer. It originally had a fast access 300-megabyte hard disk for storage. Because of the large scheduling and plot files generated and the desire to keep them on the file server, a larger 600-megabyte hard disk was installed. Ethernet cabling was used to connect the seven 386SX 16-MHz workstations.

To print and plot the various reports, several output devices were provided. For large plots, an E-size pen plotter is used. For A-size plots, a laser printer with a plotter cartridge is used. The same printer is used for tabular printouts. A laser printer capable of Postscript output is also on the network for producing reports and graphics.

It was recommended that the contractors use a 386-based computer with at least an 80-megabyte hard disk and that they purchase a D-size pen plotter. Another recommendation was for the purchase of a laser printer because of the many pages of output required to successfully use the system.

A high-end project management software project was selected. The software was selected because of its ability to handle a large number of activities and to be customized to meet the project's needs.

Software Customizations

There are basically two items in a CPM schedule that can be challenged: logic and activity duration. Logic can be simplified by using mostly finish-to-start relationships; the succeeding activity cannot begin until the preceding activity is completed.

However, the duration of an activity is more complicated. Duration of an activity is usually determined by the resources allocated to that activity. Resources include hours per day, productivity of the crew, and quantity of material to be installed. Amount and size of equipment also influence the duration.

Inaccurate durations are a typical problem with most contractor-supplied schedules. Often when schedules are developed, little attention is given to activity durations. Also, large chunks of work get lumped together into one activity.

Based on the Metropolitan Transit Authority of Harris County, Texas (METRO) specifications, support staff, together with the software vendor, customized the product to use resource quantities and production rates to calculate durations. In addition to the software vendor's customization, we have made system modifications, created special dBase programs, and written custom reports.

Without the activity resource information it is difficult to know what the contractor was thinking when the activity was originally planned/scheduled. The data documenting the duration of each activity are usually stored in one person's mind. By requiring the duration to be calculated, the contractor is forced to share assumptions and estimate information with the owner.

This information becomes an integral part of the schedule. Crew size, quantity of material to be installed, material production rate, and equipment are all stored in the schedule. The information documents the contractor's assumptions when the schedule was developed. Resource management is the key to constructing a project on time, and for the contractor it will determine whether money is made or lost.

