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Fast-tracking of Construction Projects: Analysis and assessment

Pierre Théberge

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ABSTRACT

Fast-tracking of Construction Projects: Analysis and assessment

Pierre Théberge

The growing use of professional construction management has been synonymous with the development of new project delivery systems such as the phased construction approach and the fast-tracking technique. This research establishes the distinction between these two types of approach which have become increasingly popular for reducing project duration. The report further illustrates, through project studies, the possible consequences of compressing and overlapping design activities in a fast-track program. The far reaching effect of mistakes during the early design/engineering phase in a fast-track program are usually underrated. Accelerating a project through fast-tracking is a major decision, and construction professionals should be aware of its implications. Based on the investigation of fast-track projects, possible trouble areas requiring special attention have been depicted and recommendations with regard to the effective use of this technique are presented. It has also been shown that if intensified effort on problem areas is lacking, such a popular accelerated technique could result in unexpected delays.

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CHAPTER I

INTRODUCTION

1.1 Management techniques

Management of engineering and construction projects has unquestionably become more complex in recent years. Prior to the 1970's, construction projects were delivered through the traditional approach with an architect/engineer for design/ inspection and a general contractor for construction, or through the design-built approach featuring an engineer/contractor involved in all phases of the project, from concept through design and construction. During the 1970's, technical complexities of projects, increased government regulations, spiraling inflation and political pressures have all contributed to the increased cost of construction which resulted in a search for new and imaginative procedures to ensure faster and more economical project completions. With the traditional project delivery system failing to meet the present challenges, the owners were finding it necessary to become more involved in the administration and management control of their projects.

In the early 1970's, new project delivery systems have emerged as part of the Professional Construction Management (PCM) approach. The PCM unites a three-party team consisting of owner, design professional - architect/engineer (A/E), and construction manager (CM) in a non-adversary relationship, and it provides the owner with an opportunity to participate fully in the construction process.

In an effort to shorten project durations and help meet overall project objectives, certain management techniques have become increasingly popular, such as the fast-track technique, which overlaps design and construction and permits the utilization of multi-prime contractors. The development of this accelerated technique brought along the need for new organizational approaches.

The stages in the development of construction projects broadly fall into consistent patterns. Without considering the minor variances inherent to each project, six basic phases contribute to a project development from an idea to reality [6]:

Concept and feasibility studies;
Architectural and Engineering design;
Procurement;
Bid and construction;
Start-up and implementation; and
Operation and maintenance.

The above basic stages can occur sequently, as in the traditionnal approach, or they can overlap to varying degrees as in a phased construction program. In the traditional approach the conceptual development, engineering and design, bid, and construction phases are seen as discrete stages, each to be completed and approved before proceding to the next. With the phased construction method, this string of activities is broken and the various phases are overlapped, featuring simultaneous design and construction.

To support these new procedures in delivering a project, numerous alternative contractual and organizational approaches are being used [6]. Figure 1.1 shows the traditional arrangement with a separate design professional, a single general contractor and a number of sub-contractors.

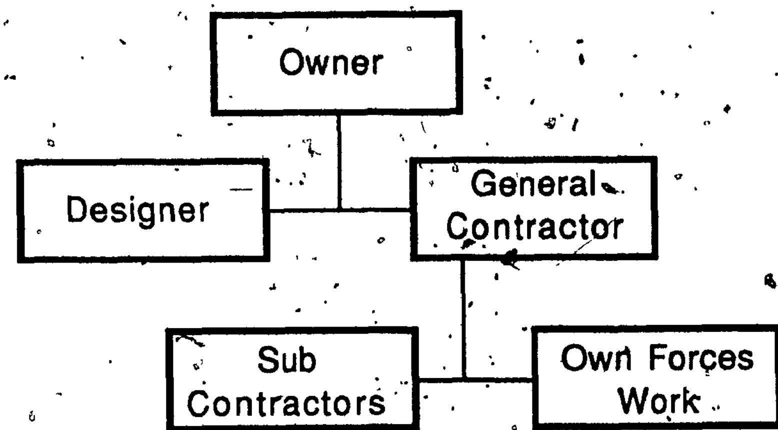


Fig. 1.1 Traditional organization [6]

The following figures illustrates the professional construction management organizations, featuring a general contractor acting as a construction manager (Fig. 1.2) and a construction manager (CM) using the multiple prime contract approach (Fig. 1.3).

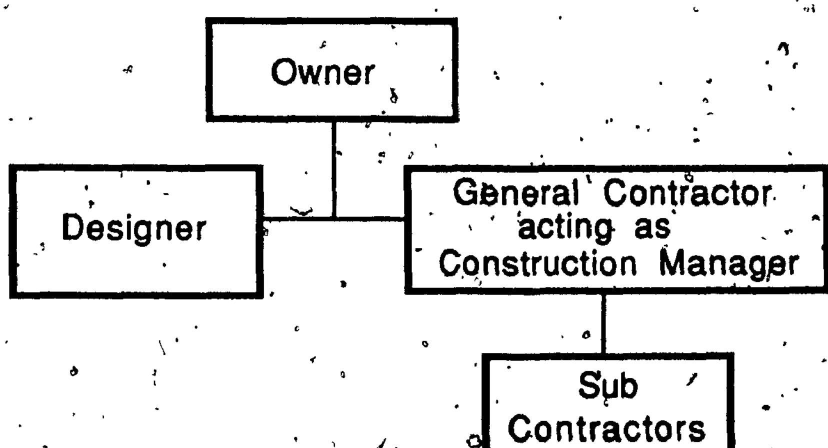


Fig. 1.2 General contractor [6]

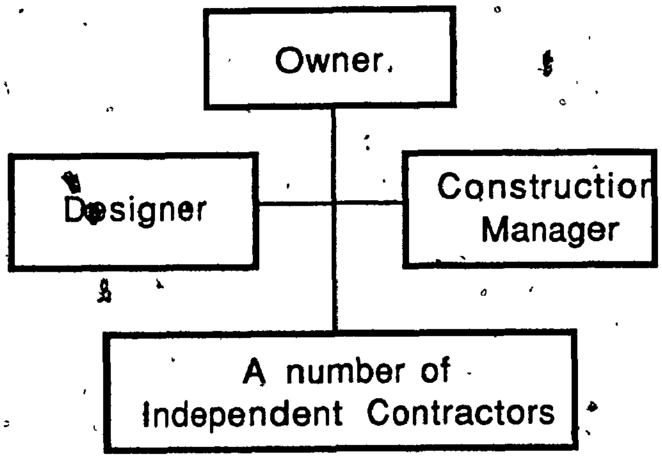


Fig. 1.3 Construction manager [6]

There exist other organizational methods with many of the individual alternatives overlapping one another; in practice, it is sometimes difficult to categorize any one particular organizational arrangement. For contractual arrangments, a variation of cost plus fixed fee or incentive programs are used for CM and A/E in combination with lump-sum contracts awarded to contractors or subcontractors.

The Professional Construction Management concept has been described in detail in numerous books [1,6,13,15] and articles [3,4,5]. However in order to clarify the concept of overlapping design and construction, it will be necessary to distinguish the phased construction approach from the fast-tracking technique.

1.2 Scope and objectives

This study is an unprecedented effort in describing and examining the fast-track construction management approach through case studies. The prime objective of this study is to identify and evaluate the possible trouble areas in fast-tracking. The study also attempts to anwser questions such as: Is fast-tracking the most efficient and reliable approach to accelerate a construction project ? What are the actual drawbacks in applying this method ? The objectives can be summarized as follows:

1. Establish the distinction between the fast-tracking technique and the phased construction approach in construction management.
2. Identify the potential problems and trouble areas associated with fast-tracking construction projects.
3. Establish under what circumstances can fast-tracking be applied effectively, outlining the required project environment and characteristics.
4. Make recommendations on the effective use of fast-tracking on future construction projects.

1.3 Fast-Track vs. Phased Construction

The basic principal behind both fast-track and phased construction approaches is to reduce the design and construction period. With the uncertainty of inflation and interest costs, and with the competitive business world requiring owners to do their utmost to beat their market competitors, these accelerated project delivery approaches have become attractive. By starting construction before the design is complete, the entire project duration is reduced.

The growth of phased design and construction has been synonymous with the growth of PCM organizations [12]. As soon as design and construction stages are overlapped, a whole new series of interrelationships amongst design professionals, contractors and owners are formed, and must be managed very efficiently to achieve construction as planned.

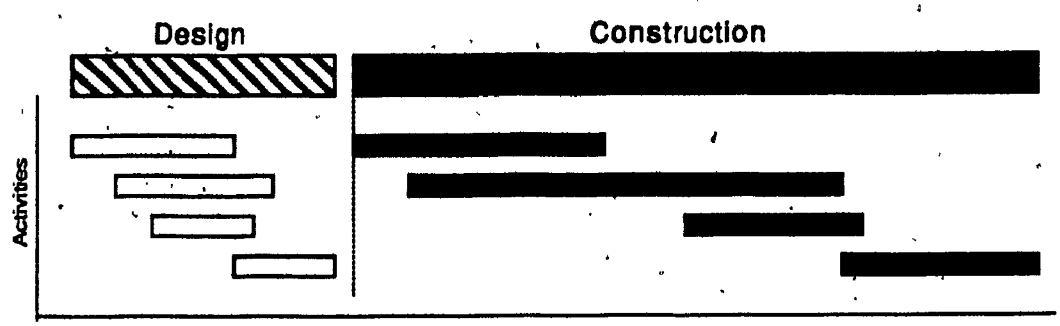
The phased construction and fast-tracking concepts are both used interchangeably in the literature and by construction professionals. Admittedly, both concepts shorten time through overlapping design and construction phases, a similarity which is often misinterpreted. In fact, in some literature, phased construction is considered to be a fast-track approach [18].

Phased construction basically calls for the overlapping of discrete work package, by issuing them at different intervals throughout the construction period. Excavation, foundations, structural, mechanical and electrical drawings are produced seperatly in a pre-determined sequence by the A/E . With each set of drawings, a "work package" is defined; which is then issued for bids and progressed in construction before the following packages is awarded. The design in each work package is substantially complete before it is put out for tender. In order to shorten the whole project duration, critical work packages are issued earlier to contractors as they become ready for construction.

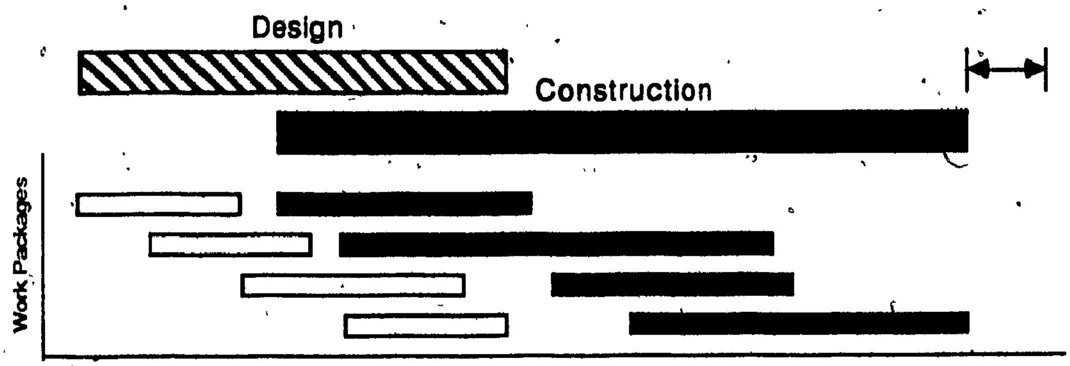
In an effort to further reduce construction duration, the fast-track technique emerged. Under this approach, overlapping goes one step further: the owner's A/E develops schematic drawings and preliminary specifications which are immediatly used to estimate the project budget and get construction started. Without a full set of detailed plans and specifications, prospective bidders, are asked to formulate a contract price. Each contract package is awarded as soon as the work of immediately preceding packages has progressed sufficiently to allow the subsequent package to start, with its design being completed in parallel during construction.

To facilitate the visualization of phased construction as opposed to fast-tracking, the following simplified bar charts have been developed (Fig. 1.4). Because no interrelation between packages has been considered, the amount of coordination effort required when overlapping occurs is not reflected in the activity durations. Therefore, this is basically a conceptual illustration.

I Traditional



II. Phased construction



III Fast-tracking

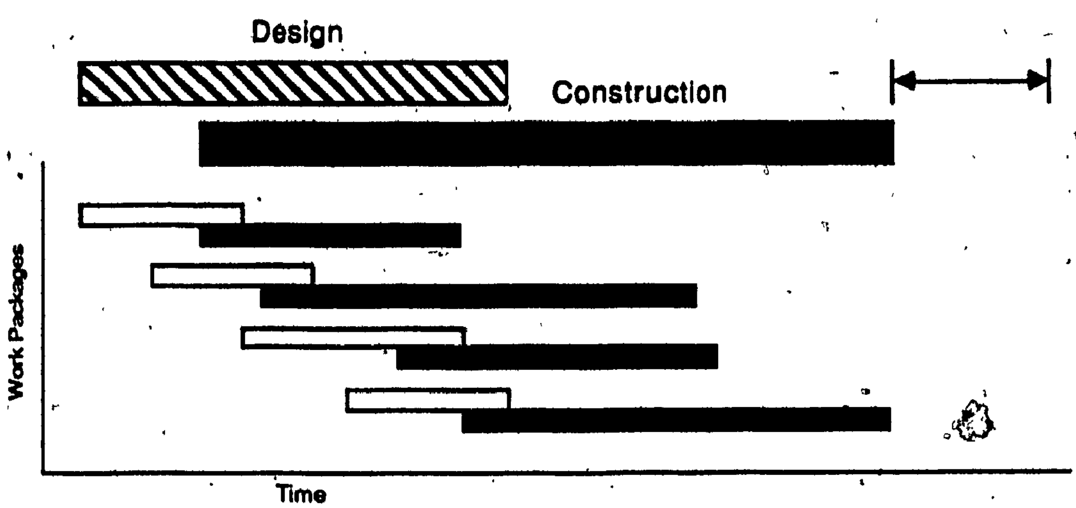


Fig. 1.4 Traditional, Phased Construction and Fast-Tracking Approaches

In the traditional approach, the construction contracts are awarded when the whole project design is completed. With phased construction, the first package (ex: foundation) can be awarded for construction while the fourth package (ex: electrical) is still on the drawing board. And as such, the construction starts before the design of the whole project is complete. This is not to be confused, however, with the design of the individual packages themselves.

When projects are delivered using a fast-track approach, the design schedule is even tighter. Work packages are awarded to contractors as soon as enough drawings have been developped to allow the start of construction. This early jump into construction is a distinct characteristic of the fast-track technique, as illustrated in Fig. 1.4.

Fast-tracking could be viewed as an "accelerated phased construction". The time normally required for the cumbersome reconciliation of all drawings and specifications is being traded for a "finish as you go along" approach. It is then the owner's responsibility to complete the drawings and specifications in a manner consistent with the initial documents used by contractors to begin construction.

The status of design development for an individual work package at time of award is therefore the prime determinant in classifying the project as fast-tracked or merely phased construction.

It should be pointed out that the schematic representation of Fig. 1.4 might be misleading; in certain circumstances, the design of an originally phased construction approach slips into the construction period, thereby causing an overlap of the design and construction phases of the work package. This converted fast-track situation bears the same characteristics as an orginal fast-track project, but with less potential for a shorter duration.

1.4 Fast-tracking conditions

It is reasonable to say that as long as uncertainty of inflation and high interest costs persist, schedule and cost benefits will continue to dictate the use of accelerated construction programs. In several instances, "the overall potential benefits to the company and the customer dictates that the project proceed at as fast a pace as possible" [12]. In theory, shortening the construction period ought to result in lower financing risk and lower indirect construction costs. Accordingly, it would seem profitable to adopt the fast-tracking technique on a general basis. In fact, however, only certain construction projects are potential candidates for this management approach.

The traditional project delivery system is still being applied to a number of commercial and governmental projects, while others that require extensive design and procurement periods such as power plants, industrial complexes, oil refineries, and projects where start-up of commercial production earlier than one's competitors may decide the ultimate profitability of the enterprise, are potential candidates for fast-track and phased construction.

The following conditions or project characteristics encourage design and construction overlapping :

1. Financial conditions:

   Important cost reductions and higher overall project profitability can be achieved by shortening the project duration.

2. Project complexity:

It is advantageous to award early separate contracts for portions of the work which are identified as potential constraints.

3. Political conditions:

Political decisions and budgetary policies can fix the start and completion dates on construction facilities.

In practice, by attempting to maximize the benefits of a shorter project duration or in order to meet a fixed delivery date, a phased construction program often slips into the characteristics of a fast-track one. There is one main condition which qualifies fast-tracking from the start of the project:

4. Market conditions:

For industrial buildings there are distinct advantages to begin production while the competition is still designing or building.

All of the above conditions, require that the project proceed at as fast a pace as possible and call for a dynamic team-work uniting the architect/engineer (A/E) and the construction manager (CM) early in the pre-construction stage of the project. Through this "team approach" a good harmony is created from design through completion, in which the CM exploits his management skills to a greater limit to integrate and coordinate design and construction phase overlapping [19].

1.5 Layout of the thesis

In Chapter II, several aspects and project characteristics of the fast-tracking technique are examined through a literature review on the subject. Many articles have been written revealing interesting lessons to be learned from actual projects which have used this accelerated construction management approach. The summary of this chapter portrays fast-tracking as it is perceived in the literature.

The limitations and assumptions regarding this research and the methodology used for the project studies are presented in Chapter III. In Chapter IV, various projects are examined to illustrate the possible consequences of issuing an incomplete design package combined with the overlapping of the design and construction. The difficulties encountered during the design phase are identified and the cummulative impact of those disruptions on the construction schedule is assesed. Conclusions and recommendations are presented in Chapter V.

CHAPTER II

LITERATURE REVIEW

2.1 General

Very little has been written on the evaluation of fast-tracking. The only material that has been published in recent years are articles advocating the theoretical benefits of this accelerated method, or else describing the single case of a particular fast-track project. The literature review confirmed, to the author's belief, that the concept of fast-tracking is often mistaken with phased construction, and is being used in different contexts without a specific definition. The fast-track management approach is often described as a construction method [24,25] or a design philosophy [30,37,33] not accounting for the overall picture which combines design, procurement and construction.

The words "phased construction" and "fast-track" are often used interchangeably without any distinction, and it is left to the reader to differentiate between the two types of accelerated construction method. Although the two methods are very similar in some respects, they differ in the extent of the design and construction overlap, as discussed in Chapter I.

Fast-tracking construction management was initially associated with composite steel frame design. Osborne [24] and Povey [25] considered the benefits of a fast erection using structural steel frames.

In order to organize the material covered in this chapter, literature has been reviewed on four fronts: Fast-track related experiences; Work packaging; Engineering design; and Fast-tracking risks.

2.2 Fast-track related experiences

The Trevino Project [29], a leach uranium plant located in South Texas, was built in 1981 using the conventional technology. This was a fast-track project in which a significant capital cost saving was realized by accelerating the schedule. The project manager on this job concluded that: "as long as the preliminary work has been done in sufficient detail to allow a running start on the project, that the initial scope of work is well defined, and all subsequent project efforts are carried out in a well-organized manner," fast-tracking will work.

Experience with a fast-track construction of 124 millions, on a geothermal project [35] has also shown savings, but significantly lower than expected, as described below. The project manager, explains how fast-track construction inherently brings with it added costs that are difficult to forcast in advance. The schedule for this project provided 2 years for preliminary design and licensing and an additional 3 years for final design, construction and commercial operation of the geothermal power plant. This represents a year's saving in time over the traditional approach which would have taken 6 years.

The estimated savings in costs for this fast-track project were as follows:

	($ Million)
Equipment and construction (cost escalation)	4
Interest during construction	5
Penalties to the steam supplier	10
Power purchases (premium price)	17
TOTAL	36

Fast-tracking construction resulted in contractor inefficiencies; the incomplete bid specifications brought about intentionally low bids and unrealistic schedules. The contractors intended to make the job profitable through extras; change orders and claims.

Five months before project completion, the cost increases were as follows:

	($ Million)
Engineering Change Orders	3
Construction Change Orders	3
Construction Claims	6
TOTAL	12

At that time a net benefit of $ 24 millions was attributed to the fast-track schedule. The finantial benefits were partially consumed by costs associated with the risks inherent in a fast-track project. Contractual problems were also mentioned to be caused by fast-tracking, increasing the administrative burden on the owner's staff.

Construction projects may also be accelerated through a fast-track approach because of political reasons. The two new Israeli air force bases constructed in the Negev Desert [39] as part of the peace treaty between Israel and Egypt is a perfect example. The schedule was compressed from over 5 years to 3 years. Problems caused by the long delays in design completion arose right from the beginning, resulting in a lack of a complete bill of quantities. The contracts negotiation, which were still taking place when construction was forced to start, finally evolved into a cost-plus fixed fee basis to two design-construct teams from the U.S.. Because of a defective fast-tracking, the project greatly exceeded the budget and barely finished on time.

By the nature of this project, it was called "fast-track", but not as a description of action but as a disease-like philosophy which excused ineffective action. Farritor [11] referred to it as "fastracosis", and he added: "Although the causes of this affliction may have been unavoidable due to the political and diplomatic pressures, its resulting symptoms were nursed by ineffective management actions."

Stern [32] in a report to the New York Governor Mario Cuomo described the problems with the Convention Center in New York City. Again a political decision was made to proceed into construction as quickly as possible through fast-tracking. The job commenced eighteen months earlier than possible under the conventional method but the center has been completed two years behind schedule and as much as $ 125 million over its $ 375 million budget. Bad decisions associated with this method of project management were cited as a major reason for the problems at the N.Y. Convention Center [38].

The increasing number of operations was the greatest challenge at the London Bridge City [24,25,34], one of the largest fast-tracking projects on site in the U.K.. At its peak in 1985, LBC Phase I had a workforce of 700 from 50 different contractors. In this respect, Osborne [24] pointed out that: "The management team needs to be conscious that fast-tracked complex building is more susceptible to coordination problems".

A research and development project in Florida used construction management in a fast-tracking approach to crash the project duration [31]. The project involves the design and construction of an on-site Coal-Oil Mixture demonstration project. Designing the facility around available equipment, using an abbreviated procurement cycle and crashing construction with engineering and procurement allowed the making and burning of coal-oil mixture to take place approximatively seven months after the project began. This resulted in an acceleration of about four months, representing 36% of the project duration of the traditional approach. However, the original estimate of $ 8.8 millions escalated to $ 18.4 millions in capital and operating expenditures. Meeting the tight schedule became more important than holding budget. When construction started, a few changes to the scope were made and a "get it done" attitude was adopted by the project manager of the owner and engineer/constructor team.

2.3 Work Packaging

The increasing complexity of modern construction leads to the development of a work breakdown structure and encouraged overlapping of design and construction. When fast-tracking a project, putting to construction every little bit of work that is available, a conscious breakdown and grouping of the work results in a division of projects into smaller, better defined jobs or packages. One of the key elements in fast-track construction is undoubtebly the way packages of work are defined to achieve high productivity on site. Work packages awarded too early reduce the design flexibility of the following work packages, and potentially increases the possibility of change orders right from the outset of the project.

In the article "U.S. productivity and fast-tracking starts on the drawing board", Gray and Flanagan [12] examined the relationship between the design of an element and its constructability on site. They described how U.S. design professionals pay attention to the way the components will be assembled on site, being concerned with the overlap of work packages undertaken by specialty contractors (subcontractors). They also stressed how important it can be for a fast-track project to have packages of work that are basically self-contained, trade oriented and containing their own tolerance adjusting provisions. It would permit managers to have a better control over the rate of production on site. With this approach the designers must find ways to allow the subcontractors the flexibility to promote alternative design.

For example, in the New York Convention Center [32] project, the main reason fast-tracking has been blamed for delays is that explicit choices on design alternatives were never developed. The design professional's ability to produce drawings while keeping the details open to different alternatives is a determinant factor for smooth progress of construction.

2.4 Design activities

Several authors [29,36,37,38] agree that the engineering phase of fast-track projects is the most important aspect of maintaining the overall project schedule.

"Fast-tracking increases the level of activity in both the office and the field because of the shortened schedule and because of the need of prompt effective decision-making" stated Baker and Boyd [2]. "It is recognized that the process of phased decision-making may commit the project to some courses which, in the light of subsequently developed information, are seen as less than ideal" affirmed Burgman [10]. Construction management input should be tailored to the increasing inflexibility of the design as it evolves.

The author of "Fast-Tracking Construction: The Management Solution" [37] describes how the planning and design stage is a critical time to influence selection of components, materials and systems because at that time the facility is being created and the decision-making process establishing the components and methods of construction is evolving. In his article he quoted a construction manager saying: "These decisions can have far greater effects on the projects than does the actual construction. Especially on a fast-tracking job, you can't afford to make mistakes during the design/engineering phase."

The impatience of owners to break the ground combined with the fast-track approach doesn't allow the A/E's to have the project or even the work packages' design complete in every detail. In this respect a project architect, Hutchinson [34] indicated that: "The contractor wants a series of fully detailed packages to go out to tender" and that is not possible until the whole building is designed. On fast-tracked jobs, packages of work are early bid on a lump sum or unit price basis, depending on how detailed the drawings are at the time.

