FINAL REPORT

Construction Project Scheduling at MDOT

An Evaluation of the
Michigan Department of Transportation
Construction Scheduling Requirements

Submitted By:

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Submitted To:

The Michigan Department of Transportation
Construction and Technology Division
Lansing, MI

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TESTING AND RESEARCH SECTION
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1.0 - Introduction

The need for schedules in just about every aspect of life today is very evident. From a schedule of events on television, to the schedules of our own daily lives, or the schedules of large, complex projects, our society has become dependent upon planning and scheduling in order to be successful. Scheduling is also a very important tool in the multi-billion dollar construction industry. A schedule turns a plan of action into a functioning timetable. "The schedule serves as a fundamental basis for monitoring and controlling project activity.... In a (construction) project environment, the scheduling function is more important than it would be in an ongoing operation because (construction) projects lack the continuity of day-to-day operations..." (Meredith & Mantel, 1995).

In Michigan, The Michigan Department of Transportation (MDOT) is responsible for numerous highway construction projects every year. Between now and 2003, MDOT will invest an average of 1.3 billion dollars each year in road and bridge repair ("Five", 1999). MDOT provides the funding, contract management, and a significant amount of the design work for these projects. In the typical construction relationship of owner, engineer and contractor, this makes MDOT function as both the owner and the engineer. Therefore the Department has an essential and active role in the successful completion of numerous construction projects. Success in the construction industry is usually measured by safely completing a quality project on time and under budget.

Since MDOT assumes a similar role on many projects over and over again, standards have been developed to control these projects to make them as successful as possible. Schedules are one of the tools that are used to plan and monitor construction projects. MDOT has standardized a process that requires contractors to submit schedules for each project. MDOT is constantly reviewing the standards to make improvements. The current system for scheduling and

monitoring construction projects is being reviewed. This report provides MDOT with some alternative approaches.

MDOT places requirements on contractors to prepare and submit schedules that outline the planned construction process for the following reasons:

1) To make sure that the contractor has actually developed a reasonable plan to complete the project in the given time.
2) To provide a means for measuring progress throughout the project so that measures can be taken to keep the contractor on schedule.
3) To document evidence for justification of decisions regarding construction time on a project, (i.e. time extensions).

The primary method for contractors to submit a schedule has been the Progress Schedule Form - 1130, shown in Appendix A. Over the past few years, this form and its use have received attention from contractors and from some MDOT personnel. In some situations there was outright criticism of the form. The form only allows for the identification of one "controlling operation" for each day of the construction time. Disputes over this stipulation and others have raised concerns within MDOT on scheduling issues. More detail of this form and the current scheduling requirements are discussed later in this report.

1.1 - History of Scheduling

Throughout the last century, several techniques have been developed to improve the scheduling process. The first scientific time management techniques were done around 1885 by Frederick Taylor to increase industrial production. Shortly thereafter, around 1911, Henry Gantt further improved production scheduling for use during World War I. His graphical representation of a schedule with activities versus time is referred to as the Gantt Chart or Bar Chart, and is still widely used today for production and project management. A sample of the Gantt bar chart is shown in Figure 1.

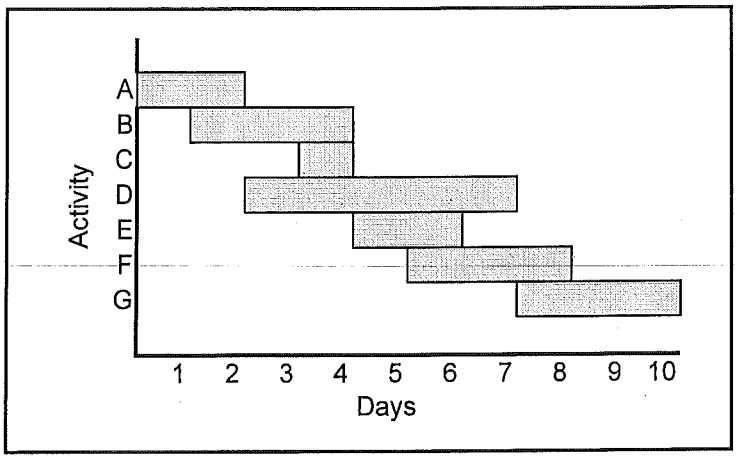


Figure 1 – Gantt bar chart

Another major development, the Critical Path Method, (CPM) came about with the development of computer hardware and software in the 1950s and 60s. New techniques were developed to utilize the capability of the computers. "It is somewhat ironic that all of the scheduling techniques developed for the computer could have been performed manually without it." (O'Brien, 1969)

The basis of the CPM is a logic network representing all of the activities, their durations, and their interdependencies, which is used to calculate starting dates, finishing dates, and float time. The Department of Defense and NASA modified the CPM method in 1957 for the planning and controlling of the Polaris Fleet Ballistic Missile program. This new method was known as the Performance Evaluation Review Technique (PERT). These two techniques along with the Precedence Diagramming Method (PDM) were developed for specific reasons, but are quite similar and all utilize logic networks. All three techniques have been modified and improved over the years by many organizations, and are now referred to almost synonymously.

Two variations in diagramming methods are used on these schedules. The first is the Activity on Arrow (AOA) method; named so because the activities are represented by arrows. The other method is the Activity on Node (AON) method, which is named because the nodes on the diagram now represent the activities and the arrows between them show the relationships.

Figure 2 shows a comparison of these two types of CPM schedule diagrams. The AON diagrams are the more popular type used today because they are easier to create and use. An example of a complete CPM network is shown in Figure 3.

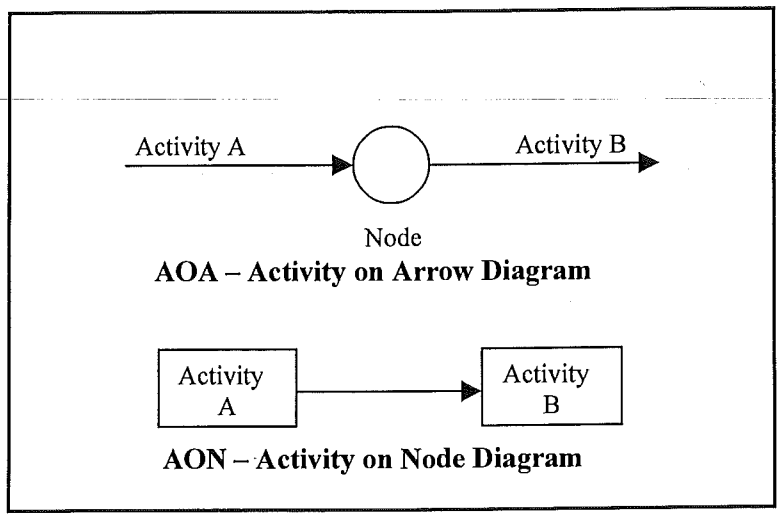


Figure 2 – AOA vs. AON Diagramming

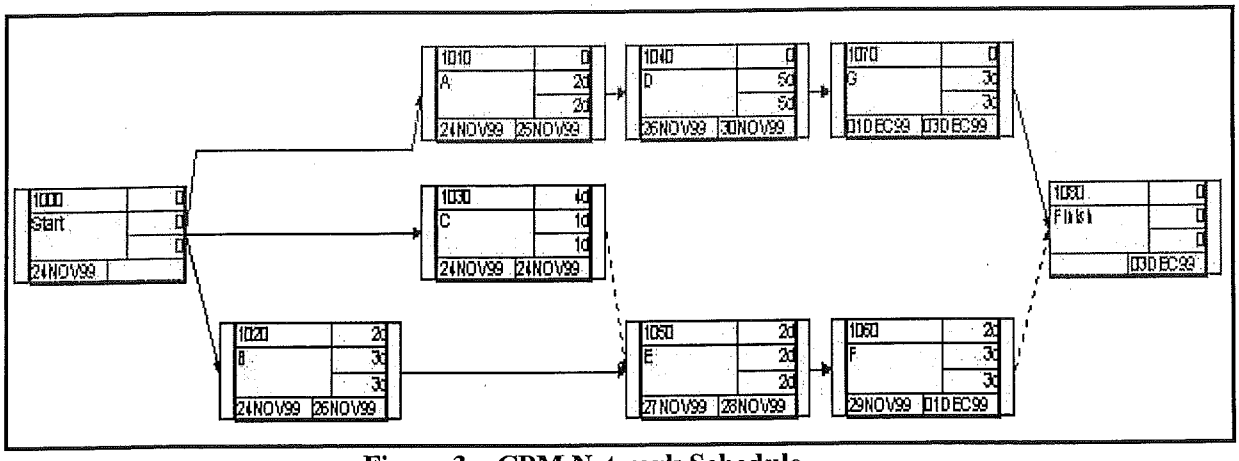


Figure 3 – CPM Network Schedule

1.2 - Linear Scheduling

Another type of scheduling technique that is available is Linear Scheduling. "Linear Scheduling is a simple diagram representing the location and time at which a given crew will be

performing a given operation (Parvin, 1993)." Linear Scheduling uses basic geometric shapes to represent activities on a two-dimensional set of axis, where the vertical axis is time and the horizontal axis is location. Linear construction projects are projects where the same activities are repeated continuously. Roadways, pipelines, tunnels and railways are all examples of construction projects that are linear in nature. Linear schedules are very easily interpreted because of the visual representation of the project. Possible conflicts between activities occurring simultaneously in the same place can easily be identified.

Three geometric shapes are used on Linear Schedules to represent activities: lines, blocks, and bars. Lines are used to represent linear activities that occur over the length of the project such as paving, grading, or trenching. Blocks represent activities that will occur at one place for an extended length of time, such as mass excavation or bridge installation. Bars are used for activities similar to block activities, but involve a smaller area (fewer stations). The use of these shapes is shown in the following Figures 4, 5 and 6.

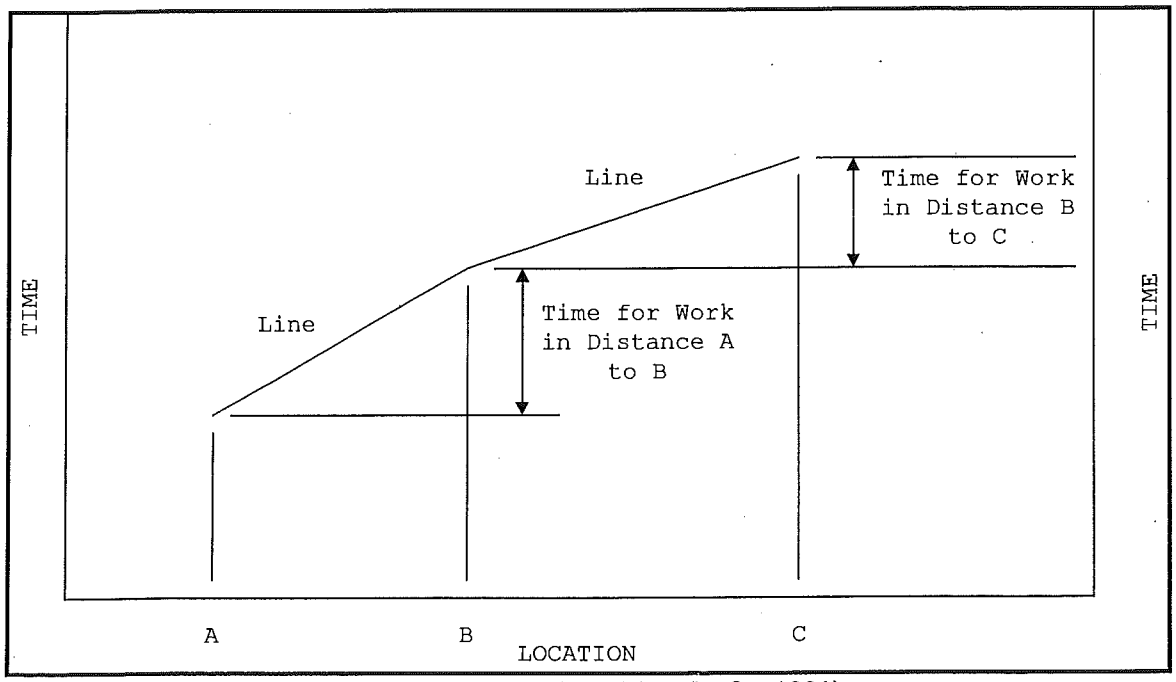


Figure 4 – Linear Activities (Bafna 1991)

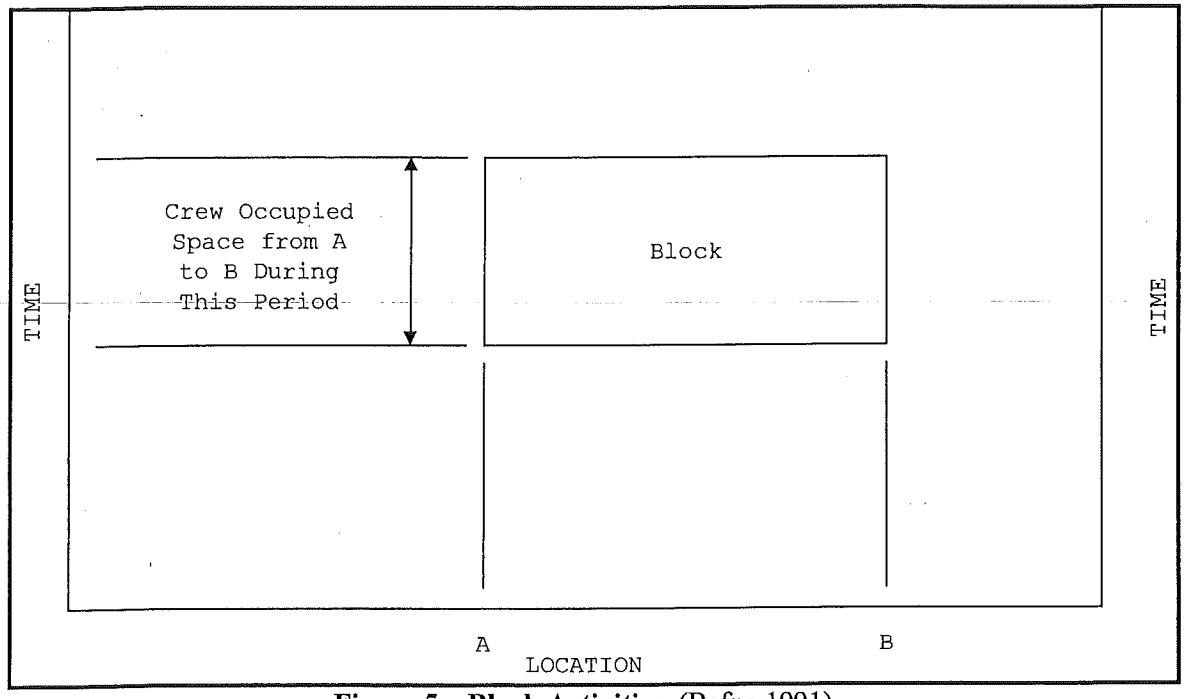


Figure 5 – Block Activities (Bafna 1991)

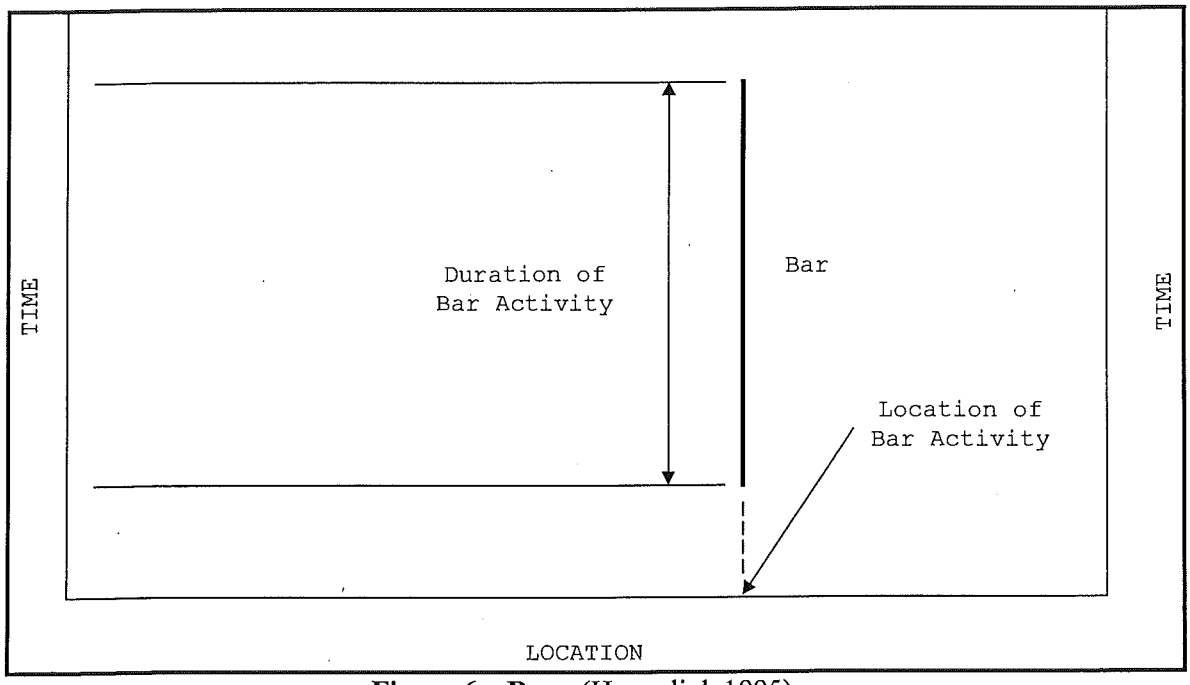


Figure 6 – Bars (Harmelink 1995)

A complete Linear schedule for a project would have a combination of these shapes representing all of the activities necessary to complete the project. An example of a linear schedule for a typical highway construction project is shown in Appendix B.

Many of the construction projects done by MDOT involve primarily linear activities. Primarily Bar Charts and CPM schedules are being used to schedule these projects. Unfortunately, neither of these techniques schedules accurately model linear construction projects (Stradel and Cacha, 1982; Charzanowski and Johnston, 1986; Reda, 1990; Cole, 1991; Suhail and Neale, 1995; Harris, 1996). The linear activities are broken down into arbitrary sections based on location to fit the Bar Chart or CPM schedule, whereas with Linear Schedules, the activities can be represented continuously.

It has been shown (Herbsman, 1987) that even though CPM scheduling is used quite often to schedule projects, contractors present the information using bar charts because they are easier to understand and work with. Linear Schedules provide a graphical display of the information that is very easy to understand and allows for a better visualization of the construction process. For these reasons, recent research has been undertaken to improve Linear Scheduling tools. The mathematical methods or techniques for calculating critical activities in a Linear Schedule have been developed (Harmelink, 1998; Harris, 1998). However, computerization of these methods has not yet occurred. Considerable work needs to be done to develop methods to do this in addition to other features of CPM software such as resource loading, crashing, and cost control. As linear scheduling becomes known and better software becomes available to create linear schedules, it could provide an alternate to current highway scheduling techniques.

1.3 - Goals

The intent of this project was to review the current MDOT scheduling requirements and to identify strengths, limitations, and rationale for current methods. MDOT personnel and contractors opinions were sought for input. Their comments and suggestions are summarized. A review of the requirements used by DOTs in other states was done to provide ideas and support for recommendations. The popular computer software used by MDOT contractors to create and manage construction schedules is reviewed.

Linear Scheduling has been suggested as an alternative means of scheduling linear construction projects, such as highways. The use of linear scheduling is demonstrated and evaluated by implementing it on three MDOT construction projects. If Linear Scheduling is found to be beneficial, criteria for its use will be offered.

2.0 - MDOT Scheduling Requirements

When this project began, MDOT was in the early stages of reviewing various scheduling requirements. The current requirements are described, and then changes are discussed.

2.1 - Current System

Since time is the function that a schedule reflects it is necessary to summarize the type of contracts that MDOT uses to control time.

2.1.1 - Contract Types

MDOT, and most other DOTs, have primarily two types of contracts to establish the amount of time given to a contractor to complete a job: workday and calendar date contracts. Workday contracts provide the contractor with a specified number of workdays to complete the project. The specifications further define what days will be charged as workdays, or portions of workdays. MDOT charges workdays for "All days when, as determined by the Engineer, it is possible for the Contractor to effectively carryout work on the controlling operation ("Michigan", 1996)." The specifications provide further definitions of workdays that allow the contractor to only be charged days for work done from Sunday to Friday. The Contractor is not normally charged for work done on Saturday or for days when events beyond the control of the contractor prevent work to be done.

Calendar date contracts provide a specified date on which the contract is to be completed, regardless of delays that may occur during the contract time. The specifications for these contracts do provide a limited number of reasons for the contractor to receive an extension of the contract time. The assumption is that the contractor assumes more of the risk for project delays and that average weather delays are already accounted for when the contract time was established.

Other special types of contracts are used primarily to expedite the schedule, thereby lessening the impact of construction to the motoring public. On projects where the amount of traffic that

will be inconvenienced by the construction is significant, MDOT attempts to complete the construction as soon as possible. One common way to do this is to provide incentives or disincentives in the contract, which will financially reward the contractor for early completion, or penalize the contractor for late completion.

Another type of contract that can be used is called an 'A+B' contract. For these contracts, no contract duration is given for the project prior to bidding. Instead, the contractor determines the number of days needed to complete the project, and submits this total with the bid. A 'user cost' per day is assigned to the project by MDOT based upon the amount of traffic carried by that roadway. This user cost is multiplied by the number of days that the contractor determines necessary to complete the job. This total is then added to the total bid for work on the project, and the contractor with the lowest total bid cost plus total user delay cost is awarded the contract.