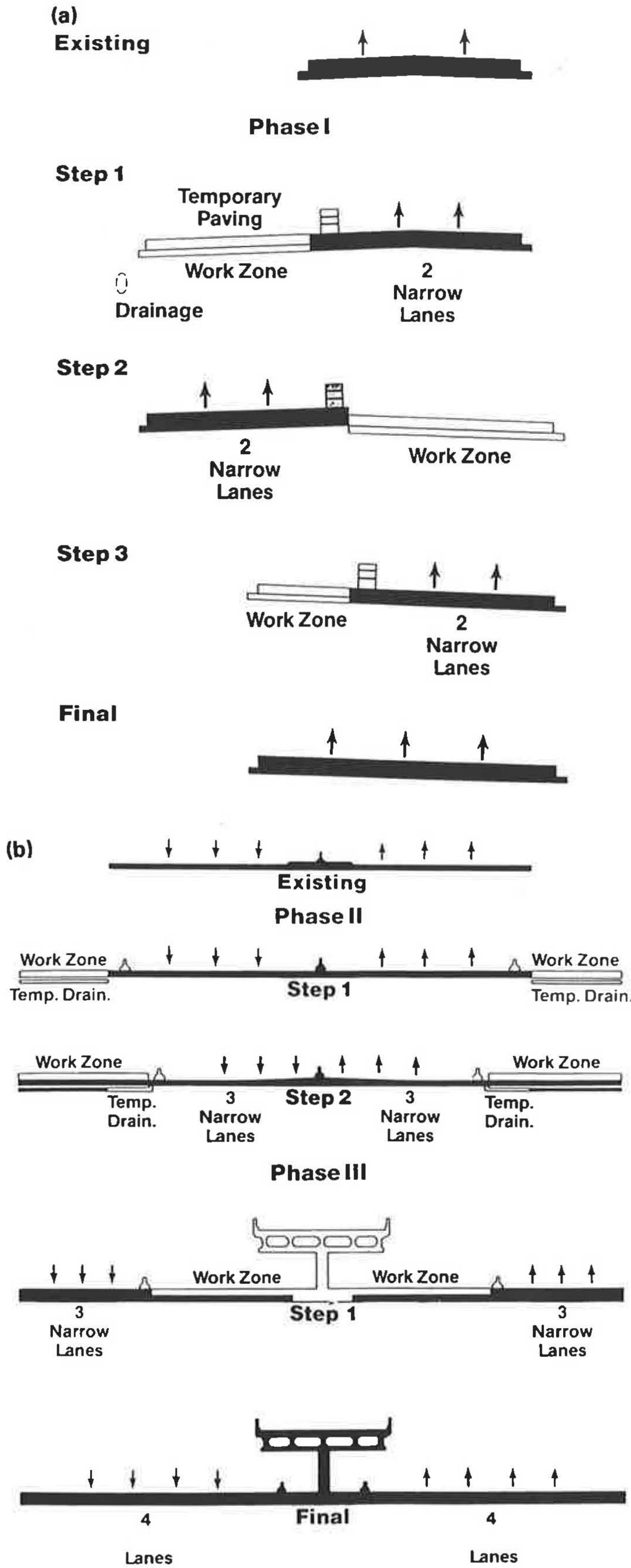

FIGURE 1 Traffic control phasing: *a*, southbound frontage roads, Phase 1; *b*, main lanes/HOV lane, Phases 2 and 3.

Figure 2 shows the information required and how it is used to calculate duration. In this example, concrete paving is the lead resource, and concrete paving crew is the labor resource.

Global changes can also be made. For instance, if one wanted to change the hours worked per day for all activities not started and recalculate the schedule, this can be accomplished with a few keystrokes.

A side benefit from this calculation is the estimated work hours required to complete each activity. With work hour information, S curves were developed for the entire project and for individual resources. Work hours by activity are useful because they indicate the intensity of activity. In other words, you can determine highs and lows in the schedule, which aids in leveling. An example of a work hour S curve is shown in Figure 3.

Given: Concrete paving Ln. 4 & 5 Sta.306+00--Sta.314+95 IB (22 ft wide)

Quantity = 19,690 sf or 2,188 sy.

Lead Resource is Concrete paving, which has a productivity rate of 0.10 manhours per unit.

Labor Resource is concrete paving crew of 22 people.

Hours worked per day is 10.

Calculated:

$$\frac{\text{Material resource} * \text{Production rate}}{\text{Labor crew size} * \text{Hours worked per day}}$$

$$\frac{2{,}188 * 0.10}{22 * 10}$$

Duration: 1 day

FIGURE 2 Duration calculation example.

This curve represents one phase of one project segment. A window is formed by lines representing the baseline early and late start dates. The backup data for each line is the accumulation of work hours for each activity spread between the start and finish dates. The earned value line is derived by spreading the work hours between the actual start and finish. The projected earned value line uses the dates calculated in the schedule.

Figure 4 is an example of the activity maintenance screen. It has fields to input the information needed to calculate the activity's duration. Once the information is input, the duration is automatically calculated.

Preparation of Preconstruction CPM Schedules

To establish a duration during which the project could be constructed, preconstruction CPM schedules were developed. When a construction contract is prepared, the Texas Department of Transportation (TxDOT) assigns the duration (usually in calendar days) in which the project is to be constructed. On the basis of past jobs, TxDOT wanted to allow 5 years—60 months—to reconstruct the Southwest Freeway. METRO felt it could be accomplished in 3 years, or 36 months.

On the basis of the traffic control sequencing, work activities were developed for each traffic control plan (TCP) phase