Schick [29] has indicated that in the preparation of bid packages, it is important that details are correct and that material takeoffs are fairly accurate (best available information); this allows the bidder to bid quickly and precisely. He has also emphasized that a good engineering job in the detailed phase will ultimately save money for the project later on. It should be indicated that bid packages are not prepared with "Released for Construction" drawings but drawings that are 40 to 60 percent complete. It is important to include estimated quantities for drawings not yet started. Finally Schick suggests that bid packages include unit prices for both additions and deletions due to changes made in detailed engineering. These unit prices would make future negotiations with subcontractors easier.

Baker and Boyd [2] stated that the historical method of change control,i.e, complete agreement of scope, schedule, cost, etc., prior to commencing work on the change, simply could not support the fast-track objective for their project. They developed a change control process which initially calls out proposed changes that are neither mandatory nor cost-effective. The remaining changes are implemented so as to support the fast-track construction schedule without waiting for resolution of all costs and contractual details. By implementing this change program they could prevent financial and contractual negotiations from holding up schedule-critical work while preserving stewardship in change control and approval.

By awarding work packages in phases as soon as the design permits a lump sum bid, the company is committed to a project without knowing the end cost. Ruby [28] compared the two approaches: In the conventional construction sequence, company management has the option of cancelling the project after opening the bids, or scaling it down to fit the original budget. Under fast-track construction, cancellation or a major reduction in the scope of a new project may be extremely costly. A large portion of the total cost has already been committed by the time the final bids are opened.

For the construction of a coal terminal [14] on the US East Coast, a fast-track approach has been adopted to rapidly meet the short-term world demands. The right design philosophy allowed the export terminal to be completed 4 months ahead of the original schedule for a total project duration of 27 months (representing a 13 % save in time). At the outset of the project, the design-engineer concentrated on the critical path design items to ensure that an early construction schedule would be maintained and the general design specification became a flexible working document to permit the immediate execution of the terminal design.

For the design activities, Trombley [34] stressed the fact that unless the contractor can identify, on any given day, which subcontractor's packages are on the critical path and which aren't, the design team will not be able to use its limited time to the best effect. Mistakes will occur, and the result will be delay and increased costs.

A research project has been conducted at M.I.T. [36], where a network analysis comparison was made between a fast-track project and an hypothetically derived conventional case. The study will be discussed later in Chapter III, but basically the results pointed out the need for intensive scheduling and planning at the start of a fast-tracking project, due to the sequential interdependencies of construction on design.

With respect to the proper timing to start construction, Schick [29] stated that engineering design efforts on the project should be done to minimize problems which may occur in later phases. He also mentioned that even though the fast-tracking goal is to mihimize the overall project time, it is not desirable to put construction forces in the field too early since this will greatly increase the construction overhead expenditure and force the designer to expedite the preparation of subsequent bid packages.

2.5 Fast-Tracking Risks

Because time is tied to money when new production capacities are coming on stream (industrial) or when new facilities are waiting to be used (commercial), fast-tracking has obvious advantages which must, however, be balanced with the risks involved.

Brunies, Brophy [9] and Heery [13] found the inherent risks in fast-tracking projects to include a loss of the planned benifits due to schedule delays and a loss of financial benifits due to the cost of claims and litigation. Trombley [34] explained how risks can be minimized provided the client knows what he wants and the architect can respect the cost plan. He suggests the architect's first question to the client should be; "does he really know when occupation of the building is required ? Can he really calculate the value of early possession and set that against the higher costs and loss of control likely to be incurred in a fast-track program ? Does he realize that he will be subjected to significant risk because he will set out on a building program not knowing precisely what is to be built ?"

Ruly [28] and Sidwell [30] pointed out two major challenges in fast-track construction: coordinating the construction work and providing subcontractors with the information they need for bidding. Schick [29] summarized his case study, indicating that: "there are always risks in fast-tracking a project, and the success of the project depends on the ability to deal with the problems as they arise, both in the engineering and in the field."

2.6 Summary

As can be found in the literature, from magazine articles to conference papers, there is no general consensus as to whether fast-tracking is a successful or inadequate construction management approach. As mentioned in a recent article by Robison [27], fast-track is great when it is properly done, but when it falls apart, it becomes a bastardized concept.

The review carried out in this chapter covers several aspects of fast-track projects. For example, Trombley [34] stresses the need for a flexible design, while Sidwell [30] explains the advantages of clearly defined independent work packages. The importance of proper management during the design phase is covered from many directions in several papers [29,30,37].

Few authors, however, have examined the consequences of a management system that could not support the fast-track approach [11,27,38]. There is much to learn from a failure to a properly managed a fast-track project. In practice, the risk can be better evaluated through a detailed examination of actual case studies.

In chapter IV; design complications, construction start-up problems, site productivity, impact costs and possible disruption of the work due to fast-tracking are examined. The method of analysis used to investigate fast-track projects is described in the following chapter.

CHAPTER III

METHODOLOGY OF THE ANALYSIS

3.1 Method of analysis

There are basically two methods of analysis available to evaluate the performance of the fast-track construction approach: The first consists of a comparison between scheduling activities of a particular fast-track project and a traditional case hypothetically derived from it. The second uses the actual fast-track project to carry out an in-depth analysis of the accelerations and delays by comparing the as-planned and as-built schedule activities and costs.

A recent study utilizing the first approach [36] is based on the "TREND" analysis technique presented in 1972 by Bennigson [7]. The "TREND" model draws upon three independent theories, namely: Interdependence, uncertainty, and prestige with due assumptions to enable the derivation of the hypothetical traditional case. Typical assumpions required to derive the traditional case include: no change in activity duration from the fast-track to the traditional approach, the same construction activity precedences, and the same level of uncertainty for activity duration.

Moreover, in this case study, work packages were issued as soon as a set of drawings was completed, actually depicting a phased construction approach. Nevertheless, this study has quantitatively shown that, as opposed to the conventional method, in the "fast-track" approach construction activities are heavily dependant on design. The "TREND" analysis also pointed out the need for intensive scheduling and planning at the start of the project when fast-tracking is employed.

In the first method, the assumptions made in deriving the hypothetical model have a direct impact on the reliability of the conclusions drawn from the comparisons. This method of analysis, although theoretically appealing, could result in misleading analysis due to its inherent limitations. Further, the method completely disregards the increased complexity in coordination and scheduling encountered on fast-track jobs. Therefore, in view of the pitfalls associated with the first method, the second method has been chosen for the investigation of fast-track projects.

In general more insight information can be gained in comparing the as-planned and as-build schedules for a particular project than in comparing the same project to a hypothetically derived one. The readily apparent advantage of the selected method of analysis is the fact that it avoids the assumptions required to generate the hypothetical case and as such enables actual comparisons and yields realistic and reliable conclusions. Moreover, by using the second approach it is possible to compare the budget amounts to the actual costs, thereby providing an additional element in evaluating the fast-track approach. Through the selected method of analysis, causes of delays and disruptions and actual problems can be identified and examined in a practical way.

3.2 Source of information

Twenty-eight contracts from eight different projects have been thoroughly examined and the relevant information has been extracted and presented in chapter IV. The following list of project documents are examined and utilized in preparing the analysis:

1. Tender documents
2. Tender estimate
3. Original schedule
4. Up-dated schedules
5. Progress schedules
6. Progress claims
7. Minutes of meetings, correspondences, and memos
8. Construction drawings and revisions
9. Daily reports
10. Addenda and Change order
11. Cost records
12. News releases
13. Claim reports

3.3 The analysis

To determine the impact of fast-tracking on a construction schedule, individual delays have been examined and classified according to their causes. Although it has at times been difficult to identify precisely the nature of a disruption in the construction process, an in-depth look at the information available on each contract resulted in the identification of major problem areas. Several figures and detailed information have been extracted from claim reports. These quoted figures, refered as such in the paper, were recognised by all parties involved in the project.

Two major impacts resulting from complications in the overlapping of design and construction will be investigated: The delays stemming from the use of a fast-track approach (time factor) and the productivity loss generated by it (cost factor). These analyses are complementary to each other, and should ideally be used simultaniously to measure the extended duration and the loss of productivity. A project can deteriorate in several ways; experiencing time extension and/or cost overrun. The assumption is, however, that "time is of the essence". Since the owner decided to go on with his project using a fast-track approach, he must have been restrained by the time factor. Incidently, by making certain assomptions, the productivity loss (in manhours) can be translated into a time factor.

In the following chapter a number of projects are examined in an effort to identify problems and complications associated with fast-tracking. The time and cost factors will be examined using a "Snap Shot Analysis" to identify delays and a "Productivity Analysis" to determine additional cost due to the loss of productivity.

3.3.2 Snapshot analysis

This method of analysis is used to determine the project delays or extended duration. More than just the automatic straight forward measurement of delays, this method enables the identification of multiple delays. As explained below, the snapshot analysis can isolate all major delays and any group of minor delays occuring within a relatively short period of time, and treat them as individual delays. The approach requires 1) the preparation of an "as-built" schedule depicting actual progress, 2) the analysis of construction schedules and its subsequent revisions, and 3) the search for all documents pertaining to each individual delay encountered on the job.

First, one has to establish how the project was actually built and when each activity was performed. Depending on the source of information available, the as-built schedule would be reconstructed from each or a combination of the following:

1) Daily reports
2) Minutes of meeting
3) Inspection reports
4) Progress cerificates for payments

Once the period of execution of each activity has been determined, the logical interdependence between them must also be established. Based on a good understanding of the technical requirements of the project, and with the help of the original as-planned schedule, the as-built schedule sequence is determined. To ensure that the as-built schedule portrays the work as actually performed, various documents are cross-checked to verify key milestone dates.

Before further analysis can take place, critical activities must be identified. The critical path method (CPM) [6,13] is a tool used to depict interrelationships and interdependencies of critical activities which control the progress of the work. In this standard network scheduling technique, the critical path is made of the longest chain of successive and uninterrupted activities which determines and controls the length of the project. It is also important to consider "sub-critical" paths, where the "float" on a chain of activities is very small.

In order to perform a snapshot analysis, one must have on hand several construction schedule up-dates. Each snapshot must coincide with the schedule up-date in order to examine the changes introduced in each of those revisions. Changes in the composition of tender packages, changes in the planning of the work, and the reorganization of construction activites at every schedule update are normal procedure in the management of a project. This new input of information, at the time of each schedule preparation, is common practice that renders the delay analysis significantly more complex. As such, the snapshot analysis takes into account all these changes, and enables the identification of any slippage or acceleration in the work since the last schedule update.

Figures 3.1 to 3.4 illustrate the approach.

From the date of the snapshot, one looks back to a period up to the previous schedule update, taking, so to speak, a "snapshot" of the project. For one single activity, the snapshot would be as shown in Fig. 3.1.

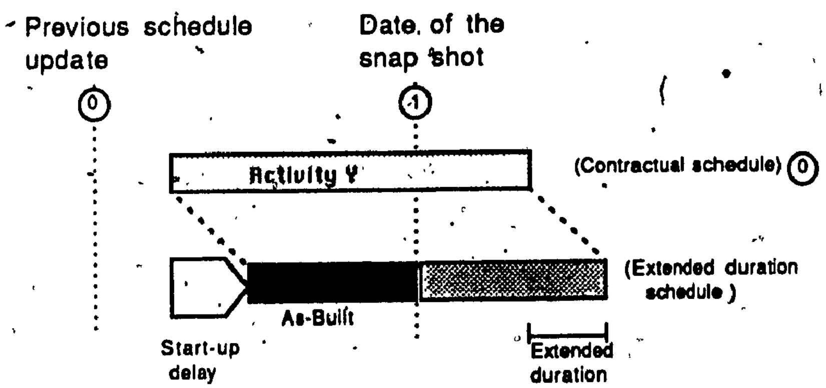


Fig. 3.1 Extended duration schedule

Coinciding with each update, the actual progress achieved up to the date of the snapshot is compared with the anticipated progress to the same date. The difference shows the delay accumulated between the date of the snapshot and the immediately preceeding schedule update, for the activity under examination. To illustrate this comparison, an "extended duration" schedule is derived from the as-built schedule by adding the work to be completed according to the prior planned schedule. This exercise allows the determination of the "would-have-been project completion date", making allowances for the delays accumulated up to the date of the snapshot, while maintaining the same sequence and activity duration used in the preceeding update (see Fig. 3.1).

The extended duration resulting from of this snapshot is then compared with the new schedule update. The difference between those two establishes the degree of acceleration, (Case A, Fig. 3.2) if any, and/or the imposed changes in the planned sequence of activities (Case B Fig. 3.2).

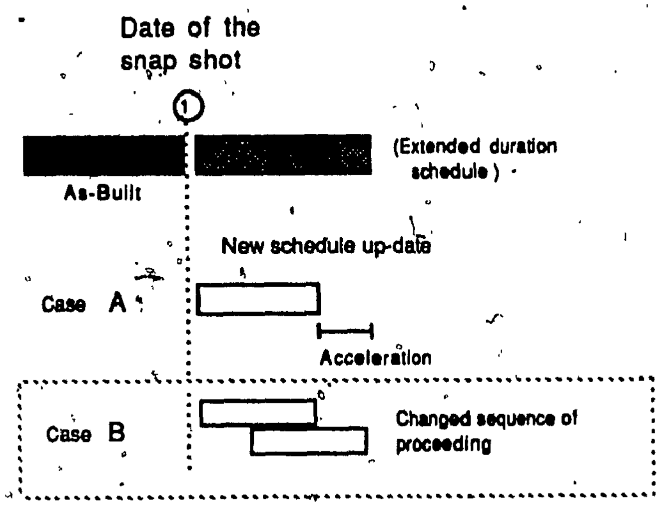


Fig. 3.2 Snapshot 1

New schedule update (A or B) are developped at the date of the snapshot, illustrating the way managers were planning the project. For each snapshot, the previous schedule revision becomes the schedule in effect up to the date of the snapshot (the as-possible schedule), which is then compared to the work performed to date. In the example under consideration (Case A), the new schedule for the next snapshot is shown in Figure 3.3.

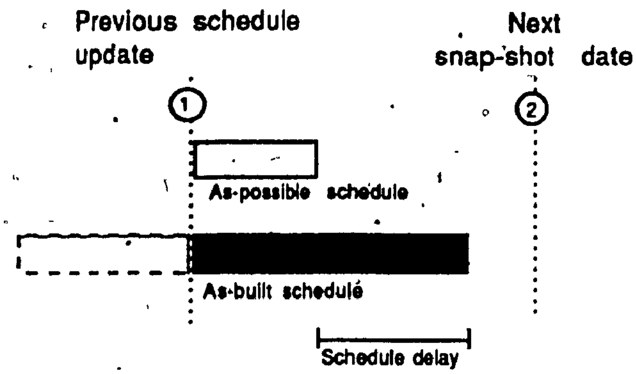


Fig. 3.3 Snapshot 2

Compared with the as-built schedule, one can observe the changes in duration, and determine the exact time of occurance of the delays. From the planned completion date, schedule delays and accelerations are added up to give the overall delay (Fig. 3.4). Every component of this delay has been allocated previously in one of the snapshot periods.

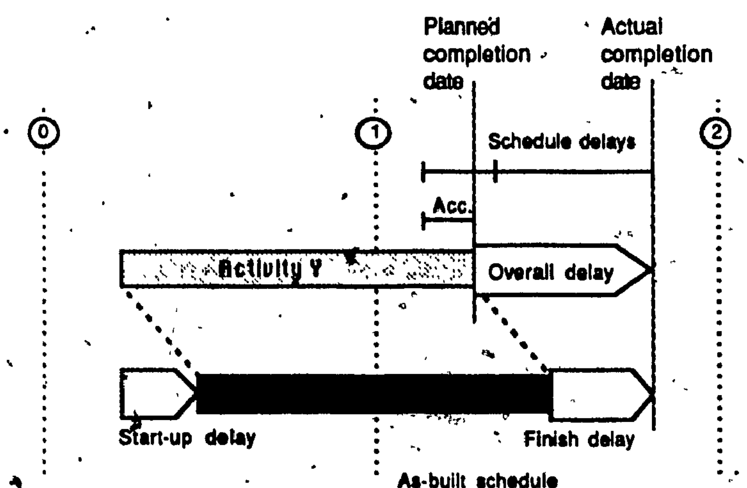


Fig. 3.4 Overall delay

The strong point of this method is that it permits the identification of shifting in both the planned and actual critical paths of the project. The snapshot method also permits to isolate what may otherwise appear to be concurrent delays. In view of the snapshot progression of the work, individual delays are identified and their causes determined. To allocate the responsability to different parties for fast-track delays, one must examine the contractual requirements of each party and determine what items or field of activity is solely in their jurisdiction. For fast-tracking delays, the causes behind an action or lack of action must be examined and the owner's motives understood.

3.3.3 Productivity analysis

In some instances, the information available on a project does not permit a detailed snapshot analysis, i.e. there are no schedule updates or accurate as-built information. In this case the productivity level acheived on each project is examined. This productivity analysis indicates how much a contractor has been affected in the execution of his work by events outside of his control. It is then possible to determine the extent in which fast-tracking has contributed to the disruptions.

"A loss of productivity is the decline in the efficiency of that person or group of persons due to the specific cause (or causes) from the level which under the particular circumstance could have been achieved, save and except for the cause(s) under examination" [26]. The multitude of factors affecting workers' productivity will not be covered herein, but could be consulted elsewhere [8,20,22]. In general management practices can adversely affect labour's motivation (i.e. his attitude to the given task) and accordingly hamper his efficiency.

The initial step in a productivity analysis is to determine the period of least interference or period of "normal" productivity. This period must be chosen, with all relevant information on hand, to truly represent the time at which the contractor was the least affected by fast-tracking. In determining this normal period, the productivity losses resulting from either (1) the contractor's own deficiencies and/or (2) the risks he must assume under the terms of his contract, are accounted for. This procedure permits to isolate the impact of the owner's actions or lack of actions on the project.

The loss of productivity calculations for the project cases considered in chapter IV are based on measuring the difference between the actual "impacted" productivity and the productivity that could have been achieved without the fast-tracking impacts. By extending the progress acheived during the normal period over the entire project duration, a probable project requirement in total man-hours is determined as shown in Figure 3.5. Although not shown in Figure 3.5, calculation of the projected duration allowed for the expected lower productivity at the beginning and at the end of the project (See Chap. 4.3 -4.4), as recognised by industry standards.

Two different extra costs have been calculated based on the above analysis; the extended duration costs and the impact costs. The consequences of fast-tracking have been accounted for not only in the duration of the delay itself (including direct costs) but also for its impact on the schedule (impact costs). These costs are extra costs over and above what the contractor would have incurred had he been allowed to

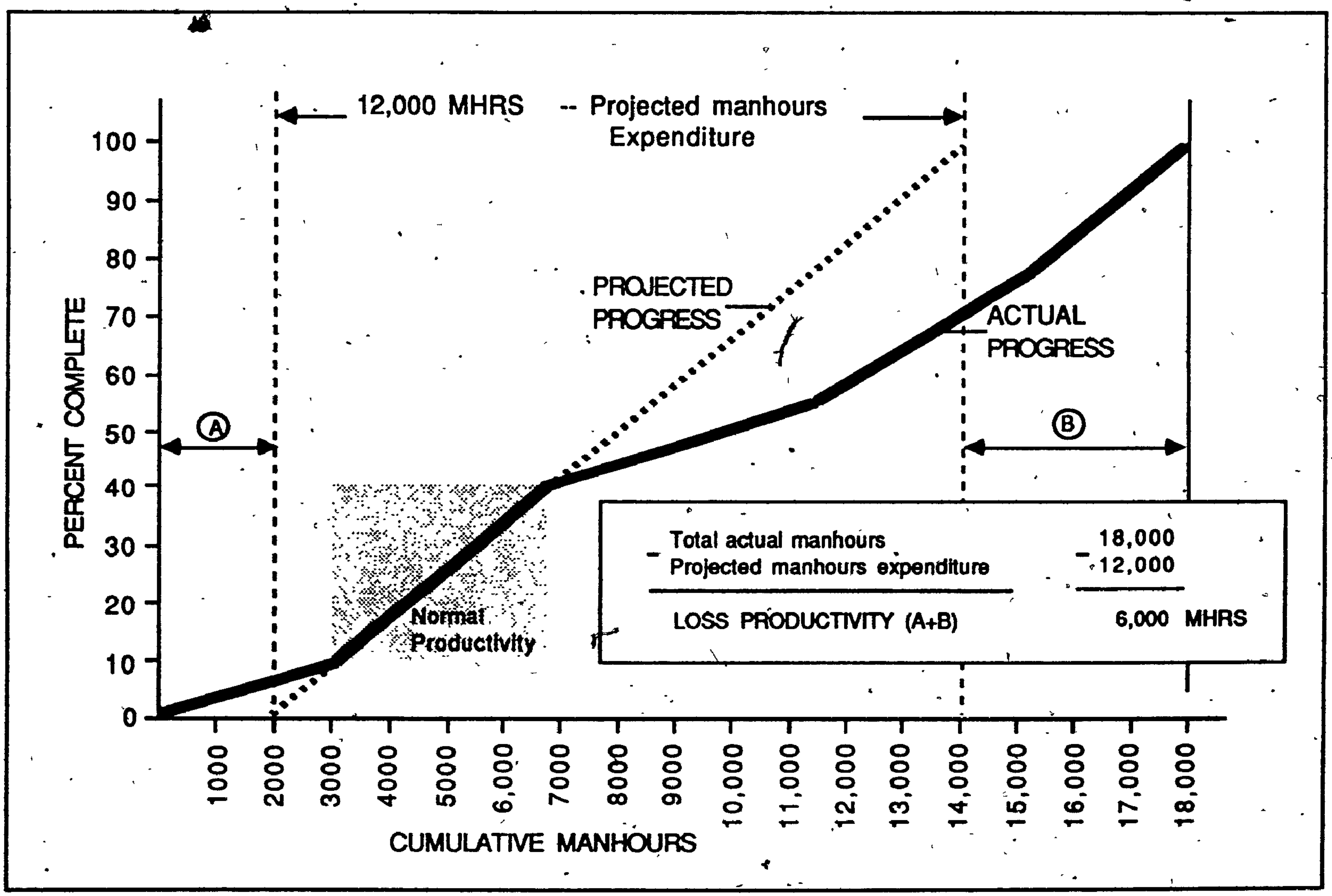


Fig. 3.5 Projected progress

complete the contract without interruptions. These impact costs are calculated from the normal productivity figures which account for the contractor's performance on the project.

To quantify impact costs, the productivity achieved during the least interfered period (man-hours per 1 percent complete) determines the total man-hours that should have been required for the work. The projected manhours expenditure is then subtracted from the total manhours actually required to complete the work. The resultant loss of productivity manhours include the contractor's complications with the fast-track approach.

The extended duration costs are determined from the delays attributed to fast-tracking. To determine these costs, the same manpower level is assumed throughout the project. The achieved progress during the normal period can then be extended into an "as-possible" project duration, allowing again for lower productivity at the begining and end of the project. This exercise permitted the allocation of a portion of the delays to fast-tracking. The difference between this "would-have been duration" and the actual duration of the project represents the delays incurred by the contractor for which the owner is responsible. Combined with the average hourly rate of the work force, this calculation represents the extra costs of an extended duration resulting from fast-tracking the project. The many causes of this extended duration have in effect been grouped together to represent the fast-tracking impact on the project. Several contracts have been analysed in this manner and the numerical results are included in chapter IV.

3.4 Advantages and drawbacks

Backed-up with a numerical analysis, the study (presented in the next chapter) of fast-track projects experiencing difficulties demonstrates clearly how this approach can impact construction activities. The in-depth analysis of "after the fact" information eliminates any unfounded conclusions possibly arising from a theoretical approach. The information used from claim reports was recognized by all parties and does not represent the point of view of a single participant.

The selected sample of projects covers the residential, commercial and industrial sectors of the industry. The cases studied are based on projects that clearly showed difficulties with the fast-tracking approach. Projects which have been selected were subjected to several claims, depicting problem areas associated with fast-tracking. Moreover, the tight schedule of fast-tracking combined with the size of the projects selected were considered helpful in identifying coordination and scheduling problems.

Besides fast-track related problems, the intrinsic characteristics of the parties involved in the construction process (owners, A/E, PM, and other contractors) are always present and do have a considerable influence on the project development. It is practically impossible to distinguish the management team's "attitude" from the technique they used. These factors might be hard to quantify in determining fast-track related delays and loss of productivity. The owner's site administration and response time to the contractor plays an important role in the outcome of the project. This factor could be considered seperatly from other fast-tracking impacts. However for the purpose of the analysis, it is assumed that these delays are part of the overall fast-track delays.

CHAPTER IV

PROJECT STUDIES

4.1 Introduction

In the first part of this chapter a detailed analysis of three fast-track projects is presented. The analysis is performed in an effort to quantify impacts of this accelerated construction management approach on the overall project schedule and cost, namely: (1) The extended duration and (2) the impact costs resulting from a productivity loss. Summary and recommendations are presented at the end of each project considered.