2.1.2 - Progress Schedule

The 1996 MDOT Standard Specifications for Construction define a Progress Schedule as follows:

> "**Progress Schedule**. A sequential listing of all the controlling operations and the estimated time the operations will remain controlling. The progress schedule is submitted by the Contractor and approved by the Department prior to award of the contract and becomes part of the contract." ("Michigan", 1996)

In order to understand the Progress Schedule the definition of a Controlling Operation is also needed:

> "**Controlling Operation**. The operation that, if delayed at the time of consideration, would delay the opening to traffic or completion of the entire project. The operation may be either on or off the job site. The size of the operation is not a factor." ("Michigan", 1996)

The information identified in the Progress Schedule definition is submitted on Form 1130 – Progress Schedule (Appendix A). This provides a standardized way to accept and approve the Progress Schedules. The requirements of this form state that the list of controlling activities and dates must be continuous throughout the contract time so that all days have only one controlling operation identified. The dates can be listed as

calendar dates or as a running total of workdays, depending on how the contract is setup. MDOT allows bar charts, CPM diagrams, or other information to supplement Form 1130.

The term 'controlling operation' is synonymous with 'critical' activity. The term 'critical' comes from CPM scheduling which means an activity that has zero 'float'. Float is the ability to begin the activity later than planned in the schedule without affecting any final or interim completion dates. It is entirely possible for more than one activity to be critical on a given day. In other words, more than one critical path could be found through a project. However, at the start of this research project, only one critical or controlling operation can be listed on Form 1130, for each day of the contract.

Form 1130 is usually submitted at the pre-construction meeting, and when approved becomes a contract document. The contractor is encouraged, but not required, to submit updates to the Progress Schedule. If approved, the updates also become part of the contract documents. Submitting updates would be in the best interest of the contractor because the form would be a more accurate representation of the actual construction sequence.

Bi-weekly construction progress reports, completed by MDOT, keep a record of the amount of work completed and the number of workdays charged to a workday contract project. These bi-weekly reports allow the MDOT engineer to determine if the project is on, behind, or ahead of schedule. However, the bi-weekly reports are not directly linked to the Progress Schedule. The MDOT engineer must take the time to compare the reports with the schedules. Aside from notifying the contractor that the project is behind schedule, no other means are available to encourage the contractor to get back on schedule. Once the project is completed the contractor is assessed liquidated damages for every calendar day used beyond the scheduled completion date.

If the contractors feel as though a controlling operation was delayed for a reason beyond their control, then the contractor can apply for an extension of the contract time.

The request for this application is supposed to occur within 14 days after the delay was caused. On many projects the applications are often times accepted beyond the required time limit. If updates occur late, or not at all, then the Progress Schedule is rarely an accurate representation of the actual construction sequence.

Ideally, the Progress Schedule should be referred to when applying for a time extension, and for the approval or disapproval of the application. The reason is that if the contractor has identified a controlling operation for each day of the project, then any delay which might warrant an extension of time would have to affect a controlling operation on the specific date in question. An example of this request might be: "The Progress Schedule identified bituminous paving as the controlling activity on the 14th workday of the job. It was unseasonably cold, 0 degrees Celsius, on the 14th day, and the specifications dictate that paving cannot occur at that temperature, so one day should be added to the duration of the contract."

The assumption is that the Progress Schedule on file with MDOT is accurate. If the Progress Schedule had instead identified cold milling as the controlling operation on the 14th day, when the contractor was actually paving, the application is not technically valid. Each individual case is reviewed individually, and the contractor may be awarded the extension regardless of the Progress Schedule accuracy. The important point is that the Progress Schedule form provides no help if it is not accurate.

2.1.3 - CPM Schedules

MDOT has recognized the benefits of requiring a more detailed form of scheduling such as, the Critical Path Method (CPM). Although the term CPM has been used somewhat loosely to describe many similar forms of scheduling. The intention is that every activity necessary to complete the project is identified, along with the corresponding relationships and durations. Then the CPM calculations are done to identify the critical path by determining the available float time on each activity. For all but the simplest projects, this process is done using computer software

that makes the entire process much easier. In addition, CPM software has advanced capabilities of cost loading, crashing, resource utilization, activity assignment, calendar control, and many more.

Because of the increased time required to prepare and work with CPM schedules, they are only required on larger jobs and on jobs where the schedule needs to be monitored closely. CPM schedules are usually required on projects with incentives and disincentives, and on A+B contracts.

The special provisions for CPM schedules require that CPM schedules be submitted in the AON diagramming method. The special provisions also give details regarding format and activity descriptions, including that no activity duration can be longer than 20 days. Updates of the CPM schedules are required bi-weekly with $100 per day fines assessable for delinquency. Also, major equipment to be used on the job must be entered into the schedule. The schedule is then labeled as 'resource loaded' meaning that major pieces of equipment with a limited supply such as cranes, pile drivers, or paving machines are connected to the appropriate activity. This way conflicts with limited equipment can be addressed in the planning and scheduling phase of the project.

The benefits of CPM scheduling, when used properly, are most evident on larger projects with numerous activities and multiple phases. This is especially true when the CPM is done using sophisticated software programs that are available today. Problems with CPM scheduling are that with its complexity a certain amount of knowledge and/or training is required to understand the schedules and be proficient with the software. Both MDOT and the contractor need personnel that are capable of using CPM software.

2.2 - Comments on the Scheduling Process

The people who create, approve, utilize and revise any of the schedules on a daily basis are MDOT personnel and contractors performing work for MDOT. Therefore, they should provide some of the best feedback on the current requirements. At the time that this research project was

beginning, the Construction and Technology Division of MDOT was hosting a meeting of MDOT engineers, MDOT contractors, and trade organizations to discuss scheduling issues. The research team, Dr. Kris Mattila, PE, and Rhett Gronevelt attended this meeting to begin gathering input about the system. Throughout the summer, the research team conducted interviews of various contractors and engineers.

2.2.1 - Scheduling Summit Meeting: June 16, 1999

On June 16, 1999 an all-day meeting of MDOT contractors, MDOT engineers from various regions, and MDOT personnel from the Construction and Technology division met to discuss issues about the scheduling process. The Michigan Road Builders Association (MRBA) and The Associated Underground Contractors (AUC) played an active role in setting up the meeting, and getting the attendees to take time away from their busy projects in the height of the construction season to participate. In an effort to make the meeting more productive an outside facilitator, J. Scott Lowe, Senior Vice-President of Trauner Consulting Services Inc. was hired as a neutral party to lead the discussion and keep it focused.

More than twenty issues (Appendix C) were identified as possible points of discussion and then voted on for their importance. A summary of the issues, and the resolutions that were reached can be found in Appendix D. The main issues that related to this project included the following:

1. The use of dual critical paths on CPM schedules and non-overlapping date requirements on the Progress Schedules.
2. Frequency of schedule updates, and the relationships between extensions of time and schedules.
3. Standardization of networks on CPM schedules.

The contractors at this meeting pointed out that on both highway and bridge construction projects it is common that at some point during construction more than one critical or controlling activity could occur on a given day. On a CPM schedule this would show up as dual or multiple

critical paths. On the Form 1130, this would cause some dates of controlling activities to overlap. The department personnel agreed that this event does occur. They were, however, concerned that if contractors were allowed to identify multiple critical paths, or controlling activities, then the contractors would take advantage of the allowance and try to list too many controlling operations, making it easier to justify an extension of time. The department was willing to change the stipulations and allow more than one critical or controlling operation, but intended to provide a means for controlling abuse of the new rule.

Significant discussion took place regarding the last two issues listed above. The contractors felt as though a more accurate or realistic schedule submittal would make it easier to examine impacts, such as extra work or overruns, on the schedule and therefore make the evaluations of time extensions easier. The contractors believed that only listing the controlling activities did not provide MDOT with enough detail to accurately assess impacts to the schedule. They also felt that making updates to Form 1130 was usually a difficult or lengthy process, and therefore updates were rarely requested or submitted. Since the Progress Schedules are not being updated, they are not very accurate.

MDOT's position on these issues was that the schedules, as a minimum, must include a listing of controlling operations. That when contractors applied for time extensions, they needed to identify what caused the delay, what *controlling* activity(s) it impacted, what days was the activity delayed, and why would it be MDOT's responsibility to compensate for the delay. The department also felt that it was the contractors' responsibility to make updates to the schedule when necessary, and that the contractors did not do this. MDOT planned to write specifications clarifying when updates are necessary. If the updates are not submitted in a timely manner, pay estimates will be withheld. They also agreed to make the updating and approval process simpler and quicker.

2.2.2 - Interviews

A task of this research project was to conduct interviews with MDOT personnel and contractors who develop and create the schedules. The identities of the interviewees were not disclosed in conjunction with their comments, so that an open discussion of concerns could take place in the interviews. Since it was the height of the construction season when the research project was underway, some contractors and MDOT personnel were too busy to interview. However, meetings were held with seven MDOT contractors and eight MDOT engineers from five regions.

Some specific questions were developed to obtain feedback on the intended topics, and then general notes were made on each interview. Some issues that were discussed and information that was learned will be mentioned here, but the complete results of the interviews have been summarized and included in Appendix E.

Generally, the contractors indicated that a project level schedule like the one submitted to MDOT was rarely used by the company. Each contractor had a means for scheduling crews and equipment for all on-going jobs, but very rarely, if ever, used schedules to plan and coordinate all of the activities on each project. The larger contractors, who did the majority of the large projects in the state, initially use CPM software to schedule projects, but rarely used it throughout the project; except when updates were required by MDOT.

The contractors overwhelmingly felt that the 1130 - Progress Schedule Form was rarely an accurate representation of how a project was actually built. The reason for some of the inaccuracy was also identified. Most of the time, the contractors felt as though the project would be completed in less time than was stipulated in the contract. They knew that the actual number of days worked on the job would usually be significantly less than the contract time. However, they needed the extra time to balance crews among other jobs, or to compensate for other delays.

In other words, they knew that there might be days they would be charged time, but would not complete any work. Since they did not know when delays might occur until well into the

project, it would be difficult to identify the exact controlling operation on each day. They are reluctant to submit a schedule showing early completion. The submitted Progress Schedule must show a complete use of the contract time. To do this, the schedules are determined not from start to finish, but from finish to start. The last possible finish date is determined and the schedule is worked backwards to the early start date. A "guess" of the controlling activity on each day is made. The sequence of the controlling operations is fairly accurate, but the durations are extended to fill the time. This usually means that the exact dates of the controlling operations will vary greatly from the dates submitted on the schedule.

Most contractors said they would only create formal schedules for very large jobs. Since most of them had been required to have CPM schedules for projects at one time or another, they already own scheduling software. A version of Primavera's scheduling software, either Project Planner or SureTrak, and Microsoft's Project 98 software are the most commonly used software.

When asked about Linear Scheduling, only one contractor was aware of it. When the idea was demonstrated to the other contractors, most of them had a positive response because it seemed easy to read and understand. Although, they suspected it would need a lot of attention to keep it accurate and figured it would be too much wasted effort.

Even though the contractors had complaints about the Progress Schedule form, they seemed to think that if they were allowed multiple controlling activities, the form could become more accurate. Most felt as though the Progress Schedule had benefits because it forced them to do some planning that they may not have otherwise done until much later. Only one contractor truly felt that he had been unjustly denied an extension of time where the Progress Schedule was used in the determination. Although, very few said that the time extensions they were granted had ever made reference to the Form 1130. This fact raises some questions as to the necessity of any scheduling requirements on some projects.

The responses from the interviews with MDOT personnel did not seem to be as consistent as the responses from contractors. One thing that has occurred is that the decentralization of MDOT

management has provided each region the opportunity to handle things slightly different. MDOT was recently divided into seven regions with Transportation Service Centers (TSCs) managing each region. One region may be much more stringent with the guidelines than another region. Although the contractors may complain about this, it seems to be more of a benefit. Conditions in the regions, such as the size, impact, or number of projects, along with the number of available contractors is very different. These differences may warrant a little more leniency in one region than in another.

All of the MDOT personnel interviewed said that the Progress Schedule is a valuable tool to them. Yet, they agreed it was not always accurate, and rarely updated. All claimed to use the Form for recommendations of time extension applications. Some used them to answer questions about when areas may be under construction and/or closed. One interviewee was very persistent about the fact that only one controlling activity should be allowed on any day, while the others agreed that the schedules would be more accurate, and thus more useful, if that rule was changed. Most of the interviewees wished to see the schedules updated on a monthly basis or even more frequently.

The main concern seemed to be that the engineers did not want any changes to the system if it meant more work for them. Most were already overwhelmed with the amount of paperwork done on each job, and did not feel as though the average-sized jobs needed any more scheduling requirements added. Because of the size and complexity of projects in the Metro region, they felt as though requiring specific software for electronic schedule updates would be helpful.

2.3 - Changes

By the time this report was written, the Construction and Technology division had already adopted some new special provision specifications and other provisions were in the drafting stages. The changes were in a direct response to issues that were resolved at the Scheduling Summit Meeting in June. Copies of the newly adopted Special Provisions (SP), 102F and 102G

are included in Appendix F. The current draft of new special provisions for CPM schedules is included in Appendix G.

SP102F dictates the conditions when contractors are required to make updates to the Progress Schedules. Basically this requires contractors to make updates whenever "The project falls behind the schedule detailed in the approved Progress Schedule" (Appendix F), or something in the project is changed, such as the quantities, or the sequence of work. The only complaints that contractors had during the interviews about this new Special Provision was that they wanted more than the 14 days allowed to submit the updates.

SP102G is the SP that the contractors have been waiting for. First, it adds some new definitions to the specifications regarding scheduling terms, such as Float and Non-Controlling Operations. The major change is that the SP allows contractors to identify more than one controlling operation on the Form 1130 and more than one critical path on CPM schedules. The stipulation though is that for each instance of overlapping controlling or critical activities, the contractor must explain in writing why the overlap occurs. In some common situations this may be easily described and accepted, while others may require a detailed explanation. This stipulation allows the engineer to prevent the contractor from listing every activity as controlling. The draft of the CPM schedule adds more detail to the previous CPM requirements. The details specify the timing of schedule submittals, the format, and update frequency. The contractors are not required to use specific software for the schedules, but they must use some form of CPM software. They also must make sure that the software allows for export of the data in a certain form that coincides with the software of the engineer for the project. That way submittals for approval can be made electronically, or on a floppy disk. This stipulation does not create difficulties since the popular CPM software programs allow for easy importing and exporting of data from other programs. The CPM requirements may seem lengthy and detailed, but they are essential to make the use of the CPMs easy for both the engineer and contractor. The reality is

that most of the formatting details are easily done, and usually the defaults in the software will satisfy the SP requirements.

2.4 - Software Review

Computer software is used to create and manage many of the schedules for MDOT construction projects. Scheduling software has evolved from the simple CPM programs that were developed in the 50s and 60s into the complex project management applications available today. Computers are not going to ensure that projects are completed on time, but they can make a lot of the management work much easier. Although some of the construction industry maybe hesitant to begin using computers for project management, many of the MDOT contractors have been using it for some time.

After meeting with MDOT contractors around the state, the following four programs were found to be in use: Microsoft© Project 98, Primavera© Project Planner (P3), Scitor© Project Scheduler 7 (PS7), and Primavera© SureTrak. SureTrak was used to schedule the test projects discussed later in this paper and therefore used extensively by the research team. P3 is the most comprehensive of the software packages listed, and probably the most popular nationwide. P3 is used in many industries around the world for management of very complex projects and operations. The capabilities of P3 exceed those of the other programs, making it more difficult to learn and use. For this reason, Primavera offers SureTrak, which is a scaled down version of P3 that still has all the capabilities of a CPM scheduling program, but not as many of the features.

MS Project 98 and Scitor PS7 would be somewhere between SureTrak and P3, offering at least all the capabilities of SureTrak, but not P3. After extensive use of SureTrak, MS Project 98 and PS7, were fairly simple to understand. No major differences were found between PS7, MS Project 98 and SureTrak.

SureTrak and MS Project were the most common programs found among MDOT contractors; only one used PS7 and a few others used P3. The biggest drawback to working with P3 seemed

to be the training required to fully utilize the software. Since the DOT still allows contractors to choose the software they wish to use for CPM schedules, MDOT personnel on projects requiring CPM schedules should be prepared to see any of these programs. However, each claims to have the ability to easily import and export data from one to the next.

The importing and exporting of data was tested between the four programs that were identified. Various methods were available to share data between software. Data can be imported and exported as ASCII (American Standard Code for Information Exchange) text files, or copied and pasted to the clipboard. The only problem with this is that the data formats must match exactly. Nonetheless, it is a relatively simple task to do.

A fifth software program that was reviewed is a Linear Scheduling program called Xposition. It is available from Transcon Consultants Inc. Xposition is the only commercially available software for creating and editing Linear Schedules. It was used on the test projects in the fourth section of this paper, so it is discussed later.

3.0 - DOT Reviews

The Michigan Department of Transportation is one of fifty state DOTs who have similar goals, organization, and tasks to accomplish. A review of selected DOTs' systems for monitoring projects and scheduling requirements they place on contractors is described in this section. The systems in use by other states were examined to provide background information for MDOT.

Six states whose size and amount of work varied from very large to very small were selected for review. The amount of money received from the Federal TEA-21 legislation provided quick and easy criteria for this selection. Texas, Minnesota, Virginia, California, and Florida were chosen for this review based upon their respective TEA-21 funds for 1998 - 2003, shown below in Table 1. California and Texas were the states with the most money, and the others were relatively close to MDOT's funding level.

Table 1 – TEA-21 Funding 1998 to 2003

State	TEA-21 Funding / year (millions)
Michigan	$ 825
Texas	$ 1,888
Minnesota	$ 392
Virginia	$ 670
California	$ 2,400
Florida	$ 1,200

3.1 - Texas Department of Transportation

The Construction and Maintenance Division of the Texas Department of Transportation (TxDOT) has recently revised their system used to schedule and monitor construction projects. TxDOT has been broken into several geographic regions or divisions in which each manages the projects in their respective areas. This allows for closer control of the projects and some variation in the control used on different projects. This is similar to MDOT's organization

TxDOT now has four different levels of scheduling requirements that can be used for project control as deemed necessary. Special Provisions to the TxDOT Specifications have been written to dictate the different requirements for each level of scheduling. The first and simplest level

requires no schedule to be submitted at all. This level can only be used for routine maintenance projects such as basic crack filling, re-striping or other common maintenance activities.

The second level of scheduling requires that the contractor submit a Bar Chart Schedule. The schedule may be created using computer software, however manually created schedules are accepted. This is the level used on standard construction projects where, "... the district considers a Bar Chart to be adequate for time administration decisions." ("Scheduling", 1997). The 1995 TxDOT Standard Specifications list the requirements for this level of scheduling, and are considered the minimum or basic requirements for all construction projects.

The requirements for the Bar Chart indicate that all major work activities be shown, including material procurement and utility relocations. Start and finish dates along with durations must also be included on the schedule. The contractor is required to update this schedule monthly or if the sequence or timing of work changes during the project. The district engineer must approve the schedule and all updates to the schedule. Timing for these approvals are included in the requirements.

The third level of scheduling is considered Basic CPM scheduling. This level requires the contractor to submit CPM schedules that may be created on computer software, although the software is not a requirement. The schedules are submitted in a hard copy format, and must use either the precedence diagram method (PDM), or activity on node, (AON) diagrams. This level can also be used on simpler construction. However, it should only be used when the district has the ability to understand and utilize the CPM schedule and intends to monitor progress closer, and manually use the CPM diagram. The requirements for activities, activity information, approval, and updates are similar to those described for Bar Chart schedules.

The fourth level of scheduling, considered Advanced CPM scheduling, requires the use of Primavera software to create, modify and submit the CPM schedules. This level of scheduling is recommended for use on large, complex projects with expected delays, and is required on all projects with an A+B Contract. The Special Provision for this level specifies the use of either

Primavera SureTrak or Project Planner depending upon the project size, ability, and intent of the district where the project is located.

The Special Provisions for this level of scheduling are very detailed in describing the format and information in the schedule. Activity durations cannot exceed 20 days. Activity descriptions must have a specific format with coding for types, and locations of work. A preliminary schedule is due at the pre-construction meeting, outlining the first 60 days of construction. A detailed schedule is developed within 35 days. The TxDOT district engineer or project engineer take a very active role in the review, acceptance, and monitoring of these schedules.

One piece of information that should be mentioned here is that in a workshop put on by TxDOT, they recognized Linear Scheduling as a current type of scheduling available. However, no guidelines or specifications have been written to accept or use Linear Schedules to fulfill the obligations of the contractor. When asked about Linear Scheduling, Bob Hundley, a Contract Claims Engineer for TxDOT explained that Linear Schedules were seldom used by the engineers or contractors to describe the overall construction process on projects or to demonstrate the progression of work around areas of special concern; such as lack of access. But, it had never been used as an official means for submitting schedules.

3.2 - Florida Department of Transportation

The Florida Department of Transportation (FDOT), like Texas and Michigan is divided into geographic districts for the management of projects. Each district appoints a District Scheduling Engineer (DSE) who is responsible for determining the type of schedule to be specified on each job, and then reviews the schedules that are submitted. FDOT does not have set levels of project schedules, however they have Special Provisions for Bar Charts, and CPM schedules, that can be used when necessary. The Construction Project Administration Manual (CAPM) dictates that Bar Charts should be used on most projects. CPM schedules should be required on projects over 5 million dollars, incentive/disincentive projects, or other large, multi-phased urban projects.

One item that FDOT uses that some other DOTs do not is called Flextime. Flextime can be added by the DSE and it allows additional time to be added between the notice to proceed and the day that contract time actually begins to accumulate. This time is to be used by the contractor to begin activities such as mobilization, utility coordination, or acquiring materials, so that the disruption to traffic can be minimized.

The FDOT Standard Specifications dictate that the typical information must be supplied in the form of a schedule. This information includes, major activities, start and finish dates, durations, and interim phasing dates. The specifications do not dictate that any graphical representation must be supplied, thus this schedule could simply be a list of the required information and is called a Working Schedule. Special Provisions are included on most projects and require Bar Charts or CPM schedules. The Special Provisions for Bar Charts or CPMs give more detailed information about what is required for each. The competed schedule (CPM, Bar Chart, or Working Schedule) is then submitted to the DSE for approval.