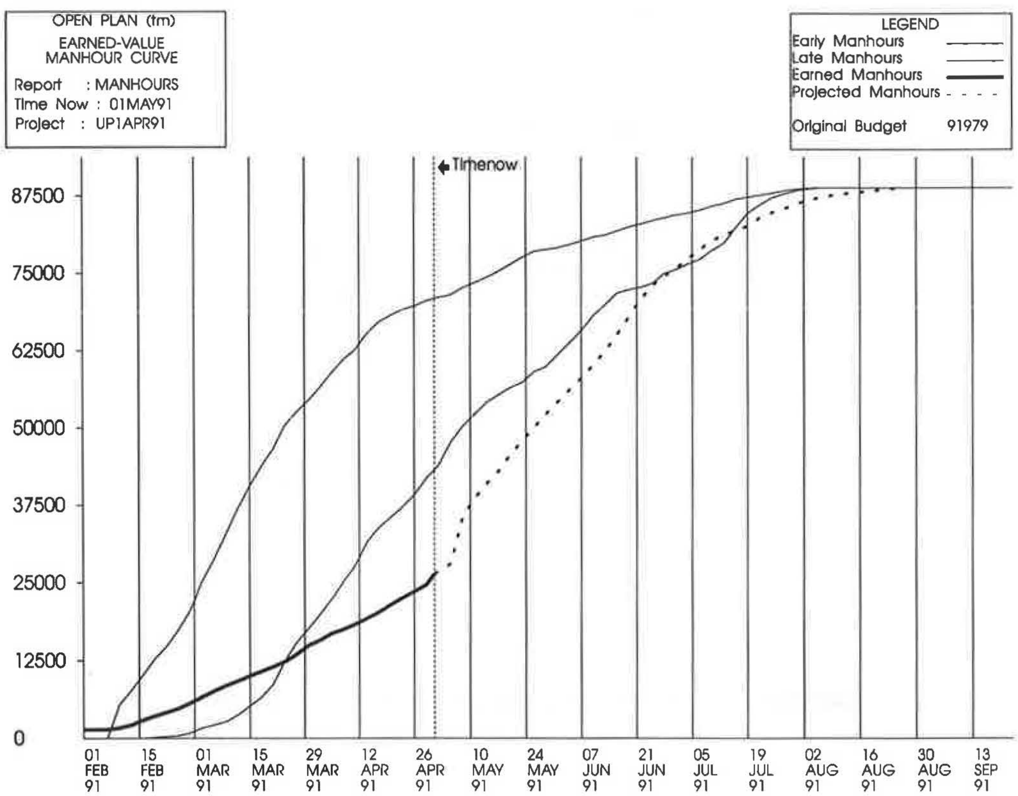

FIGURE 3 Work hour S curve, US-59 Southwest Freeway, Segment 1.

```
ACTIVITY MAINTENANCE SCREEN

Activity ID 1221501                 Calendar   1

Description
PAVE LN 4&5 306+00-314+95 IB        Duration   1
----LEAD RESOURCES----------------------------------
Material CPAV   Qty       2188 Manhrs          219

Labor      PAV          Hours Per Day  10
                                   TARGETS
Activity Type              Start        /  /
RS Class                   Finish       /  /
CODES

1 122111MI 2 0366             Budget Cost      59076
```

Bold items are input and used in duration calculations.

CPAV is the material resource (production rate of 0.10 mh/sy).
PAV is the labor resource (crew of 22).
Qty is the quantity of the material resource (2,188 sy).
10 is the hours per day worked.

The underlined items are calculated given the above information.

Duration is the calculated length of this activity in days (1 day).
Manhrs is the total manhours calculated for this activity (219 mh).

The italicized items were also input but were not used in the calculations.

FIGURE 4 Activity maintenance screen.

and step. The activities were resource-laded with quantities of material to be installed and the manpower needed to install them. The system used this resource information, along with production rates and planned hours per day, to calculate the activity's duration. All activities were linked together in a logical sequence of progression and applied against a preselected calendar, yielding a time frame to complete the project.

Once the basic model was constructed, "what-if" games were developed by changing one variable at a time and noting the results. For example, one scenario changed the hours per day from 10 (one shift) to 16 (two shifts). The results of this change were calculated in less than 30 min. Many "what-if" games were played; in fact, it got out of hand. Three scenarios were finally settled on: a regular work schedule (5 days/week, 10 hr/day), a moderate work schedule (5 days/week, 16 hr/day) and an accelerated work schedule (7 days/week, 16 hr/day). TxDOT selected the moderate work schedule, which yielded a total construction duration of 40 months, including contingencies for items such as bad weather. The schedules were presented to the Association of General Contractors, and the project duration met with its tacit approval.

The following list gives some of the direct and indirect benefits of reducing the Southwest Freeway construction duration from 60 to 40 months. These benefits are a direct result of the model employed.

1. As mentioned previously, road user costs were estimated at $450,000 per day for this project. This cost is based on a study performed by a traffic research institute. They used several commonly accepted methodologies to arrive at this amount. Translating this daily cost into a lump sum to reflect the 20 months (600 day) saved yields $270,000,000.
2. TxDOT and METRO staffs will only be required to be on the project for 40 months, not 60, thus freeing staff for other projects.
3. People who have to travel the freeway will be inconvenienced for just 40 months, rather than 60 months.
4. Merchants along the freeway will not have to endure a 5-year construction duration, lessening their hardship.