Three representative projects are examined in-depth; one large industrial plant and two medium-sized commercial and residential buildings. These three projects have been selected to show the dynamic interrelations between work packages, coordination difficulties, trade interferences and other complications encountered on fast-track projects. This investigation of fast-track projects will enable a qualitative evaluation of the approach supported by several examples and specific situations.

Project study I investigates the construction of a large industrial plant. This typical fast-track project contains several examples of design difficulties and coordination problems. As the main study, the repercussions of design activities on the construction schedule of this project are closely examined using the "snap-shot" analysis.

Two other projects (II and III) are examined to determine the causes and effects of problems associated with fast-tracking on construction activities. Using the productivity analysis, the extra costs associated with fast-tracking are calculated together with an evaluation of the extended duration. Project study II has been selected to illustrate the effect of incomplete design on construction, and as such concentrate on the planning and coordination aspects. Project study III illustrates the complications associated with the interface between work packages and related coordination problems.

The second part of this chapter briefly examines 5 other fast-track projects, comprising an additional 12 work packages. Cumulative results, identifying problem areas common to all these projects are presented at the end of Chapter IV.

4.2 Project Study I

In fast-tracking, design sequences and procedures are critical elements to the overall planning of the job. The industrial plant project considered in this study illustrates the importance of design activities in preparing individual work packages. Fast-tracking design activities can create problems and jeopardize the early construction start. Design difficulties in putting work packages together are examined in detail to reveal coordination problems when activities are overlapped. This fast-track project is characterized by numerous drawing revisions and their impact on the scheduling and progress of construction activities. After a thorough examination of the design effort, the construction's critical path is examined to determine delays which can be attributed to fast-track.

4.2.1 Project characteristics

The selected project is a typical fast-track construction of a large industrial plant in the United States with an estimated value of $100 millions. The estimate includes all the procurement contracts, major construction packages and the design engineering services. The project was originally planned to span 27 months, with a design period of 14 months overlapping the construction phase of 21 months (Fig. 4.1). In reality, the construction period started 5 months behind schedule, and spanned 26 1/2 months. The plant finally went into operation after a construction delay of 10 3/4 months, extending the planned project duration by 40%.

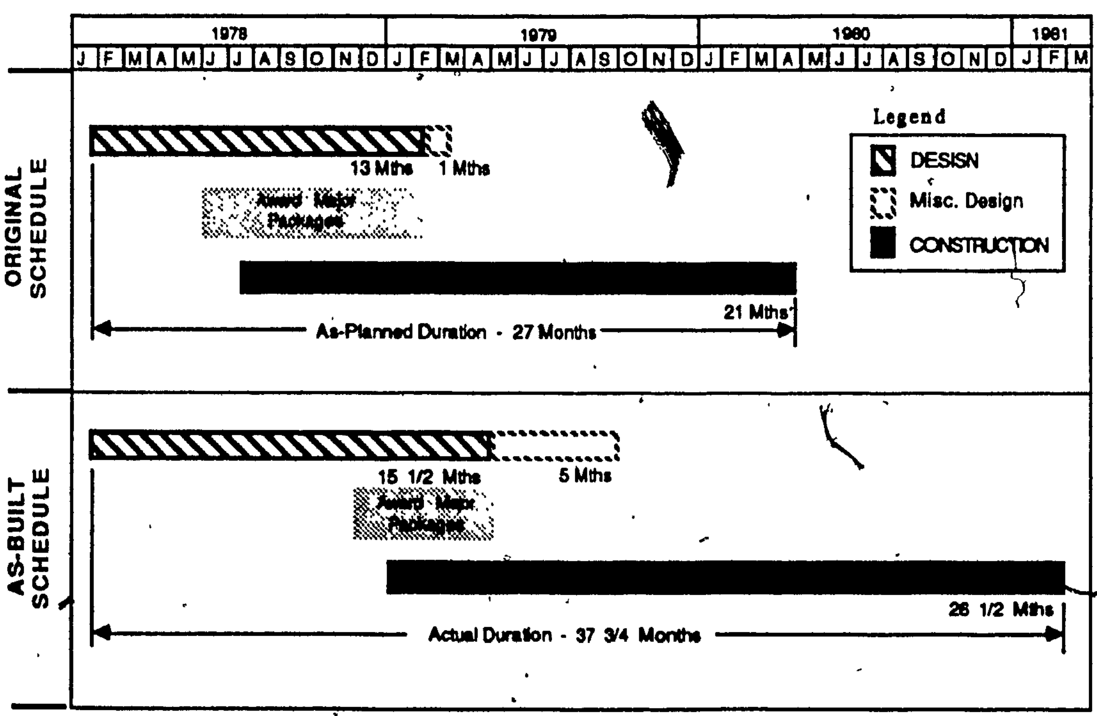


Fig. 4.1 Summary Schedule Comparison

An experienced design/engineering firm took over the design development of the plant after a significant amount of preliminary design work had been accomplished by the owner. After award of the design contract, the owner's engineering group worked with the consultant on detailed engineering and preparation of construction documents.

The scope of work of the design/engineering firm included the preparation of all technical drawings and specifications for equipment supply and construction contracts in sufficient detail to allow the owner to enter into firm price contracts with various contractors. The design contract included all the necessary work related to process engineering, mechanical engineering, civil engineering and electrical engineering, as well as the management of all design functions. During the preconstruction phase the design firm had the responsibility for project planning which included the preparation of a project schedule showing when the various construction contracts had to be awarded and executed in order to complete the new facility by April 27, 1980. The construction work was separated into several self contained packages each awarded individually to a different contractor in a multi-prime arrangement. Both the owner and the design/engineering firm acknowledged that the schedule was very tight and that it needed a good management program to support it.

Once construction began, the owner's construction management group took over the scheduling and control functions.

4.2.2 Design Activities

Although basically done by the engineering firm, the design development of the plant included an important contribution from the owner. Tendering of major contract packages, as shown in Figure 4.2, illustrates the delay (in most cases) in advertizing the packages. Nine major packages (i.e. civil, mechanical and electrical packages) will be looked at in depth. Even though the other packages are of importance, they didn't prove to be critical to the completion of the project.

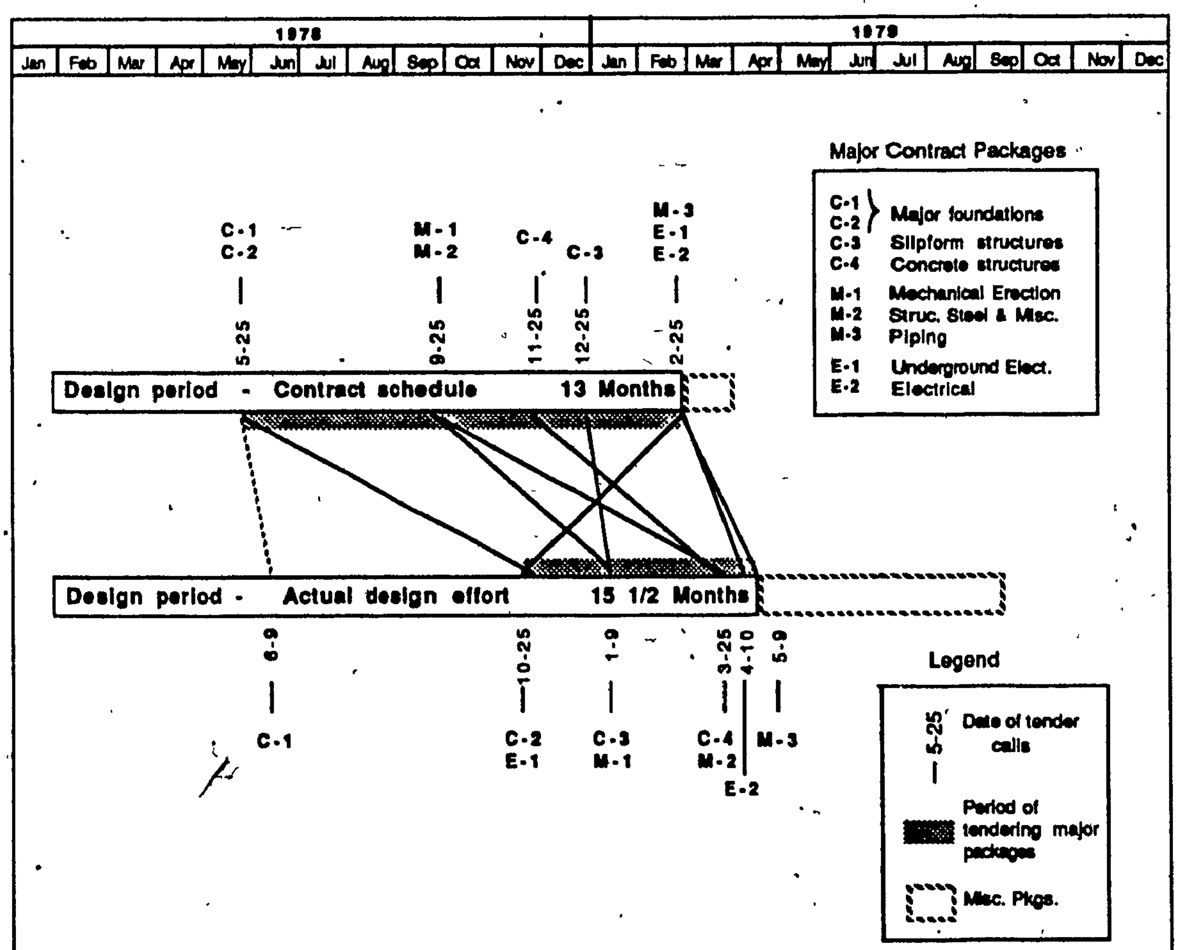


Fig. 4.2 Tendering of Major Contract Packages

As shown in Fig. 4.2, the tendering of main construction packages were postponed and compressed towards the end of the design period. All major contract packages were intended to be prepared, ready for tender within a period of 9 months (from May 25 '78 to Feb. 25 '79 - Fig. 4.2). Instead, the actual design effort had to be compressed in order to advertize the major contract packages in 6.5 months (from Oct. 23 '78 to May 9 '79), with the exception of package C-1. Following scheduling problems and coordination difficulties, this slippage in bid dates disturbed the original sequence of contract awards and significantly affected the construction schedule.

Planned tendering period	9 Months
Actual tendering period	6.5 Months

Although the advertizing and awarding of the first major construction package (C-2) had slipped 4.5 months during the design period, the final project schedule submitted to the owner by the engineering design firm showed only one month delay in project completion.

Trying to meet the intended date of commercial production, the engineering consultant and the owner didn't hesitate to reschedule activities, overlap work or revise activity durations through compression or acceleration. The structural, mechanical, electrical and piping work were overlapped and durations revised in various bid packages, considerably affecting the project schedule. This reorganization illustrates the determination of the project team to stick to the project completion date.

Five main packages, representing the various trades, were selected amongst the nine examined, for schedule comparison of tendering period as presented in the bar chart Fig. 4.3 . The chart shows how the design progressed even during the tendering period. It also indicates that the design was not complete at the time contracts were awarded.

A large number of drawings were revised, added or deleted in several contract packages. In some cases up to 7 addenda were issued. This resulted, for example, in a slippage of up to 6.5 months in the award of the structural steel package (M-2). The bid closing date of this package was delayed 3 times, 190 drawings were added while 109 drawings needed revisions. This represented, respectively 50% and 28% of the number of drawings on hand at bid opening. A large number of drawings were also revised just before bid closing. These included the revision of 87% of the drawings in the electrical package (E-2) and 90% of those in the piping installation package (M-3). These last minute revisions affected the accuracy of the bids and contributed to the low productivity of the contractors at the outset of their contracts.

The incomplete design resulted in a large number of drawing revisions required after contract awards (Fig. 4.3). It is particularly important to stress the case of the structural steel (M-2) and electrical installation (E-2) packages with, respectively, 56% and 168% of the total number of drawings revised, with possibly more than one revision for the same drawing.

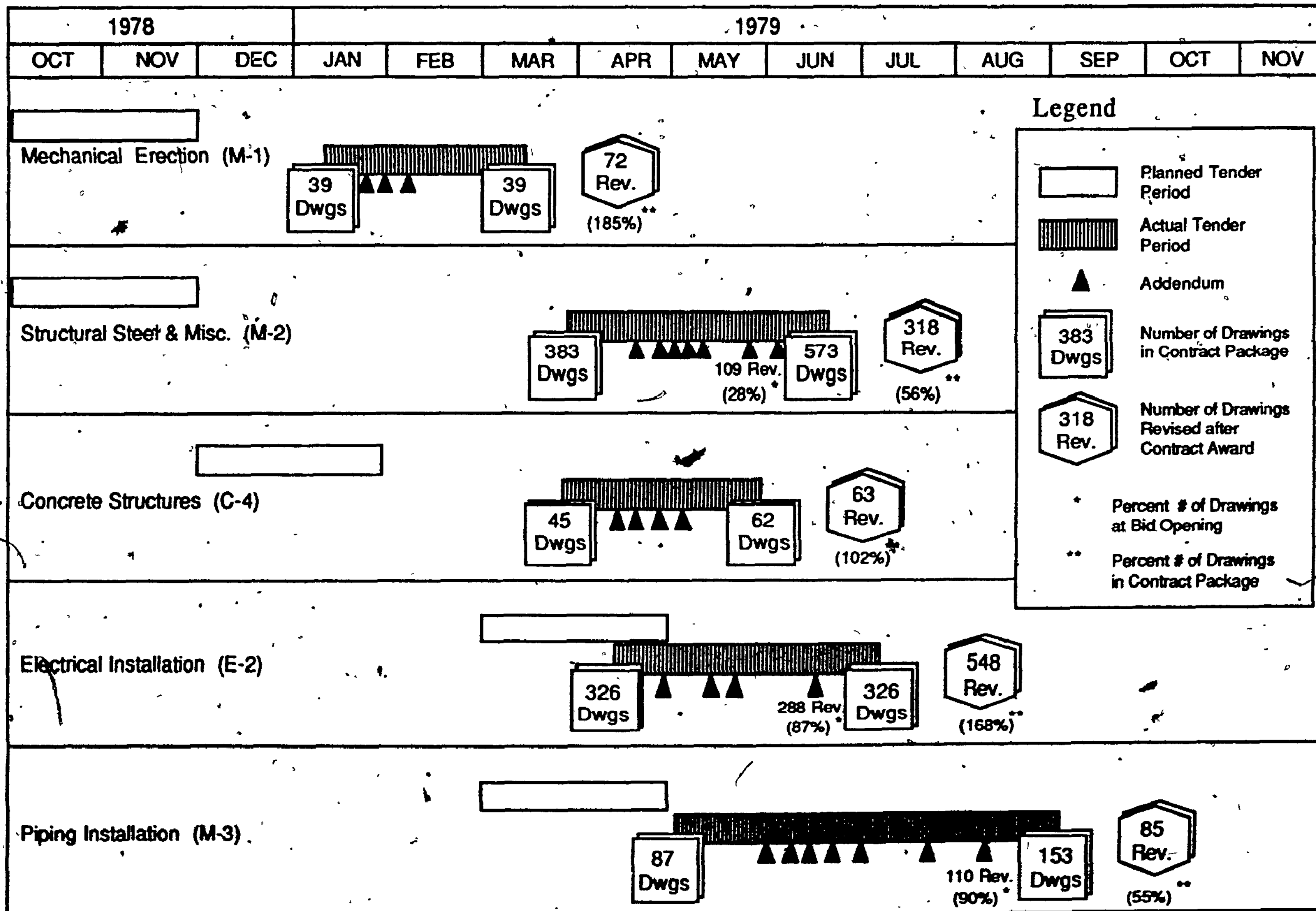


Fig. 4.3 Schedule Comparison of Tendering Period

By looking at the design manhours histogram and design packages bar chart it can readily be seen that the design activity continued long after the individual contract had been awarded. The three charts on civil, mechanical and electrical engineering design are shown respectively in Figures 4.4, 4.5 and 4.6. These figures clearly show the considerable amount of design engineering performed during and after the tender period of contract packages.

The first major foundations' package for concrete foundations (C-2), was to be ready for tender call by May 25, 1978. Because of late information from the equipment manufacturers, the tender call of this critical package was delayed by 5 months. Consequently the work on this package had to be accelerated in order to minimize the effect of this slippage on construction schedule.

The concrete structures package (C-4) was also delayed by almost 4 months for the same reasons of late information from the equipment manufacturers. The mechanical design packages M-1 and M-2 were delayed by 2.75 and 5.5 months respectively. These mechanical packages were awarded on a lump sum basis even though the completeness of the design drawings and specifications suggested a unit price arrangement.

For the civil work (Fig. 4.4) and the electrical work (Fig. 4.6), 30% of the design manhours were spent after award of their last contract package. It has been determined by comparing the planned and actual design manhours to their corresponding schedule, that the civil and electrical packages were issued with more design work to be completed after award than they had originally planned.

Fig. 4.4 Civil Design Manhours & Contract Packages

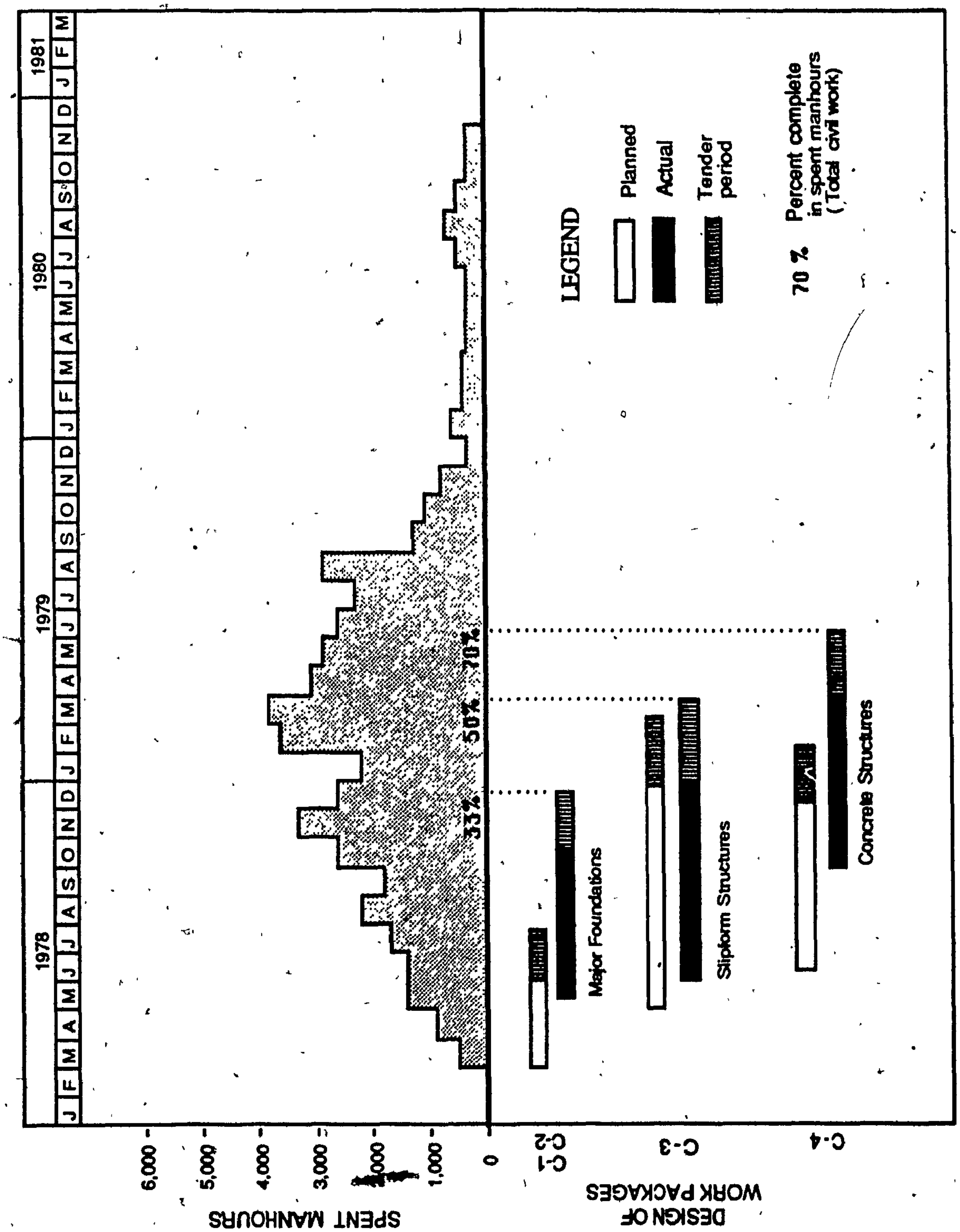


Fig. 4.5 Mechanical Design Manhours & Contract Packages

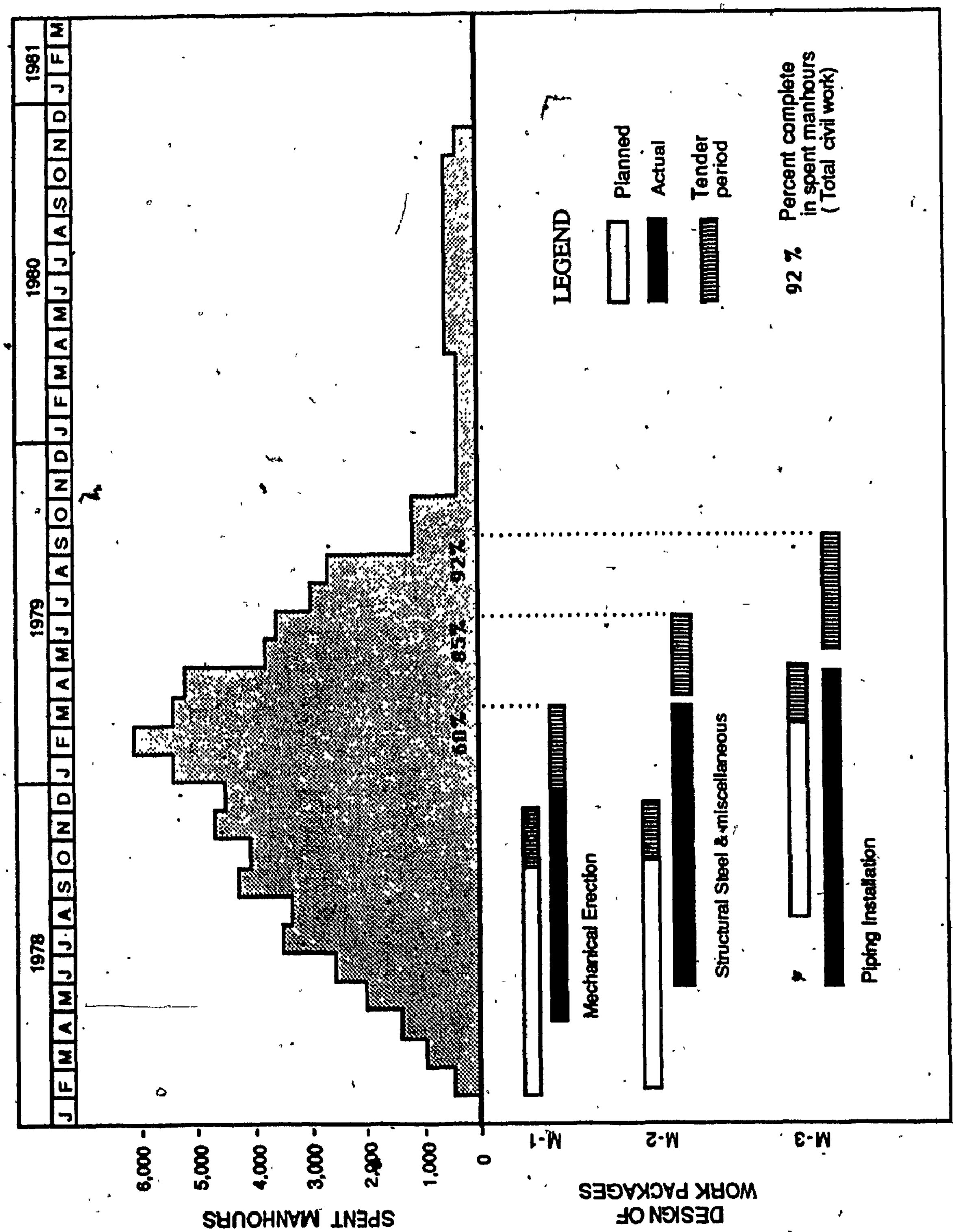
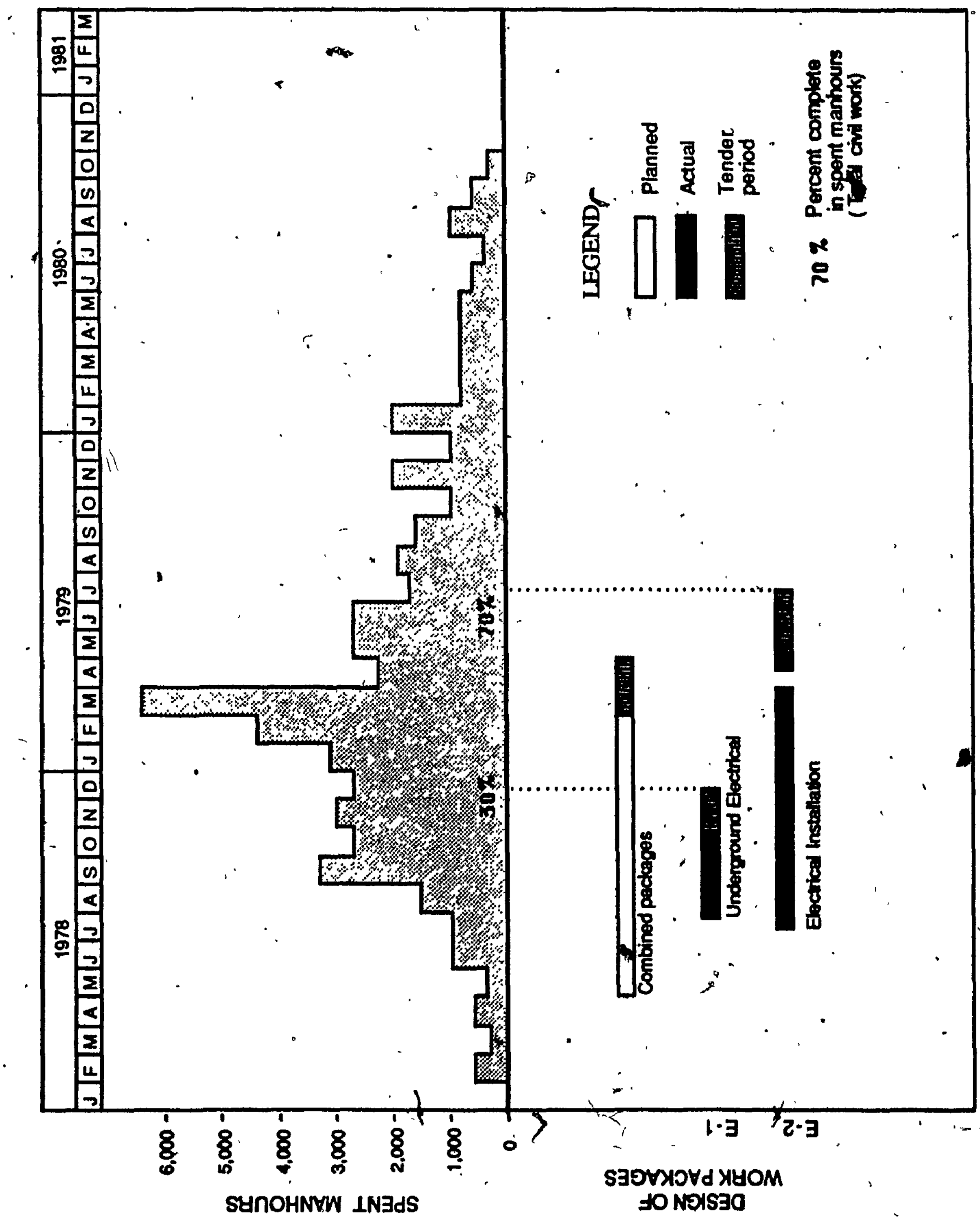


Fig. 4.6   Electrical Design Manhours & Contract Packages



To give an example of the owner's effort to recover time lost, the generally accepted bid procedures for the procurement of structural steel was abandoned , in favor of a piece-meal issue of drawings to selected fabricators. In this respect, the design professional was called upon by the owner to adopt the procedure of issuing drawings first for procurement and then for detailing, before checking of the design and drafting would normally have been completed. Drawing revisions had to be made in many cases after issue for procurement or detailing, simply because the design was not complete in all respects. The coordination and design difficulties forced the design/engineering firm to alter considerably the way packages of work were put together in order to meet the start-up target date.