FDOT had a system that was used to tie the schedule to progress payments. The system gave them the ability to withhold payment on jobs that were a certain percentage behind schedule. A representative of FDOT, John Schriner, said that the system was not used very often, and was not an effective tool to use on contractors to bring projects back on schedule; so it was eliminated. No other means of forcing contractors back on schedule has been implemented.

One difference between FDOT and other DOTs is that updates to the schedules are required monthly for all forms of the schedule. If the sequence of work changes in between the monthly updates the contractor is not required to update the schedule at that time. Only when requested by the engineer, is the contractor expected to make interim updates to the schedule.

3.3 - Minnesota Department of Transportation

Minnesota's Department of Transportation takes a little less active role in the scheduling and monitoring process than the other DOTs surveyed. The Standard Specifications state that five days before construction begins, the contractor shall furnish the engineer with a progress schedule

for approval. The schedule must be in the form of a Bar Chart or Critical Path Diagram that shows the standard information (i.e. description, dates, durations) for major construction operations. The specifications say that the schedule must cover all 'progress controlling items of work'. MnDOT defines a progress controlling item of work as "one that must be completed either partially or completely to permit continuation of progress" ("Minnesota", 1995).

This definition of controlling items is different from what other DOTs use. The more frequently used definition makes reference to the fact that controlling items have no available float. MnDOT uses the progress schedule to determine controlling items of work, and to check on the rate of progress. MnDOT will give a weekly statement to the contractor showing a total of the working days charged to the job to that date. The statement will include all delays for that period and will classify each of the delays as avoidable or unavoidable.

The specifications give detailed descriptions of avoidable and unavoidable delays. Unavoidable delays occur in situations where MnDOT, another contractor, a natural disaster, or other rare event takes place. The contractor assumes risk for normal weather delays on Calendar Day contracts. On Workday contracts, the weekly statements will not count the time where work on controlling operations could not be completed due to weather. Specifications are given for charging partial days, but the contractor does not assume risk for the weather on Workday contracts.

Based on the above system, the only extensions of time that are awarded are for additional work added to the contract. A contractor can dispute the charging of workdays on a weekly basis but rarely does. This system is one of the simplest systems that was examined. MnDOT puts a little more of the risk onto the contractors than some of the other DOTs.

3.4 - California Department of Transportation

The California Department of Transportation (CalTrans) takes an active role in monitoring construction projects. The Standard Specifications require the contractor to submit a "Progress Schedule". The contractors can submit schedules in the form of their choice, or on a form

provided by the engineer. The requirement is that the typical information, such as activities, dates, logic, durations, be supplied for major items of work and that the form is updated monthly to show the status of work performed throughout the month. If a satisfactory progress schedule is not submitted monthly, payments to the contractor will be held until it is submitted.

The basic scheduling requirements described above are fairly standard. However, the CalTrans Special Provisions for CPM are much more detailed than other DOTs. The CPM provisions require that the contractor provide a complete computer system with specific hardware requirements and the latest version of the contractors scheduling software to the engineer(s) on the project. Training for the software for two departmental employees must be provided, and the contractor must have an individual proficient with the software. The contractor can chose from Primavera Project Planner, SureTrak or an equal software package

The Special Provisions for the CPM schedule are ten pages long and very detailed on every aspect of the schedule. Specific activity coding, phasing, responsibility, and formatting is specified. Not only are critical activities referenced, but 'near critical activities' are defined as activities with less than 10 working days of float time. The contractor must submit revised schedules if the project is twenty days behind schedule, or if any critical or near critical path has changed or if changes are anticipated. At the beginning of each month, the schedule must be updated to the twenty-first day of the previous month, for review and approval for monthly progress payments. For any period where the required scheduling updates are not submitted, CalTrans will keep twenty-five percent of the estimated progress payment.

The cost for the CPM scheduling system is to be included as a bid item in the original contract. The Special Provisions also include details for when payment of this item will be made to the contractor. Of the scheduling systems reviewed, the CalTrans process was the most stringent and detailed system.

3.5 - Virginia Department of Transportation

After speaking with Mr. Rick Miller, an engineer with the Virginia Department of Transportation (VDOT), it was understood that VDOT has been reviewing and revising their project scheduling system for the past few years. The Special Provisions for different levels of scheduling have been, and will continue to change until the system is finalized. Currently, VDOT is somewhat flexible on the format of the schedule that is required for ordinary construction projects. As long as the required information is included, the contractors can submit just about anything. Schedules have been submitted as Bar Charts, CPMs, and even Linear Schedules. Some are created with computer software and some are drawn manually.

Special Provisions to require more complex CPM schedules, called 'Working Schedules' are available and are used on larger projects. Large projects are typically over 180 days long, although that criteria is not stringent. The Working Schedule requirements do not specify certain software, or that schedules be submitted electronically, although the department is leaning to the adoption of the Primavera software.

The important information, whether on the basic schedule or on the Working Schedule, is that the contractor identifies major activities, dates, durations, relationships and critical activities. The department wants to know the critical activities throughout the job, and have a dollar value associated with those activities. These values are required and called an 'Earnings Schedule'. The engineer keeps monthly totals of work done on critical activities and compares them to the earnings schedule. The specifications allow the engineer to withhold a five percent retainage if the progress on the critical activities is ten percent behind schedule.

The primary reason for requiring schedules to be submitted is to keep track of the progress and try to force the contractor to catch up when progress is unsatisfactory. The schedules may be referenced if contractors apply for extensions of time, but that is not the primary reason for the schedules.

3.6 - Wisconsin Department of Transportation

The entire system used by the Wisconsin Department of Transportation (WisDOT) was not reviewed as the previous DOTs were. Instead, only WisDOT's involvement with the use of Linear Scheduling was investigated. One particularly large highway construction project of Interstate 94 in Wisconsin required the use of Linear Scheduling. This project was large enough that it was being built in many stages, through many different contracts and contractors. A specific division of WisDOT worked solely on this project, allowing close involvement between WisDOT and the contractors.

The project team specified certain things in the contracts that were different from the rest of the projects in the state, including the use of Linear scheduling. The project team felt as though Linear Scheduling could allow them to easily piece together the various contract sections and phases to coordinate all of the work. The Linear schedule allowed for an easy view of the entire project at once. An example of a Linear schedule for one section of the project has been included in Appendix H.

4.0 - Linear Scheduling and the Test Projects

The use of Linear Scheduling on some MDOT projects could help to improve the scheduling system. Some contractors are already using Linear Scheduling and may want to submit them to MDOT. To demonstrate the use of Linear Scheduling, it was used on three MDOT projects. These projects were also monitored to evaluate the accuracy and effectiveness of the current MDOT scheduling system.

Three MDOT construction projects were identified as being suitable to be scheduled and monitored. The three projects needed to contain linear construction activities, be relatively simple to schedule, and be located relatively close to Michigan Technological University. Also, the contractor for each job needed to be willing to share information and help in the creation of schedules before work started in order to make them as accurate as possible.

It was the intent to select high impact projects. However, due to the starting date of the research project some MDOT projects that were initially thought to be appropriate had been completed or were too far along to be used. Therefore, with the help of MDOT personnel, contractors, and with the height of the construction season, three projects were selected. A map showing the locations of the three projects is in Appendix I. The three projects identified were all awarded to Payne and Dolan Inc. of Gladstone, MI, and they agreed to help with the investigation. It was the intent to demonstrate the use of Linear Scheduling, to evaluate linear scheduling software, and to assess the current MDOT scheduling requirements on actual construction projects.

The first project was a "Mill and Resurface" of US-41 highway between Marquette and Negaunee. A " Mill and Resurface" is a type of rehabilitation project which consists of a milling operation which grinds off a certain depth of the existing pavement, before resurfacing. This is a very common highway rehabilitation project and the activities are linear in nature since the same operations are repeated at relatively constant rates.

Another project that was selected was a "Crush and Shape" of M-553 from Gwinn, north towards Marquette. The "Crush and Shape" is a common highway reconstruction project in which the existing pavement structure is completely milled off in-place, then graded and compacted to provide a very stable base for a new bituminous roadway. Again, these operations are linear activities so the project lends itself well to a linear schedule.

The third project selected was on M-203 in Calumet. This project included milling, crushing, sewer installation, and paving. The combination of different repairs along with the sewer installation made this project a little more complex than the previous ones and would provide a more complex linear schedule.

The Linear Scheduling software, Xposition, does not use any logic network to actually create schedules. Xposition simply plots the required shapes from the dates and locations that are entered. For this reason, the projects were first scheduled in SureTrak to determine the starting and finishing dates that needed to be entered into Xposition. Updates and changes were made to the schedules using SureTrak, then the new information was entered into Xposition.

For each of these projects a CPM schedule was created by the project team in Primivera SureTrak, using the information obtained from the contractor and from the Progress Schedule Form 1130 that was submitted to MDOT by the contractor. The information from SureTrak is displayed in a typical bar chart schedule.

Once the projects were underway, regular site visits were made to update the schedules, to determine the accuracy of the schedules and to discuss with MDOT and the contractor the usefulness of the schedules. Upon completion of the project, a final schedule was created to accurately depict how the project was constructed. The final "As-built" schedule was created from information obtained during the site visits and from the Daily Construction Reports made by MDOT personnel on each job.

Since an objective of the project was to evaluate the current MDOT requirements, this proved to be a good time to determine the accuracy of the 1130 Progress Schedule Forms. A comparison

was made between the contractors' planned list of controlling work items (from Form 1130 – Progress Schedule) and what the actual major items of work were during each day of the project. The actual major items of work were obtained from the Daily Construction Reports made by field engineers.

4.1 - US - 41 Resurfacing

The US-41 resurfacing project was straightforward to schedule since the major activities are milling and paving. This roadway was originally a concrete road that had been resurfaced with bituminous pavement. It is common during this type of rehabilitation to make some repairs to the concrete in deteriorated areas, primarily around the joints. After the existing bituminous pavement is milled off, a crew proceeds through the length of the project and repairs any of the joints that need repair before the new bituminous surface is placed.

This project was a workday project with 25 workdays in which to complete the project. The project had to start between July 5 and July 19. Prior to construction, the contractor completed Form 1130 - Progress Schedule which identified the controlling operations for each day. As mentioned, this was a very simple project and so the Progress Schedule, shown in Appendix J-1, has only 4 controlling items. One aspect that made this project difficult to schedule accurately was the amount of joint repair that was needed. This was not known until the existing bituminous pavement was milled off, and the MDOT engineer could determine which joints to repair. As it turned out there were twice as many joints repaired in the eastbound lanes than in the westbound.

The roadway consists of two lanes in each direction, separated by a grass or paved median. The original plan was to begin with the eastbound lanes, mill both lanes, follow with the joint repair and paving, then move to the westbound lanes. This is a fairly basic plan to schedule and can be seen in bar chart format in Appendix J-2. The data from the bar chart schedule was then used to create a linear schedule with the Xposition software. The linear schedule is shown in Appendix J-3. It should be noted that in all cases the bar chart and linear schedule were not

submitted to MDOT, by the contractor, but only developed as part of this research project. As required in the contracts, only Form 1130 was submitted.

Once the construction was underway, periodic visits were made to check on progress. As with most construction projects, the sequence of activities changed due to problems that arose in the field. On this project, after the eastbound lanes were milled, the traffic was riding on the old exposed concrete surface while the necessary joints were repaired. Problems arose when the concrete began to rupture at the unrepaired joints due to traffic and the hot, humid weather which was causing expansion. Pieces of concrete were being thrown through windshields and large potholes formed in the pavement. As fast as the contractor made temporary patches, new holes were forming. To deal with this problem, the sequence of activities was changed. First, one of the eastbound lanes was completed and covered with new pavement as soon as possible, rather than completing both lanes simultaneously. Then, when work began on the westbound lanes, one lane was completed all the way through then the second lane was done. This allowed for traffic to always be driving on a smooth, clean surface instead of the milled areas; keeping loose concrete to a minimum.

The decision to change the schedule was initiated by both the contractor and MDOT engineer. Although the MDOT engineer wanted to have both lanes exposed before making decisions on which joints to repair, the contractor was responsible for claims such as blown tires and windshield cracks. In order to reduce the occurrence of these problems the schedule was changed. Appendices J-4 and J-5 show the final sequencing of activities and are fairly accurate representations of how the job was constructed.

Appendix I-6 shows a list of all the possible workdays on the job, what activities occurred, and what the contractor originally identified as controlling items. Two days on this job were delayed due to weather, so they are not counted as workdays on the table. On the 23rd day, the job was 99% complete and the remaining cleanup took place during the next 2 days, so essentially the project was completed ahead of schedule.

4.2 - M – 553 Reconstruction

This project was a "Crush and Shape" of about 7.5 miles of M-553 north of Gwinn. M-553 is a bituminous, two-lane highway, with paved shoulders. The basic construction plan was to put both directions of traffic on the northbound side (traffic lane and shoulder) of the existing pavement. Crushing, shaping and paving of the leveling coarse would occur on the southbound side. Then the traffic would be moved to the southbound side and the same sequence would be used to construct the northbound side. The top coarse would then be placed on both lanes to complete the job. Besides these basic linear activities, two angled intersections were rebuilt to make them ninety-degree intersections, and the guardrail on an elevated section was replaced. After speaking with the project manager from Payne and Dolan, it was determined that the linear operations would take place from north to south so that trucks coming loaded from the north could dump, then turn around empty at the south end of the job and return for another load. The submitted Progress Schedule, prepared by Payne and Dolan is included in Appendix K-1

The original plan was scheduled on SureTrak and is shown in bar chart format in Appendix K-2. As before, this data was used to create the linear schedule, which is presented in Appendix K-3. The major problem that arose which impacted the schedule of this job was that after construction had started the contractor determined that there was not enough space between the guardrails of the elevated section to allow for two way traffic on half of the existing pavement. Therefore, both halves of this section were constructed simultaneously while traffic was controlled with a flagging operation. The rest of the roadway was constructed in the original sequence. Other changes that occurred were in durations of some activities and the timing of the work done at each intersection. Since the intersection work was not a controlling operation it was not critical to the on-time completion of the project. Although the contractor and the MDOT engineer discussed the changes to the construction sequence, no update was ever submitted to MDOT to reflect any of these changes. Therefore, at this time the submitted Form 1130 – Progress Schedule became useless.

The schedules in Appendices K-4 and K-5, respectively, are bar chart and Linear Schedules of the actual construction sequence. The intersection work and the guardrail are not linear activities they are represented by bars and a block respectively in the Linear Schedules. This project was also a 'workday' project with 35 workdays available for completion. All possible workdays were counted with no delays due to weather. The project was completed in exactly 35 workdays, so penalties or extensions of time were not an issue. Payne and Dolan's project manager did feel as though if they had completed late, he would have been justified to request an extension of time for 2 days based upon some culvert work that was added to the project, but it didn't matter since the job was completed on time. Had there been a need to request an extension, the submitted Progress Schedule would have been of no use to determine what operations were controlling on any given day.

4.3 - M – 203 Rehabilitation

The section chosen for this rehabilitation project is two miles of M-203, near Calumet to the US-41 intersection. The existing surface was bituminous. In some locations this was over some very old and historic brick paving in the Village of Calumet. The Village wanted to save the old brick paving, so these sections were to be milled and repaved, while the rest was crushed and shaped for a new base. At the US-41/M-203 intersection there was concrete curb and sidewalk to be placed. Additionally, about 300 meters of storm sewer installation, and adjustment of existing utility structures needed to be done.

As with the other projects, the Progress Schedule (Appendix L-1) was used to create the bar chart and linear schedules in SureTrak and then Xposition. The corresponding schedules are in Appendices L-2 and L-3. This project had more activities than the previous case studies and required more effort to create the linear schedule.

This project was also different because it was a Calendar Date contract. This meant the contractor had to be finished by a certain date, no matter how many days were worked to complete it. For the contractor this meant the Progress Schedule, Appendix L-1, was filled out

similar to the method described in section 2.2.2. The completion date, October 8, 1999, was entered in at the end, and the earliest possible start date at the beginning. All of the activities were positioned on the schedule to use the maximum available time.

Appendix L-6 compares the originally identified controlling work items from Form 1130 – Progress Schedule to the actual major items of work that were done each day. The table in Appendix L-6 shows that beyond September 9th, the progress schedule is never again accurate. Since there was more than a week in the middle of the project where no work was done, all operations were delayed. The sequence on the progress schedule is fairly accurate, but the durations of most of the controlling operations are wrong. The delay combined with the duration error created an essentially useless document.

At the time that this report is being written, the final outcome of this project has not been determined. The project was not completed until October 21, however it was considered substantially complete on October 15. The contractor could be assessed liquidated damages for the 13 total days that the contract was late, but it was the opinion of the engineer that 7 days of damages will be charged since the job was opened to traffic and substantially complete on the 15th.

The contractor may apply for an extension of time to try to minimize any damages. However, there would be no justification for the application. There were ten days where work could have been done, but wasn't. This is a situation where the engineer has a close relationship with the contractor from this and other concurrent MDOT jobs. The engineer is well aware that the contractor worked all possible hours of each day this past summer on construction projects, and simply may have had too much work to do. Although the contractor will probably be fined, some leniency may be granted because there are not many other contractors to work with in the area.

4.4 - Xposition

Creating the linear schedules using Xposition was not as easy as it first seemed. First, Xposition does not allow activities to be entered with their durations and relationships. Instead, the user must enter each activity's starting and finishing date, and the starting and beginning location. The software is really only plotting points on a set of axis, then drawing in the correct shapes to create the activities. This could just as easily be done by hand, or on any software that will plot points on a two dimensional graph, such as a spreadsheet program.

The software does not have any of the functions that CPM programs do. The user cannot enter any logic network allowing quick and easy updates to the entire schedule when one change is made. The software cannot be resource loaded or leveled. It has no means of identifying critical activities and the formatting options are very basic.

Transcon claims that once a schedule is created in another scheduling software such as Primivera's P3 or Suretrak, the data can easily be exported and imported into Xposition. This process may be possible, but it did not prove to be as easy as Transcon had claimed. The data must be in exactly the right format for Xposition to import it, and the location (or station) of beginning and ending for each activity must be entered into the exported file. After using both SureTrak and Xposition to create a few schedules, it was easier and faster to enter the data into Xposition manually. Unfortunately, at this time, Transcon does not intend to update the version of Xposition that is currently available.

The Linear Schedules included in the appendices were not formatted ideally. Some of the activity names are printed over top of each other, making some of the activities difficult to identify. This should be fixed by including only the ID number on the schedule and then having a legend of activity Ids, but this function is also not available with Xposition. The intent was to demonstrate the use of a software program to create these schedules, so they were formatted the best possible way with the limitations that existed.

5.0 - Summary

The objectives of the research were to review the current MDOT requirements and to identify the purpose, capabilities, and problems. Some suggestions for improvement based upon interviews of MDOT personnel and contractors, and reviews of other state DOT requirements were made. The three test projects provided the ability to not only demonstrate and review Linear Scheduling, but also add to the evaluation of the MDOT scheduling requirements.

The MDOT requirements revolve mostly around the 1130 – Progress Schedule Form. Between the interviews and the three test projects, the frequent inaccuracy of the information on this form was illustrated. Again, the three reasons that MDOT has for requesting any schedule are:

1) To make sure that the contractor has actually taken the time to develop a reasonable plan to complete the project in the given time.
2) To provide a means for measuring progress throughout the duration of the project so that measures can be taken to keep the contractor on schedule.
3) To document evidence for justification of decisions regarding construction time on a project, such as time extensions.

If the Progress Schedule is inaccurate, only the first of these three goals is addressed. The inaccurate Progress Schedule does show that the contractor developed a planned sequence for construction. The durations and dates are often wrong, but the sequence of activities typically remains the same through the project. The inaccurate Form 1130 does not provide a way to evaluate progress, and it provides very little help in determining the legitimacy of an application for a time extension.

One reason that the Progress Schedules are often inaccurate is because of the means used to fill them out. As discussed in section 2.2.2, contractors fill out the Form 1130 to show a complete use of the contract time, when they know the job may be completed in less time. This could mean that MDOT ought to review the system used to establish contract time.

To make the Progress Schedule more accurate, two changes have already been proposed. The two Special Provisions discussed, 102F and 102G, (Appendix G) should help to improve the accuracy of the Progress Schedules, if they are used. The use of these Special Provisions is still at the discretion of the project engineers. If an engineer doesn't want to see multiple controlling items, then Special Provision 102F can be excluded, or the Progress Schedule can be rejected. Special Provision 102F needs to be used and accepted statewide. Special Provision 102G, pertaining to schedule updates, must also be used and enforced on all contracts. It is imperative to make updates to the Progress Schedule if it is to be accurate.

MDOT should consider monitoring the effectiveness of the new Special Provisions, when they are used. A possible way to test the impact of the new Provisions would be to compare projects that were built during 1999 or 2000, without SP 102F or SP102G to projects built with the new Special Provisions during 2000. The comparison would be between those items listed as controlling operations and the major work items actually done each day. This would be similar to what was done on the three test projects in this research. The test would help MDOT determine if the new Provisions improved the accuracy of the Progress Schedules.

Another suggestion is the possibility of completely eliminating schedule requirements, at least for smaller projects. Certain projects are simple enough that the time and money spent submitting, reviewing, and updating any schedule is not justified by the benefits of the schedule. The MDOT engineers say they already have an excess of paperwork, and the contractors feel as though the schedule is often a waste of their time on simple projects. The criteria for choosing which projects are small enough or simple enough would still need to be developed.

An extension of the idea mentioned above would be to let the contractor assume all risk for any delays except work added to the contract, and request no schedule at all. As long as the scope of the work involved does not change throughout the contract time, then simply penalize the contractor for everyday that the contract is over the finish date. If work is added to the contract, then additional time will be given using the standard work production rates that MDOT

publishes. This way MDOT would not be involved in the scheduling at all. If the contractor fails to complete work on time, then the contractor would pay damages and possibly lose eligibility for future contracts. The contractor could even be given the option. The option would be to use the current system, submit a Progress Schedule and update it; or submit no schedule, and assume all risk for delays except added work.