The list goes on. CPM modeling provided sufficient evidence to convince TxDOT to reduce the construction duration. TxDOT usually uses a conservative estimate when setting the duration of a construction project, since they rely on experience, which can be subjective. The CPM model provided a more objective and scientific approach to setting the project duration. On this project the contractors were required to construct the project in 1,200 days.

The CPM model example, in terms of benefits derived, is as comprehensive a model as could be constructed [saving more than $100 million, half of the estimated project cost (at least on paper)]. It basically depicts all the "right" elements that make modeling a successful endeavor. The cost of constructing this model was approximately $100,000, which includes METRO labor and purchase of the microcomputer, plotter, scheduling software, and programming and consultant services. The total estimated project cost for the Southwest Freeway is $200,000,000. The ratio of cost to construct the model to total estimated project cost is 0.05 percent. The ratio of cost to construct the model to the potential road user delay costs saved is 0.04 percent.

The CPM employed to construct the model is, as far as we know, the most precise method to simulate a situation such as this. This method of predicting events over time and total project duration is widely accepted in industry today.

There are many advantages for using models in making policy decisions. Simply put, these advantages are a result of the model's ability to simplify and predict consequences faster, cheaper, and safer than actually implementing each alternative or making an educated guess about which one is correct.

The durations calculated in the preconstruction schedules were used to substantiate the length of time needed to perform each traffic control phase. In other words, they were the basis on which each of the four project segments' duration was based.

Preparation of Specifications: Important Factors To Consider

Specifications and special provisions are included with design drawings to instruct the contractor to perform the work in a particular manner. They specify items that cannot be stated on the drawings or are better stated elsewhere. On TxDOT projects, and in most states, if not all, specifications and special provisions take precedence over the drawings. In other words, if there is a conflict between the specifications and the drawings, the specifications rule.

Specifications and special provisions of interest in the management of this project include (*a*) description of project, scope of contract, and work sequence, which generally describes the project scope of work and, in writing, details what is to be accomplished in each traffic control phase/step; and (*b*) prosecution and progress, which is a catchall for telling the contractor how the project is to be constructed. This is where specifications for the CPM scheduling system appeared. Also included in this section are the time requirements for the project and the liquidated damages clause.

Preparing a management specification is arduous. Many people must be interviewed and their objectives considered. People from several organizations were interviewed, including METRO, TxDOT, the Attorney General's office, various contractors, and the Association of General Contractors. All had different ideas on what they wanted to see in a management specification.

The specification dictated the common scheduling system to be used, how to establish activity numbers, coding of fields, and resource requirements. In fact, the specification also stated how to name the monthly update files submitted by each of the four contractors. The system was developed with much thought to afford the maximum flexibility in sorting and selecting data and to ease downstream management of data. Figure 5 shows an example of how activities and code fields were used.