Considering the design difficulties described above and illustrated in Figures 4.1 to 4.6, the impact stemming from drawing revisions can be grouped into four major categories : 1) delaying bid openings, 2) extending the tender periods, 3) affecting the contractor's ability to plan and execute his work efficiently and 4) creating additional work through change orders (revisions after contract award).

The above grouping illustrates the impact of compressing and overlapping design activities. As a result, the design effort for major contract packages in this plant spanned over a period of 15.5 months instead of the 13 months as specified in the contractual arrangement (Fig. 4.1).

There are other factors, not directly related to fast-tracking, which have contributed to the initial delay on this project. The time at which procurement contracts were awarded for major equipment dictated the period at which vendor design information was available to the design firm. The late award of major equipment contracts resulted in late issuance of vendor design information, which in turn delayed the design process.

A change in design criteria even at this early stage, considering the tight schedule, can have a detrimental impact on the design efficiency. For example, in order to increase mill capacity, the foundation package was completely redesigned by the vendor, resulting in a delay of approximately 3 months for this particular item.

The owner must also pay important attention to the acquiring of permits. On this project the lenghty time involved in obtaining the "approval to construct" permit was running concurrently with other design delays.

The first year of this project was intended for design and coordination of the various equipment vendors, with a view to be ready in February 1979 for tender call of all major construction packages.

From what has been discussed earlier one will agree that the design firm could not keep up with their own schedule. The impact of the design difficulties have surfaced in the construction period as will be discussed in the next section.

4.2.3 Construction delays

According to the original schedule, the project completion date was April 21st 1980, including a construction duration of 21 months (see Fig. 4.1). The initial delay in design activities resulted in a late start of 5 months in construction. Through further fast-tracking overlapping and compression, the owner and construction manager were able to reduce this delay to only one month. This schedule depicted the manner in which the remaining contracts could be let, and the sequence in which work could be performed to achieve a May 23, 1980 completion date. The delays which had occured prior to February 8, 1979, the date at which the new construction schedule was issued, were accounted for in this schedule.

Yet, during construction the project suffered an additional 9 3/4 months delay. This slippage occured despite an acceleration in the work of both the mechanical and electrical contractors through formal orders by the owner.

Until the completion of the project, a dozen schedules have been issued or prepared by the owner. Some schedules were prepared just as a general planning tool and never issued to the contractors, and others were only issued by the design firm.

A detailed schedule analysis has been carried out on the critical activities of the whole project. In determining the critical work several schedule up-dates have been examined, each having somewhat different critical paths. Of all facilities in this industrial complex, the work on the processing plant repeatedly proved to be more important to the project completion date. Parallel critical paths were present throughout the construction period. In determining the delays, several factors have been accounted for in order to insure that those delays were in fact on the critical path and did actually delay the project. Concurrent delays were taken into account and overlaps eliminated. Sub-critical delays have also been considered, in acknowledgement of the relatively short float (i.e. few days) existing on some of the construction network paths. For example the mechanical installations and piping work were at times critical to the project completion and therefore included as sub-critical paths, see Appendices A to F.

There were basically three main schedules. The original/contractual schedule of January 25, 1978, the as-planned construction schedule issued February 8, 1979, and the as-built schedule issued after March 17,1981. Some other schedule up-dates, in between those three, were also selected. A total of nine schedules were examined, as listed below.

1 - Contractual schedule : January 25, 1978

2 - Up-date of May 16, 1978

3 - " September 15, 1978

4 - As-planned construction schedule : February 8, 1979

5 - " July 4, 1979

6 - " November 30, 1979

7 - " April 23, 1980

8 - " August 4, 1980

9 - As-built schedule : March 17, 1981

In preparing a detailed analysis, two distinct expert reports on the project's activities have been examined along with accompanied documents. Similarly, the snap shot schedules presented in Appendices A to F have been reconstructed from two sets of schedules. It is through this "snap-shot" progression of the work that the cause and effect relationship of the identified delays has been determined.

As part of the snap-shot analysis, the actual progress between the two construction schedule up-dates have been compared with the anticipated progress for the same period. As explained in Chapter III, the comparison between what was supposed to be done and what was actually done within a given time frame permits a better analysis of each delay. For example, the first snap shot schedule (Appendix A) shows an 80 day delay from the extended duration schedule. On the next snap shot (Appendix B) all but 7 days of this projected delay has been recuperated when the main electrical package was awarded and project activities rescheduled.

In addition to determining which activities were delayed (or accelerated) and when, each individual delay needed to be examined in detail to determine both the extent to which it has affected the project schedule and the causes. The figures in Tables 4.1 to 4.3 were extracted from expert reports on the project. These numbers were examined from a fast-track point of view, trying to trace back the true causes of each delay. Consequently, the schedule analysis involved further investigation and classification of delays according to their causes combined with the snapshot schedules (see Appendices A to F).

In perspective, the new as-planned schedules show very little compliance with the planning of the various contractors (e.g. electrical and mechanical). The start dates and activity durations assumed by the contractors found no support in the then-current schedule as far as the planned completion date of the immediately preceding activities were concerned. This constant changing both in the sequence and the duration of various activities, and the apparent lack of coordination among the different contractors have created significant difficulties on the job.

The impacts of compressing schedules have been examined by looking at interferences between the various contractors on site. The loss in productivity resulting from these trade interferences reflects the contractor's difficulty to plan adequately in this constantly changing environment.

Several other items or events were identified as being potential causes of delay to the processing plant, but were not analyzed in greater detail as they have not affected the critical path, or were completely overshadowed by a much more predominant and controlling delay.

For simplicity, fast-track delays have been grouped into two basic categories: 1) delays directly caused by fast-tracking and 2) delays indirectly related to fast-tracking.

Delays directly related to the fast-track approach include the slippage of work packages on the critical path affecting the construction start date, design errors and omissions resulting from poor coordination between work packages, and design changes attributed to the accelerated approach. The total delay to completion of the processing plant and the start of production was 324 days (10 3/4 months) from April 27, 1980, the original completion date, to March 17, 1981, the actual completion date of the project. Individual delays directly related to the fast-track concept have been identified and allocated as follows:

Table 4.1 Direct Fast-Track Delays

	Nature of Delay	Days
(1)	Award of main electrical package	7
(2)	Additional steel	5
(3)	Design error - Elevator shaft interference	18
(4)	Additional steel	15
(5)	Design error - Interference	1
(6)	Electrical design changes	33.5
(7)	Revised burner system	22
	TOTAL DELAY	101.5 days

The brief discussion on each of the above delays indicating the source thereof should be examined along with the snap shot schedules presented in Appendices A to F.

A delay of 7 days has been linked to the tardy design completion of the main electrical package, allocated between May 23 and May 30, 1980. The actual award of this contract was delayed considerably beyond that which was planned in the February 1979 schedule, from April 25, 1979 to July 6, 1979 : a slippage of 72 calendar days. When the package was awarded the project had an anticipated delay of 80 days, but by overlapping structural steel and mechanical with electrical work, a major portion of this slippage was recuperated.

Major design revisions to the processing plant floors required the erection of additional structural steel not included in the original bid package. Both design changes, identified as Additional Steel were linked to the fast-track approach.

Due to a design error, also attributed to fast-tracking, the stationary equipment extended into the space occupied by an elevator shaft. Eventually the equipment had to be relocated. After the revised location was determined, the mechanical contractor had to modify the connecting duckwork as required.

The electrical design changes encompass revisions to electrical work as the result of omissions, or modifications to conduit, cable and termination work in the main package. They include revisions, additions or deletions issued to the electrical contractor in seven addenda (0 through 6) and several extra work orders. These addenda were the direct result of an incomplete design of the electrical package. Again for this impact analysis, only the changes which impacted work on the critical path through the processing plant were accounted for.

As a result of the owner's decision, a revised burner system had to be installed which would use natural gas rather than oil as a secondary fuel. Considered to have originated from a lack of information, this late decision inflicted more work on the engineering firm and the supplier of the burner system, resulting in a delay of 22 days in the completion of the related work.

In a second category, the delays indirectly caused by fast-tracking include: trade interferences, work disruptions, and productivity losses. Loss of labour productivity usually reflects the contractor's difficulty to plan adequately because of the numerous drawing revisions and extra work required. From the expert report and the snapshot analysis, individual delays resulting in productivity losses and disruptions have been summarized in Table 4.2:

Table 4.2. Indirect Fast-Track Delays

	Nature of Delay	Days
(8)	Late start of platform	34
(9)	Loss of productivity	52
(10).	Fabrication errors and rework	26
	TOTAL DELAY	112 days

Following completion of the processing plant slipform, the mechanical contractor could not start platform erection as planned because of several schedule problems and trade interferences. Late execution of the slipform construction resulted in noticeable coordination problems. The contractor's scaffolding requirements for clearance where not meet by the concrete contractor when dismantling the slipform structure.

This work was also impeded by pier construction work and the installation of underground conduits which took place in an interfering area. These interference problems prevented the contractor from starting structural steel erection (see Appendix E).

The mechanical contractor then experienced several disruptions in completing the platforms. The extra time required to finish this work was attributed to a loss of productivity resulting from the numerous changes, design revisions and extra work required, for a total delay of 52 days. This type of delay was incurred from extra work that required resourses, primarily manpower and crane usage, which were deferred from critical items of work.

Another 26 days of delays to the completion of the platforms was associated to the structural steel erection. This contractor's work was impacted by several fabrication errors giving rise to rework in the field. Other complications causing delays like late delivery and modifications have been attributed to the fact that designs were not complete or thoroughly checked before they were issued for construction.

In summary, on the project's critical path a total of 213.5 days (7 months) out of the 324 days (10 3/4 months) delay-period can be attributed directly and indirectly to the fast-tracking approach; this represents 66% of the total project delay. Two and 3/4 months were identified as excusable delays (rain, strikes, etc...), owner caused delays and delays due to labour shortage.

Table 4.3 Delay Summary on the Critical Path

Nature of Delay	Days	Months
Initial Delay	26	1
Direct Fast-Track Delay (Design related problems)	101.5	3
Indirect Fast-Track Delay (Productivity loss and interferences)	112	4
Others (incl. Manpower shortage and excusable delays)	84.5	2 3/4
TOTAL PROJECT DELAY	324 days	10 3/4 mths

The total delay of 10 3/4 months (324 days) represents 40% of the planned project duration of 27 months, while those caused by fast-tracking amounts to 26%.

4.2.4 Summary and recommendations

The project study presented here illustrates the type of design coordination problems one can, and usually does, encounter on a fast-track project.

The construction start was delayed mainly by design related problems of: tardy input from vendors, lengthy review and revision periods, and design coordination difficulties resulting in a slippage in award of critical contract packages.

The management decision to recuperate the initial 5 months of vendor delays by accelerating both the design and construction activities, awarding work packages on incomplete design and demanding extensive trade overlaps, gave rise to a totally opposing result: i.e. the project was further delayed. The extensive rescheduling efforts required by project personnel to limit the consequences of this fast-track approach were overridden by the severity of the problems.

Design errors and revisions, slippage of contract award, additional work and rework are all common project delays, but in this case the fast-track approach seriously amplified the impact of those disruptions as evidenced by their frequency and severity. The schedule compression and trade overlaps inflicted a burden on the contractors in terms of available space and restricted time periods to do the work. This in turn, gave rise to significant losses in productivity and poor morale among the workers.

Accelerating a project through fast-tracking is a major decision and the construction professionals often do not realize what they are getting into. On this particular project study, 66% of the total delays were attributed directly and indirectly to fast-tracking. Spending only a couple more months on the detailing of design packages before awarding contracts, as can be seen in Figures 4.4 to 4.6, would have eliminated a major portion of the fast-track related delays (a maximum of 7 months in this case). Ideally, there would be much less design errors and omissions. Without the revisions and extra work and subsequent acceleration, the productivity loss could have been practically eliminated since the contractors would have had the necessary information for proper performance. Trade interferences would have also been reduced to a level of normal working conditions.

The following project studies will be examined from a construction stand point. The construction difficulties on fast-track projects are identified through the investigation of the work done by different contractors and the level of production they have achieved. It is understood that problems or complications in the design procedures and coordination will have their impact during the construction period.

4.3 PROJECT STUDY II

This project study relates to the electrical and mechanical works of an office building in the Province of Quebec. The project consists of 9 inter-connected office towers varying in height from 6 to 21 floors above grade and 2 floors below grade. The total floor area is approximately 2,500,000 square feet.

Although the project was not originally envisaged to be fast-track, the owner's decision to award electrical and mechanical packages with incomplete design reflects their intention to perform design in parallel with construction. The contractors were told the project would be managed through the construction management technique. The owner knew at tender call that the design was not yet complete to allow a lump sum firm price. Dispite this fact, several contract packages were called for tender.

The owner, a government agency, hired a construction management firm for the overall administration and supervision of the project, the design being done by a separate architect firm. Three contracts on this job, representative of the fast-track conditions, have been selected for investigation in the present study. Over 1600 change notices were issued to the various contractors working on this project, indicating the high degree of design complications encountered throughout the job. The impact of fast-tracking construction on the productivity and schedule of these selected contracts, are demonstrated in this section.

On the first contract, refered to later as Contract 1 - main mechanical package, the owner has called tenders for the supply and installation of heating, ventilation, and air conditioning. This mechanical work has been awarded on May 20th 1975 for the amount of $4,900,000 with a contractual duration of 66 calendar weeks. The contract was delayed by over a year (54 weeks), representing 81% of the planned duration.

The main electrical system package (Contract 2) has been called for tender and awarded at the same time as the main mechanical package (Contract 1). Subsequently the owner has called tender for the construction of an electrical sub-system and the fire protection (Contract 3). Both electrical contracts have been awarded to the same contractor for the amounts of $ 7,100,000 and $ 1,400,000 respectively.

The main electrical contract was going to be performed in 66 weeks, but it required double that amount of time to execute the work. This represents a delay of 66 weeks or 100% of the planned duration. Contract 3, the electrical and fire protection work, went from a contractual duration of 44 weeks to an actual duration of 73 weeks, representing a 29 weeks delay or 66% of the expected duration.

Being performed in the same time frame, these three contracts have been subjected to similar project conditions. Common difficulties are illustrated and discussed in the following sub-sections with specific examples drawn from the individual cases. The main electrical and mechanical contracts depended basically on the same packages for the start and completion of their work.

4.3.1. Incomplete design and numerous contemplated change notices

The contractor's progress was seriously hampered in placing orders for material, laying out the work and letting sub-contracts solely due to lack of drawings and specifications. With regard to shop drawings, details were inadequatly engineered and not clearly described in the specifications and on the drawings. Numerous shop drawing approvals were delayed for excessively long periods of 4 to 16 weeks. This delay is attributed to the fact that the design of the building was incomplete at the beginning of the work and subsequently caused design back-logs. In several cases the changes made by the owner and delay in approval of shop drawings delayed equipment purchase, which in turn delayed the final installation.

Several contemplated change notices (CCN's) were issued by the owner. The HVAC mechanical contract alone received 195 CCN's representing 8 percent increase of the contract value. Altough cost impacts were minimal, scheduling of the work has been affected severely by the numerous changes. The issuance of a CCN generally requires that if work affected is in progress, the work must stop until a change order is issued or until cancellation of the CCN. Similarly, the main electrical contract received 250 CCN's representing a 21 percent increase in the contract value, representing over $ 1,500,000 in changes.

The "start-stop" type operation resulting from the numerous changes was a substantial factor in the contractor's productivity losses. The as-built schedule showed a series of small durations for the same activity instead of a continuous progress line (not shown here for confidentiality reasons). On several occasions, the owner was placing large areas of the building on "HOLD" simply because no design had been done. The releasing of areas of work for construction long after the contract was awarded prevented the contractor from working on an effective schedule.

Following a slow start in construction, both the mechanical and electrical main contracts have been accelerated to cope with the delays incured. A new schedule issued on March 29th 1976 (46 weeks after contract award) called for acceleration over the next 20 weeks in order to correct the situation and reach the contractual completion date of August 25, 1976. This straightening up in progress curve is most evident on the mechanical contract (Fig. 4.7).

Forcing the contractor to make-up for lost time, the acceleration resulted in an additional productivity loss from the overmanning of the work and the use of overtime. During acceleration, on Contract 1, the optimum labor force rose from an average of 45 to 90 thinsmiths, helpers and foremen, combined with an average rate of 8.1% overtime. On Contract 2, the labor force grew from an average of 50 to 100 electricians, helpers and foreman on-site. Again this was combined with a 17.8 % overtime.

4.3.2 Inadequate scheduling and coordination

For a project of this size with a comtemplated duration of over 1 year for the main contracts, a detailed comprehensive scheduling and monitoring system would seem to be essential for a successful performance by all contractors. Unfortunately, at the outset of the project the scheduling system never evolved beyond the basic "Project Summary Schedule" level, which became the project schedule from July 1975 until

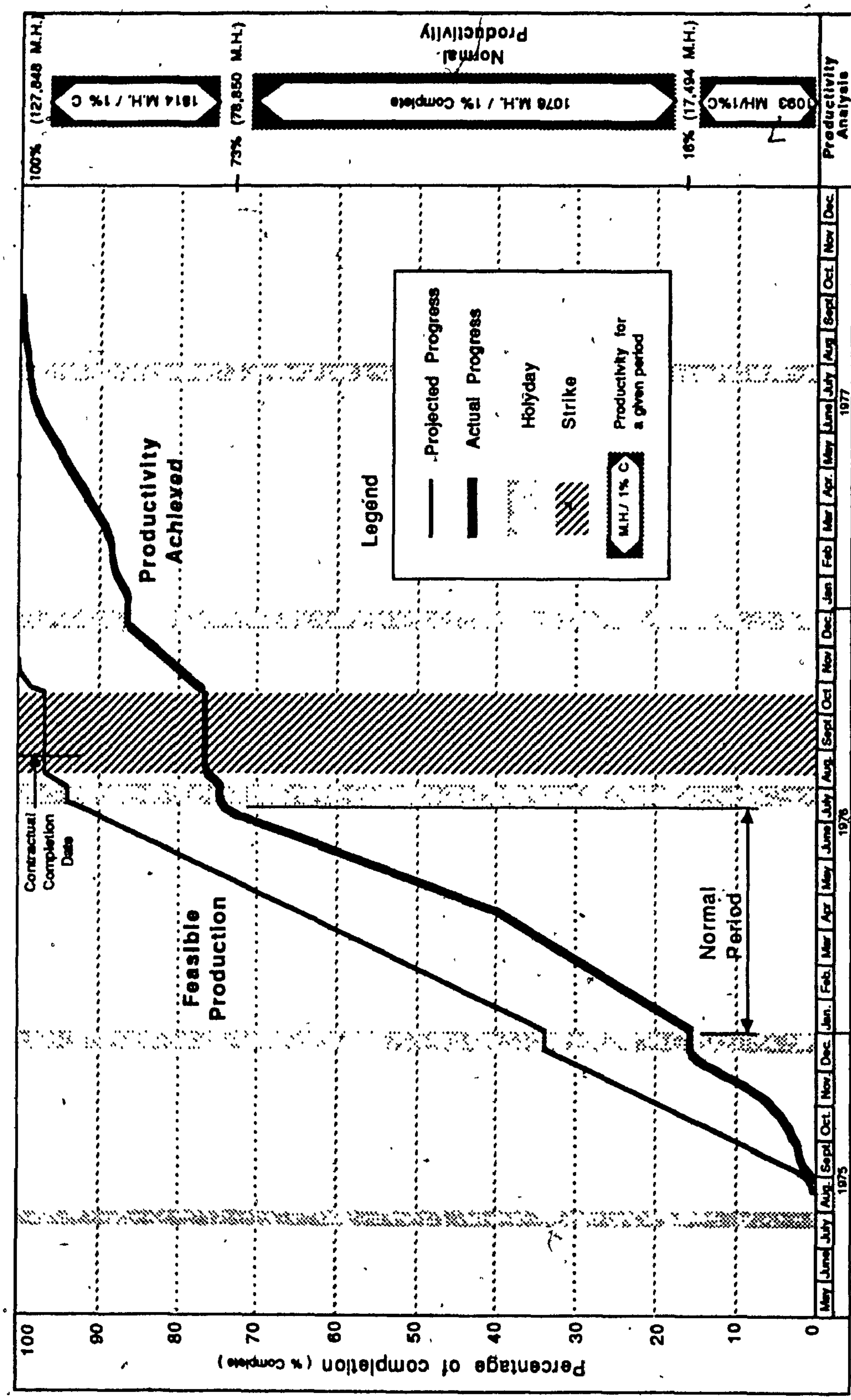


Fig. 4.7 Productivity analysis — Contract 1 HVAC Mechanical

the end of March 1976. At the time this original schedule was prepared, major contracts were still being let (e.g. architectural sub-trade packages) and therefore it was impossible to establish the data required for the schedule critical path(s).

The contractor worked with this type of schedule until the end of March 1976. Masonry, drywalls and ceiling installation works were not included in the schedule and the above sub-trades worked in an unplanned sequence. Block partitions requiring electrical and mechanical input were being erected at random without any coordination between contractors. Lighting fixtures were installed on partially supported ceiling structures. Drywalls, once awarded, were not being erected where required for lateral support of the ceiling structure. Without the necessary schedule, the situation became utterly chaotic. Job delays were cumulating in parallel with the growing number of change orders necessary to correct the situation. On March 29 th 1976, a detailed control schedule was produced by the owner and issued to the main contractors. This schedule required that all previous time lost due to coordination problems and other schedule disruptions be made up in the 5 months to follow, to ensure on time completion of the project.