There are obviously projects that are complex enough, large enough, or have a high enough impact on the motoring public, where MDOT would still want to monitor contract time very closely. For these projects, the CPM Special Provision should be used, as it has been in the past. In fact, it should be used more often than in the past. As of now there are not specific criteria dictating when CPM Special Provisions should be used. MDOT should establish criteria requiring CPM scheduling on more projects, at least all high impact, A+B, and incentive/disincentive projects. However, the benefits of CPM scheduling are only available if the personnel on the job understand the schedule and can work with the software. MDOT should be sure that enough people in each region have had training with CPM software before it is required on more jobs. Not only should the engineers be able to use the CPM software, but also the field personnel.

For projects that still require the Form 1130 – Progress Schedule to be submitted, MDOT should encourage contractors to submit additional information. A listing of controlling operations should still be included, but it can help the engineer reviewing the schedule or time extensions to see the entire schedule. The current MDOT requirements do allow the contractors to submit more information that what is on the Form 1130. The additional information could be in any form: bar chart, network diagram, or even a Linear Schedule.

Linear Schedules provide a alternative means to bar charts of visualizing the overall construction sequence on a project. Linear Scheduling did not demonstrate to be any more accurate than another form of scheduling, without updates. This is no surprise

though, a schedule is constantly being updated to reflect changes on the job, and any form of a schedule requires updates. Two of the three test projects, US-41 and M-553, were excellent examples of projects that are candidates for Linear Scheduling. Once the schedules were updated to reflect changes in construction sequence, they were very good representations of the construction process.

On site visits, the schedules gave a fairly accurate idea of where a particular crew would be working on an activity that day. The Linear Schedules were easy for personnel to read and understand. They do take a little more effort to create at this point in time.

The Linear Schedules could be just as easily created on a spreadsheet program, or by hand, as they can with the available software. The work involved is not so much from drawing or plotting the schedule; the work is in determining starting and finishing dates and locations. Once a sequence of activities is determined, the dates need to be determined, either using CPM software, or manually. The dates, along with location can then be used to create the schedule.

At this point, MDOT should be aware of Linear Schedules and allow them to be submitted as supplemental information to a Progress Schedule. MDOT may even want to consider requiring them to supplement the Progress Schedule. However, the computerization of Linear Scheduling software equal to that of CPM or bar chart scheduling has not been done. Further development of Linear Scheduling must occur before it will be as widely used and accepted as CPM or bar charts.

List of References

Bafna, T. (1991). "Extending the range of linear scheduling in highway construction." *Masters Thesis*, Dept. of Civil Engineering, Virginia Polytechnic Institute & State University, Blacksburg, Virginia.

Charzanowski, E. N. Jr., and Johnston, D.W. (1986). "Application of Linear Construction." J. of Const. Engrg., ASCE, 112(4), 476-491.

Cole, L. J. R. (1991). "Construction Scheduling: Principles, Practices and Six Case Studies." J. of Const. Engrg., ASCE, 117(4), 579-588.

"Five Year Road and Bridge Program: 1999 to 2003.", (1999), Michigan Department of Transportation, Lansing, MI.

Harris, R. B. (1996). "Scheduling projects with repeating activities." UMCEE Report No. 96-26, Civil and Environmental Engineering Department, University of Michigan, Ann Arbor, MI.

Harris, R. B. (1998) "Scheduling Projects with Repetitive Activities." J. of Const. Engrg., ASCE, July/August 269-278.

Harmelink, D. J. (1998). "Linear Scheduling Model: Development of Controlling Activity Path." J. of Const. Engrg., ASCE, July/August, 476-491.

Herbsman, Z. J. (1987). "Evaluation of scheduling techniques for highway construction projects." Transportation Research Record 1126, Transportation Research Board, 110-120.

"Michigan Department of Transportation 1996 Standard Specifications for Construction." (1996). Second Printing, Michigan Department of Transportation, Lansing, MI.

Mattila, K. G. (1997). "Resource Leveling of Linear Schedules: A Mathematical Approach Using Integer Linear Programming." Ph.D. These. Purdue University, West Lafayette, Indiana.

"Minnesota Department of Transportation 1995 Metric Standard Specifications for Construction." (1995), Minnesota Department of Transportation, St. Paul, MN.

Meredith, J. R., and Mantel, S. J. Jr. (1995). *Project Management: A Managerial Approach*. 3rd Edition, John Wiley and Sons, New York, NY.

O'Brien, J. J. (1969). *Scheduling Handbook*. McGraw Hill, New York, NY.

Parvin, C. M. and Vorster, M.C. (1993) *Linear Scheduling: Visual Project Planning and Managaement.* P & W Publications, Richmond, VA.

Reda, R. M., (1990). "RPM: Repetitive Project Modeling." J. Const. Engrg. And Mgmt.., ASCE, 116(2), 316-330.

"Scheduling Workshop for Construction." (1997). Construction and Maintenance Division of The Texas Department of Transportation, Austin, TX.

Stradel, O., and Cacha, J. (1982) "Time Space Scheduling Method." J. of the Const. Div., ASCE, 108(CO3), 445-457.

Suhail, S. A., and Neale, R.H. (1994). "CPM/LOB: New Methodology to Integrate CPM and Line of Balance." J. of Const. Engrg., ASCE, 120(3), 667-684.

List of Appendices

Appendix A – Form 1130 – Progress Schedule

PROGRESS SCHEDULE

FILE 102

Michigan Department
of Transportation

Information required by MDOT in order to establish a construction schedule.

1130 (2/86)

CONTROL SECTION	JOB NO.

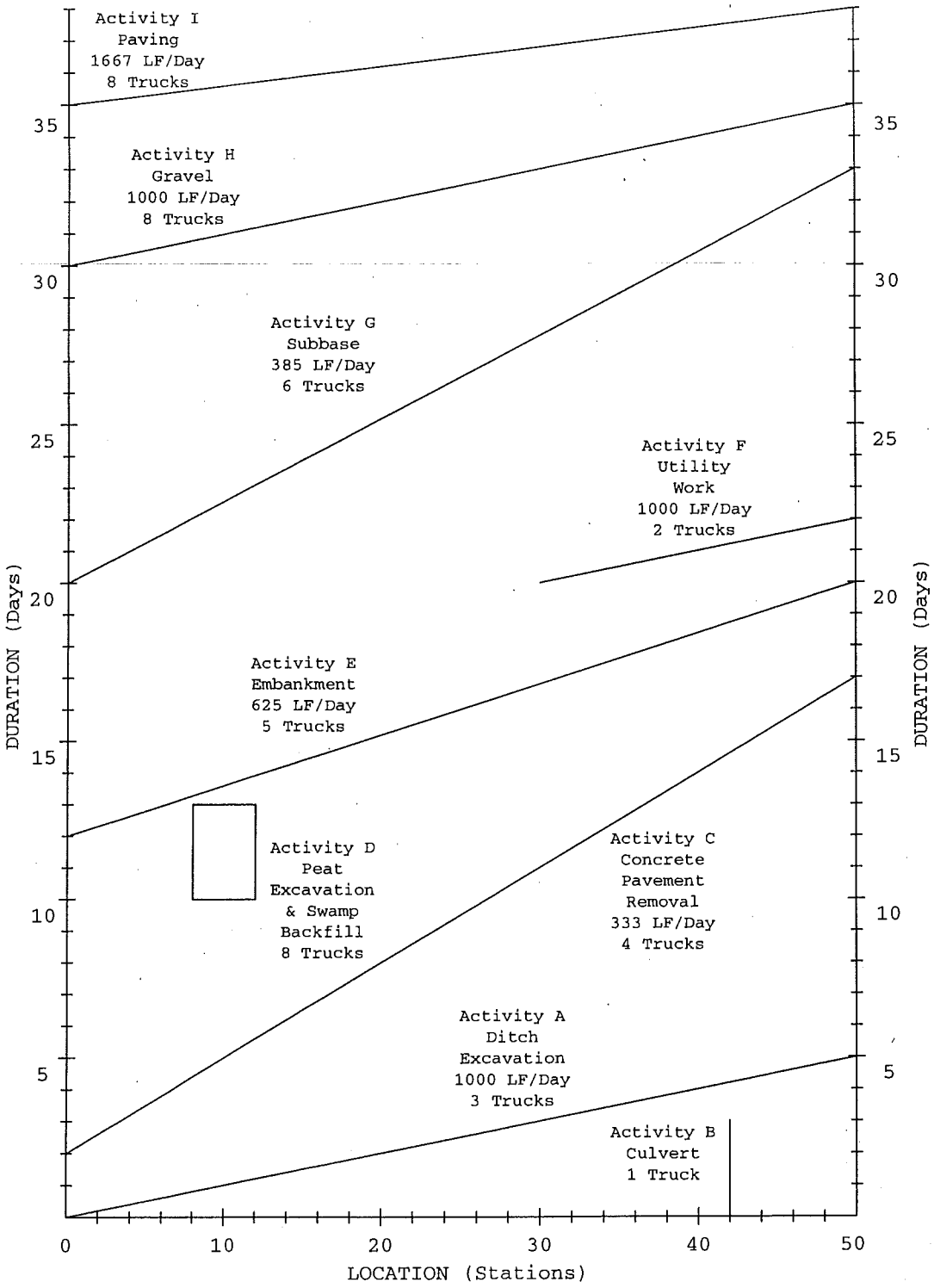
OUTLINE OF PROPOSED ORDER OF WORK FOR MAJOR ITEMS INCLUDED IN PROPOSAL — If approved, this outline will become part of the contract.

ITEM OF WORK	PROPOSED STARTING DATE OR ELAPSED WORK DAYS	PROPOSED COMPLETION DATE OR ELAPSED WORK DAYS

REMARKS

OPEN TO TRAFFIC WORKDAYS	DATE	CONTRACT COMPLETION WORKDAYS	DATE
SUBMITTED BY CONTRACTOR	DATE	BY	DATE
SUBMITTED BY SUBCONTRACTOR	DATE	BY	DATE
APPROVED BY DISTRICT FIELD ENGINEER	DATE	APPROVED BY CONSTRUCTION ENGINEER	DATE

Appendix B – Sample Linear Schedule of Typical Highway Construction Project



Sample Linear Schedule (Mattila, 1997)

Appendix C – MDOT Scheduling Issues Identified for Summit Meeting

ISSUES

1. Use of dual paths during CPM submittal prior to award.

2. Non-lapping date requirement for critical items on the progress schedule.

3. Who owns the "float" and should it be a pay item?

4. General information on path logic and unusual methods (should logic be more appropriate?)
   a. Start to start
   b. Finish to finish
   c. Finish to start

5. What constitutes a "sufficient" number of activities to determine the CPM?

6. How often should a schedule be updated?

7. What constitutes a contract being behind schedule?

8. How extras and overruns impact the job and the critical path.

9. Use of a standard method for critical path.

10. Definition of an activity on the path. How detailed should it be? i.e., general statements on the path (grading, sewers, paving)

11. What happens when a non-critical activity becomes critical?

12. Should there be a standard way of making networks on MDOT projects?

13. Breaking down the work operations.

14. Redrawing the network.

15. When should networks be submitted and how should they be approved?

16. Extension of time relationships to networks.

17. Crashing schedules and their relationship to normal work.

18. Making the contract requirements for progress schedules a special provision.

19. Should MOOT's CPMs be available prior to letting? Potential problems.

20. User delay issues:
    a. No work allowed on high tourist routes during peak travel periods (weekends)
    b. Compressing work schedules to minimize total inconvenience
    c. Night work to avoid peak traffic periods
    d. Project accelerating clauses

21. User Inconvenience:
    a. "Corridor approach"
    b. Contractor provided public information campaign

22 Contractor ideas:
    a. Constructability reviews
    b. Value engineering
    c. Contractor furnished traffic control plan

Appendix D – Summary of Resolutions from Summit Meeting

Summary of Resolutions
Progress Schedule Summit
June 16,1999

The following issues discussed were determined to be resolved by the combined industry/MDOT group:

Issue #1: Use of dual paths during CPM submittal prior to award of contract.

Contractor's position: That in many situations, a bridge contractor's work, as well as the road contractor's work on many projects, will often follow parallel critical paths that have dual items or more as critical all at the same time. This exists on many projects and is often prevalent due to the nature of highway construction. This also reflects reality on those projects that have CPM's specified.

MDOT's position: that if dual paths are allowed, then how will extensions of time be determined if there are numerous controlling operations present at any one time on the project?

Resolution: MDOT will allow dual critical paths on projects with justification by the contractor with the submittal. These justifications may be appropriate for future issues relating to extensions of time and delays.

Issue#2: Non-overlapping date requirement for critical items on the progress schedule.

Contractor's position: Feels that this is an unrealistic requirement for most projects that does not reflect reality or represent how the project is actually being constructed. Progress schedule is submitted at the pre-con and never seen or used again. This position as stated above for the CPM issue, was that numerous dual or overlapping "controllingoperations" exist on highway work and should be represented as such on the progress schedule.

MDOT's position: If extras/overruns/delays affect the project, some rational method should be in place to enable the State to analyze these impacts and either be able to deny or approve them.

Resolution: MDOT will allow a more realistic progress schedule to be submitted on all projects if the schedule's controlling operations (which may be overlapping) are of a more detailed nature that provides the rationale for the overlap. This schedule may be submitted on regulation forms or may be of a bar or CPM nature as determined by the contractor as to what would be appropriate.

ACTION PLAN: For issues #1 and #2 above, both the Department and Industry will jointly write a specification that will allow dual critical paths or overlapping operations on projects with the above resolution incorporated. Department (John LaVoy) will write the first draft and submit to industry no later than July 7, 1999.

Issue#6: How often should a schedule be updated
Issue#7: What constitutes a contract being behind schedule
Issue#8: How extras and overruns impact the job and the critical path
Issue#16: Extension of time relationships to networks

Contractor's position: On all of these issues was that with more realistic schedules, the impacts and resulting extension of time requests would be more easily justifiable.

MDOT's position: It would be difficult to analyze impacts on projects unless the controlling operation that is delayed is determined, the dates of the delay are determined, and the reason why it would be MDOT's responsibility to mitigate the delay is established. Some method of analyzing the delay impact must be incorporated into any change that is made to our existing method now and our specifications, especially with trying to analyze a progress schedule with multiple critical paths and overlapping controlling operations.

Resolution: It will be necessary to require the contractor, by contract language, to submit progress schedule updates (possibly monthly) to establish how the critical path has changed from the original schedule if(l) the project falls behind schedule, (2) there is a significant change to the project that would impact the outcome of the project ,or (3) there is a revised sequence ofoperations that impacts the project outcome. Pay estimates will be withheld if the agreed-to revision is not submitted within a designated time of occurrence of the above stated impacts possibly by 30 days. The contractor, when addressing costs for extra work and overruns, must also address the impacts to the controlling operation's duration.

ACTION PLAN: Department (Marge Lauer) will develop a draft specification that will require progress schedule updates if the project is impacted by the above criteria. This specification will also be jointly shared with the industry groups by July 7, 1999. Department (John LaVoy) will change the standard work order form to include a required time amount as a mandatory requirement prior to approval by the resident engineer. Department will also attempt to change the "contract modification" form currently produced by Field Manager to include these time impacts on the schedule.

Issue #20: User Delay Issues

A. **No work allowed on high tourist routes during peak travel periods (weekends)**
B. **Compressing work schedules to minimize total inconvenience**

C. Night work to avoid peak traffic periods
D. Project accelerating clauses

Contractor's position: Was reiterated, as has been done atjoint meetings in the past. To continually specify these types of contract requirements on a regular basis will put severe burdens on the road building community in general. Many requirements in various parts of the state seem to be unreasonable. Adopting these types of progress schedule requirements for all projects willultimately unfairly strain the industry. An example includes the "October U"' completion date on most projects that would require industry workforces to be laid off much sooner than expected, subsequently impacting the livelihood of those people facing no work between October 1 and November 15 (their traditional end of work date).

MDOT's position: Has been that each region has a clear understanding of the type of progress schedule requirement that works best for the project's location and user impacts. The resident engineer that administers the project is totally responsible for the progress schedule requirements and all special project clauses. MDOT will continue to be very attuned to anything that impacts the motoring public in a major way.

Resolution: Although this issue is very important to all parties concerned, it was the feeling of the group that there was little time within this venue for sufficient discussion and resolutions of these issues. It was decided that an attempt would be made to standardize the requirements for the use of these progress schedule clauses relative to the location in the state and local user impacts for various types of projects.

ACTION PLAN: Department personnel (John LaVoy) will meet with MRBA (Tony Milo) and AUC (Mike Nystrom) in an attempt to form a discussion group that may lead to a recommendation on standardization of the special clauses that are inserted into the progress schedule.

Issue #5 : Wbat constitutes a "sufficient" number of activities to determine the CPM
Issue# 12: Should there be a standard way of making networks on MDOT projects
Issue #15: When should networks be submitted and how should they be approved
Issue # 18: Making contract requirements for progress schedules a special provision

Contractor's position: They are faced with a multitude of requirements for CPMs on progress schedules that may change from project to project and between regions. Many of the requirements like submittal times for the updates and maximum length of activities are not uniform from project to project. Also at issue for some contractors is the liquidated damages along with the holding of the pay estimate requirement. Contractors would also like to submit their CPM after the contract award on large complicated projects.

MDOT's position: All project schedules are developed for the individual project and may not lend themselves to a uniform standard. However, there is a question relating to the progress schedule as a contract requirement. There should be some uniformity on this issue.

Resolution: Department should try to make all of the CPM language in the progress schedule a special provision. Updates for CPMs should be no less than every 30 days and no activity should be longer than 20 days. Acceptable activity definitions will also be addressed as per issue #5. Department should update its construction manual to include typical language that requires a CPM.

ACTION PLAN: Department (John LaVoy) will produce a special provision that sets uniform CPM requirements and include its use on the frequently used list. CIM also will go out to regions with a typical progress schedule language for use with the special provision for CPM.

Issue #3: Who owns the float and should it be a pay item.
Issue # 11: What happens when a non critical activity becomes critical
Issue # 17: Crashing schedules and their relationship to normal work

Contractor's position: The float is a contractor's for his use. Due to the necessity to schedule the same equipment on many operations on A±B projects with I/D there usually is not enough float on any activity to allow even the slightest change from the as bid schedule due to changed conditions extras or overruns. Ultimately on these projects all activities could overlap and be designated as critical. The addition of extra manpower and equipment on these projects is very hard to do due to the fact that the schedule is expedited or "crashed."

Department's position: The float on approved schedules is for the Department's use. There have been many projects, both A+B or regular, that have additional work added to operations that everyone agrees are non critical. Example is the addition of extra stop lights to a major grading project that has a very minor amount of electrical work. Work will continue to be added or subtracted from all projects as a natural occurrence.

Resolution: Impacts on the float should be noted as they occur and worked out between the contractor and the Department. It was agreed that the float on a project should be a shared commodity.

ACTION PLAN: Department (John LaVoy) will include in its special provisions for CPM and Progress schedules that the float will be shared between the two entities.

The following issues were discussed but not resolved:

Issue # 19: Should MDOT's CPMs be available prior to letting? Potential problems

In order for MDOT to make these available for the contractor's use some form of protective or hold harmless language would be needed that any errors or omissions would not be binding on the Department.

Issue #9: Use of standard method for the critical path

One type of program for CPM submittal was discussed. This could allow uniform ransmittal between the contractor and state for easier updates and checks. No consensus on the type of program could be reached by the group.

Issue # 10: Definition of an activity on a path. How detailed should it be.
Iissue # 13: Breaking down the work operations.

These issues were discussed within other issue discussions. General consensus was that the lev of detail on a critical path activity was fairly consistent with the current acceptable practice. Thi will be addressed in the proposed special provision for CPM developed by the Department.

The following issues were not discussed and not resolved

Issue # 14 Redrawing the network
Issue # 21 User inconvenience

A. Corridor approach
B. Contractor provided public information campaign

Issue# 22: Contractor ideas

A. Contractibility reviews
B. Value engineering
C. Contractor furnished traffic control plan

Appendix E –Summary of Interviews

Questions for MDOT Contractors Concerning Scheduling

Are schedules created for every job?

1. No, only when required by the contract, most jobs are simple enough and simple enough that the sequence doesn't change much from job to job, so they are 'roughly' scheduled in the mind of the project manager and changes will be made as necessary when the job is actually built.
2. Not really, mostly when required by the contract.
3. No, only the Progress Schedule from is filled out for MDOT projects, and no schedule is created for Private jobs.
4. A schedule is created for almost every job. The larger jobs will have a more detailed schedule. Almost all jobs are scheduled to some extent when they are bid.
5. Schedules are not created for every job, but every job is scheduled on a master Bar Chart schedule for the company so that crews can be scheduled for the construction season.

Who primarily creates the schedule?

1. Each Project Manager bids his/her jobs and schedules it in his/her mind at that time, then required schedules are created at the appropriate time as dictated by the contract.
2. Project Manager
3. One person in the company is responsible for creating almost all of the schedules, and scheduling all of the work crews and equipment.
4. Primarily one person in the company does the almost all of the work to create the schedules.
5. Project Manager

What is the schedule used for?

1. The job schedules that are required (such as Progress Schedules) really are not used for anything. Each Project Manager has some type of schedule to coordinate equipment between jobs.
2. Managing equipment and crews.
3. Internally, the schedules created for the owner (MDOT) are not used. Primarily one person is responsible for scheduling crews and equipment, which is done by hand.
4. The schedule is mostly used to coordinate equipment and crews. In the beginning it is used to familiarize managers/foremen with the planned sequence of construction.
5. The schedules of each individual job are used to develop a master schedule for the company to schedule crews and equipment for the construction season.

What type of schedule is created and what information does it include?

1. A Bar Chart schedule is created to schedule equipment, for all jobs. Job schedules are whatever the owner requires.
2. It varies considerably from job to job.
3. CPM or Bar Chart, CPM seems to be used more.
4. The master schedule is a sort of Bar Chart.

Is the schedule updated throughout construction? How often?

1. Job schedule is very rarely, if ever, updated. Equipment schedule is updated daily.

2. Rarely, only when required by the contract or owner.
3. Has never updated one.
4. Updated quite often in the beginning, especially on larger jobs, probably every week. After that it is hardly ever updated, unless required.
5. Schedule is updated weekly.