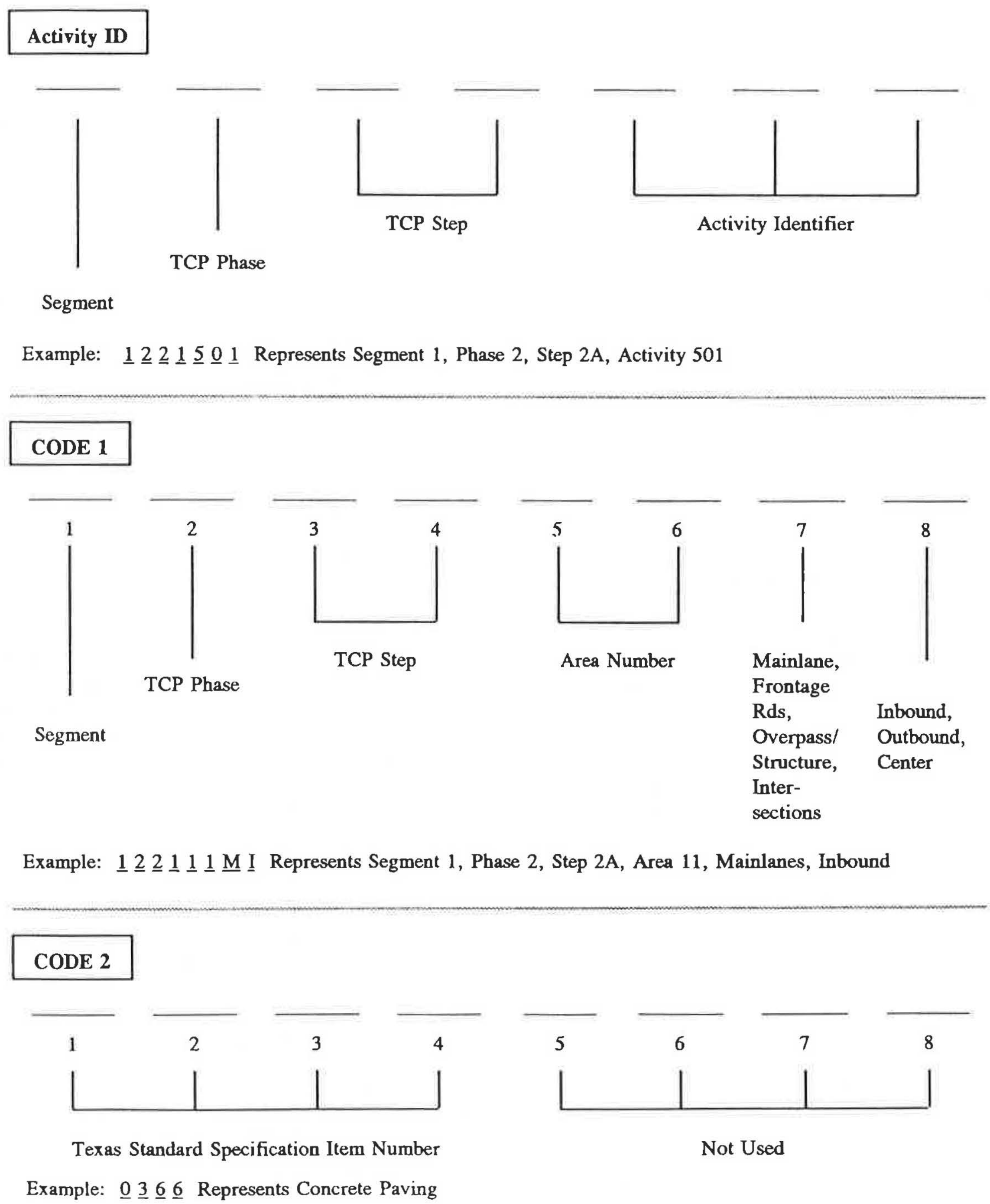

FIGURE 5 Coding field structure.

Some were in favor of what was being done, and others were skeptical. There were problems on other construction projects where CPM schedules were used because these projects had less-than-desirable results. Some people blame the management specification for these problems. We blame the lack of some specifications and the lack of attention paid to monitoring the work.

Specifications are like a set of instructions, or a recipe. The truth is you cannot prepare a specification and expect that to be the end. To make a cake you have to buy the ingredients, mix them together, and bake them. If you fail to complete each step correctly, the results will not be what you expected.

The specification only establishes the ground rules. The specification must be monitored for compliance, and staff must be dedicated to enforcing the rules established.

The Simpler Said, the Better

The most important lesson learned is to prepare specifications in the native language where they will be applied. In Texas they should be prepared in English. Not a lawyerese version of English, but good old plain English. The simplest, most straightforward way to say it is the best way to say it. Eliminate all the "whereto's" and "whereas's." Say what you mean in simple, concise, proper English.

One person interviewed said that a major problem he was aware of on one job was that the contractor fell behind schedule and began working 24 hr/day, 7 days/week to catch up. TxDOT was not staffed to work these hours. It resulted in burnout. On the Southwest Freeway, a specification states, "The Contractor can work between the hours of 6 am to 11 pm unless he obtains written permission from the Engineer." This simply written specification eliminated ambiguity.

Another problem TxDOT was experiencing on other projects was that contractors typically would move on to TxDOT right-of-way and begin tearing it all up. The contractors started working on the frontage roads, the main lanes, the major intersecting streets, everywhere they could, all at one time. To say the least, this had a major impact on the traveling public. These were the projects that never seemed to get finished.

Again, a simple specification was written stating that "the contractor could not begin a succeeding phase of work before completion of a preceding phase without the written permission of the Engineer." Simply put, this specification controlled where the contractor could work. It forced him to organize his work.