No detailed schedule was issued for the electrical Contract 3. But to some extent, allowances were made for the confusion existing on site. Proportionally, the loss of productivity in Contract 3 is less significant due to the prior knowledge which the owner gained from administrating the previous electrical contract (Contract 2).

4.3.3. Late award of other contracts

The project schedule provided for both Contracts 1 and 2 clearly indicated the various tender award dates and start dates of other work packages on the project. These dates were not maintained. As a result, major portions of the work packages have been compressed at the later part of the schedule. In order to maintain the project completion date, several activities were accelerated.

The absence of a detailed schedule has greatly impaired the progress of this entire project by failing to monitor and coordinate all trades. The incomplete design not only gave rise to an unreasonably high number of changes, but at the same time prevented the owner from calling tenders in a timely manner for other work packages.

In May 1975, when the main contracts (Contract 1 and 2) were awarded, many other major contracts essential for the completion of the electrical and mechanical packages were not yet awarded. Two of these essential contracts were the drywall partitions contract, and the acoustic ceilings contract and associated T-bar system. Work started on these contracts three to four months behind schedule, as shown in Figure 4.8. The late award and start of the drywall partition made it virtually impossible to install mechanical units and lighting fixtures on the ceiling T-bar system as the partitions were necessary for lateral support of the ceiling.

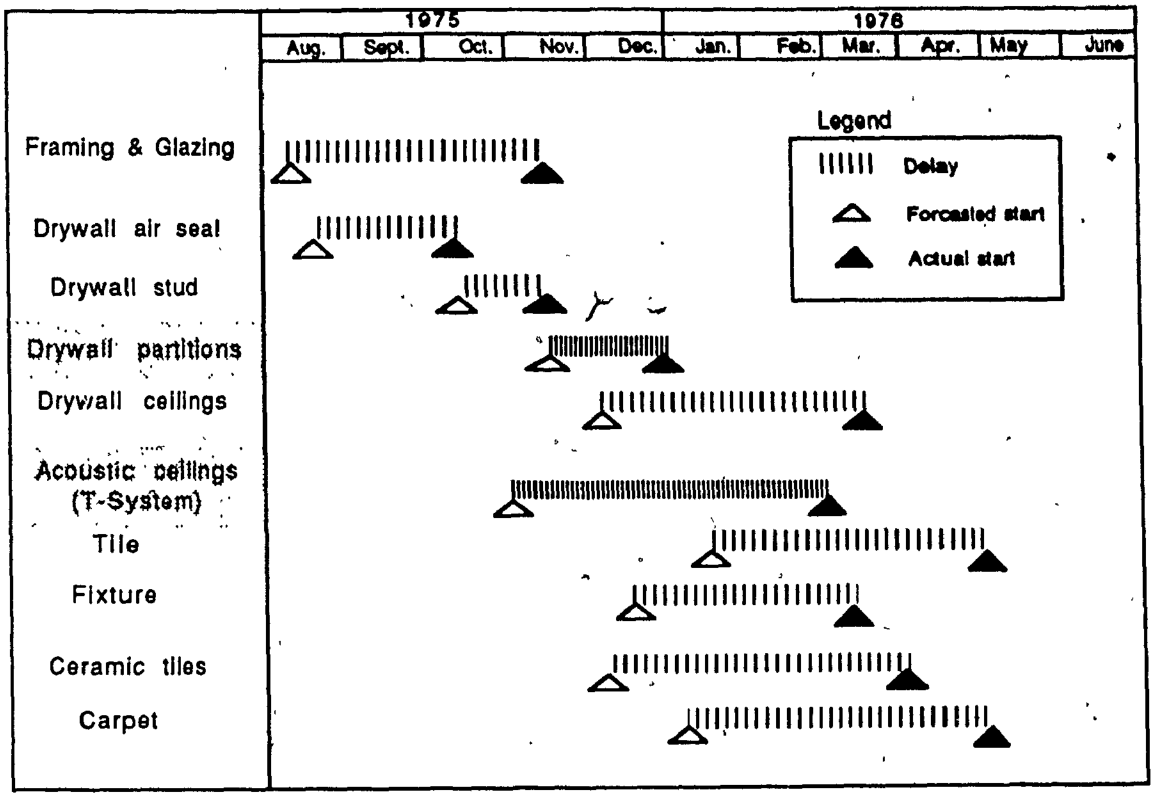


Fig. 4.8 Forcasted vs. Actual start of other contractors

4.3.4. Fast-track impact on productivity

As a result of the above mentioned problems, the project was carried out in a start-stop fashion: Typically an activity would start late but rather than continue on a steady basis, the work would be executed sporadically over a much longer period of time; up to 4 times the scheduled duration period. This productivity loss occured principally after a 2 months construction worker's strike on all three contracts.

The initial productivity loss can be observed in the first few months of Contracts 1 and 2 (Figures 4.7 and 4.9 respectively). In this

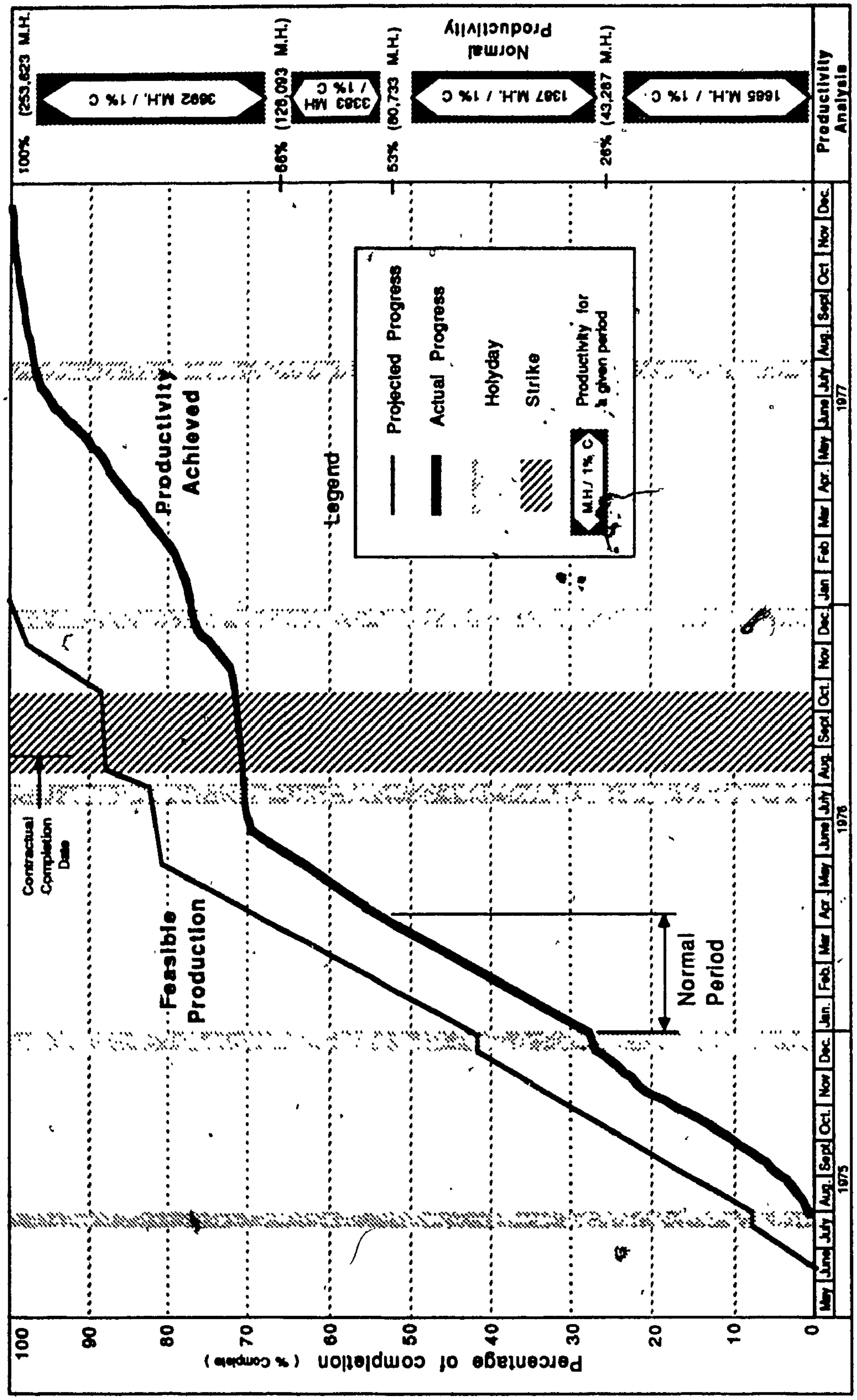


Fig. 4.9 Productivity analysis — Contract 2 Main Electrical

period the lenghthy approval of shop drawing combined with the numerous CCN's and the lack of a detailed schedule contributed to the slow start of those contracts. Moreover, the productivity level at the end of both electrical and mechanical contracts have been largely affected by a lack of coordination between the trades, combined with the start-stop situation.

To evaluate the fast-tracking impact on this project, the normal productivity method was favored over the snap shot method in view of the available information. The remainder of this section elaborates on the procedures required to evaluate the additional costs of productivity losses attributed to fast-tracking.

For the mechanical contract, the actual recorded man-hour expenditure to a 100 % completion (Sept. 11th 1977) was 127,848 man-hours (excluding 14,625 man-hours of extra work). The progress achieved by the contractor on a weekly basis and the man-hour expanded to achieve this progress are shown in Fig. 4.7. In evaluating the fast-tracking impact on the contractor's productivity, a period of least interference must be established. As referred to in the methodology chapter, this period would identify the achievable progress the contractor was able to attain on this specific project. Between Jan. 1st 1976 and July 16th 1976, 57 % of the project was completed in 42 % of the time allowed. In this 28 week period, the contractor achieved a productivity of 1076 man-hours per 1 % completion (Fig. 4.7). This normal progress corresponds to a time where the contractor was least affected by disruptions. It is interesting to note that even in periods of normal productivity, the contractor was quoting on an average of 9 CCN's in any week and the owner was holding for approval an average of 8.

Based on this normal productivity of 1076 man-hours per 1 % completion, the linear projection to 100 % gives 107,600 man-hours. According to industry standards, allowing a three weeks start-up and four weeks completion at a reduced productivity (1614 man-hours per 1 %) to reflect the real conditions (equivalent to 5,000 man-hours extra), the project could have been completed with a man-hour expenditure of 112,600 man-hours. The actual recorded man-hour expenditure to 100 % completion (Sept. 11th 1977) was 127,848 man-hours. Therefore, the additional man-hour expenditure as a result of loss productivity is 15,248 (127,848 - 112,600). Combining this figure with the average hourly labour cost of $14.20/hr for this project, the additional cost of the loss productivity amount to $216,300.

To evaluate the time impact this productivity loss represents, the manpower level during the least affected period is kept constant (See Chapter III). From this assumption, the achieved rate of production has been projected from contract award to 100 % completion, allowing a three weeks start-up and four weeks completion at a slower rate to reflect the real conditions. Making due allowance for the strike, completion could have been achieved on Nov. 1st 1976 (Fig. 4.7).

The achieved rate of production accounts for any contractor's inefficiency including that incured during the acceleration period. Therefore, from the contractual completion date, Aug. 25th 1976, to the achievable completion date, Nov. 1st 1976, nine weeks have been allocated for the strike, labour slow down and contractor's inefficiency. The remainder 45 weeks (extended duration from Nov. 1st 1976 to Aug. 31st 1977), represent delays attributed to the management technique adopted by the owner on this project which were beyond the control of the contractor. On this basis, it took 68.2 % (45 wks/66 wks) more time to complete the project using the fast-track approach than it would have normally taken without disruptions and productivity loss.

Indirect costs associated with the extended duration were calculated as described in Chapter III, taking into consideration the amounts already paid for through change orders, not including overhead and profit. From the productivity loss in man-hours and the extended duration attributed to fast-tracking, impact cost can be evaluated:

Additional cost due to productivity loss (Direct labour costs)	$ 216,300
Additional cost due to extended duration (Indirect costs)	$ 105,800
Sub-total	$ 322,100

This represents a 7 % (($ 322,100 / 4,900,000) X 100) increase in contract value.

Incomplete design at the beginning of the main electrical contract (Contract 2 - Fig. 4.9) considerably impeded the work progress in comparison to the available contract time. Both the mechanical and main electrical work packages were executed at the same time, sharing basically the same period of the least affected productivity. For the main electrical work, the contractor demonstrated that a productivity factor of 1,387 man-hours per 1% completion could be achieved when owner's interferences were minimal. In this normal period of 16 weeks, 27% of the work was performed.

After April 1976 the contractor was directed to accelerate the work. The increased work force resulted in a loss of productivity due to overmanning and extended working hours. Combined with a labour slowdown, the production dropped to only 13 % of the work complet in a 12 week period.

Productivity was seriously affected by numerous changes in a start-stop environment. Even in a period of normal productivity between Jan. 1st 1976 and April 24th 1976, the contractor was quoting on an average 19 CCN's in any week and the owner was holding for approval an average of 25.

Based on the achieved normal production, and accounting for the low productivity at the beginning and at the end of the job, the main electrical work could have been completed with an expenditure of 143,700 man-hours (138,700 + 5,000) bearing serious interferences. The actual recorded man-hour expenditure to 100 % completion (Dec. 3rd 1977) was 253,623 man-hours.

The fast-tracking impact on productivity resulted in an additional man-hour expenditure of 109,923 (253,623 - 143,700). Multiplying this figure with the average hourly labour cost of $9.37/hr for this contract yields $1,029,800 of additional cost due to productivity loss.

To determine how this productivity loss impacted the schedule, an extended duration calculation was performed, as described previously for Contract 1. A linear projection of the acheived production on Contract 2 indicated completion could have been achieved on Jan. 7 1977. Hence, the period from Jan. 7th 1977 to Dec. 3rd 1977, has been viewed as an extended duration period, resulting from causes beyond the control of the contractor. Therefore, 47 weeks delay out of a total of 66 weeks delay can be attributed to the owner and the fast-tracking technique. For the purpose of this analysis, the owner's administration procedures and the fast-tracking technique used on this project were not distinguished even though they could include distinct characteristics.

For a contract duration of 66 weeks, it took 71.2 % ((47 weeks/ 66 weeks) X 100) more time to complete the project using the fast-track approach than it should have normally taken. From the extended duration generated above the indirect cost is calculated.

Additional cost due to productivity loss (Direct labour costs)	$ 1,029,800
Additional cost due to extended duration (Indirect costs)	$ 164,000
Sub-total	$ 1,193,800

The direct and indirect costs represents a 17 % (($ 1,193,800 / $ 7,100,000) X 100) increase in contract value.

The same principles were used to establish the fast-track impact on the productivity for Contract 3, the electrical and fire protection contract. Similar calculations for this work, revealed an additional man-hour expenditure of 6,262 man-hours, resulting from a productivity loss (Fig. 4.10). The additionnal cost due to this productivity loss has been evaluated as $ 71,600.

It should be noted that for this contract, there is no extended duration, therefore no extra indirect costs. The cost of productivity loss alone represents a 5 % increase in the contract value. Because this

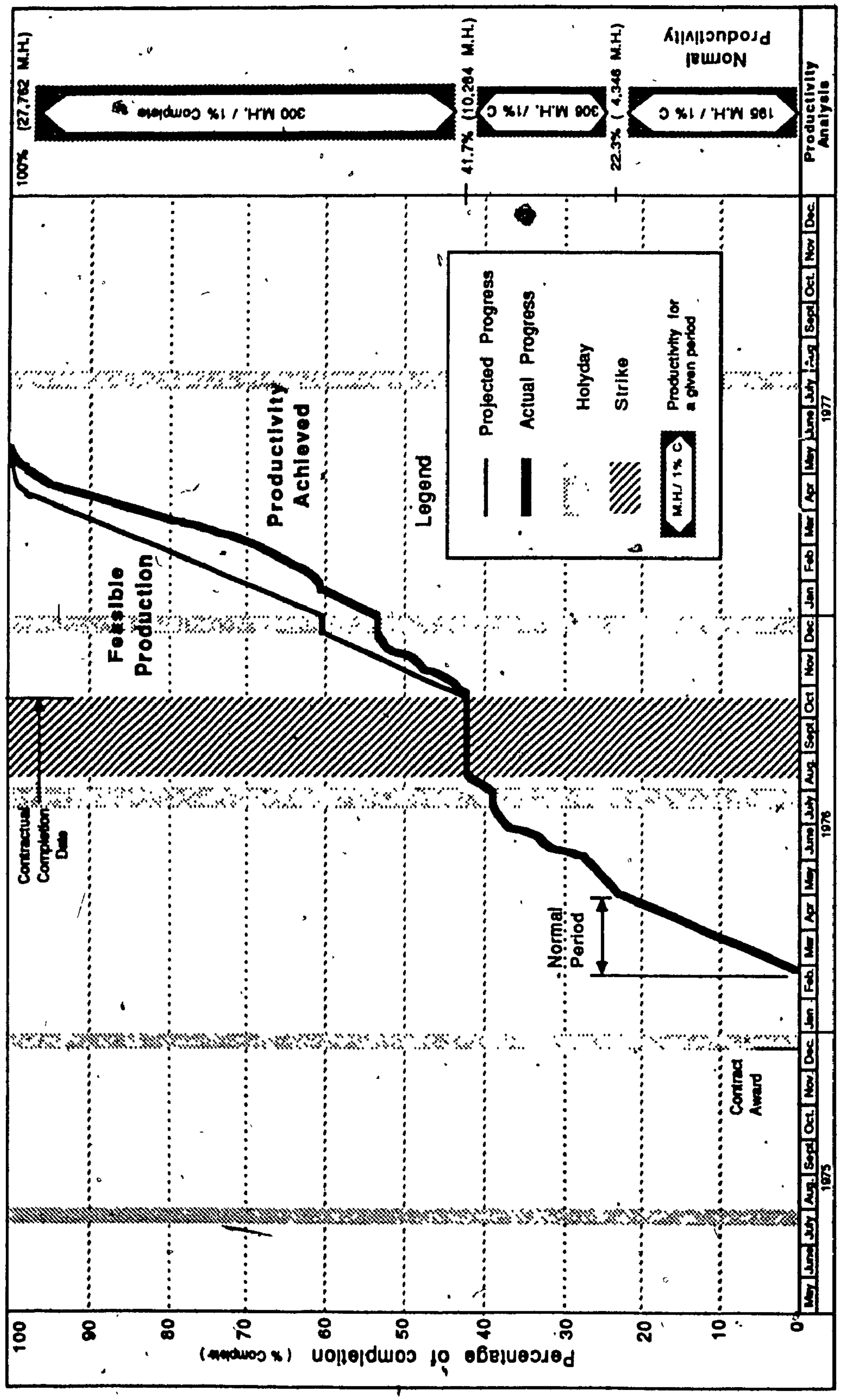


Fig. 4.10 Productivity analysis — Contract 3
Electrical & Fire Protection

contract was awarded several months after the other two contracts examined herein, the owner was more aware of his own administrative difficulties. Consequently the electrical and fire protection package did not suffer from major fast-tracking delays. The owners' efficiency in applying fast-track technique can affect considerably the fast-track indirect costs and is therefore an additional factor in the fast-tracking impact.

Table 4.4 summarizes the impact costs of all three contract packages examined on this project.

Table 4.4 Fast-tracking impact summary - PROJECT II

Type of Work	Overall project					Fast-tracking impacts					
				Delays		Extra costs				Delays	
	Contract Amount	Contractual Duration Wks	Actual Duration Wks	Total Delay Wks.	Percent of Contract Duration %	Loss productivity (Direct labour Cost)	Extended Duration (Indirect Cost)	Total extra Costs	Percent of Contract Value %	Fast-track Delay Wks.	Percent of Contract Duration %
Mechanical	$ 4,890,000	66	120	54	81%	$ 216,300	$ 105.800	322,100	7%	45	68%
Main Electrical	7,100,000	66	132	66	100%	1,029,800	164,000	1,193,800	17%	47	71%
Electrical & Fire	1,400,000	44	73	29	66%	71,600	–	71,600	5%	–	–
Total of 3 contracts	$ 13,390,000					$ 1,317,700	$ 269,800	$ 1,587,500	12%		

4.3.5 Summary and Recommendations

The large number of changes resulting from an incomplete design seriously delayed completion of this project. Late approval of shop drawings for electrical and mechanical equipment, lack of coordination between the ceiling design and various electrical and mechanical systems, and the large amount of redesign and remeasuring required for mechanical equipment impacted considerably the electrical and mechanical installations. Compression of work and delays resulting from the late shop drawing approvals also contributed to the loss of productivity experienced by the contractors.

Large areas of the project were put on "HOLD" throughout the early stages of the work, reducing the areas available to the contractors. The "HOLD" and change notices stopped work at the areas affected. Both required a demobilization and remobilization activities resulting not only in delayed duration but in a loss of productivity.

The inadequate coordination of the trades on a construction level holds its roots in the sporatic manner in which the drawings were issued. The owner did not award, and could not award, other major contracts which were essential to completion of the electrical and mechanical works until, in some cases, four months after the scheduled dates. The late starts of these contracts interfered significantly with the main electrical systems, fire protection, heating, ventilation and air conditioning works.

Without the necessary information, it was practically impossible to properly schedule and monitor the work to be executed. Many finishing sub-trades did not have a schedule and were performing work in an unplanned sequence, which obviously affected the work of other contracts.

Several factors played an important role in the acheived productivity of the contractors on this project:

A) Initial problems:

- Inadequate and incomplete design
- Holds placed on various areas
- Slow approval and receipt of shop drawings
- Late issuance of drawings
- Late delivery of pretender equipment

B) Subsequent problems:

- Inadequate coordination of the trades
- Inadequate scheduling and monitoring
- Owner's efficiency in applying the technique

C) Productivity loss:

- Out of sequence work
- Stop and go operations
- Interference with other trades
- Acceleration ; Overmanning, overtime.

The main problem on this project was that the design progress was not sufficiently advanced and that the planning and coordination prior to the award of contracts for construction were inadequate.

In particular, the coordination of the design activities should have been supervised more carefully to insure a timely award of construction packages without any premature calls for tender. The design should have been sufficiently complete to allow a realistic lump sum price based on a true representation of the scope of work.

4.4 PROJECT STUDY III

In this study the construction of a residential building in Ontario is examined. The project consists of 4 buildings connected together in a radial arrangement. The concrete structure construction goes up to 8 floors with each level divided in 16 unit bays symetrical between the east and west sides as illustrated in Figure 4.12..

The owner, a crown corporation, made it clear both in the specific terms of the tender documents and during the pre-tender site visit, that the project is to be constructed using the fast-track method. The project was divided into several self-contained contract packages to be awarded in a pre-determined sequence depending on the completeness of the design and the preceding construction activity.

Monitoring of the design progress and associated construction activities and the timing of tender calls of different contracts were under the control of an independant construction management firm within a project organization structure similar to that shown in Figure 1.3. The owner appointed a construction manager (CM) to organize the work, administer contracts and to direct the work of all contractors on this project. A separate consultant (A/E) has been retained by the owner to develop the design documents required for the fast-track construction of the project.

Extracts from the contract documents do provide a guideline of the project engineer's duty and expected performance of the contractor. For example, the engineer was responsible for establishing a system of control based upon "precedence type" critical path network analysis. This also included monitoring and control procedures for cost .

The contractors were asked to cooperate amongst themselves in the carrying out of their duties and obligations. In this respect, the special conditions of construction contracts calls for the coordination during the execution of the work with other contractors to the satisfaction of the engineer. The owner, on his part, must provide the site and technical information required by each contractor for the orderly carrying out of their respective contracts.

The project turned out to be entirely different both in the complexity and scope than any contractor had originally anticipated based on the tender documents and the site visit.

Five contracts that were considerably impacted by the fast-tracking approach are examined in detail in the following sections. The difficulties encountered by each contractor are identified and their impact on the contract schedule and overall costs is evaluated. The first three contracts awarded were foundation works, masonry and superstructure. With extensive interrelations and overlapping work, the study of these contracts illustrates the importance of work packaging and the interferences created between closely related types of work. The fourth contract includes the supply and installation of aluminium windows, doors and metal wall panels which depended on the concrete and masonry work. Finally the drywall contract study illustrates the snow-balling effect of the fast-track approach on the progress of these finishing trades.

4.4.1 Foundation and structural package (I)

The work on this package consists of the majority of foundation work and some structural work up to the third floor level including some excavation, backfill, concrete footings, slabs and walls, miscellaneous metals, structural steel suspended ceilling system and masonry work. This foundation and structural package, refered to hereafter as "Package I", was awarded on November 9, 1979 for $1,310,000. The contract was scheduled for a 26 weeks duration. Its has actually taken 66 weeks to achieve substantial completion, representing a total delay of 34 weeks or 133% of the planned duration.

Although examined separately, this package should be viewed in parallel with the masonry and superstructure package, refered to as "Package II". The interdependance and work overlap between those two contracts are examined closely in section 4.4.2.

This package was under a lot of pressure to be awarded as fast as possible because succeeding packages, with sufficient drawings, were already awarded (i.e. Package II). Consequently as soon as enough design and layout drawings (to put together the foundation package) were produced, the package was awarded for construction.