Is the schedule a fairly accurate representation of how the project is constructed?

1. The job schedule is a fairly accurate representation of the sequence of activities, but dates and durations change dramatically.
2. Usually it is fairly accurate, as always problems arise and things change. Feels as though the durations are fairly accurate, but starting dates change too often.
3. For the job schedules that have been created they were very inaccurate since things change so often.
4. The Progress Schedule (form 1130) is not accurate at all, way too simplified for the type of jobs they build.
5. Yes, most projects are very similar and relatively simple, so the schedules are accurate.

Who looks at the schedule?

1. The schedule submitted to owner is rarely used or looked at ever again.
2. Internally, one is not created unless required, so no one looks at them.
3. Engineering Staff, Superintendent.

If a software program is used, which one? Why?

1. Personally has never used a scheduling software. Equipment schedules are created on MS Excel.
2. Has used SureTrak and MS Project, as required by owners.
3. Didn't remember, hardly ever used, thought it was SureTrak.
4. Project Scheduler 6 version 7.....company wide.
5. Has used Primavera for Bar Charts when required.

Would you object to MDOT requiring a single, specific software program?

1. No
2. Yes
3. No
4. Not if it was what they had...
5. No

If MDOT did not require a schedule to be submitted, would you use one anyway? How would it be different than the requirement?

1. For Large projects, yes. It would include all activities, not only the critical ones.
2. No.
3. No.
4. No.

Do you create dual construction progress schedules, one to meet MDOT's criteria and one that you actually use? Why? Does the MDOT required Progress Schedule serve any useful purpose to you?

1. Two are not necessarily created, but the MDOT Progress Schedule is filled out to use all contract time, when it actually will go much quicker.
2. (Same answer as previous one)
3. No, only the one is created.
4. Yes, MDOT schedule uses maximum contract time, but the job is built much faster.

MDOT primarily uses the schedule to grant time extensions, have you requested these in the past? Were you granted or denied the extensions, and was the Progress Schedule used in the determination?

1. Yes, they have been requested, and were almost always granted, rarely making reference to Progress Schedule.
2. Yes, they have been requested and the Progress Schedule was used in the determination, some granted some denied.
3. They have usually been granted because you usually don't apply unless you know it will be awarded. Has one dispute going with MDOT right now and will probably reach compromise.
   Felt as though time extensions for an increase in quantities should be given on all increased quantities, not only for critical activities, and thought increase should be based on MDOT production rates, not from the percentage of bid equation.
4. When they have been denied reasons were given for denial, but the progress schedule was rarely referenced.
5. Has only requested one and the progress schedule was used in the determination.

Have you heard of Linear Scheduling? If so, have you used? And what did you think? Was it beneficial?

1. Hadn't heard of it, but since the rates vary so much from day to day, thought it would be difficult to update often enough.
2. Felt as though it would not apply very well to bridge construction.
3. Yes, would require updates very often to maintain accuracy.

In your opinion, what type or kind of construction progress schedule should be used for different levels of project complexity? What should be the criteria?

1. CPM – for almost anything.
2. Progress Schedule form seems to serve the purpose of granting time extensions.

Questions for MDOT Personnel Concerning Scheduling

What type of schedule would you like to see contractors submit?

1. Bar Charts are nice, but really nothing more than the critical activities are necessary.
2. Type of Schedule doesn't matter so much, but critical activities are essential
3. CPM or Bar Charts are the best, but the 1130 form serves its purpose for smaller projects. Wants to see critical activities.

What are the schedules submitted by contractors primarily used for?

1. Only to approve or disapprove time extensions, nothing more.
2. Only looked at to evaluate time extension applications.
3. Ideally they are referenced when reviewing applications for time extensions. To answer questions about where work will be on what days.

Do they effectively accomplish these tasks?

1. Yes
2. No, because they are not updates regularly, if ever.

How could they be improved to handle these tasks better?

1. No improvement is necessary, the form 1130 works fine.
2. Allow for more than one controlling operation on a given day, to make them more accurate.
3. Force contractor to make updates regularily, or give all time risk to contractor, do not allow for any time extensions, and don't even look for a schedule.

Should a single, uniform type of schedule be required by MDOT? How about a specific software?

1. No, the list of critical activities is all right for most projects. On some projects, it is nice to see a Bar Chart. Don't require single software, will only add more work to the, already busy, engineer.
2. It really wouldn't matter if only one type of schedule is required, as long as the the important information such as critical activities and dates are shown. The contractor can create them on whatever software he/she has.
3. It would be advantageous to MDOT to only have on type of schedule, making things less confusing. Specifying one software could make things simpler also, as long as the engineers already know, or are trained on the software.

How often should the contractor's schedule be updated to be accurate enough?

1. Don't need to be updated at all, who really cares to see it. Updates will only add more work for myself, the engineer.
2. Bi-weekly on jobs in this region if they were to be at all accurate. Although it is rarely done.
3. Bi-weekly to be accurate. Realistically, to get a contractor to update it on a monthly basis will be difficult.

Are the current Progress Schedules an accurate representation of the construction sequence?

1. Yes, for the most part they are.
2. Not unless they are updated.

General Notes from Interviews:

First:

- "To get the contractor to submit an update, I would have to ask for it every time. It is simply not worth my time to do that."
- When asked to comment on the "dual critical paths", the response was that he will never approve a schedule with more than one critical activity on any given day.
- Linear Scheduling seems like an unnecessary amount of information, would not accept one.
- Doesn't agree with state's production rates, uses his own experience and gut feeling to determine contract times.

Second:

- Little experience with CPM scheduling would need help to really use/understand one.
- "Often times contractor shows to pre-con meeting with his own schedule and gets engineers help to fill out Form 1130, so that it is approved."

Appendix F – Adopted Special Provisions 102F and 102G

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
UPDATES TO THE APPROVED PROGRESS SCHEDULE

C&T:MLL 1 of 1 08-11-99
C&T:APPR:JTL:PAL 08-18-99

The Contractor shall update the approved Progress Schedule and submit the updated Progress Schedule to the Engineer when any of the following events occur:

1. The project falls behind the schedule detailed in the approved Progress Schedule.

2. Extra work, changes in quantities, or adjustments to the contract, when ordered by the Engineer, that impact the controlling operation indicated in the approved Progress Schedule.

3. There is a revised sequence of operations that impacts the approved Progress Schedule.

Failure by the Contractor to update the approved Progress Schedule within 14 days of the occurrence of any of the above events may result in the withholding of biweekly pay estimates.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
PROGRESS SCHEDULE

C&T:JTL 1 of 2 08-11-99

Add the following to Subsection 101.03 Definitions, which begins on page 1.2 of the 1996 Standard Specifications for Construction.

Float. The total available time to complete the non controlling operation or sequence of non controlling operations as designated by the Contractor in the Progress Schedule minus the total planned duration associated with the non controlling operation or sequence of non controlling operations. float time shall be equally shared between the Contractor and the Department.

Non Controlling Operation. The operation that, if delayed at the time of consideration, would not immediately delay the opening to traffic or completion of the entire project. The operation may be on or off the job site. The size of the operation is not a factor.

Delete the definition for **Progress Schedule** from Subsection 101.03 Definitions, on page 1.7 of the 1996 Standard Specifications for Construction, and add the following.

Progress Schedule. A sequential listing of all the controlling operations and the estimated time the operations will remain controlling. Non controlling operations may also be listed in order to determine the float associated with those operations. The Progress Schedule is submitted by the Contractor and approved by the Department prior to award of the contract and becomes part of the contract.

Delete Subsection 102.15 on page 1.17 of the 1996 Standard Specifications for Construction, and replace with the following.

102.15 Construction Progress Schedule. In addition to any progress clause in the Proposal Form, the successful bidder will be required to submit a Progress Schedule (see Subsection 108.02). When approved, the progress schedule will become part of the contract. The progress schedule shall include, as a minimum, the controlling items for the completion of the project and the planned dates (or days for workday projects) that these work items will be controlling

operations. Non controlling operations may be submitted in order to provide clarity of the Contractor's proposed order of work. When specified in the bidding proposal, the date the project is to be opened to traffic, as well as the final project completion date specified in the bidding proposal, shall be included in the progress schedule. The start date of any subsequent controlling operation may follow the completion date of the preceding one. Controlling operations may be identified as concurrent. Overlapping of controlling operations may be allowed if explained, in writing, by the Contractor for the associated overlap for each controlling operation. The explanation shall be included with the Progress Schedule. If the reasons for the overlap change at any time during the contract, a revision to the original Progress Schedule shall be submitted by the Contractor. Unless otherwise specified, the Progress Schedule may be submitted on regulation form or by a Critical Path or Bar Chart diagraming method in which all work activities to be accomplished are described with their associated interdepencies. Dual Critical Paths or overlapping Bar Charts will be allowed provided appropriate reasons are submitted in writing. If the Bidding Proposal specified other controlling dates, these shall also be included in the Progress Schedule.

If a critical path or a bar chart is submitted as the progress schedule, a regulation form shall be submitted for the purpose of obtaining signatures and approvals only. In these cases, the critical path and/or bar chart shall be attached to the regulation form.

Failure on the part of the Contractor to carry out the provisions of the Progress Schedule as established may be considered sufficient cause to prevent bidding future projects until a satisfactory rate of progress is again established.

Appendix G – Draft of CPM Special Provision

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
Critical Path Network Schedule

C&T:JTL **10-26-99**

APPR:MLL:MF:

Description: In addition to the progress schedule provisions contained within this Contract, the low bidder(s) for the work covered by the Contract proposal will be required to submit a Critical Path Network (CPM) Schedule to the Engineer for approval. This schedule shall be used to monitor the sequence of construction operations and the progress of the work. The CPM schedule shall also be used for co-ordinating and monitoring all work under the Contract including the activities of subcontractors, vendors, suppliers, and other Contract related activities, including but not limited to, the submittal and approval of plans and working drawings. The Contractor shall ensure that the schedule presented meets specified overall Contract and milestone dates.

Preparation of Initial Schedule:

Within 15 calendar days of Contract award, the Contractor shall submit a detailed initial schedule for the Engineer=s approval. The schedule shall meet the requirements set forth herein.

Within seven (7) calendar days of the Contractor=s submittal, the Engineer will review the schedule and provide the Contractor in writing corrections or comments needed to approve the schedule. The Contractor must make all corrections and resolve all comments within 30 calendar days of Contract award for the Engineer to approve the schedule. If the schedule is not approved within 30 calendar days of Contract award, the Department will withhold all Contract payments until the schedule is approved.

The approval of the schedule by the Engineer in no way attests to the validity of the assumptions, logic constraints, dependency relationships, resource allocations, manpower and equipment, or any other aspect of the proposed schedule. The Contractor is and shall remain solely responsible for the planning and execution of work in order to meet project milestones or Contract completion dates and to conform to the Contract plans and specifications.

The construction time for the entire project, or any milestone, shall not exceed the specified Contract time. Logic or activity durations will be revised in the event that any milestone or Contract completion date is exceeded in the schedule.

Schedule Requirements:

CPM networks shall be submitted using the standard activity-on-node or PERT diagraming method to describe all work activities to be accomplished and their independencies. The schedule shall include all subcontractor, vendor, supplier, and Department Contract-related activities. A sufficient number of activities (tasks) will be required with sufficient detail that the controlling operation (critical path) may be identified. The work activities shall also be correlated on the diagram to the proposed sequence of construction operations included in the staging for the

project. Notation on each activity shall include a brief work description and activity time duration.

Additional Requirements:

1. Activity ID

2. Activity description

3. Only Finish to Start relationships with no leads or lags will be allowed.

4. Duration (working days): No activity will have duration greater than 20 working days unless approved by the Engineer. Activities allowed with greater than 20 working days include, but are not limited to, working drawing approvals or other activities not under the control of the Contractor. If requested by the Engineer, the Contractor shall furnish any information needed to justify the reasonableness of activity time durations. Such information shall include, but not be limited to, estimated activity manpower, unit quantities and production rates.

5. Procurement and Submittals: Separate procurement into at least two activities, fabrication and delivery. When the procurement also requires a submittal to and approval by the Department, such as shop drawings, insure these separate activities are shown in the schedule logic. Insure all work activities that require a submittal are preceded by submittal and approval activities.

6. Constraints: Use only contractual constraints in the schedule logic. No other constraints are allowed unless approved by the Engineer.

7. Float: Float is defined within the Special Provision for Progress Schedule. It is understood by the Department and the Contractor that float is a shared commodity. Either party has the full use of the float until it is depleted.

8. The activities are to be described so that the work is readily identifiable and the progress on each activities can be readily measured. For each activity, the Contractor shall identify the work force involved by trade, subcontractor, equipment, work location, duration of activities in work days, and dollar value Base dollar value of each activity on the labor, materials, and equipment involved. Ensure that the total dollar of all activities equals the Contract price.

9. The Contractor shall also provide the following information: workdays per week, holidays, number of shifts per day, number of hours per shift, and major equipment to be used.

10. Activity codes: Activities shall be identified by codes to reflect the following information related to an activity:

    Responsible party for the accomplishment of each activity (generally, only one party can be responsible for an activity). Two or more responsible parties may be listed when approved by the Engineer.

11. Computer capability: The CPM schedule must be processed through a computer and be compatible with the format section contained within this special provision. It is the Contractors responsibility to ascertain the software compatibility with the resident Engineer.

Initial Schedule Submittal Requirements:

Provide one reproducible original and three copies of each of the following to the Engineer for approval for both the initially submitted schedule and all updates:

1. Submit a plotted activity-on-node diagram. Ensure that the diagram network is legible, readable, and easily understandable.

2. Computerized sorts by:

   Activity ID
   Predecessor/successor sort
   Total float
   Early start
   Trade responsibility
   Area/Early start sort

3. 60-day look ahead bar charts by early start

4. Time Scale/Logic diagram: Produce diagram with no greater than 100 activities per ANSI D (24-inch x 36-inch) size sheet. Insure each sheet includes title, match data or diagram correlation and key to identify all components used in the diagram.

Schedule Updates:

The Contractor shall update the schedule monthly to show current progress. The update shall be submitted to the Engineer regardless of any unresolved requests for extension of time during this period. The update will include:

1. Dates of activities= actual start and completion

2. The percentage of each work activity remaining for activities started but not complete as of the update date.

3. Narrative report which includes a listing of monthly progress, the activities that define the critical path, and any changes to the path of critical activities from previous update, sources of delay, any potential problems, requested logic changes, and work planned for the next month.

4. The update submittal will include:
   Predecessor/Successor sort
   Total float sort
   Responsibility/Early start sort
   Area/Early start sort

5. Fragnet or logic diagram for all requested logic changes, including but not limited to, any of the events as addressed in the Special Provision for Updates to the Approved Progress Schedule.

6. **Updated** logic diagram and time scale/logic diagram as required by the Engineer

7. Regular job site progress meetings with the Engineer will be required to verify CPM accuracy. Update as required to reflect actual work modifications and progress and to document approved Contract modifications.

The Department may withhold all Contract payments if the schedule update is not submitted within 14 days of the date due.

Schedule Revisions:

The Contractor will revise the schedule for the following: delay in completion of the project or contractual milestones, actual prosecution of the work which is, as determined by the Engineer, significantly different than that represented on the schedule; or the addition, deletion, or revision of activities required by Contract modification. Request time extensions only for Department-caused delays that affect milestone dates or overall Contract completion date. Include support documentation.

Schedule Revisions to Utility Work:

Utilities shall be provided with ten (10) days notice when revisions in the schedule of work affect operations of a utility unless previous arrangements have been made with the utility company involved.

Format:

In addition to the above requirements, all job network schedules shall be submitted on a 3.5 inch floppy disk in accordance with one of the following formats. In lieu of the format requirements, the Contractor may submit for the Department=s use, during the life of the project, one complete copy of the scheduling software used for this Contract. Submittal shall be in accordance with the copyright requirements for the applicable software.

1. **Standard Electronic Media Format** is a standard ASCII text file containing the data elements below, in the order specified. This file can be created using any text editor or word processing application (i.e., MS-Word, WordPerfect, Notepad, or Write) but must be saved as an ASCII file.

   The **first line** will provide a descriptive header describing the submittal and containing:

   Job number
   Contract number
   Contractor name
   Data as-of-date
   Report date

   The next line will be **blank**, followed by multiple data lines.

Each **data line** will contain one record pertaining to one task of the job. Separate data fields by a comma. Fields within each task line are as follows:

(Note that the term Atask≅ is synonymous with Aactivity.≅ Leave fields that are not required blank.)

A. Task number (Job number followed by a hyphen followed by this task=s unique four-digit task number. This is the Preceding Event Activity Code)
B. Description of Task, Milestone or Hammock, blank if this record is a constraint
C. Calendar (see attached list)
D. Duration of task, blank for constraints
E. Task number of the next task (succeeding event) - leave blank if this record is not a constraint or hammock
F. Type of constraint (FS, SS, SF, HAM) - leave blank if this record is not a constraint or hammock. A hammock is a special type of constraint that groups several tasks together. The hammock starts with the first task in the group and finishes with the finish of the last task. (F = Finish, S = Start)
G. Delay, if required
H. Original Abaseline≅ start date
I. Original Abaseline≅ finish date
J. Current (forecast) start date (early start)
K. Current (forecast) finish date (early finish)
L. Estimated completion date (if different from early start + current duration)
M. Late start date
N. Late finish date
O. Actual start date
P. Actual finish date

Example - each line contains the following:

Task number (preceding event), description, calendar, duration, next task number (succeeding event), constraint type, delay, baseline start, baseline finish, estimated completion date, late start, late finish, actual start, actual finish, total float.

2. **Export Files:** If the Contractor chooses to use packages with export capabilities, they shall include all items listed in the Standard Media Format in a text or ASCII-type file.

Michigan Department of Transportation (MDOT) Calendars: The Contractor=s calendar shall be based on a 4-, 5-, or 6-day work week in accordance with the attached MDOT calendars unless otherwise superceded by the Contract requirements.

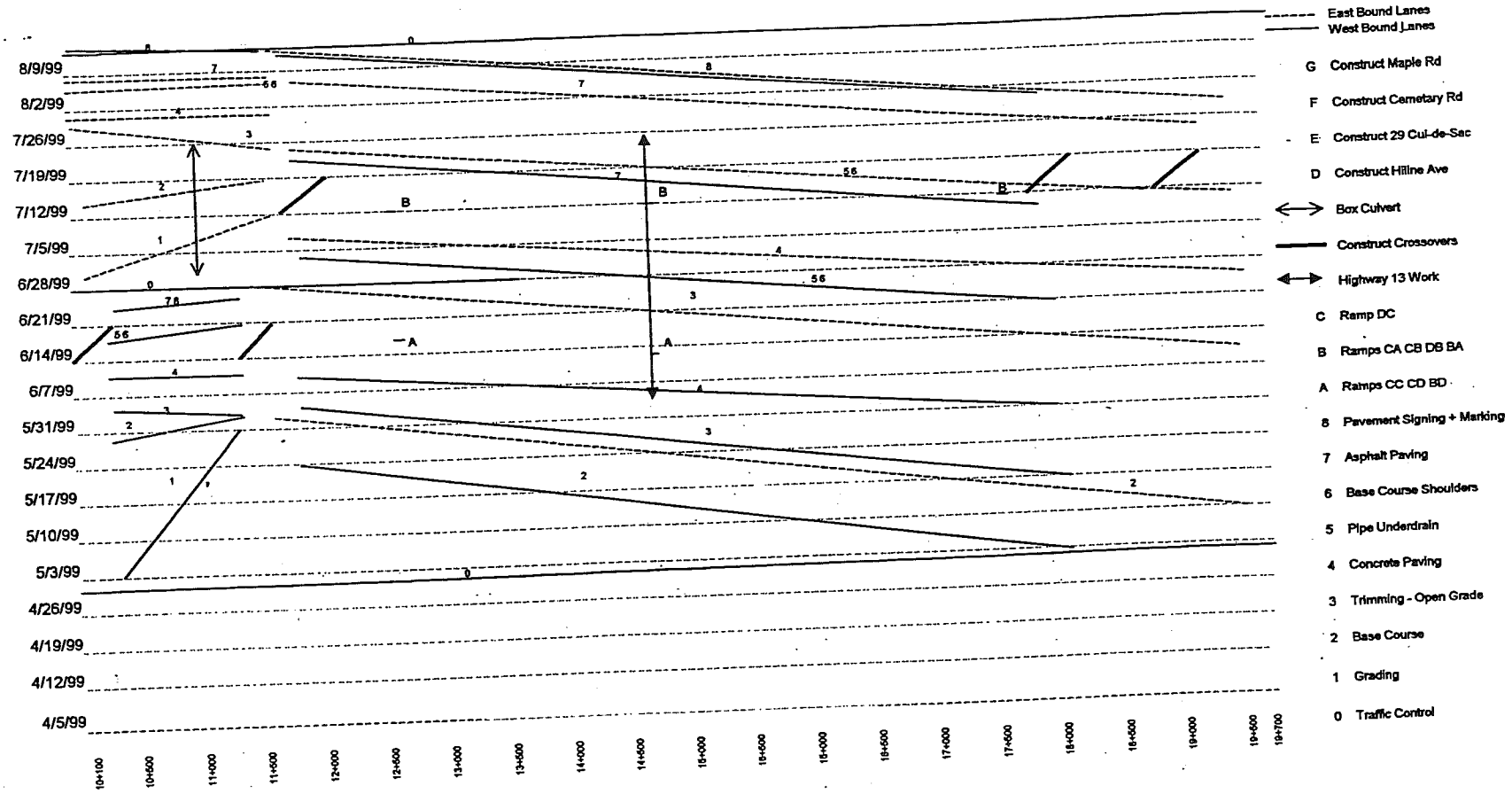
Measurement and Payment:

The Contractor=s cost to provide this information and software to the Michigan Department of Transportation will not be paid for separately, but shall be included in costs for other pay items.