The key point here is, tell the contractor what you want and do not want him to do, and say it in the simplest terms—and most of all, tell him before the contract is signed.

CONSTRUCTION PHASE

Project Organization

The contractors are under contract directly to TxDOT. TxDOT manages and inspects all work and ensures compliance with the contract documents.

METRO is in a support role to TxDOT, providing construction management services including scheduling, claim prevention and review, design support services, and preparation of construction status reports.

This organization works well. There is a clear division of responsibility. TxDOT gives all direction to the contractors. METRO supports TxDOT in its areas of expertise.

METRO has a staff of 4.5 people assigned to this project (the 0.5 person, the manager, divides his time between design and construction responsibilities). There are two project managers, one construction engineer, and a project secretary. To accomplish METRO's scope of work, a project manager is assigned to two project segments. This project manager, along with the assistance and experience of the senior construction engineer, reports on the project's status and works to resolve problems that arise.

TxDOT has a staff of approximately 70 people, including 12 administrative and 58 inspection staff.

Review and Approval of Contractor Schedules

By specification, contractors are required to submit a resource-loaded CPM schedule. Resources include the number of workers, types and number of pieces of equipment, and material to perform the work for each activity.

Through the flexible report-writing capability of the scheduling software, reports were generated that summed each of the resources by TxDOT standard specification item numbers. These quantities were compared with the planned quantities to determine whether the contractor considered all quantities to be installed (scope of work).

Even though we had all the capabilities for writing and producing many different types of reports, the process of reviewing more than 14,000 activities almost killed us. We had to bring in outside consultants to help in this review. However, this was known beforehand, so consultants were under contract and ready to begin their review on a moment's notice.

Monitoring the Work

With a staff of three professionals, all activities in the field are monitored weekly, sometimes two to three times a week. In fact, at any time the scheduling software can provide up-to-date information about the status of any of the projects. The staff converses on the schedule activity level, so everyone is on the same page.

The projects that are, or appear to be, behind schedule are monitored more closely. Activity update reports are produced (see Figure 6) and updated two to three times weekly. Updates include information about resources on each activity (number of workers and pieces of equipment) and a description of what work is being performed. This information is compared with the contractor's planned information, located on the top of the form. This form is printed directly from the information stored in the scheduling system, without further modification.

Date-stamped progress photographs also are taken two to three times weekly. Along with the completed progress sheets, they depict the activities' status or lack thereof.

As discussed previously, a project manager is assigned to two project segments. The project manager and the senior

OPEN PLAN PAGE: 1

ACTUP Activity Update Report REPORT DATE:09SEP91

UP1FEB91 US - 59 SOUTHWEST FREEWAY: SEGMENT 1 TIME NOW:01MAR91

1221501 PVAE LN 4&5 306+00-314+95 IB Org Dur = 1 Rem Dur = 1 Total Float = 0

Budgeted Cost = 65640 Manhours = 219 Code 1 = 122111IM Code 2= 0366
Material Resource Code = CPAV CONCRETE PAVING Productivity Rate = .10000
Total Quantity = 2188 SY Remaining = 2188 SY

BASELINE Start 08MAR91 Finish 08MAR91 ACTUAL
EARLY Start 23MAY91 Finish 23MAY91 LATE Start 29JUL91 Finish 29JUL91

Resources
PAV PAVING CREW Crew Size = 22

Date	OBSERVATIONS

FIGURE 6 Activity update report form.

construction engineer provide the necessary input to determine the status of the project and provide alternatives to keep the project moving forward.

CPM Schedule as a Management Tool

Using the Schedule To Prevent Delays

Different industries use different methods for communicating ideas. In the construction industry, CPM schedules are the most effective method for communicating what the contractor plans to accomplish and when the contractor plans to accomplish it.

The information in the schedule gives advance notice to the owner of when and where the contractor plans to work. For example, if the owner has not acquired all the property or has not had all the utility adjustments made (this does not happen in Texas), the CPM schedule will tell the owner when the contractor is planning to work in these areas.

It is up to the owner to use this information to keep ahead of the contractor, clearing the way for the contractor and preventing delays. It takes at least two to communicate, one to talk and the other to listen. The information in the CPM must be updated and reviewed constantly in order to establish the two-way communication.