In tendering this lump-sum job, the contractor has assumed an orderly flow of work for good productivity and an efficient performance. When starting the work, the contractor also assumed all relevant information needed to execute the work were available to him to complete the contract in accordance with the dates set forth in the specifications.

Omissions and neglected details on the drawings were found by the contractor when verifying dimensions, prior to the laying out of the walls. Dimensions applicable to both structural and architectural drawings, and dimensions from drawings of different floors did not correspond. The contractor continuously had to request clarification of dimensions to be used for the layout of walls.

Due to these dimensional discrepencies, the contractor was not able to layout and build the foundations and walls in an orderly fashion and had to skip around to different areas, causing delays and giving rise to important productivity losses. In fact, he was forced to continuous series of "stop and go" operations.

The total number of dimensional changes and/or clarifications that were indicated up to the issuance of the approved for construction drawings in April 1977 was in excess of 1000 for this contract only. In addition, drawings approved for construction after this date contained more than 300 dimensional revisions.

Specifically, there were 188 architectural detail drawings issued with the tender and addenda, of which 163 were revised (87 %) in the volume issued in April 1977, with approximatly 287 revisions. Moreover, approximatly 207 new architectural detail drawings were issued and later included 62 revisions.

The delays due to dimensional discrepencies and clarifications has forced the contractor to execute various foundation work on the structure under adverse conditions. The excavation and backfill work of the underground services were delayed because of change orders. The mechanical work required prior to the backfilling was not executed on time, substantially delaying the contractor and increasing excavation and backfill costs.

The proposed construction schedule submitted by the contractor on November 30, 1976 emphasises the importance of a timely issue of structural steel drawings which were identified to be critical to meet the schedule. The shop drawings turn around period has been confirmed by the construction manager not to exceed 3 weeks. The structural steel sub-contractor advised the construction manager that, considering the many discrepencies already evident on the contract drawings, no fabrication would start until shop drawings have been approved.

The turn-around period for review of some critical shop drawings required between 5 and 7.6 weeks, as opposed to the planned 3 week period. If the contractor had waited for the as-built conditions of the structural walls before designing and fabricating the structural steel, this work would have been delayed by over 6 weeks. Trying to keep a steady rate of progress,the contractor went ahead with fabrication and erection of the structural steel, despite the long period required to receive the clarification or technical information needed. As a result of this tardy reaction on the part of the owner, the structural steel had to be re-fabricated on site, causing additional work and further delays.

Following foundation work and structural steel erection, partition walls were going to be erected. This activity could not proceed immediately, awaiting slabs on grade to be poured by other contractors. In another instance the contractor could not start the brickwork because door frames were not available. He was then instructed to proceed with the brickwork and to tooth out for the door frames which would be installed at a later date.

So even though the contractor was ready to start his work, several interferences restrained him from doing so; door frames, dimensional discrepencies, holds and restrictions, work by others, etc.

Dimensional discrepencies were an on going problem that was never fully resolved to permit the contractor to proceed with the work in an orderly and efficient manner. Dimensional problems translated into holds and restrictions, slowing down the work progress and causing important productivity losses.

To determine the impact fast-tracking construction has on this contract, the normal productivity method is utilized. In evaluating the additional manhours expended by the contractor, actual manhours expended are compared with the manhours that could have been spent to finish the work if the contractor had not been hampered by the fast-track approach. To determine this projected manhours expenditure, a period of least interferences must be identified. Based on the manhours required to complete 1% of the work for this period of satisfactory performance by the contractor, the manhours that should have been expended on the whole work can be calculated. As explained in Chapter III, the impact cost of this productivity loss is evaluated using an average hourly rate for this type of work. The loss productivity calculation shown in Table 4.5 divides the work on this package into 1) excavation, formwork and concrete, and 2) masonry work.

Table 4.5 Loss Productivity Calculation - Package I

Package I	CONTRACT MHrs	Extra Work & C.O. MHrs	% *	ACTUAL MHrs (1)	Projected MHrs Expenditure (2)	Avg. Hourly Rate (3) **	PRODUCTIVITY LOSS ((1)-(2)) X (3)
Excavation Formwork & Concrete	20,808	5,808	28	37,707	23,638	$11.45	$161,100
Masonry	8,971	3,166	35	14,317	11,195	$12.00	$ 32,500
Total	29,779	8,974	30	42,023	34,833	$12.00	$193,600

* Percent of contract hours

** Taken from claim reports

The contractor has incurred additional costs in the performance of the work as a result of unforeseen delays rooted in the fast-track approach. The work was not completed until December 30, 1977, representing a total delay of 34 weeks.

In an attempt to determine the delays attributed to fast-tracking, the normal productivity of the contractor is projected to 100% completion (see Fig. 4.11). The result of this exercise indicates an extended duration of 21 weeks, from August to December 1977.

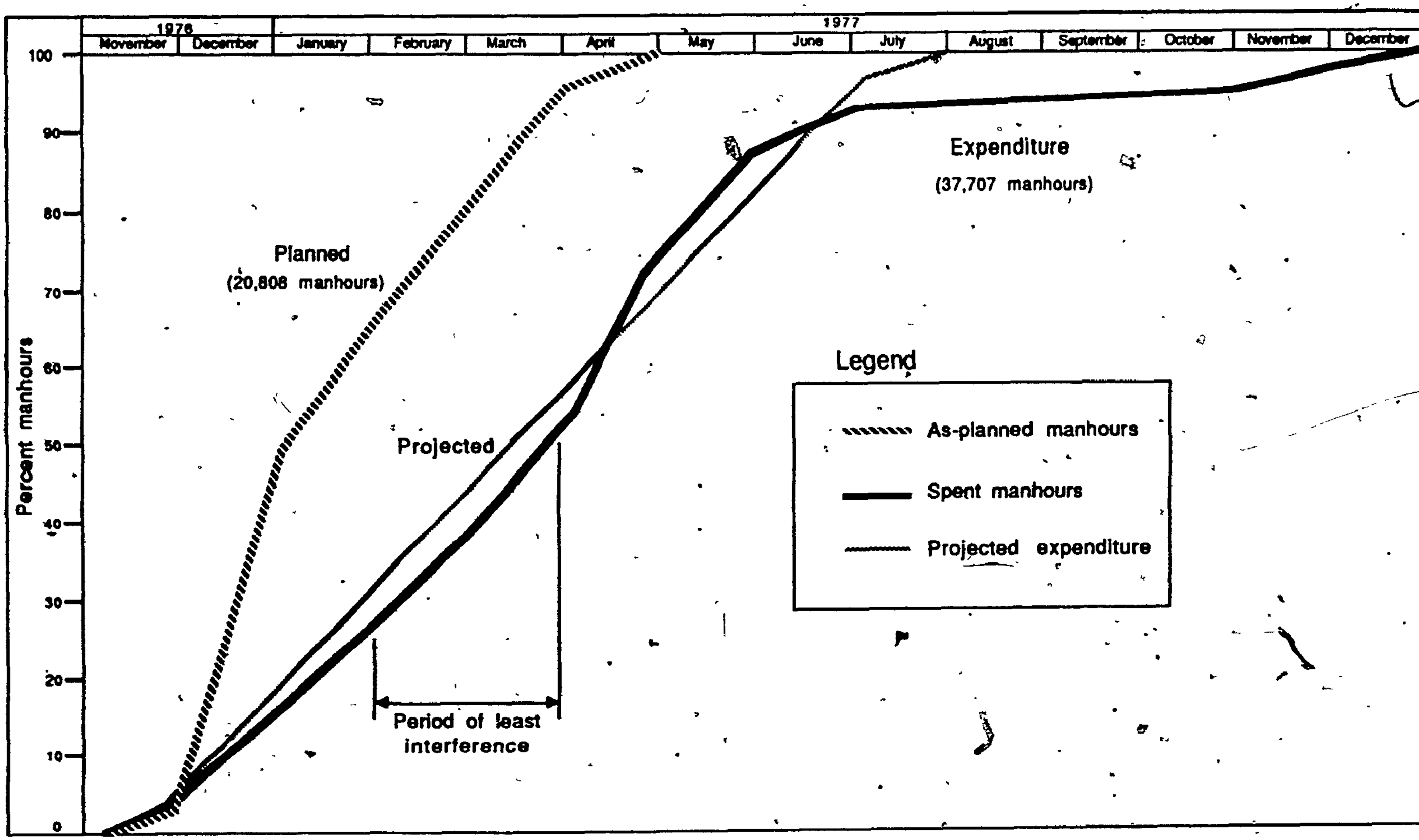


Fig. 4.11 As-planned vs. As-spent (Cumulative manhours)
Package I

The costs of site personnel and equipment, extracted from project documents, were multiplied by the extended duration period to result in the following extended duration additional costs.

EXTENDED DURATION

Site supervision cost	$ 21,645
Site service cost	$ 8,592
Equipment cost	$ 44,993
Sub-Total	$ 75,230

The total additional costs caused directly and indirectly by the fast-tracking approach are then:

Due to productivity loss	$ 193,600
Due to extended duration	$ 75,230
TOTAL	$ 268,730 *

* (22 % of contract value)

Note that these figures and previous ones do not include the office overhead and profit for the extended duration, which could be added to this impact cost. The total amount is in 1976 dollar value and no interest factor has been included.

This increase of 22 % over the original contract price represents the unadjusted impact cost of a fast-track program that didn't perform as expected. Moreover, the initially short schedule suffered a delay of a minimum of 21 weeks attributed to the incomplete design and lack of coordination on the job. Because of complications solely due to fast-tracking, 85 % more time was spent to substantially complete the contract. This situation stands out to be in direct opposition to the benefits originally anticipated.

4.4.2 Masonry and structural package (II)

The masonry and super-structural work, hereafter refered to as "Package II", essentially consists of the supply and erection of most masonry work and concrete slabs required for the 4 residencial buildings. The package however, excluded all the building foundations and slab on grade which were part of "Package I".

The work in Package II was further broken down into succeeding starting dates spread out over the four residences construction. On June 1976, bid closing of the masonry and structural package determined the successfull bid to be in the amount of $ 2,000,000. Shorlty thereafter, but before the award of the contract, the representatives of the engineer and the selected contractor met to discuss the tenderers' queries and to review the bid for possible savings and schedule acceleration. It had been agreed that construction schedule could be shortened and overall cost reduced by adopting a new floor system design and incorporating part of the foundation work of Residence 4 in this contract. This type of arrangement provided Package II with more independance; being less affected by the performance of required preceeding work included in other packages, like the foundation and structural Package I.

Ironically at the time when tenders for Package II were called, the design work on Package I was not complete. Package II was issued regardless of the field conditions, assuming there was enough time to complete the design of related work in Package I, while the work on another part of this contract progressed.

On July 8th 1976, Package II was awarded for the original sum and included the construction of the foundation of Residence 4 by way of a change order in the amount of $ 91,000. The work was scheduled for a duration of 56 weeks, but was delayed by 13 weeks or 23% of the planned duration.

The biggest single problem on this contract resulted from the interferences created by Package I. As described in the previous section, this package includes the work for most of the foundations, slab on grade, some masonry, and slabs up to the 3rd floor of Residences 1 and 4. Half of the work in Residence 4, to be executed by Package II, was dependent on this preceding work (see Fig. 4.12).

Foundation and structural work in Residence 4 was critical to the project completion but yet Package I was issued several months later than anticipated. Even though design and layout drawings were not ready on time to put together the main foundation package I, the structural package II was awarded. The rational behind this procedure is examined below and the impact of this fast-track approach is discussed in the next section.

A couple of months after the award of Package II (as oppose to the planned 4 weeks), Package I was called for tender and awarded for construction in November 1976. The same contractor was awarded this foundation package in hope to facilitate co-ordination between the two

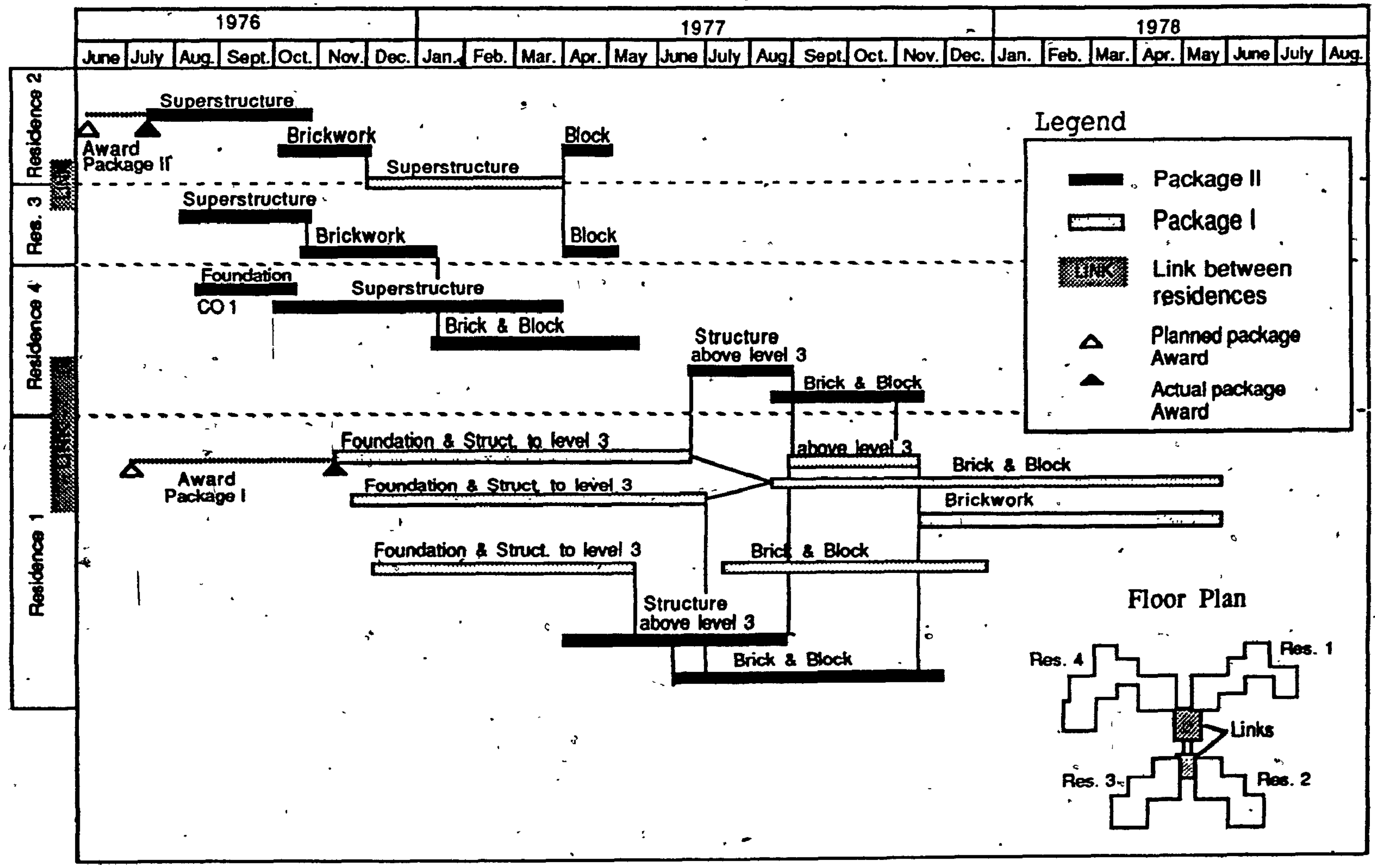


Fig. 4.12 As-built Schedules for Package I and II

packages and avoid interferences. Despite the fact that both contracts ended up being executed by the same contractor, the work on Package II could not proceed at its normal pace because of delays associated with Package I.

The as-built schedule has been reconstructed (Fig. 4.12) in order to better understanding of the complex interrelationship between Packages I and II. On this schedule, several dependences or logical connections between activities have been identified. The 12 most important interdependancies between these two packages have been examined carefully (Vertical connection on Fig. 4.12). Seventy five percent of the time (9/12), activities in Package II depended on the work completion of Package I's activities. This sequential dependancy considerably impacted the schedule of Package II especially for Residences 1 and 4.

With a fast-tracking approach philosophy, the owner and construction manager wanted to start construction of the superstructure as fast as possible. Realizing the important dependence of Package II on the foundation work to be performed in Package I for Building 1 and 4, the owner attempted to ease this constraint by incorporating part of the foundation work of Residence 4 into the contract Package II, and rescheduling the superstructure work for this building two months ahead. By rearranging the work at this stage, the owner released the sequential dependance constraints between those two construction packages and induced considerable overlapping.

The last minute decision (for optimum savings) to change the floor system required that drawings be approved as submitted. Unfortunately, the alternate design generated difficulties in adapting it to the overall concept and paused problems of unfamiliarity to the design consultant. Shop drawing approval regarding the floor system lead to continuous discussion and disagreement between the design consultant and contractor, which was further complicated by problems of dimensional discrepencies. The new design decision is not related to the fast-track approach, although it was chosen on the basis of considerable saving in time.

The contractor's extra effort in continuously requesting classification of dimensions and the unusually long period of time taken by the crown to correct those errors are attributed mainly to the fast-track environment instigated by the owner.

With the exception of the progress payment reports indicating scheduled completion dates, the first schedule issued was on June 8th 1977, or one full year after contract award. No detailed schedule were or could have been issued before, seemingly because of the unique way work packages were prepared and awarded under this fast-track approach. In other words, the owner was not in a position to show starting dates for preceeding work because of the ongoing changes applicable to various packages. It is in fact the cummulation of minor incidents under this specific environment that generated unforeseeable delays.

Package II was awarded before Package I because some of the works could have commence immediatly on Residence 2 and 3. Superstructures in Package II were erected on foundations poured by others, in accordance to dimensions and layout on drawings. The dowel installation work previously contracted needed to be redone in numerous locations, as the wall layout for this package developped. Moreover, the contractor could not complete the walls in an orderly manner as he did not possess nor did he receive in due time the size and location of electrical and mechanical openings in slabs and walls.

In an attempt to evaluate the impact of fast-tracking on this contract, a similar method has been used to calculate the contractor's losses as described in the previous section. The actual manhours expended on the job were credited for change orders, claim items and miscellaneous extra work. The loss of productivity calculations are based on direct labour hours, not including supervision, etc.

Table 4.6 Loss Productivity Calculation - Package II

Package II	CONTRACT MHrs	Extra Work & C.O. MHrs	% *	ACTUAL MHrs (1)	Projected MHrs Expenditure (2)	Avg. Hourly Rate (3) **	PRODUCTIVITY LOSS ((1)-(2)) X (3)
Masonry & Structural Work	70,057	5,949	7	89,387	75,678	$12.00	$164,500

* Percent of contract hours

** Taken from claim reports

Based on a projection of the contractor's normal productivity on this contract, the extended period of time attributed to the fast-track approach amounts to 13 weeks, or approximately 3 months, representing $68,160 extra in site supervision and equipment costs.

The total extra costs resulting from productivity loss and extended duration amounting to $ 232,660 ($164,500 + 68,160) represent a 12% increase in the contract value attributed to fast-tracking.

This estimate of the extra cost incurred associated with the fast-track approach does not depict the side effects of complications in project completion. Increase winter work, labour cost escalation, and winter shut-down could actually be included in the calculation of extra costs as indirect consequences of delays.

4.4.3 Masonry package (III)

Another masonry contract, hereafter refered to as "Package III", closely related to the previous one, was awarded for $ 290,000. Package III had to be completed by July 31st, 1977, a contract duration of 26 weeks. The actual execution of the work took 41 weeks with 15 weeks of delay, representing a 58% increase in the planned duration.

The unavailability of work areas seriously affected the productivity of the masonry contractor. In order to execute the work within schedule, the availability of work areas would have to follow a systematic sequence to permit the contractor to organize and execute his work in an efficient manner, minimizing the remobilization.

In the present circumstances, the contractor was forced to work in a stop and go manner since the items to be built into the masonry were either not installed and/or supplied by others.

The mechanical and electrical fixtures were not installed in due time to allow for these to be built into the masonry walls. The late delivery of door frames also forced the contractor to tooth out, rack back or leave out masonry walls. When the mechanical and electrical fixtures were installed and door frames were eventually supplied, the contractor had to return to the various areas to complete the remaining work.

The contract had to be completed in two phases: the interior and exterior work. The schedule was dependant upon the time duration of the following:

a) award of contract

b) delivery of door frames

c) completion of elevators

d) slab on grade

e) supply of electrical and mechanical built-in items

f) erection and testing of pipes enclosed by masonry

During the course of the work, the contractor had to leave out and/or hold up areas of work while awaiting dimensions and/or information to be supplied or decisions to be made in order to permit the work to proceed. The motivation of the work force and the productivity achieved was affected by this manner in which the work progressed. When the workers found the work was being performed in a haphazard manner, i.e. work being left out here and there, stopping the work in mid-course, moving about in random fashion, etc., the attitude changed and the performance dropped.

The overridding reasons for the productivity losses and delays may be summarized as follows:

1. Late award of other contracts.
2. Delays occasionned by other trades and/or supply of materials.
3. Delay in supplying required clarifications and/or technical information.

In order to meet the 7 week time frame to execute the interior masonry work, the project should not have started until July 1977. The unavalaibility of work areas has contributed largely to the delays encountered.

The projected manhours expenditure of 13,843 is subtracted from the actual man-hours expended, excluding extra work, to give the additional man-hours due to productivity losses: 6,938 Mhrs (20,781 - 13,843) . At an average labour rate of \$ 12.13/Mhrs this representes an extra labour cost of \$ 84,160. The additional field expences determined from the extended duration amounted to \$ 18,760. The extra costs are summerized below:

Due to productivity loss	\$ 84,160
Due to extended duration	\$ 18,760
TOTAL	\$ 102,920

This \$ 102,920 does not include any interest nor does it account for present value dollars. The extra cost attributed to fast-tracking is therefore equivalent to 35 % of the contract value.

The next two packages to be examined on this project are not as critical to the work progress but still require considerable interfacing with the previously described structural works. The first one calls for the supply and installation of aluminum windows, doors and metal wall panels. The last package examined refers to the drywall work. They have been retained mainly to illustrate the importance of maintaining well coordinated scheduled work and to show the cascading down impact of fast-tracking on these finishing trades.

4.4.4 Supply and installation package (IV)

The contract for supply and installation of aluminum windows, doors and metal wall panels, refered to hereafter as "Package IV", was awarded on the 26th of November, 1976 for $ 1,150,000. The scheduled completion date was Nov. 30th, 1977, one year later. The substantial completion of Package IV has not taken place until the end of June,1979, or 78 weeks behind the scheduled completion date, representing a 150% increase in the planned duration.

The contractor was required to "fabricate and erect the work to suit field dimensions and field conditions", assuming the conditions were known and measurable as required and outlined in the specifications.

If "as-built drawings" of the opening in which the contractor was to install his part of the work were available, or had been made avalaible in time to meet his schedule requirements, then most of the problems encountered would not have occured.

The field conditions or prepared openings were the responsibility of others. Amongst them, the reference documents calls for the execution of the contract Package I and particularly the masonry and superstructure in Package II. The difficulties encountered on the preceding contracts did definitly affect, as will be shown here, the planned progress of these finishing trades. The accumulated delays were simply passed on to the next contractor to which his own difficulties were added to further delay the actual completion date.

There were basically two conditions which were not respected by the construction management organisation. Sufficient coordination had not taken place in the design to ensure the work of one contract package would fit with that of the adjoining and following packages, and the work performed by others was not complete and accurate. This is an example of coordination problems between the design of related packages and coordination problems between design and on-site construction.

In order to meet the contractual schedule, the contractor planned production of frames at the rate of 50 frames a week, for an overall duration of 20 weeks. Because of the conditions stated above, production did not start until June 20th, 1977, 26 weeks later, and lasted 84 weeks.

It would have been a relatively simple matter for the contractor to have prepared his shop drawings from the information supplied on the contract drawings, taken field dimensions from prepared openings, and accordingly fabricate the panels and windows on a continuous and uninterrupted production schedule. Instead, the pace of the job was established and the flow of the work dictated by the supply of information to the contractor. Despite the contractor's numerous attempts to solve the design coordination problems, dimentions were simply not available to him. The contractor actually suffered additional losses in attempting to find solutions to design deficiencies, in participating to the coordination and corrections of other contractors work, and in carrying out the work of other contractors to which the work of his contract depended.

The basic problems on Package IV, namely the lack of complete design and poor coordination between trades are strongly linked to the fast-tracking approach on this project. Being dependent on several other contract packages further complicated the work coordination of this package. The smooth flow and momentum which is so necessary for a contractor to carry out his work in an efficient and economical manner was never established.

Using the same procedures as described previously, the cost of productivity loss in the field was determined to be $396,325, compared to $36,255 in the shop. The contract suffered mainly from the consequences of fast-track impacts on previous work packages.

Large additional direct costs were reported because the project completion was delayed considerably. In order to assess the extended duration costs, an analysis of the progress billings for both shop and field work has been performed. It has been calculated that the contractor spent $ 288,550 more in direct cost because of a 78 week delay. This figure includes the increase in wages both in the shops and the field, extended overhead cost, extended material cost and indirect costs. The increase in engineering and coordination costs have also been included.