MDOT Calendars: The following are the MDOT 4-, 5-, and 6-day calendars:

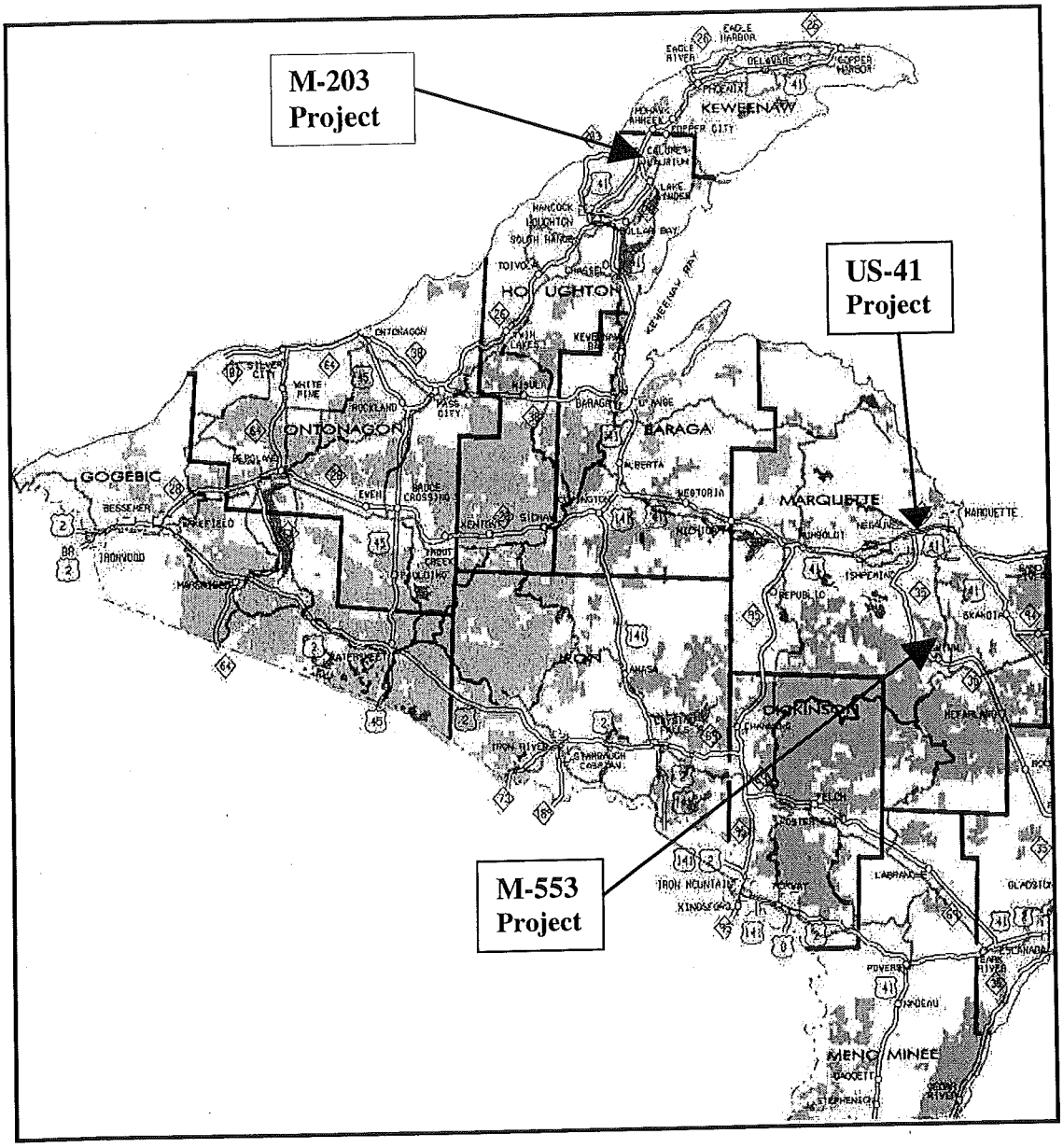
Calendar	Description	Start	Finish
1	Std - Apr 16 - Nov 15 - 4 day	Apr 16	Nov 15
2	LP - Bit Stab - 4 day	May 15	Oct 15
3	UP - Bit Stab - 4 day	Jun 01	Oct 01
4	LP S of M-46 - Bit Pave - 4 day	May 05	Nov 15
5	LP N of M-46 - Bit Pave - 4 day	May 15	Nov 01
6	UP - Bit Pave - 4 day	June 01	Oct 15
7	LP - Bit Seal Coat - 4 day	Jun 01	Sep 15
8	UP - Bit Seal Coat - 4 day	Jun 15	Sep 01
9	Tree Planting - Deciduous - 4 day	Mar 01 Oct 01	May 15 Nov 15
10	Tree Planting - Evergreen - 4 day	Mar 01	Jun 01
11	South LP - Restoration - 4 day	May 01	Oct 10
12	North LP - Restoration - 4 day	May 01	Oct 01
13	UP - Restoration - 4 day	May 01	Sep 20
14	Full Year - Winter Work - 4 day	Jan 01	Dec 31
21	Std - Apr 16 - Nov 15 - 5 day	Apr 16	Nov 15
22	LP - Bit Stab - 5 day	May 15	Oct 15
23	Up - Bit Stab - 5 day	Jun 01	Oct 01
24	LP S of M-46 - Bit Pave - 5 day	May 05	Nov 15
25	LP N of M-46 - Bit Pave - 5 day	May 15	Nov 01
26	UP - Bit Pave - 5 day	Jun 01	Oct 15
27	LP - Bit Seal Coat - 5 day	Jun 01	Sep 15
28	UP - Bit Seal Coat - 5 day	Jun 15	Sep 01
29	Tree Planting - Deciduous - 5 day	Mar 01 Oct 01	May 01 Nov 15
30	Tree Planting - Evergreen - 5 day	Mar 01	Jun 01
31	South LP - Restoration - 5 day	May 01	Oct 10
32	North LP - Restoration - 5 day	May 01	Oct 01
33	UP - Restoration - 5 day	May 01	Sep 20
34	Full Year - Expedited - 6 day	Jan 01	Dec 31

Appendix H – I-94 Linear Schedule from WisDOT



Abbotsford Schedule Stage 1+2

Appendix I – Locations of Test Projects



Locations of Test Projects

Appendix J – Schedules for US-41

1- 1130 Progress Schedule
2- Bar Chart Schedule
3- Linear Schedule
4- As – Built Bar Chart Schedule
5- As – Built Linear Schedule
6- Controlling Activity Summary

Michigan Department
of Transportation
1130 (5/92)

PROGRESS SCHEDULE

FILE 102

Information required by MDOT in order to establish a construction schedule.

CONTROL SECTION	JOB NO.
52042	47322A

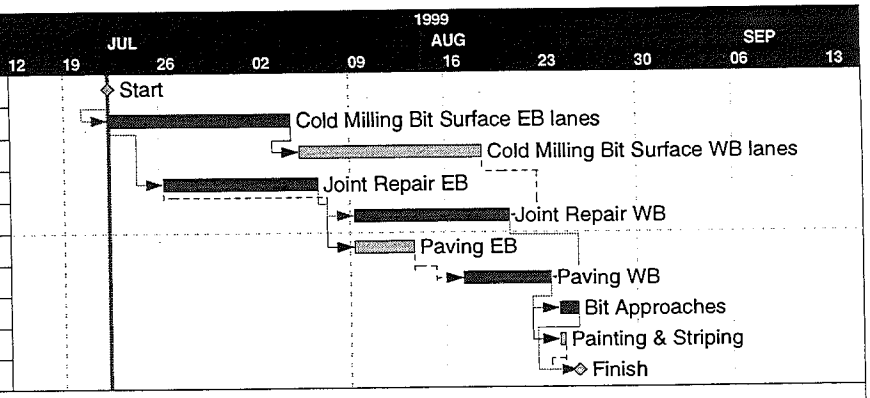
OUTLINE OF PROPOSED ORDER OF WORK FOR CONTROLLING WORK ITEM - If approved, this outline will become part of the contract.

CONTROLLING WORK ITEM	DURATION OF CONTROLLING OPERATION	
	START (Date/Work Day)	COMPLETE (Date/Work Day)
MILLING	July 19	12 WORKDAYS
JOINT REPAIR (CONCURRANT WITH MILLING)		
PAVING	13 WORKDAYS	23 WORKDAYS
PAINTING	24 WORKDAYS	25 WORKDAYS

REMARKS

OPEN TO TRAFFIC WORK DAYS DATE	CONTRACT COMPLETION WORKDAYS 25 WORK DAYS DATE
SUBMITTED BY CONTRACTOR PAYNE & DOLAN BY Aaron Kodl DATE 4-13-99	LOCAL AGENCY BY DATE
SUMITTED BY SUBCONTRACTOR BY DATE	APPROVAL - DISTRICT FIELD ENGINEER (SIGNATURE) DATE For Steven L. Lawrence 4-13-99
SUMITTED BY SUBCONTRACTOR BY DATE	APPROVAL - CONSTRUCTION ENGINEER (SIGNATURE) DATE

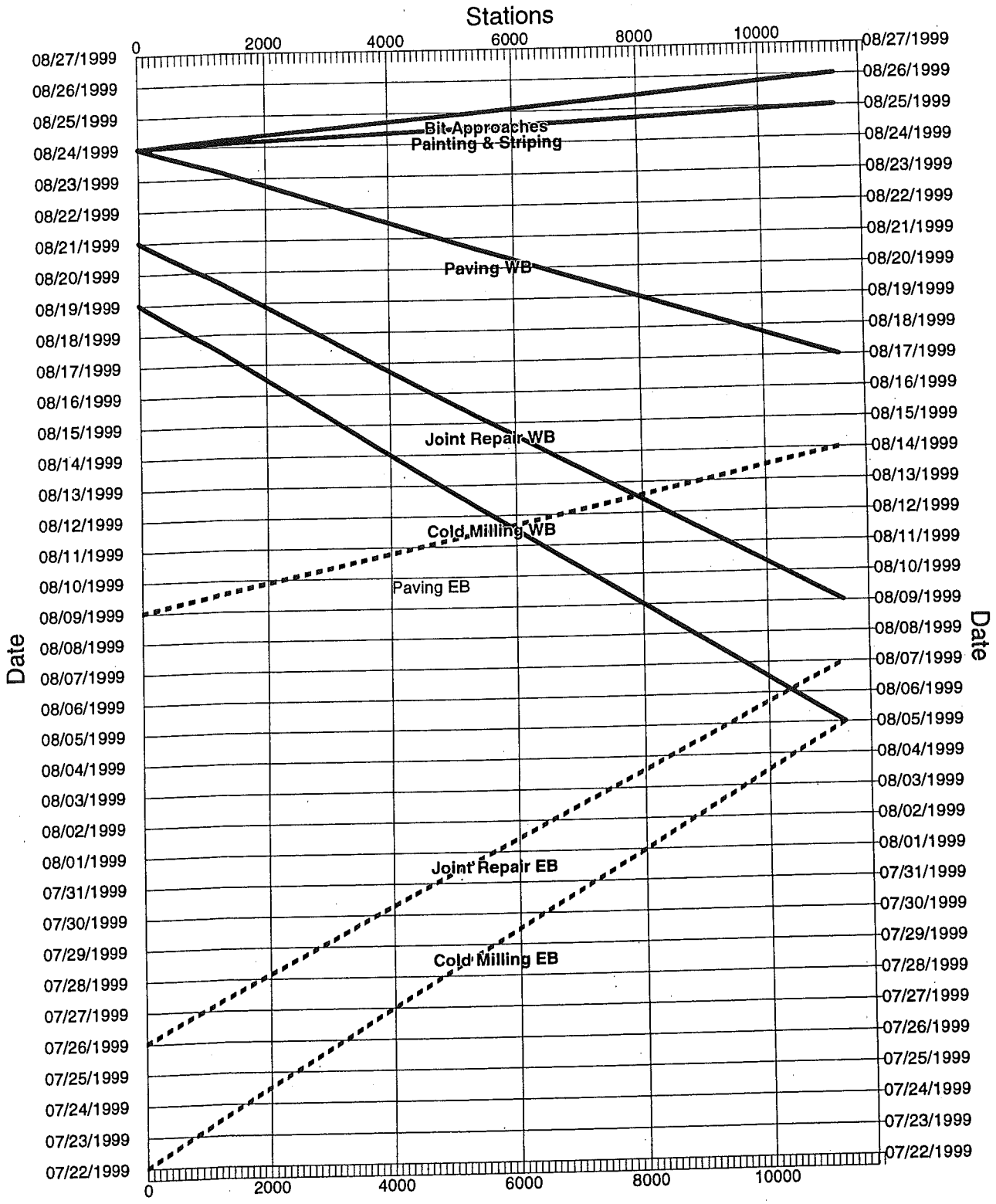
Act ID	Description	Orig Dur	Early Start	Early Finish
1000	Start	0	22JUL99	
1010	Cold Milling Bit Surface EB lanes	10d	22JUL99	04AUG99
1020	Cold Milling Bit Surface WB lanes	10d	05AUG99	18AUG99
1030	Joint Repair EB	10d	26JUL99	06AUG99
1040	Joint Repair WB	10d	09AUG99	20AUG99
1050	Paving EB	5d	09AUG99	13AUG99
1060	Paving WB	5d	17AUG99	23AUG99
1070	Bit Approaches	2d	24AUG99	25AUG99
1080	Painting & Striping	1d	24AUG99	24AUG99
1090	Finish	0		25AUG99



Start date	22JUL99
Finish date	25AUG99
Data date	22JUL99
Run date	07DEC99
Page number	1A

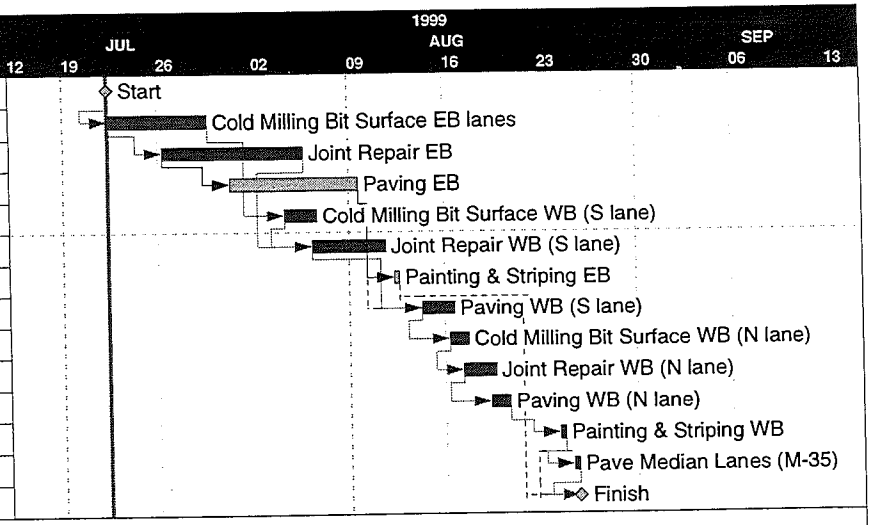
MTU / Payne & Dolan
US-41 Resurfacing Marquette

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone point



Project Description: US-41 Resurf.
Project Contractor: Payne & Dolan
Revision Date: 7/14/99
Schedule Type: Baseline

Act ID	Description	Orig Dur	Early Start	Early Finish
1000	Start	0	22JUL99	
1010	Cold Milling Bit Surface EB lanes	7d	22JUL99	29JUL99
1030	Joint Repair EB	10d	26JUL99	05AUG99
1050	Paving EB	7d	31JUL99	09AUG99
1020	Cold Milling Bit Surface WB (S lane)	3d	04AUG99	06AUG99
1040	Joint Repair WB (S lane)	4d	06AUG99	11AUG99
1080	Painting & Striping EB	1d	12AUG99	12AUG99
1060	Paving WB (S lane)	2d	14AUG99	16AUG99
1025	Cold Milling Bit Surface WB (N lane)	2d	16AUG99	17AUG99
1045	Joint Repair WB (N lane)	3d	17AUG99	19AUG99
1065	Paving WB (N lane)	2d	19AUG99	20AUG99
1085	Painting & Striping WB	1d	24AUG99	24AUG99
1087	Pave Median Lanes (M-35)	1d	25AUG99	25AUG99
1090	Finish	0		25AUG99



Start date	22JUL99
Finish date	25AUG99
Data date	22JUL99
Run date	07DEC99
Page number	1A
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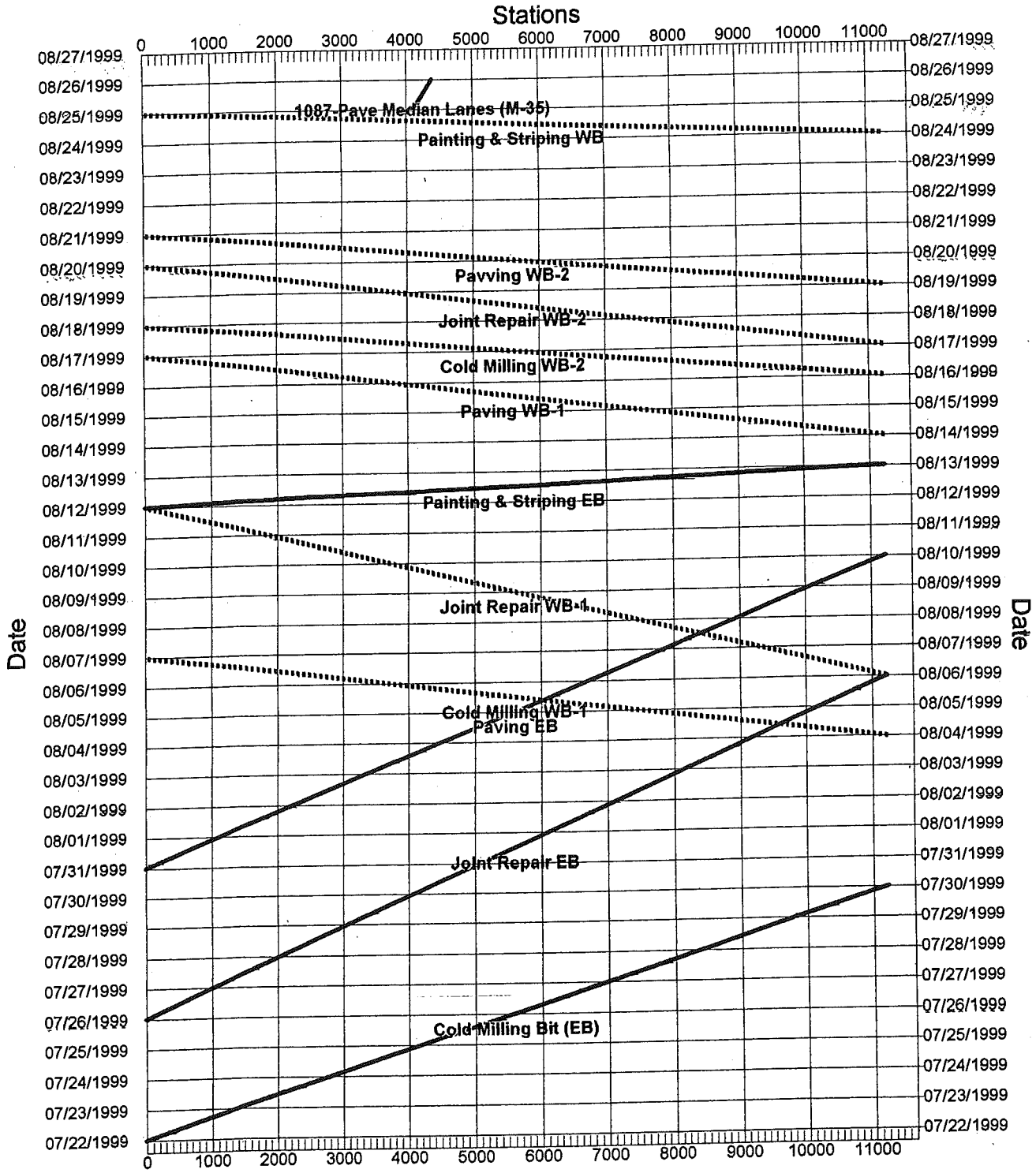
MTU / Payne & Dolan
US-41 Resurfacing Marquette

- Early bar
- Progress bar
- Critical bar
- Summary bar
- Start milestone point
- Finish milestone point



Project Description: US-41 Resurf
Project Contractor: Payne & Dolan
Revision Date: 9/8/99
Schedule Type: Update

Controlling Activity Summary: US - 41

Date	Day of Week	Workday	Original Controlling Operation	Actual Major Item(s) of Work
7/20/99	Tuesday	1	Milling / Joint Repair	None
7/21/99	Wednesday	2	Milling / Joint Repair	None
7/22/99	Thursday	1	Milling / Joint Repair	Milling
7/23/99	Friday	2	Milling / Joint Repair	Milling
7/24/99	Saturday	N		Milling
7/25/99	Sunday	N		
7/26/99	Monday	3	Milling / Joint Repair	Milling
7/27/99	Tuesday	4	Milling / Joint Repair	Milling
7/28/99	Wednesday	5	Milling / Joint Repair	Milling / Joint Repair
7/29/99	Thursday	6	Milling / Joint Repair	Joint Repair
7/30/99	Friday	7	Milling / Joint Repair	Joint Repair
7/31/99	Saturday	N		Joint Repair / Paving
8/1/99	Sunday	N		
8/2/99	Monday	8	Milling / Joint Repair	Joint Repair
8/3/99	Tuesday	9	Milling / Joint Repair	Joint Repair
8/4/99	Wednesday	10	Milling / Joint Repair	Paving / Joint Repair
8/5/99	Thursday	11	Paving	Paving / Joint Repair
8/6/99	Friday	12	Paving	Joint Repair
8/7/99	Saturday	N		
8/8/99	Sunday	N		
8/9/99	Monday	13	Paving	Paving
8/10/99	Tuesday	14	Paving	Joint Repair
8/11/99	Wednesday	15	Paving	Joint Repair
8/12/99	Thursday	rain		Painting
8/13/99	Friday	rain		None
8/14/99	Saturday	N		Paving
8/15/99	Sunday	N		
8/16/99	Monday	16	Paving	Milling / Paving
8/17/99	Tuesday	17	Paving	Paving / Joint Repair
8/18/99	Wednesday	18	Paving	Pave Leveling / Crush & Shape
8/19/99	Thursday	19	Paving	Pave Leveling / Approaches
8/20/99	Friday	20	Paving	Pave Surface / Approaches
8/21/99	Saturday	N		Pave Surface
8/22/99	Sunday	N		
8/23/99	Monday	21	Paving	Pave Surface
8/24/99	Tuesday	22	Paving	Pave Surface
8/25/99	Wednesday	23	Paving	Pave Surface
8/26/99	Thursday	24	Painting	
8/27/99	Friday	25	Painting	Painting

Appendix K – Schedules for M-553

1- 1130 Progress Schedule
2- Bar Chart Schedule
3- Linear Schedule
4- As – Built Bar Chart Schedule
5- As – Built Linear Schedule
6- Controlling Activity Summary

Michigan Department
of Transportation
1130 (5/92)

PROGRESS SCHEDULE

FILE 102

Information required by MDOT in order to establish a construction schedule.