On one of the project segments the TxDOT resident engineer used the work hours curve (see Figure 3) to support his "gut feeling" that the contractor was behind schedule. The resident engineer believed that he was behind schedule because of a lack of resources (workers and equipment). Several letters were written to the contractor, supported by the resource information extracted from the scheduling software and actual head counts, demanding that more resources be assigned to the project.

Utilizing the Schedule To Prove or Disprove Claims

The CPM schedule is a powerful tool in proving or disproving construction claims. A construction project is riddled with negotiations. People on both sides are always looking out for their own best interest. The CPM becomes invaluable for negotiating both time and money.

However, it is a two-way street. If work is disrupted and this work is on the critical path, the contractor is probably due time if, of course, he is not able to work on any other critical path items.

A highway project is linear in nature. Many similar activities can be worked on simultaneously. Therefore, a contractor delayed in one area could probably be allowed to work in another area performing similar work.

This is not always true and can be analyzed through the CPM schedule. If the delay does not affect the critical path, float is used up until the delay is resolved. On this project, float is not for the exclusive use of either the owner or the contractor. It is for use by whoever uses it first.

The ability to use resources as the basis for activity durations created a third dimension for managing the project. For example, if work is not proceeding as scheduled in one area, one could analyze not only the time elements but also how the time elements were originally derived, the production rates used, and the type of equipment used. All this information gives the insight needed to correctly and completely analyze a schedule. There have been several instances where the resource information has been the key item in disproving a claim.

For example, one of the contractors stated he was submitting a time impact on his Phase 2 work because of delays in relocating utilities. After a thorough analysis it was determined that the delay was really associated with the construction of retaining walls, or the lack thereof. The contractor had this activity staffed as indicated in his schedule; however, there was a flaw in the production rate. The production rate was a factor of three to four times less than the other contractors. This resulted in durations of one-fourth of what they should have been. This information was discussed with the contractor and his claim was never submitted.

Using the Schedule To Plan Owner-Required Resources for Inspection of the Work

Because of the sort and selection capability of the scheduling software, planned and actual quantity curves can be produced that indicate intensities of operations. A traditional CPM schedule tells you when an activity is to start and stop. The system developed on the Southwest Freeway tells you resource intensity, enabling the owner to plan staffing more precisely.

This information allows TxDOT to know when, what type, and how many people are needed for the inspection. Optimization of the owner's resources is accomplished more precisely using this method.

What the Schedule Will Not Do

A CPM is like any other system; if left unattended, its results will be less than desirable. CPM schedules require constant nurturing.

CPM provides you with a communication of how the job is to be built. It is up to human resources to make sense of what is being communicated and how to best use the information. CPM alone does not make one job better than one without CPM. Without a dedicated staff that understands CPM and the project being constructed, the effort is token at best.

CPM will not control the project unless the CPM is controlled. A plant without water will eventually die. CPM without constant attention will also lead you down a primrose path. The old "GIGO" rule applies: garbage in—garbage out.

What makes a project successful is thorough planning before and during execution. One must anticipate problems and resolve them before they become problems. CPM gives you the ability to thoroughly plan your work. However, as we all know "things happen" during the construction phase that you hadn't planned for. CPM makes it easier to analyze downstream effects of these changes and allows one to "crystal ball" what will happen.

CMS Working Together—CPM Schedule, Specifications, and Dedicated Staff

The CPM schedule, the specifications, and a well-founded organization have all worked together to form a synergic bond. Without any one of these elements the outcome would be less desirable. As a result of this bond, unexpected benefits were derived from the CMS.

One of the most powerful management tools resulting from the CMS was the ability to better negotiate time extensions with the contractors. The specifications established milestones for three distinct phases. The milestones were set up as "finish on" dates. The specification, as stated previously, said that "the contractor could not begin a succeeding phase of work before completion of a preceding phase without the written permission of the Engineer." When a contractor began work in a succeeding phase before completing the work in the current phase, we were in a much better position to negotiate time extensions.