Totaling all extra costs attributed to

(1) Impeded site availability

(2) Dimensional discrepensies and

(3) Late supply and approval of required information,

the resulting additional cost can be summerized as follows:

Due to extended duration	$ 288,535
Due to productivity loss in the field	$ 396,325
Due to productivity loss in the shop	$ 36,245
Total	$ 721,100

This amount represents a 63 % increase in the contract value associated with a 150 % increase in contract duration.

4.4.5 Drywall package (V)

The drywall contractor on this project was also severely affected by the lack of coordination between trades. This type of finishing work is often interfered by others even in conventionnal projects. The duration of the contract was envisaged to be 2 months, but it actually took 13 months including a 2 month strike.

Being at the end of the construction chain, this drywall contractor was seriously affected by the delays of other contractors which have themselves been impacted by the fast-track approach. This includes the window and curtain contractor, the glazing contractor, the roofing contractor, and the mechanical contractor.

The contract initial value of $320,000 has incurred additional costs in the amount of $149,760 or a 46 % increase in contract value. Again, this figure is based on the difference between the actual man-hours expended and the achievable man-hours expenditure which excludes fast-tracking interferences and delays.

This contract shows again interferences and lack of coordination arising from:

1. Unavailability of work site
2. Faulty design
3. Incomplete and faulty information on tender drawings
4. Owner's hesitation in giving proper instruction.

4.4.6 SUMMARY AND RECOMMENDATIONS

Table 4.7 shows the impact costs of each of the packages examined and indicates the estimated fast-track related delays derived from the productivity loss. The tabulation of these results give a quantitative indication of fast-track impacts on this project. The relative importance of the figures (in percentage) depict clearly the consequences of an improperly managed fast-track project.

Through the analysis of 5 contracts on this project, the difficulties in preparing work packages and overlapping them has been examined. Several particular situations combined with fast-tracking have prooved to be very harmfull to the timely completion of this residential building. The problems are summarized as follows:

1. Dimensional discrepencies
2. Major changes
3. Poor work packaging
4. Unacceptable work by the others
5. Delay occasioned by other trades and/or supply of material.

Table 4.7 Fast-tracking Impact Summary - Project III

Type of Work	Overall project: Contract Amount	Contractual Duration Wks	Actual Duration Wks	Delays: Total Delay Wks.	Delays: Percent of Contract Duration %	Fast-tracking Impacts – Extra costs: Loss productivity (Direct labour Cost)	Extended Duration (Indirect Cost)	Total extra Costs	Percent of Contract Value %	Delays: Fast-track Delay Wks.	Delays: Percent of Contract Duration %
Foundation & Mas.	$ 1,310,000	26	60	34	133%	$ 193,600	$ 75,230	$ 268,830	22%	21	81%
Concrete & Masonry	2,000,000	56	69	13	23%	164,500	68,160	232,660	12%	13	23%
Int. & Ext. Masonry	290,000	26	41	15	58%	84,160	18,760	102,920	35%	10	.38%
Windows Sup.&Inst.	1,150,000	52	130	78	150%	432,570	288,530	721,100	63%	78	150%
Drywall	320,000	2	13	9	450%	149,760	*	149,760	46%	9	450%
Total of 5 contracts	$ 5,070,000					$ 1,024,590	$ 450,680	$ 1,475,270	29%		

* Not evaluated

These problems resulted in a productivity loss due to: out of sequence work, stop and go operations, interference with other trades, and extra-time to prepare the as-built drawings.

The first two packages examined on this project, foundation and masonry, were closely linked packages with considerable overlapping and interface. The way these work packages were put together and subsequently manipulated as the construction picture changed illustrates a fundamental difficulty associated with fast-tracking, namely, the definition of independant packages. The problem of awarding contract in a timely manner also surfaced.

Particularly while using a fast-track approach, the owner should have determined the optimum construction duration of both the total project and individual contract packages. The timing of tender calls for various packages should have been determined in close coordination with the completion of required design and the preceding construction operation. Yet, it seems that the desire to finish this project within the set schedule has had the reverse effect.

In expediting the design of this building, incomplete drawings have been issued to the contractors. They were incomplete in the sense that not enough time had been spent in coordinating design details and checking dimensions. The resultant dimensional discrepencies forced the contractor to check every design and ask for clarifications when necessary. Although common on every construction project ,the large amount of discrepencies and the unusually long time in supplying the required information seriously affected the work progress.

The way work packages are divided and defined ought to limit the possible interference of related packages. The issuance of the contract should have been more carefully coordinated. Up to date field information and forecast should be present in the next package to be awarded. Being an accelerated construction approach, progress of the work is very sensible to any unforeseen changes. If those changes in schedule or work conditions are not incorporated in the succeeding packages, severe interferences can jeopardize the anticipated time savings.

4.5 Other project studies

In the second part of this chapter, 5 additional fast-track projects will be examined in order to substantiate the previously discussed problem areas and establish their frequency of occurrence. The characteristics of each project study and their identified problems are summarized in Table 4.8. They are analyzed identify the qualitative impact of fast-tracking rather than the quantitative part, and as such there were no need to carry out an in-depth delay analysis for each project. The problems are not unique but it is the context in which they occur that makes them so critical to the project schedule.

The first project examined in this section is the construction of a power plant in Canada. Two electrical and one mechanical contracts have been investigated on this fast-track project to find that untimely design information severely affected the construction process. The lack of coordination on the part of the owner was further affected by the late delivery of equipment. The cascading effect of these delays produced interferences to all contractors on the project. Several site location were not ready and the contractors' work was encumbered in congested areas.

The considerable increase in total number of drawings (from 101 at tender call, to 587 at the contract completion) has been marked by frequent CO's and CCN's. Inadequate coordination of the design work with respect to the field conditions, resulted in a flow of design and engineering information which was both late and inadequate.

The whole construction job has been delayed 24 weeks as a result of the cascading effect of the disruptions on all contract packages. In general, the project suffered severe losses because of the difficulties in coordinating design information.

The second project examined is a processing facility built in 1977-78 using a construction management approach. On this project, two electrical contracts, a masonry and a painting contract were studied, as shown in Table 4.8. The owner was eager to get construction started but yet he did not emphasised or put intensified effort into certain areas which were critical to the success of this fast-tracking program. Important design related problems characterised this project, followed by a lack of coordination between packages of work.

Drawings and informations were improperly coordinated, resulting in numerous design conflicts. The order of awarding different work packages was not respected and interferences caused by others created limited access to the work areas and hence considerably reduced the contractor's productivity. During the course of the project, 107 change orders were issued with a total value amounting to 28 % of the original contract amount.

The initial 22 weeks delay on the interior and exterior masonry contract, shown in Figure 4.13, reflects the cumulative impact of previous packages which were the result of inadequate coordination by the owner. Interferences between different contractors trying to work in the same areas, because of priority, proved to be the main cause in greatly extended duration and serious productivity losses.

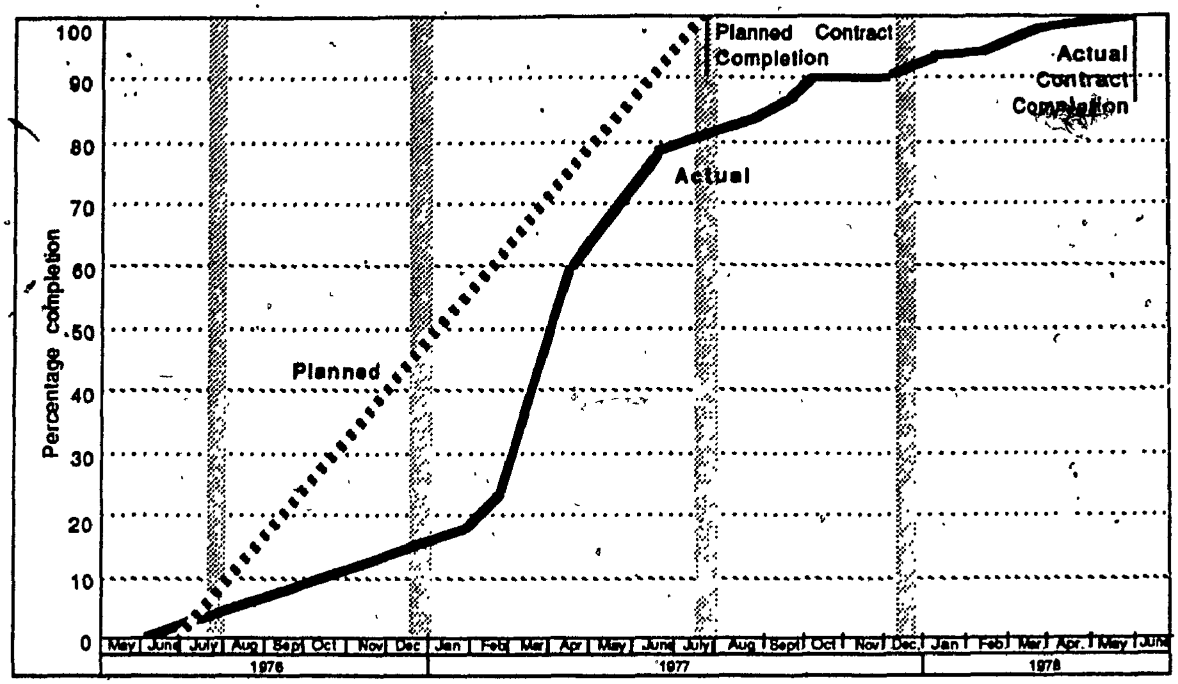


Fig. 4.13 Comparison of as-planned vs. as-built schedule
- Masonry work -

It is important to note, on this project, that the consultant was dealing with new and untried design concepts. This situation hampered considerably the fast-track difficulties and the project ended up being delayed by over a year.

The next case study looks at a general contractor who has been awarded a contract of $ 76,550,000 for the erection of a commercial facility. Of this amount, $ 71 million was allocated to nominated sub-contractors. The prime contractor was responsible for the administration and control of the sub-contracts with little direct work on his part, generally acting as a construction manager.

The total cost of the project has reached $ 110 million; an increase of $ 34 million, representing 45 % of the contract value. The majority of the cost increases resulted from the considerable amount of changes required to complete the job. The project schedule was not affected considerably; from a planned duration of 115 weeks, only 7 weeks were added to completion. Rather the fast-tracking approach induced numerous changes in the work because of the expedite way in which the contracts were awarded.

Another case study examines the work of a mechanical sub-contractor in a public building. The design was defective for installing the work which incorporated many new energy efficient concepts. The set of working drawings were not adequately coordinated into the overall design of the facility. The contractor suffered productivity losses because of incomplete design and working drawings, pending decisions on changes and untimely design clarification. Late award of the electrical contract related to this work affected the progress of the mechanical installation. With very little schedule impact, this case study shows how fast-tracking impacts are often the result of ripple effect of changes and/or coordination problems.

The last project examined involves the construction of a power generating station in Eastern Canada. The superstructure contract, including concrete and mechanical piping, and the masonry contract of this project needed close coordination with the structural steel. As it turned out the structural steel was late in all areas. Because the design did not have sufficient lead time over construction, the owner could not hold on to the initial schedule dates. Despite this fact, the owner awarded several contracts on their scheduled dates, but they were eventually delayed because of the unavailability of working areas.

The increased difficulty in overlapping design and construction and in coordinating the work of all contractors resulted in interferences, congestion and lack of access. These disruptions gave rise to an uneven work pattern and consequent loss of productivity.

The electrical installation contractor on this project had to stop the work altogether for some 30 weeks because the site was simply not ready. When the work started again, the contractor was forced into an accelerated program, in an attempt to recover as much accumulated delays as possible. Throughout the project, the uncoordinated work also gave rise to a great fluctuation in the manpower level. A labor shortage actually occured as a result of extensive overlapping of the work, demonstrating how fast-tracking can create a shortcoming in manpower requirements. On this generating station project, the incomplete design concept and undefined parameters were not coordinated efficiently with the construction work, where packages were awarded as fast as possible. In a fast-track context, this approach gave rise to unprecedent productivity losses and delayed the project considerably.

4.6 Analysis of project studies

To visualize fast-track related problems discussed in the first sections of this chapter, a tabulated format of information collected on all fast-track projects examined is presented in Table 4.8. The information has been summarized and presented in this form to provide a medium for comparison between the different types of projects analysed, each involving various types of work and contractual amounts. The project duration and total delay give an indication of the severity of the problems encountered on each of those projects. The recorded total delay, expressed in percentage of contract duration does not represent exclusively fast-track delays. The additional costs due to productivity loss and extended duration related to the fast-track approach were computed only for the first three projects and therefore excluded from this comparison.

The fast-track related problems have been divided in two main categories: (1) Inadequate design and (2) Inadequate scheduling. In addition, problem areas often associated with fast-tracking are identified in Table 4.8 and then ranked for their frequency of occurance in Figure 4.14. The aggregated result indicate a stronger schedule problem impact on fast-track project. The severity of each problem and its relative importance are discussed in the following section.

Table 4.8 Summary of Analysis Result

No.	Type of Project	Type of Work	Contract Amount	Contractual Duration Wks	Actual Duration Wks	Delays: Total Delay Wks.	Delays: Percent of Contract Duration %	Fast-track related problems: Inadequate Design: Lack of sufficient info / details	Lack of coordination	Frequent CCN's & CO's *	Late issue of CO's **	Inadequate Scheduling: Design/Constr. Coordination	Interface between packages	Untimely award of packages	Other causes of impact: Associated problems: Delayed procurement items	Long shop dwgs. approval	Acceleration
1	Industrial Project	Major foundation	$2,780,000	19				■	■			■		■	■		■
2		Slipform structures	3,160,000	28				■				■		■			
3		Concrete structures	2,600,000	81	127	46	57%	■				■					
4		Mechanical Erect.	3,650,000	35		Overall Project			■	■	■	■	■	■	■		■
5		Struc. Steel & Misc.	3,300,000	44				■		■	■	■		■	■	■	■
6		Piping	1,400,000	35				■	■	■	■	■	■		■		■
7		Underground Elect.	240,000	23								■	■	■			
8		Electrical	4,800,000	46					■	■		■		■	■		■
9	Office Complex	Mechanical	$ 4,890,000	66	120	54	81%	■		■	■	■	■	■		■	■
10		Main Electrical	7,100,000	66	132	66	100%	■		■	■	■	■	■	■	■	■
11		Electrical & Fire	1,400,000	44	73	29	66%	■				■		■			
12	Residencial Building	Foundation & Mas.	$ 1,310,000	26	60	34	133%	■	■			■				■	
13		Concrete & Masonry	2,000,000	56	69	13	23%		■		■	■	■	■		■	
14		Int. & Ext. Masonry	290,000	26	41	15	58%					■	■	■		■	
15		Windows Sup.&Inst.	1,150,000	52	130	78	150%	■	■			■	■		■		
16		Drywall	320,000	2	13	9	—	■				■	■	■			
17	Power Plant	Main Electical	$ 4,960,000	60	67	7	17%		■	■			■		■		
18		Electrical	1,380,000	19	29	10	53%	■	■			■	■				
19		Mechanical	2,290,000	47	62	15	32%	■		■		■	■		■		
20	Processing Facilities	Main Electical	$ 4,390,000	78	81	3	4%	■		■	■		■			■	■
21		Electrical	2,250,000	68	114	46	68%	■	■	■	■	■	■			■	
22		Masonry	2,000,000	54	96	42	78%			■		■	■				
23		Painting	318,800	26	44	18	69%					■	■				
24	Comm Bldg.	General Contract	$ 5,140,000	122	115	7	6%	■	■	■					■	■	
25	Power Generation Station	Superstructure	$ 4,480,000	49	78	29	59%		■	■	■	■		■		■	
26		Masonry	1,090,000	30	73	43	143%			■		■	■				
27		Electrical	302,700	38	85	37	97%			■		■					■
28	Public Bldg.	Mechanical	$ 1,830,000	100	110	10	10%	■			■	■	■	■	■	■	■

* Contemplated Change Notice (CCN)
** Change Orders (CO)

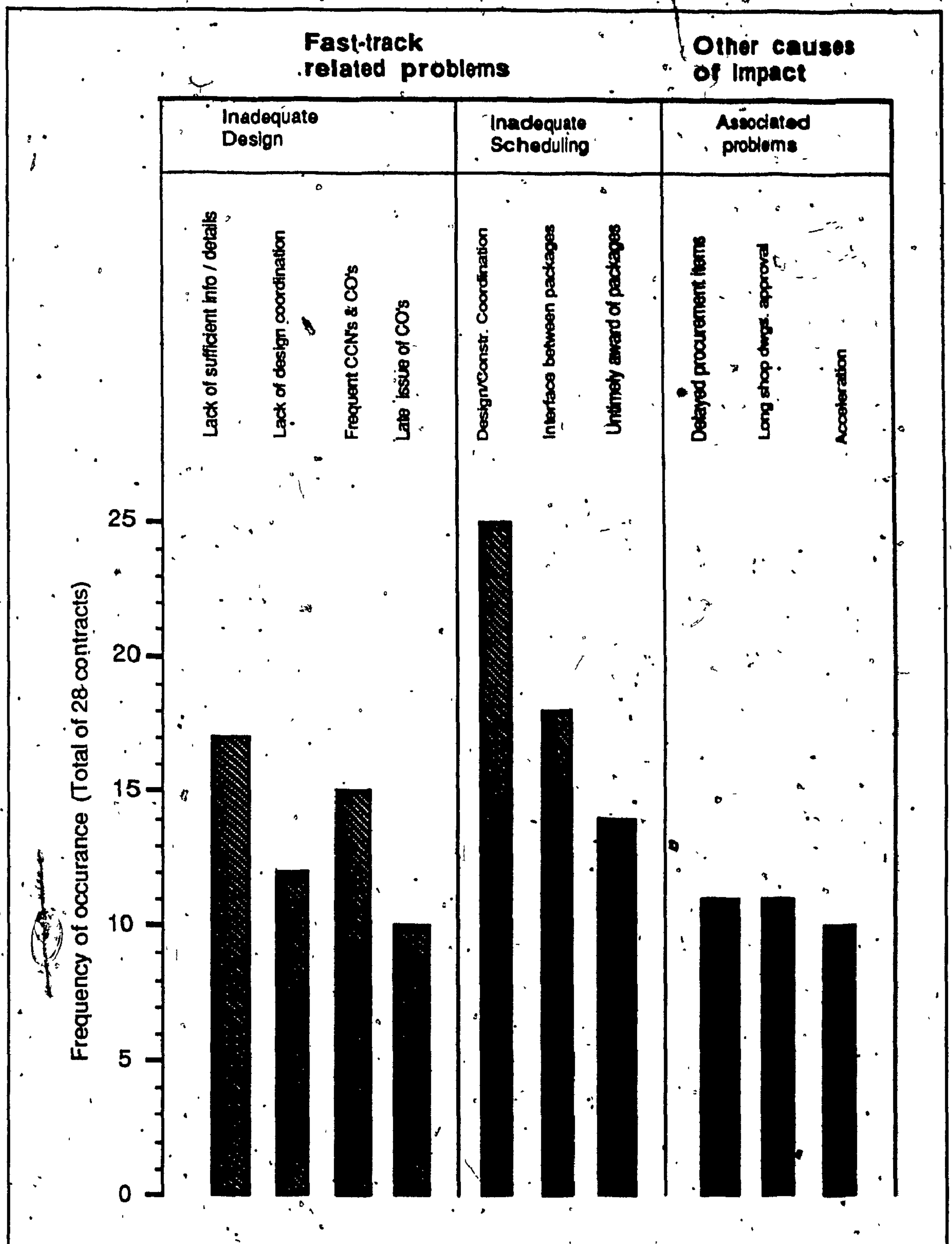


Fig. 4.14 Relative importance of fast-track related problems

According to the result of this study, it is the scheduling problems that most severely affect fast-track constructions. Table 4.9 lists all problem areas in ranking order according to their relative importance. These fast-track related problems are discussed in the next section.

Table 4.9 Ranking order of fast-track related problems

Fast-track related problems	Percent **
1. Design/Construction Coordination	89 %
2. Interface between packages	64 %
3. Lack of sufficient information and details	60 %
4. Frequent CCN's & CO's	54 %
5. Untimely award of packages	50 %
6. Lack of design coordination	43 %
* 7. Delayed procurement items	39 %
* 8. Long shop drawings approval	39 %
9. Late issue of CO's	36 %
* 10. Acceleration	36 %

* Not fast-track related problems
** Percent frequency of occurance (28 contracts examined)

4.6.1 Fast-track related problems

1. Design/Construction coordination

By far the most frequently noticed problem related to fast-tracking is the coordination between design and construction. With construction activities starting before the completion of all design phases, the process of coordinating basic design work for all disciplines before awarding any contracts is no longer applicable. Consequently, the options of resolving conflicts between the various designs are limited. Because previous packages are already awarded while other packages are being designed and scheduled, there are more constraints on the organization of the work to fit the overall schedule. New design information at this stage might affect the pre-determined sequence of activities as execution established in previously awarded packages. At the mercy of design professionals, contractors are often forced to stop their current work because of a contemplated change notice (CCN's). While waiting for the required information, they demobilize and remobilize their working crews to another work area. The resulting "stop and go" operation has a great impact on the productivity of contractors, and is often cited as their major reason for loss of efficiency and inability to schedule their work (See Figures 4.8, 4.9 and 4.11 included in the present study and References [17] and [27]).

In a fast-track environment, the contractor has to come up with a fixed price based on incomplete drawings and specifications. From bid award on, this contractor has to rely on the ability of the design team to produce the remaining drawings expeditiously to support the construction in progress.

2. Interface between packages

Problems associated with the coordination between work packages (also referred to as "interferences by other trades") is the second most important reason for productivity loss and delay, cited by contractors (See Figures 4.7, 4.12 and References [12] and [21]). The dependency of a work package on the preceding package(s) is similar as that of an activity on the preceding activity(ies). If the work of one preceding package is delayed, it will have a direct time impact on the following contract packages. Depending on the degree of independancy, work packages are affected to various degrees by the schedule coordination problems.

Besides the fact that contractors are often faced with construction starting on partially completed drawings and specifications, in a fast-track environment a more pronounced overlapping of construction activities inevitably increases the problem of coordinating work between the various contractors in the field. This tight schedule, combined with the different degree of interdependance between work packages, is more susceptible to be affected by the ripple effect of problems on the critical path.

3. Lack of sufficient information and details

As a distinct characteristic of a fast-track project, the design of work packages are issued to the field for construction with incomplete details. The whole principle would be perfect if design professionals could submit the required details and information to contractors in a timely manner. Fast-tracking construction necessarily means a rearrangement in the design procedures and sequences. With this new approach, drawings and specifications often end up being done on a rushed basis, thereby leaving room for a greater margin of error and omissions. The contractors often cite the lack of sufficient information and details as a mojor cause of their delay.

4. Frequent CCN's and CO's

As a direct consequence of incomplete design or because the owner did not know exactly what he wanted, contractors, in the cases studied, were issued an unusually high number of change orders. The high number of CCN's and CO's did severely impact the contractors' performance and ability to execute his work in an organized manner.

With considerable overlapping of work packages and with construction following close behind the completion of each phase of the design, there is less opportunity for design professionals to consider the design as a whole and make changes at that stage without causing delay and increased cost in the field. The increased intolerance to design changes imposes a stringent demand on the performance of design professionals.

5. Untimely award of packages

This next item relates to the time period in which the work is going to be performed. Work packages or contracts were frequently awarded without evaluating the field conditions. The activities of certain packages could not physically commence because they were awarded too early. The working areas were not available or they were already congested with preceding contractors. The resulting interferences and lack of access directly impacted the schedule of succeeding phases of the work.

6. Lack of design coordination

The lack of design coordination has a considerable impact on fast-track projects. All critical elements have to be coordinated between various inter-related phases of the design work. For example, a structural package would be awarded with a specified head room between the false ceiling and the next floor in order to satisfy ventilation system requirements. However, without proper design coordination, the final duct size might be bigger than the head room provided on the previously awarded package. This type of problem would result in design complications for the ventilation system , and in the issuance of a change order to the superstructure contractor. The former design problem might further delay completion of the HVAC mechanical package with all its undesirable consequences. Changing the already issued package requires the issuance of Contemplated Change Notices (CCN's) and/or Change Order (CO's). In this situation the CO is attributed to fast-tracking, instead of being issued for a changed design criteria which isn't directly related to the fast-track approach.

The lack of design coordination occasionally requires a new construction approach to be adopted or simply generates rework. Without proper design coordination, field work will soon be missing design details, creating delays on site and further affecting the workers' moral and hence productivity. Dimensional discrepancies have also been associated with this problem.

Other causes of impact were tabulated because there are certain links between those problems and fast-track related problems. Fast-tracking difficulties can certainly not be isolated completely from their environment. For this reason, associated problems have been included to give the reader a better overview of the characteristics of each project. The other causes of impact (marked with an asterix) were considered to have aggravated the fast-tracking problems.

* 7. Delayed procurement items

The supplying of equipments and materials by the owner is often critical to the schedule of work packages. The delayed procurement items (delivery of equipment and/or material) certainly contribute to the difficulty in issuing associated drawings to the contractor in a timely manner. In this respect, it has a large influence on the schedule coordination of fast-track projects.