CONTROL SECTION	JOB NO.
M52055	4807A

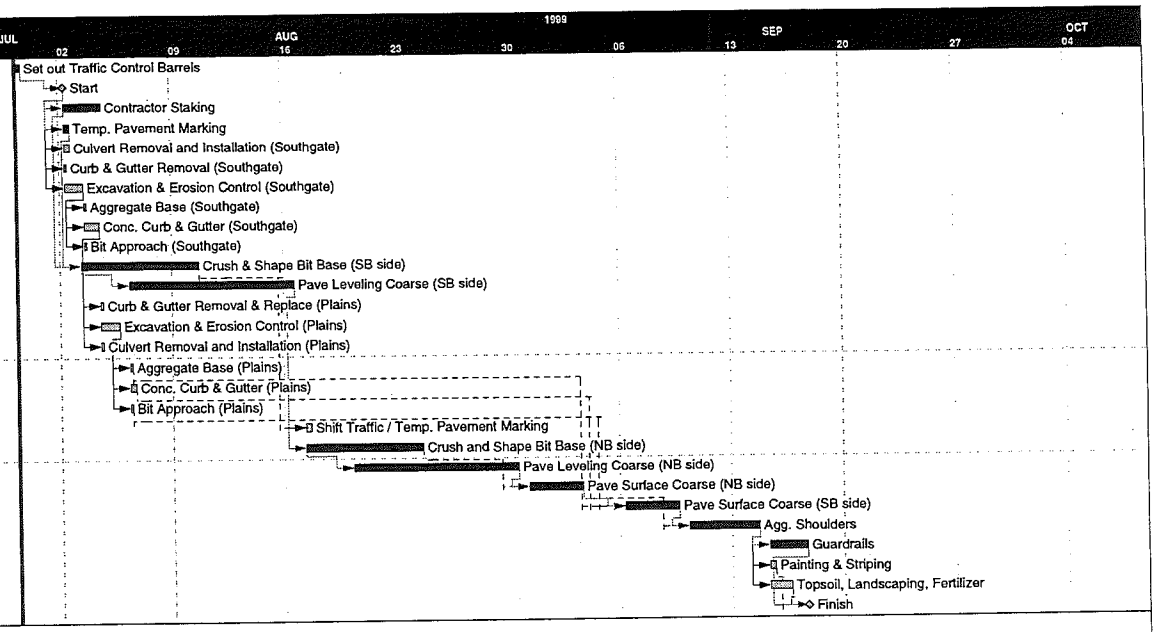
OUTLINE OF PROPOSED ORDER OF WORK FOR CONTROLLING WORK ITEM - If approved, this outline will become part of the contract.

CONTROLLING WORK ITEM	DURATION OF CONTROLLING OPERATION	
	START (Date/Work Day)	COMPLETE (Date/Work Day)
CULVERT	8/2/99	3
CRUSH & SHAPE	4	8
PAVE LEVELING	9	13
CRUSH & SHAPE	14	18
PAVE LEVELING	19	24
PAVE SURFACE	25	30
SHOULDERS	31	33
PAINTING + CLEANUP	35	35

REMARKS
Late start date is 8-02-99, per proposal

OPEN TO TRAFFIC WORK DAYS _____ DATE _____	CONTRACT COMPLETION WORKDAYS 35 DATE _____
SUBMITTED BY CONTRACTOR PAYNE & DOLAN BY Aaron Yoder DATE 5-19-99	LOCAL AGENCY _____ BY _____ DATE _____
SUMITTED BY SUBCONTRACTOR _____ BY _____ DATE _____	APPROVAL - DISTRICT FIELD ENGINEER (SIGNATURE) for Steven L. Loosemore DATE 5-19-99
SUMITTED BY SUBCONTRACTOR _____ BY _____ DATE _____	APPROVAL - CONSTRUCTION ENGINEER (SIGNATURE) DATE _____

Act ID	Description	Orig Dur	Early Start	Early Finish
900	Set out Traffic Control Barrels	1d	30JUL99	30JUL99
1000	Start	0	02AUG99	
1010	Contractor Staking	3d	02AUG99	04AUG99
1015	Temp. Pavement Marking	1d	02AUG99	02AUG99
1020	Culvert Removal and Installation	1d	02AUG99	02AUG99
1030	Curb & Gutter Removal (Southgate)	4h	02AUG99	02AUG99
1040	Excavation & Erosion Control (Southgate)	1d4h	02AUG99	03AUG99
1050	Aggregate Base (Southgate)	4h	03AUG99	03AUG99
1055	Conc. Curb & Gutter (Southgate)	1d	03AUG99	04AUG99
1060	Bit Approach (Southgate)	4h	03AUG99	03AUG99
1080	Crush & Shape Bit Base (SB side)	6d	03AUG99	10AUG99
1090	Pave Leveling Coarse (SB side)	7d	06AUG99	16AUG99
1100	Curb & Gutter Removal & Replace (Plains)	4h	04AUG99	04AUG99
1110	Excavation & Erosion Control (Plains)	1d4h	04AUG99	05AUG99
1115	Culvert Removal and Installation (Plains)	4h	04AUG99	04AUG99
1120	Aggregate Base (Plains)	4h	06AUG99	06AUG99
1125	Conc. Curb & Gutter (Plains)	1d	06AUG99	06AUG99
1130	Bit Approach (Plains)	4h	06AUG99	06AUG99
1140	Shift Traffic / Temp. Pavement Marking	1d	17AUG99	17AUG99
1150	Crush and Shape Bit Base (NB side)	6d	17AUG99	24AUG99
1160	Pave Leveling Coarse (NB side)	7d	20AUG99	30AUG99
1170	Pave Surface Coarse (NB side)	4d	31AUG99	03SEP99
1175	Pave Surface Coarse (SB side)	4d	06SEP99	09SEP99
1180	Agg. Shoulders	3d	10SEP99	14SEP99
1190	Guardrails	3d	15SEP99	17SEP99
1200	Painting & Striping	1d	15SEP99	15SEP99
1210	Topsoil, Landscaping, Fertilizer	2d	15SEP99	16SEP99
1220	Finish	0		17SEP99



Start date	30JUL99
Finish date	17SEP99
Data date	30JUL99
Run date	07DEC99
Page number	1A
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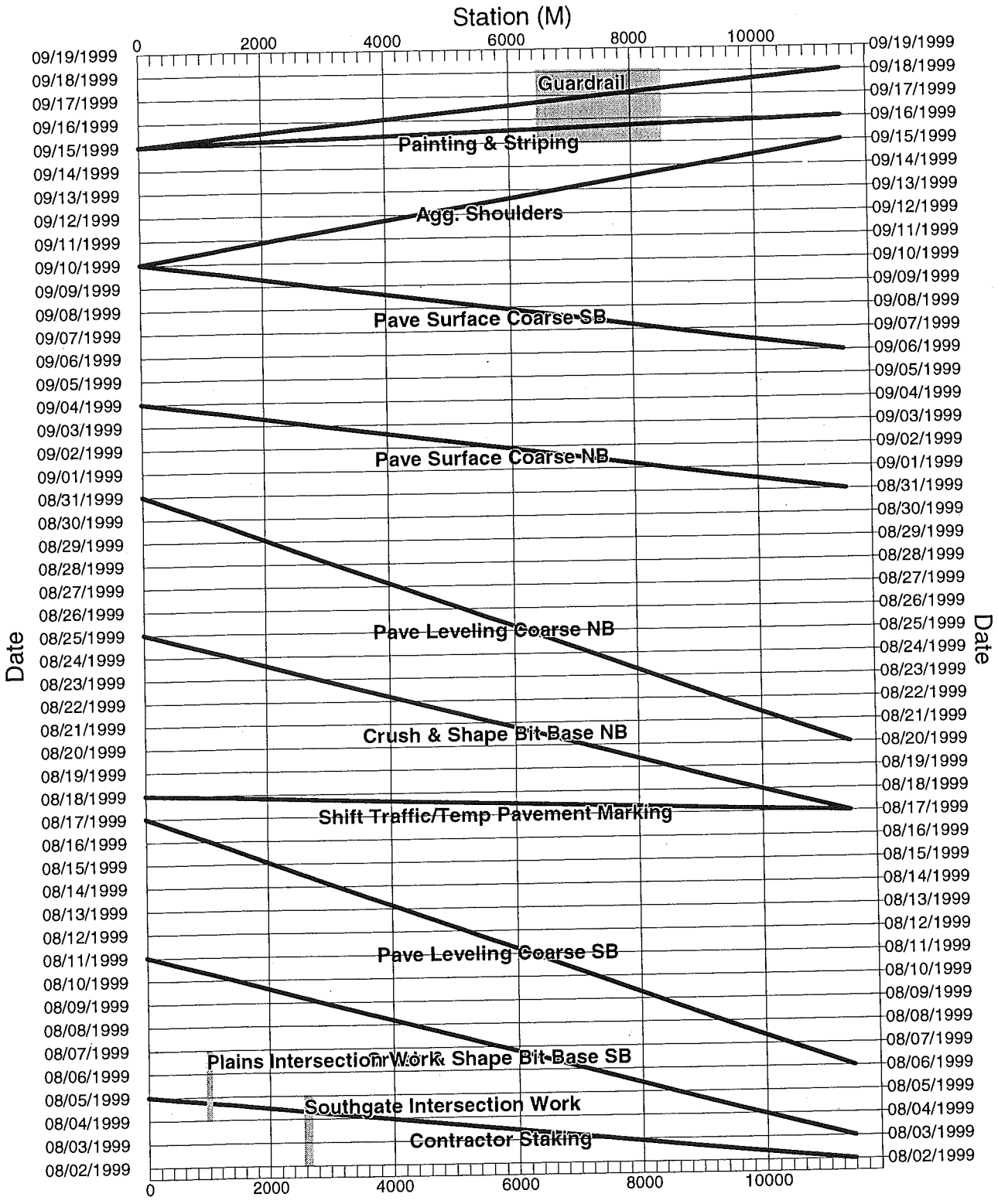
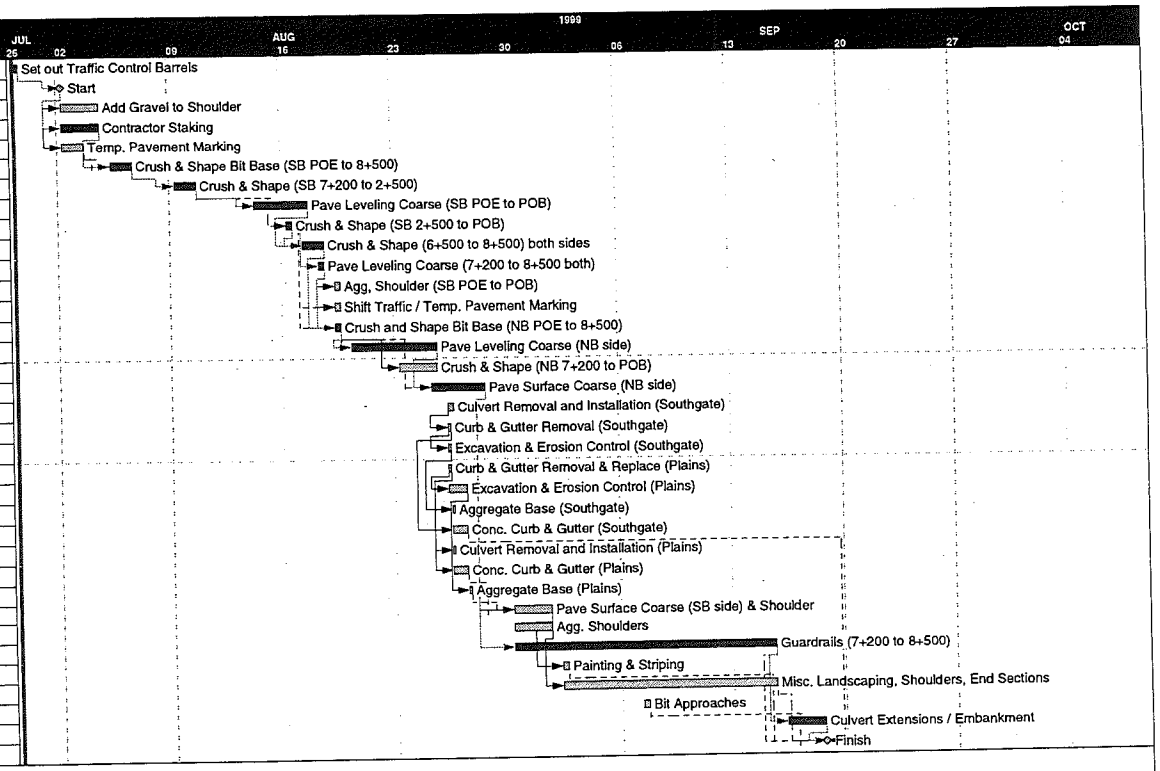
MTU / Payne & Dolan
M-553 Crush and Shape

- Early bar
- Progress bar
- Critical bar
- Summary bar
- Start milestone point
- Finish milestone point



Project Description: M553
Project Contractor: Payne & Dolan
Revision Date: 7/14/99
Schedule Type: Baseline

Act ID	Description	Orig Dur	Early Start	Early Finish
900	Set out Traffic Control Barrels	1d	30JUL99	30JUL99
1000	Start	0	02AUG99	
1005	Add Gravel to Shoulder	3d	02AUG99	04AUG99
1010	Contractor Staking	3d	02AUG99	04AUG99
1015	Temp. Pavement Marking	2d	02AUG99	03AUG99
1080	Crush & Shape Bit Base (SB POE to 8+500)	2d	05AUG99	06AUG99
1082	Crush & Shape (SB 7+200 to 2+500)	2d	09AUG99	10AUG99
1090	Pave Leveling Coarse (SB POE to POB)	3d	14AUG99	17AUG99
1083	Crush & Shape (SB 2+500 to POB)	1d	16AUG99 *	16AUG99
1085	Crush & Shape (6+500 to 8+500) both sides	2d	17AUG99	18AUG99
1095	Pave Leveling Coarse (7+200 to 8+500 both)	1d	18AUG99	18AUG99
1097	Agg, Shoulder (SB POE to POB)	1d	19AUG99	19AUG99
1140	Shift Traffic / Temp. Pavement Marking	1d	19AUG99	19AUG99
1150	Crush and Shape Bit Base (NB POE to 8+500)	1d	19AUG99	19AUG99
1160	Pave Leveling Coarse (NB side)	5d	20AUG99	25AUG99
1165	Crush & Shape (NB 7+200 to POB)	3d	23AUG99	25AUG99
1170	Pave Surface Coarse (NB side)	4d	25AUG99	28AUG99
1020	Culvert Removal and Installation (Southgate)	1d	26AUG99 *	26AUG99
1030	Curb & Gutter Removal (Southgate)	4h	26AUG99	26AUG99
1040	Excavation & Erosion Control (Southgate)	4h	26AUG99	26AUG99
1100	Curb & Gutter Removal & Replace (Plains)	4h	26AUG99 *	26AUG99
1110	Excavation & Erosion Control (Plains)	1d4h	26AUG99	27AUG99
1050	Aggregate Base (Southgate)	4h	26AUG99	26AUG99
1055	Conc. Curb & Gutter (Southgate)	1d	26AUG99	27AUG99
1115	Culvert Removal and Installation (Plains)	4h	26AUG99	26AUG99
1125	Conc. Curb & Gutter (Plains)	1d	26AUG99	27AUG99
1120	Aggregate Base (Plains)	4h	27AUG99	27AUG99
1175	Pave Surface Coarse (SB side) & Shoulder	3d	30AUG99	01SEP99
1180	Agg. Shoulders	3d	30AUG99 *	01SEP99
1190	Guardrails (7+200 to 8+500)	14d	30AUG99	15SEP99
1200	Painting & Striping	1d	02SEP99	02SEP99
1210	Misc. Landscaping, Shoulders, End Sections	11d	02SEP99	15SEP99
1205	Bit Approaches	1d	07SEP99 *	07SEP99
1215	Culvert Extensions / Embankment	3d	16SEP99	18SEP99
1220	Finish	0		18SEP99



Start date	30JUL99
Finish date	18SEP99
Data date	30JUL99
Run date	07DEC99
Page number	1A
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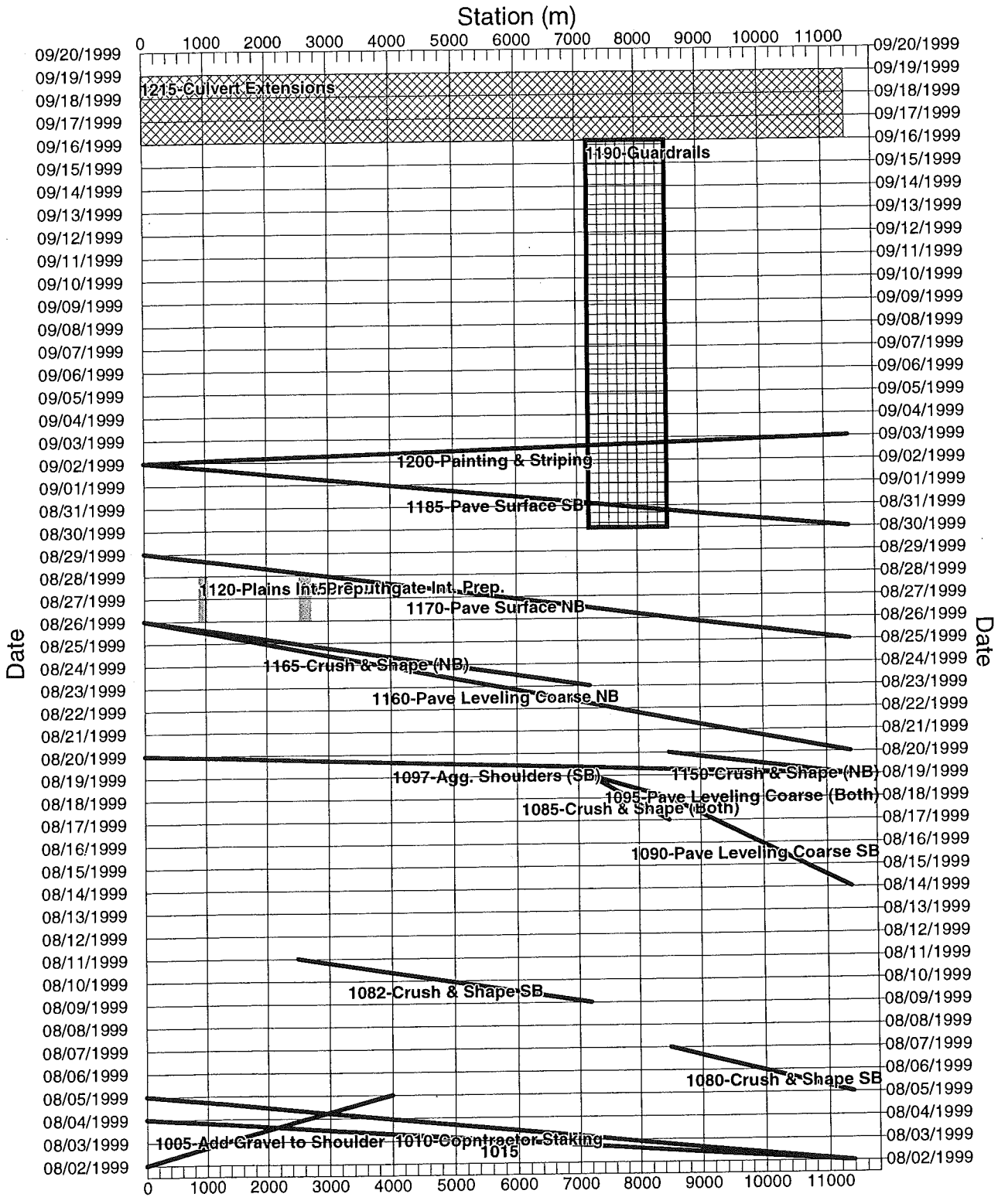
MTU / Payne & Dolan
M-553 Crush and Shape

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone point



Project Description: M553 - Crush & Shape
Project Contractor: Payne & Dolan
Revision Date: 10/14/99
Schedule Type: Update

Controlling Activity Summary: M-553

Date	Day of Week	Workday	Original Controlling Operation	Actual Major Item(s) of Work
7/30/99	Friday	1		
7/31/99	Saturday	N		
8/1/99	Sunday	N		
8/2/99	Monday	2	Culvert	
8/3/99	Tuesday	3	Culvert	
8/4/99	Wednesday	4	Culvert	Pvmt. Marking
8/5/99	Thursday	5	Crush & Shape	Crush & Shape
8/6/99	Friday	6	Crush & Shape	Crush & Shape
8/7/99	Saturday	N		
8/8/99	Sunday	N		
8/9/99	Monday	7	Crush & Shape	Crush & Shape
8/10/99	Tuesday	8	Crush & Shape	Crush & Shape
8/11/99	Wednesday	9	Crush & Shape	No Work
8/12/99	Thursday	10	Pave Leveling	No Work
8/13/99	Friday	11	Pave Leveling	No Work
8/14/99	Saturday	N		Pave Leveling
8/15/99	Sunday	N		
8/16/99	Monday	12	Pave Leveling	Pave Leveling / Crush & Shape
8/17/99	Tuesday	13	Pave Leveling	Pave Leveling / Crush & Shape
8/18/99	Wednesday	14	Pave Leveling	Pave Leveling / Crush & Shape
8/19/99	Thursday	15	Crush & Shape	Pave Leveling / Crush & Shape
8/20/99	Friday	16	Crush & Shape	Pave Leveling
8/21/99	Saturday	N		Pave Leveling
8/22/99	Sunday	N		
8/23/99	Monday	17	Crush & Shape	Pave Leveling / Crush & Shape
8/24/99	Tuesday	18	Crush & Shape	Pave Leveling / Crush & Shape
8/25/99	Wednesday	19	Crush & Shape	Pave Leveling / Crush & Shape
8/26/99	Thursday	20	Pave Leveling	Pave Leveling / Approaches
8/27/99	Friday	21	Pave Leveling	Pave Surface / Approaches
8/28/99	Saturday	N		Pave Surface
8/29/99	Sunday	N		
8/30/99	Monday	22	Pave Leveling	Pave Surface
8/31/99	Tuesday	23	Pave Leveling	Pave Surface
9/1/99	Wednesday	24	Pave Leveling	Pave Surface
9/2/99	Thursday	25	Pave Leveling	Painting / Guardrail
9/3/99	Friday	26	Pave Surface	Guardrail
9/4/99	Saturday	N		
9/5/99	Sunday	N		
9/6/99	Monday	N	Pave Surface	
9/7/99	Tuesday	27	Pave Surface	Paving Approaches
9/8/99	Wednesday	28	Pave Surface	Paving Approaches / Culverts
9/9/99	Thursday	29	Pave Surface	Guardrail / Topsoil
9/10/99	Friday	30	Pave Surface	Guardrail / Topsoil
9/11/99	Saturday	N		
9/12/99	Sunday	N		
9/13/99	Monday	31	Shoulders	Guardrail
9/14/99	Tuesday	32	Shoulders	Guardrail / Shoulders
9/15/99	Wednesday	33	Shoulders	Culverts
9/16/99	Thursday	34	Painting & Clean-up	Culverts
9/17/99	Friday	35	Painting & Clean-up	Topsoil

Appendix L – Schedules for M-203

1- 1130 Progress Schedule
2- Bar Chart Schedule
3- Linear Schedule
4- As – Built Bar Chart Schedule
5- As – Built Linear Schedule
6- Controlling Activity Summary

Michigan Department of Transportation 1130 (5/92)

PROGRESS SCHEDULE

FILE 102

Information required by MDOT in order to establish a construction schedule.