For example, when the Segment III contractor was in Phase 1 (frontage road reconstruction), he began prosecuting Phase 2 work with the engineer's permission—approximately 8 months early. After 5 months of working in Phase 1/Phase 2 simultaneously, there was a field change to the drainage system

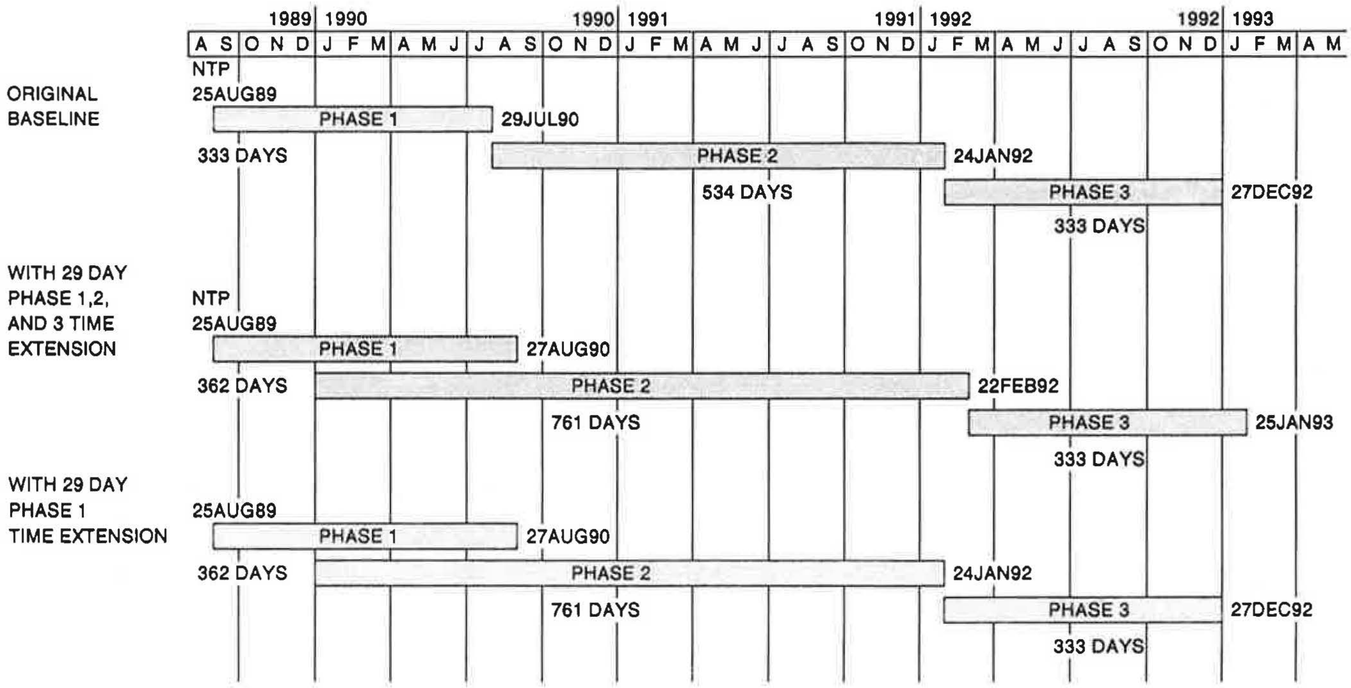

FIGURE 7 Results, Segment III proposed time extension.

being completed in Phase 1. The contractor asked for a 29-day extension in Phase 1, Phase 2, and Phase 3, which would have extended the end date of the project.

The contractor was awarded 29 days in Phase 1 only. As the basis of this decision, we pointed out that he had already worked 5 unscheduled months on Phase 2 and had another 3 months of Phase 2 work he could accomplish while still in Phase 1. The CPM verified that the contractor had earned more than the 29 days of Phase 2 work while in Phase 1. The contractor was reminded that it was a privilege, not a requirement of the contract, to allow him to work in a succeeding phase. He was also told that this privilege could be revoked at any time. Figure 7 shows the results of time granted.

The contractor's request for a time extension in all three phases was reduced to a time extension in Phase 1. A simple concept became a powerful management tool. The integration of the CPM schedule and the specification provided the ability to accomplish this.

LESSONS LEARNED—THINGS THAT MIGHT BE DONE DIFFERENTLY

Basically, we would do nothing different. However, some operational refinements could be made to the specification. When a comprehensive management specification is written for a project, the owner, as well as the contractor, must have experienced dedicated staff to make it work. It is a shared responsibility, and the degree of its success is measured on both sides; it's not a one-way street.

As of the writing of this paper, there have been no construction claims. In the event of future claims, the comprehensive information provided by the system should assist both the owner and the contractor in effectively resolving these disputes. The project is approximately 70 percent complete and is 3 months ahead of schedule.

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