CONTROL SECTION	JOB NO.
EDA 31031	47167A

OUTLINE OF PROPOSED ORDER OF WORK FOR CONTROLLING WORK ITEMS - If approved, this outline will become part of the contract.

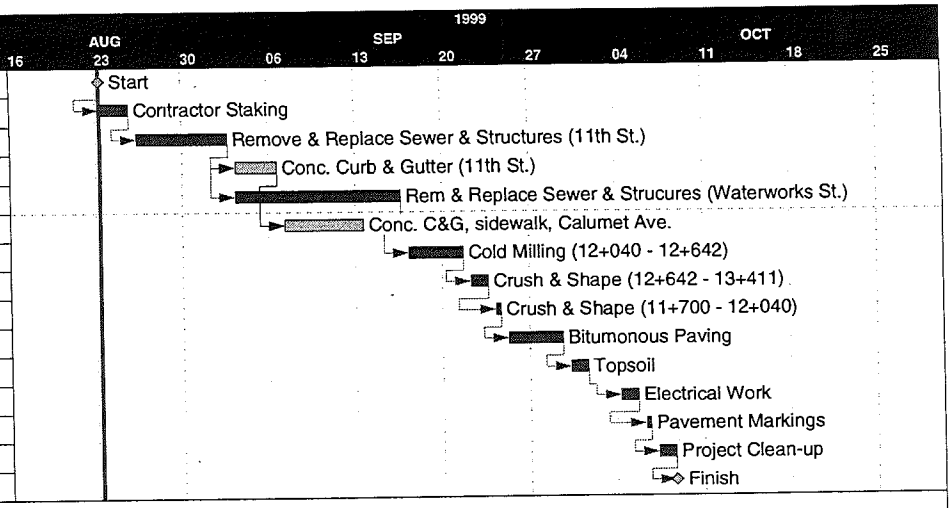
CONTROLLING WORK ITEM	DURATION OF CONTROLLING OPERATION	
	START (Date/Work Day)	COMPLETE (Date/Work Day)
Contractor Staking	8-23	8-25
Sewer & Structure	8-26	9-10
Concrete Work	9-11	9-18
Cold Milling	9-19	9-21
Crush & Shape E & W	9-22	9-23
Bituminous Paving E & W	9-24	10-1
Topsoil	10-2	10-3
Electrical Work	10-4	10-5
Pavement Markings	10-6	10-7
Project Clean up	10-7	10-8

REMARKS Start work on 8-23 or within 10 days of award

OPEN TO TRAFFIC		CONTRACT COMPLETION	
WORKDAYS	DATE	WORKDAYS	DATE
SUBMITTED BY CONTRACTOR Payne & Dolan Inc		LOCAL AGENCY	
BY Tim Otto	DATE 7-19-99	BY	DATE
SUBMITTED BY SUBCONTRACTOR		APPROVAL - DISTRICT FIELD ENGINEER (Signature)	DATE 7-19-99
BY	DATE		
SUBMITTED BY SUBCONTRACTOR		APPROVAL - CONSTRUCTION ENGINEER (Signature)	DATE
BY	DATE		

TOTAL P.01

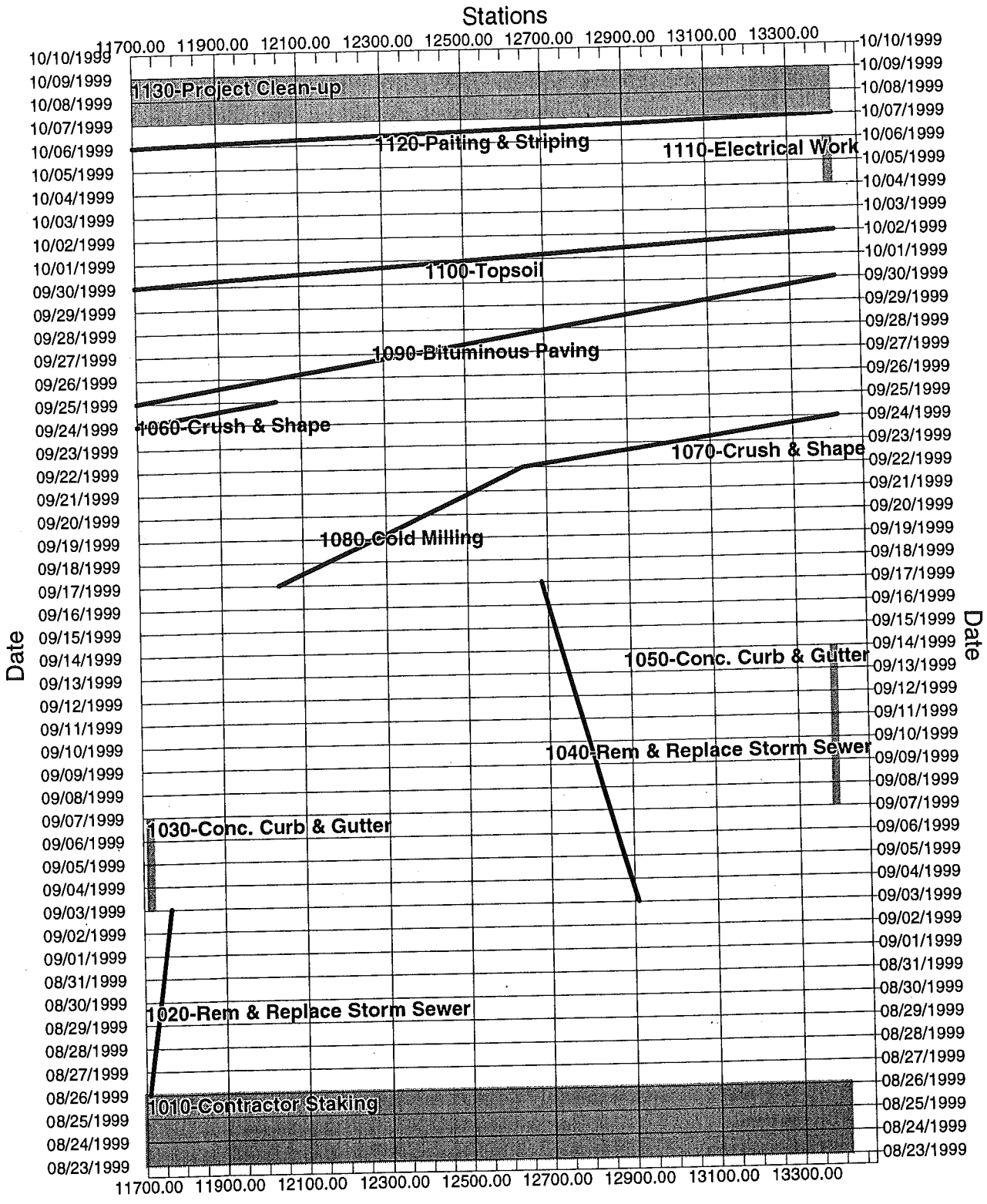
Act ID	Description	Orig Dur	Early Start	Early Finish
1000	Start	0	23AUG99	
1010	Contractor Staking	3d	23AUG99	25AUG99
1020	Remove & Replace Sewer & Structures	6d	26AUG99	02SEP99
1030	Conc. Curb & Gutter (11th St.)	2d	03SEP99	06SEP99
1040	Rem & Replace Sewer & Strucures	10d	03SEP99	16SEP99
1050	Conc. C&G, sidewalk, Calumet Ave.	5d	07SEP99	13SEP99
1080	Cold Milling (12+040 - 12+642)	3d	17SEP99	21SEP99
1070	Crush & Shape (12+642 - 13+411)	2d	22SEP99	23SEP99
1060	Crush & Shape (11+700 - 12+040)	1d	24SEP99	24SEP99
1090	Bitumonous Paving	4d	25SEP99	29SEP99
1100	Topsoil	2d	30SEP99	01OCT99
1110	Electrical Work	2d	04OCT99	05OCT99
1120	Pavement Markings	1d	06OCT99	06OCT99
1130	Project Clean-up	2d	07OCT99	08OCT99
1140	Finish	0		08OCT99



Start date	23AUG99
Finish date	08OCT99
Data date	23AUG99
Run date	07DEC99
Page number	1A

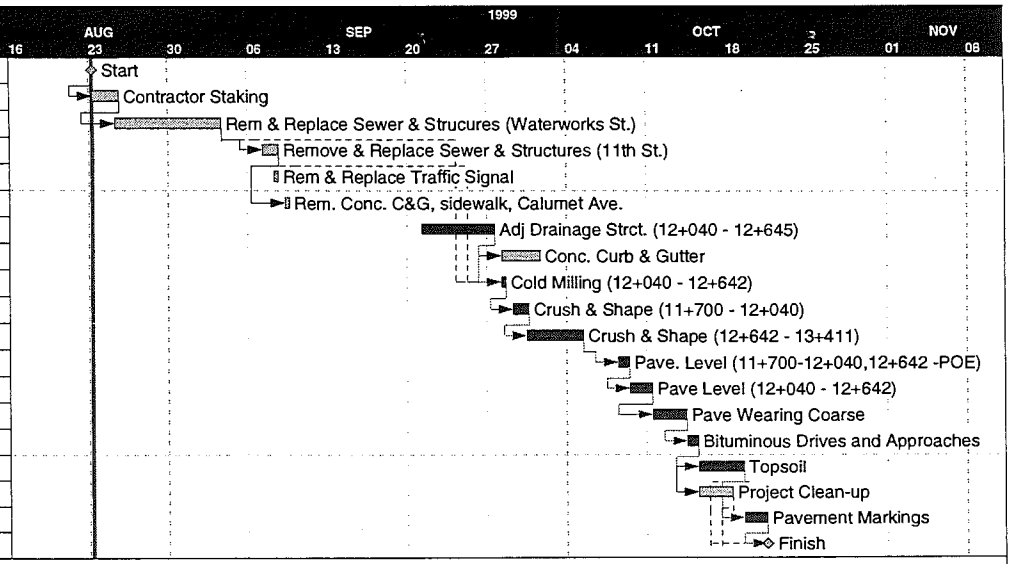
MTU / Payne & Dolan
M203 Improvements

- Early bar
- Progress bar
- Critical bar
- Summary bar
- Start milestone point
- Finish milestone point



Project Description: M203
Project Contractor: Payne & Dolan
Revision Date: 9/8/99
Schedule Type: Baseline

Act ID	Description	Orig Dur	Early Start	Early Finish
1000	Start	0	23AUG99	
1010	Contractor Staking	3d	23AUG99	25AUG99
1040	Rem & Replace Sewer & Strucures	8d	25AUG99	03SEP99
1020	Remove & Replace Sewer & Structures	2d	07SEP99	08SEP99
1025	Rem & Replace Traffic Signal	1d	08SEP99 *	08SEP99
1050	Rem. Conc. C&G, sidewalk, Calumet Ave.	1d	09SEP99	09SEP99
1055	Adj Drainage Strct. (12+040 - 12+645)	5d	21SEP99 *	27SEP99
1030	Conc. Curb & Gutter	4d	28SEP99	01OCT99
1080	Cold Milling (12+040 - 12+642)	1d	28SEP99 *	28SEP99
1060	Crush & Shape (11+700 - 12+040)	2d	29SEP99	30SEP99
1070	Crush & Shape (12+642 - 13+411)	3d	30SEP99	05OCT99
1090	Pave. Level (11+700-12+040,12+642 -POE)	1d	08OCT99	09OCT99
1095	Pave Level (12+040 - 12+642)	1d	09OCT99	11OCT99
1096	Pave Wearing Coarse	3d	11OCT99	14OCT99
1106	Bituminous Drives and Approaches	1d	14OCT99	15OCT99
1100	Topsoil	2d	15OCT99	19OCT99
1130	Project Clean-up	1d	15OCT99	18OCT99
1120	Pavement Markings	1d	19OCT99	21OCT99
1140	Finish	0		21OCT99



Start date	23AUG99
Finish date	21OCT99
Data date	23AUG99
Run date	07DEC99
Page number	1A
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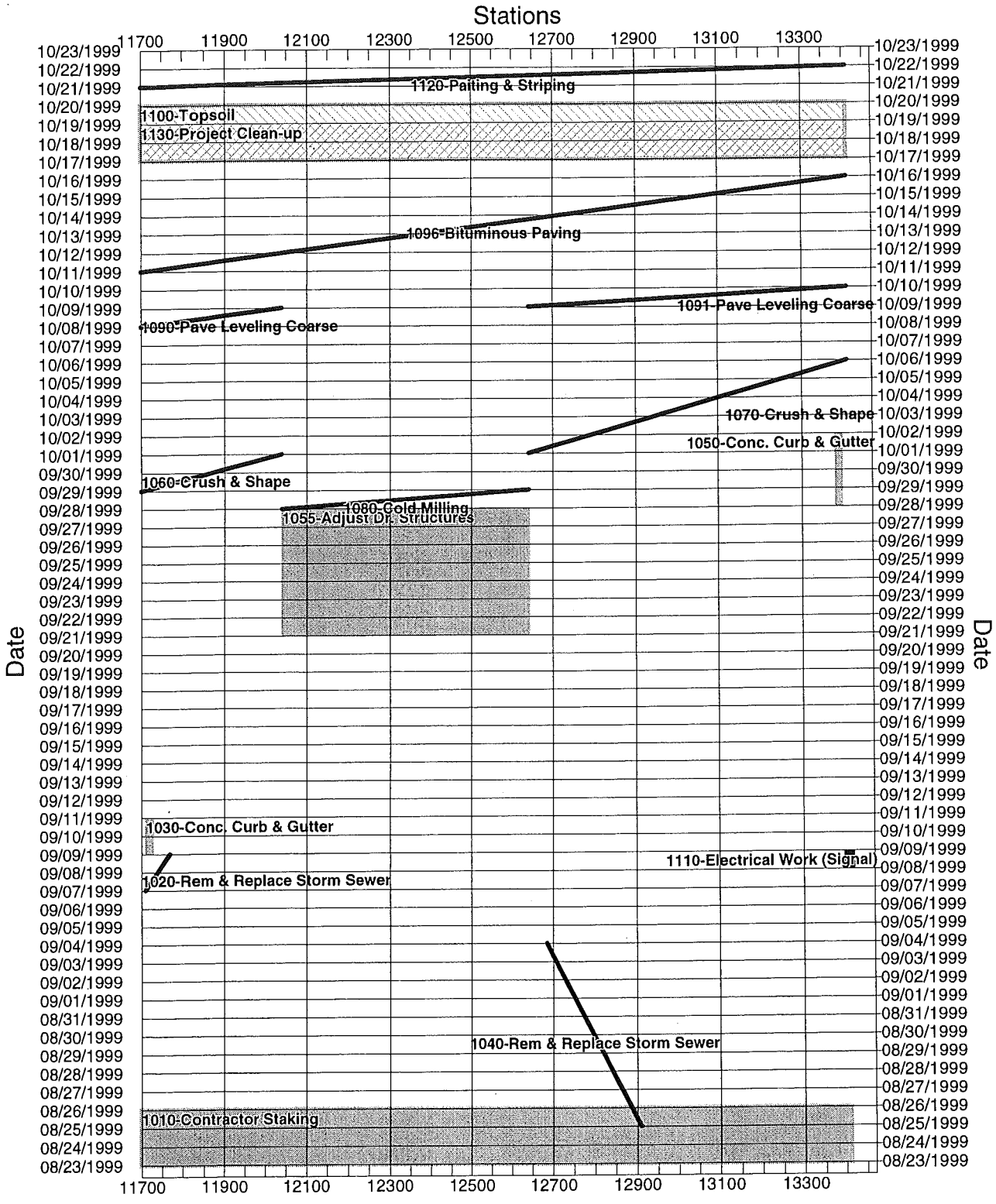
MTU / Payne & Dolan
M203 Improvements

- Early bar
- Progress bar
- Critical bar
- Summary bar
- Start milestone point
- Finish milestone point



Project Description: M203
Project Contractor: Payne & Dolan
Revision Date: 11/1/99
Schedule Type: Update

Conrolling Activity Summary: M-203

Date	Day of Week	Original Controlling Operation	Actual Major Item(s) of Work
8/23/99	Monday	Contractor Staking	
8/24/99	Tuesday	Contractor Staking	
8/25/99	Wednesday	Contractor Staking	Sewer & Structure
8/26/99	Thursday	Sewer & Structure	Sewer & Structure
8/27/99	Friday	Sewer & Structure	Sewer & Structure
8/28/99	Saturday	Sewer & Structure	
8/29/99	Sunday	Sewer & Structure	
8/30/99	Monday	Sewer & Structure	Sewer & Structure
8/31/99	Tuesday	Sewer & Structure	Sewer & Structure
9/1/99	Wednesday	Sewer & Structure	Sewer & Structure
9/2/99	Thursday	Sewer & Structure	Sewer & Structure
9/3/99	Friday	Sewer & Structure	Sewer & Structure
9/4/99	Saturday	Sewer & Structure	
9/5/99	Sunday	Sewer & Structure	
9/6/99	Monday	Sewer & Structure	
9/7/99	Tuesday	Sewer & Structure	Sewer & Structure
9/8/99	Wednesday	Sewer & Structure	Electrical Work
9/9/99	Thursday	Sewer & Structure	Concrete Work
9/10/99	Friday	Sewer & Structure	
9/11/99	Saturday	Concrete Work	
9/12/99	Sunday	Concrete Work	
9/13/99	Monday	Concrete Work	
9/14/99	Tuesday	Concrete Work	
9/15/99	Wednesday	Concrete Work	
9/16/99	Thursday	Concrete Work	
9/17/99	Friday	Concrete Work	
9/18/99	Saturday	Concrete Work	
9/19/99	Sunday	Cold Milling	
9/20/99	Monday	Cold Milling	
9/21/99	Tuesday	Cold Milling	Sewer & Structure
9/22/99	Wednesday	Crush & Shape	Sewer & Structure
9/23/99	Thursday	Crush & Shape	Sewer & Structure
9/24/99	Friday	Bituminous Paving	Sewer & Structure
9/25/99	Saturday	Bituminous Paving	
9/26/99	Sunday	Bituminous Paving	
9/27/99	Monday	Bituminous Paving	Sewer & Structure
9/28/99	Tuesday	Bituminous Paving	Cold Milling
9/29/99	Wednesday	Bituminous Paving	Concrete Work
9/30/99	Thursday	Bituminous Paving	Concrete Work / Crush & Shape
10/1/99	Friday	Bituminous Paving	Concrete Work / Crush & Shape
10/2/99	Saturday	Topsoil	
10/3/99	Sunday	Topsoil	
10/4/99	Monday	Electrical Work	Crush & Shape
10/5/99	Tuesday	Electrical Work	Grading
10/6/99	Wednesday	Pavement Markings	
10/7/99	Thursday	Project Cleanup	Removed Material

10/8/99	Friday	Project Cleanup	Bituminous Paving
10/9/99	Saturday		Bituminous Paving
10/10/99	Sunday		
10/11/99	Monday		Adjust Dr. Structure Covers
10/12/99	Tuesday		Bituminous Paving
10/13/99	Wednesday		Bituminous Paving
10/14/99	Thursday		Bituminous Paving
10/15/99	Friday		Bituminous Approaches
10/16/99	Saturday		
10/17/99	Sunday		
10/18/99	Monday		Topsoil
10/19/99	Tuesday		Sodding
10/20/99	Wednesday		
10/21/99	Thursday		Striping