* 8. Long shop drawings approval

The long time required in approving shop drawings can be caused by different factors. The reason, pertinent to the present discussion, is the inefficient design coordination and/or anticipated design problems. Those complications can slow down the contractor, and impact his work to the same extent as a delayed CO approval. On the other hand, this delay in shop drawing approvals can be an indication of the managements' reaction time and inefficiency on the job.

9. Late issue of CO's

Change orders can take a long time for approval, and in some instances, the owner would put "holds" on the work until he approves or rejects a CO. There are many reasons for late issuance of CO's with respect to fast-tracking. The stages of a CO's approval were often too complicated or too long, and could not keep pace with the accelerated construction of a fast-track project. Refusing to take corrective actions, based on a lack of information, has often been cited as a reason for delaying the approval of CO's. The large number of CO's, generated by the fast-track approach also imposes great pressure on the A/E to solve several problems simultaneously. Although this item is amongst the lowest ranked in frequency of occurance, its impact on the schedule can be very important.

* 10. Acceleration

The last item, acceleration, is often viewed as a remedy to all previous delays regardless of their causes. Accelerating a project can be effective to recuperate some delays, but the associated costs and impacts must also be considered. The increase in manpower resources might result in overmanning and congestion in the work place, or might not be possible at all. Increasing the work week by adding overtime will accelerate the work but certainly reduces the efficiency of the workers. The loss of productivity in overtime work must be compared with the apparent gain in time. In Table 4.8, acceleration represents an additional measure the owner adopted to expedite project delivery. These accelerations would amplify the fast-track related impacts. Although pretty much independent of the approach, acceleration is frequently used to correct the situation on delayed fast-track projects. The resulting overmanning and congestion have ripple effect on the scheduling of the work and hence can aggravate the already critical situation.

4.6.2 Summary

The above problems have been categorised by trades to identify their relative impact on the different types of work as shown in Fig. 4.15. The overall examination of Fig. 4.15 indicates that electrical and mechanical works have been considerably more affected by fast-track related problems than civil works. From this observation, we can say that work packages or trades which have the greatest dependence on others are more vulnerable to fast-tracking impacts. On the other hand, civil work, including foundation, concrete superstructure and masonry, are mainly affected by the lack of design coordination and the problem of long shop drawing approval for structural steel. These problems are usually associated with the first trades on site.

All trades were affected by design/construction coordination, but only electrical and mechanical work have been severely impacted by the interface between packages. Again, this indicates how important the degree of dependance of the different trades is with respect to fast-track impact. The relatively more pronounced impact on mechanical work can partly be explained by the problem of late delivery of equipment and/or material. This postponed equipment delivery in turn lead to an acceleration of the program, thereby putting pressureon the mechanical contractor's work.

In the following chapter, recommendations are made to enable a better utilization of fast-tracking by reducing the risks involved and ensuring faster project delivery.

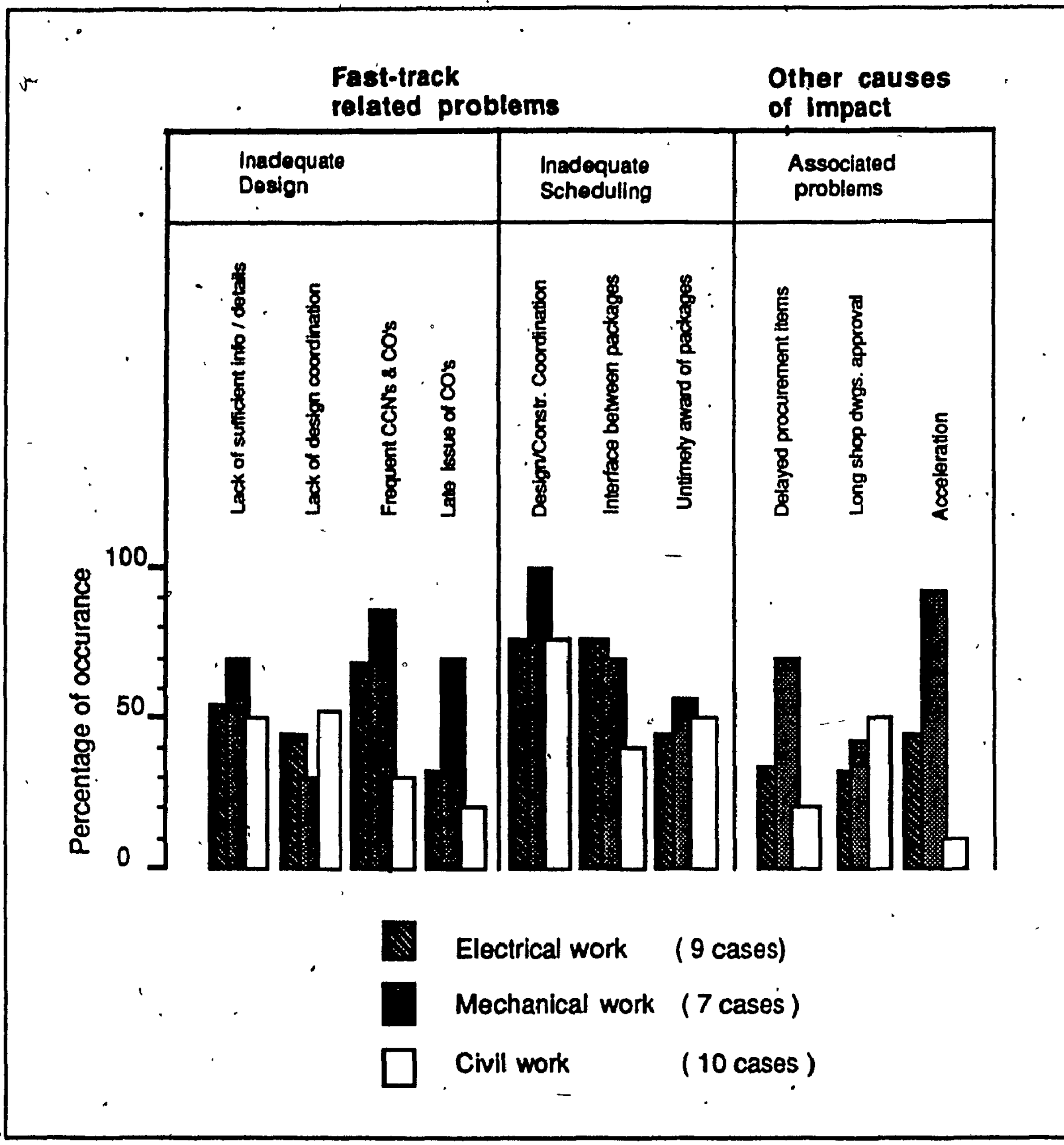


Fig. 4.15 Fast-track related problems (by trades)

CHAPTER V

CONCLUSION and RECOMMENDATIONS

5.1 Conclusion

In this thesis, the fast-tracking construction approach has been examined through the investigation and analysis of a number of completed construction projects. Phased construction and fast-tracking approaches have been compared, clarifying the terminology and the aspects which distinguish them. Starting with the pre-ordering of long-lead items, phased construction approach developped into a sophisticated network of activities overlapping each other in an organized way, to achieve early completion of the project. The logical sequence in which construction work packages are to be awarded, in certain circumstances, forced owners to issue incomplete sets of drawings and specifications to avoid construction schedule delays.

Frequently, in an attempt to maximize the benefits of a shorter project duration or because of a fixed delivery date, the owner or his representative might decide to accelerate their phased project and embark on a fast-track program. Not being prepared to assume the consequences of such a decision, planning and scheduling of those projects were found to be frequently impacted by the accelerated approach.

Before a decision can be taken as to accelerate a construction project using fast-tracking, several factors must be considered. Aside from the financial picture of the project which must be examined closely, others aspects such as the A/E experience and the type of construction must also be included in the decision process.

The financial benefits of a shorter project duration must de considerable. These benefits should be quantify and compared with the extra costs of shortening the project. The cost/benefits ratio must be evaluated with respect to the risks involved in fast-tracking the project. For industrial plants, it could be determined that each extra day of production can generate additional revenues of $ 50,000, for example, or that an early start in production would bring about a bigger share of the market. For commercial facilities the benefits can be measured from the revenues of renting the available space several months earlier. In any cases, the reduced overhead cost of a shorter construction period can represent a significant saving over the conventional approach. Other savings on material and equipment purchased earlier might justify the use of an accelarated approach, especially in periods of high inflation or if important cost increases are forecasted. A forecasted labor strike or contract negociation can also suggest the project should finish earlier.

The typical extra cost in accelerating a project using fast-tracking primarily lie in the additional A/E resources requirement both in design and construction. More design professionals and contract supervisors are required than in a conventional construction project, representing extra costs. To keep construction progress on an accelerated program, impact costs, lower productivity, rework and additional change orders are to be expected as part of the risks of overlapping design and construction; and should therefore be reflected in the costs.

All extra costs combined with the higher risk of fast-tracking a project must be offset by the forcasted benefits. On the other hand, if the rate of return of secured bonds or safe placements is higher than the returns expected in using a fast-track approach, there might be no advantage to start construction right away.

Observations stemming from the projects studied show that there are other conditions , aside form financial, which do permit the effective use of fast-tracking: 1) The A/E must be experienced with this type of construction managment and have the necessary manpower to keep up with the construction progress in the field. 2) The A/E must be familiar with the type of construction, particularly on unique projects which bear greater risks. If the A/E are learning as they go along, it is likely that the design schedule will not be able to support construction work in the field, because, at this stage, design revisions would probably cause rework. A good fast-track project will be tackled by an efficient team work with a timely reaction to complications. Some developpers for example, can fast-track projects efficiently because they have the required structural organization and knowhow to make it happen.

The whole philosophy behind fast-tracking is rooted in the planification aspect of any project. Doing things (activities) in a more organized fashion and taking into account more and more factors that could possibly affect the outcome of a certain action, is exactly what fast-tracking attemps to do.

When fast-tracking a project, it is important to identify potential problem areas which must receive considerable attention in order to have a "smooth" progression of the work . To identify the problem areas generally associated with fast-tracking, twenty-eight troubled fast-track cases have been analyzed. The analysis did not account for all possible complications, but rather examined those with a high frequency of occurence.

Managing the interface between design and construction is crucial to the project performance. The inherent risks of fast-tracking projects include: 1) the loss of financial benefits due to the cost of changes and claims, 2) the loss of planned time savings due to schedule delays and 3) the reduction of control over project costs due to the early elimination of design options normally encountered, incomplete tender specifications, and overlapping of the construction work.

5.2 Recommendations

In an effort to reduce the risks of fast-tracking it is recommended to:

A. Spend more effort during the design phase

The far reaching effect of mistakes during the early design/engineering phase in a fast-track program is usually underestimated. More time and effort, in terms of coordination and planning, should be spent on the design preparation with special attention to trade and/or work packages interface areas. Early in the design phase, decisions which will limit future flexibility in the design should be highlighted and their impact evaluated.

In a fast-track program, design and construction activities should be treated as integral parts of the overall project. Various inputs from other packages can establish interim milestones from which a critical path could be determined. This effort will result in a better and tighter coordination between work packages before they are issued for construction. Although this could be viewed as contradictory to the fast-tracking concept, it nevertheless has to be stressed.

B. Develop an effective design change system

The rushed delivery of drawings combined with an overlapping of work packages contributes, to a great extent, to an increase in the number of drawings to be revised. At the outset of the project, an efficient review system must be established, with clearly defined channels of communication, to compensate for this probable increase in design changes. A change control process must be developed to ensure that essential changes are not delayed by detailed cost or contractual problems, while retaining adequate management control. The effectiveness and timeliness of information exchange through drawings and specifications becomes the focal point in accelerating the project delivery. This precaution would ensure a fast and effective review of drawings and would also provide a good interaction between design activities and those performed on site.

C. Increase information input from the field work

Proper timing in awarding different work packages is critical in a fast-track construction. A package issued too late or too early might delay or interfere with other work packages. Once construction has started, the award of subsequent work packages must be more sensitive to the on-going construction activities and the availability of the site.

More than just eliminating the impact of issuing work packages too early, this approach will help integrate the latest field conditions to the plans and specifications of the following work packages. This can also considerably reduce revisions after contract award and minimize possible interferences.

D. **Increase involvement of participants in all stages of the project.**

Fast-tracking will be given a chance to succeed only if a real team approach can be reached. The attitude of all participants should be influenced by defining their roles in the project to increase "co-operation". Contractors should be brought in the design phase for scheduling and constructability purposes. A member of the design/engineering team should be appointed full time as design coordinator and work with the contractors for an improved response to design originated problems. Innovative and imaginative contractual arrangement and organizational structures such as PCM should be utilized and enhanced to share responsabilities and authorities. This would eliminate the adversary conditions associated with conventional projects, avoid conflicts and favor a better exchange of information through well defined communication channels.

In conclusion, there is nothing new about the individual elements of fast-track construction. What is unique is their innovative combinations. Accelerating a project through fast-tracking is a major decision, and construction professionals should be aware of its implications. Analysis of fast-track construction projects indicated that despite the apparent advantages, only few projects lend themselves to a successfull application of the fast-track approach. Adequate precautions must be taken with respect to the previously identified problem areas in order to reduce the overall project duration. The project team has to be flexible and expeditious in response to complications stemming from a combination of incomplete designs, with an overlapping of design and construction. Then, even with the high consttuction costs frequently associated with fast-tracking, overall project profitability could be achieved.

The fast-tracking management concept can certainly challenge the limit of accelerated project delivery. The awareness of pitfalls in this approach and the adoption of adequate measures early in the project, will considerably increase the possibilities of achieving faster construction.

5.3 Suggestions for future work

On the basis of the work presented in this study, it is recommended that the following aspects be considered for further research:

- Given that a project is going to be fast-track, what is the level of design development needed before any construction starts? Determine the type of drawings required and their percent completion at that moment.

- Explore the feasibility of a faster design systems using computer aided design (CAD) with fast-tracking.

- Investigate the possibility that a delayed fast-track project could still have a shorter duration than if the conventional approach would have been used.

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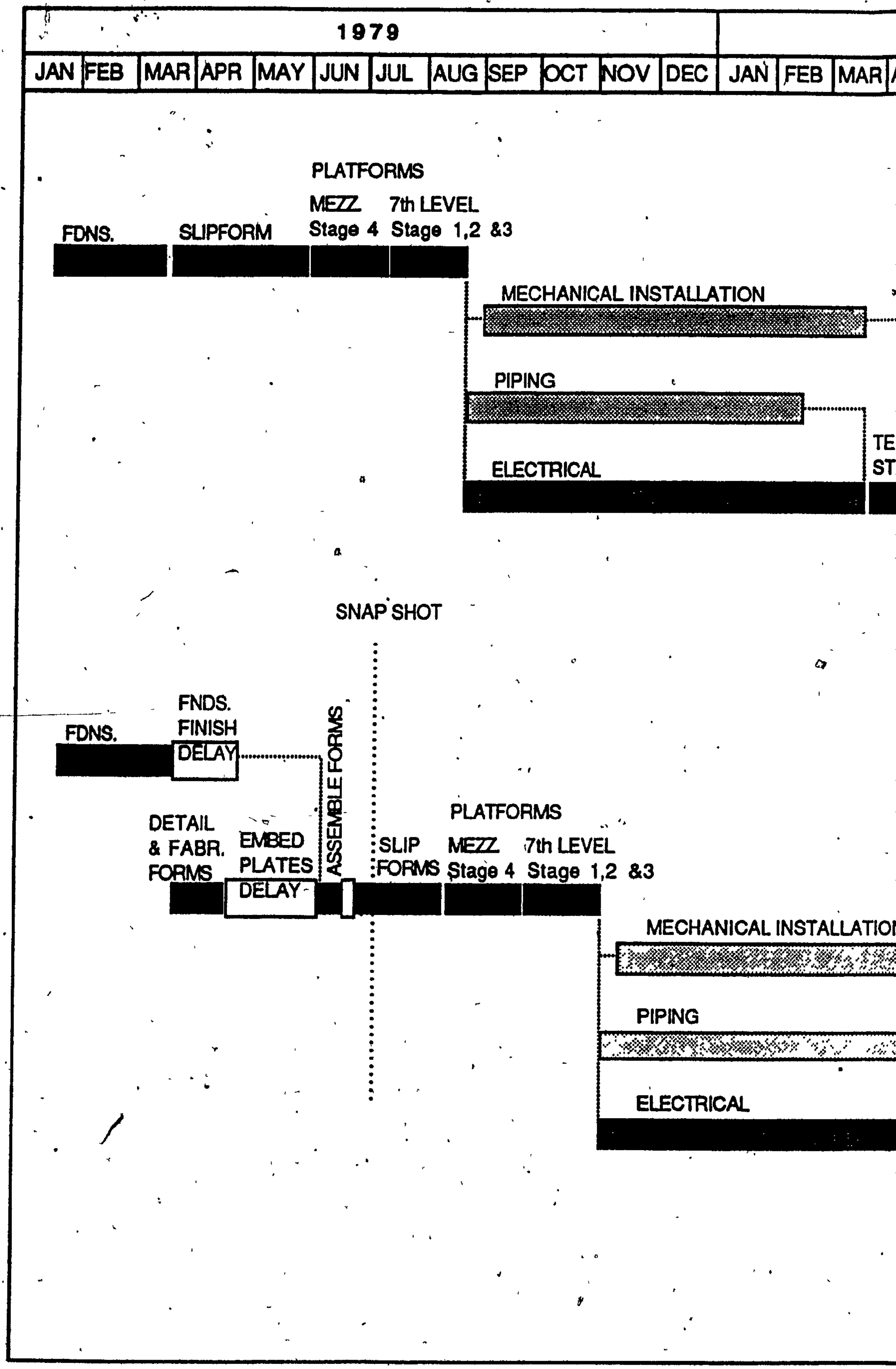
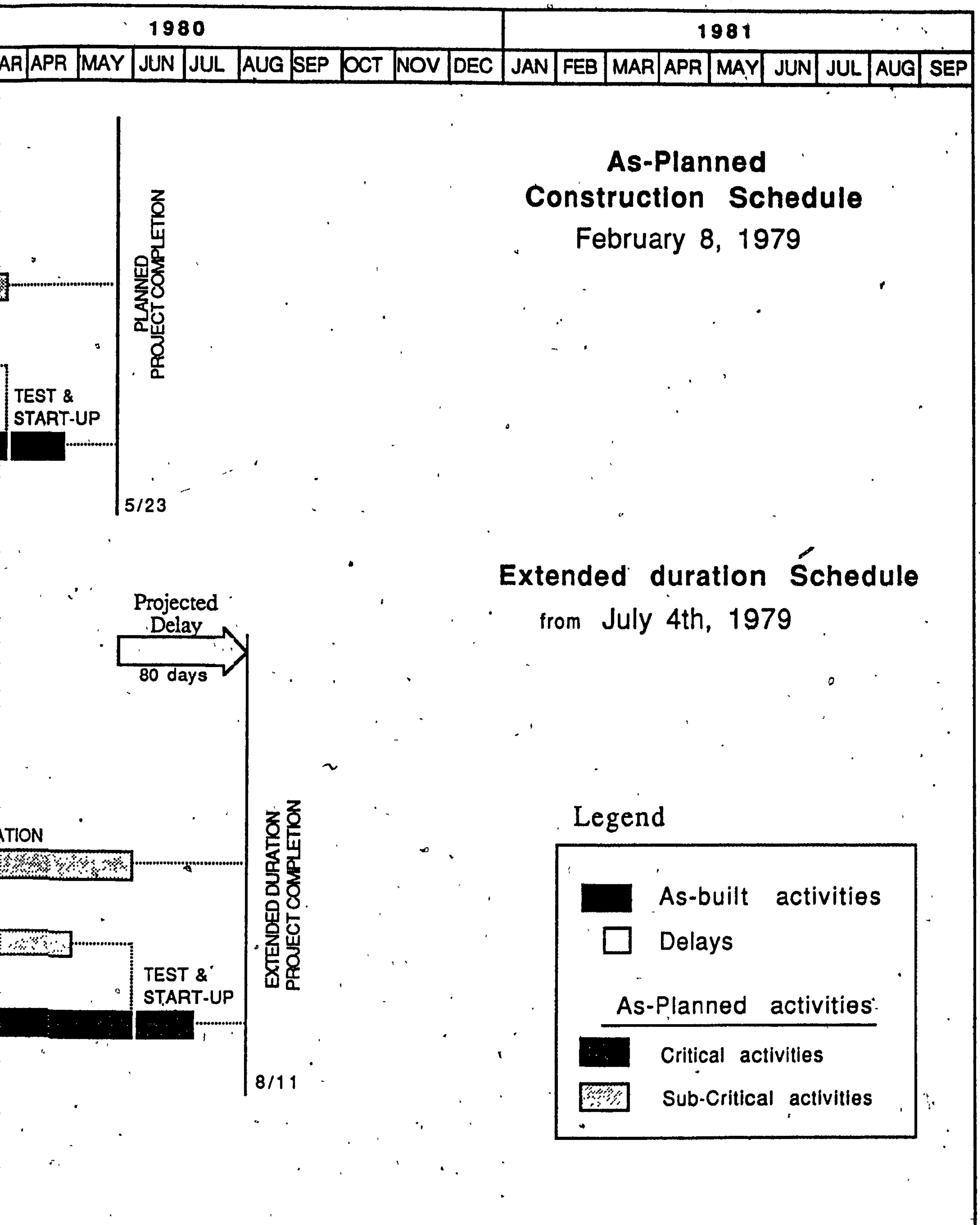
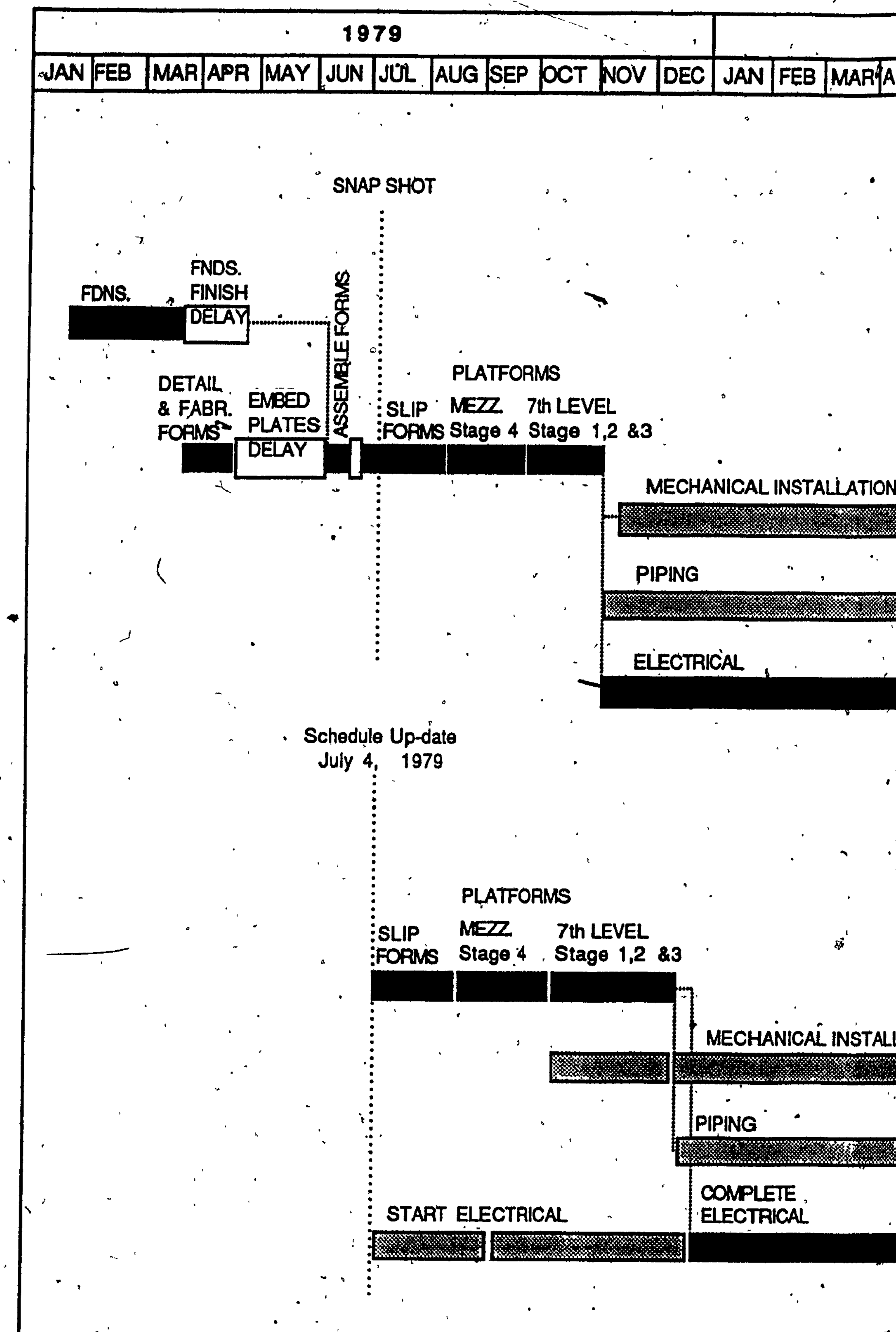
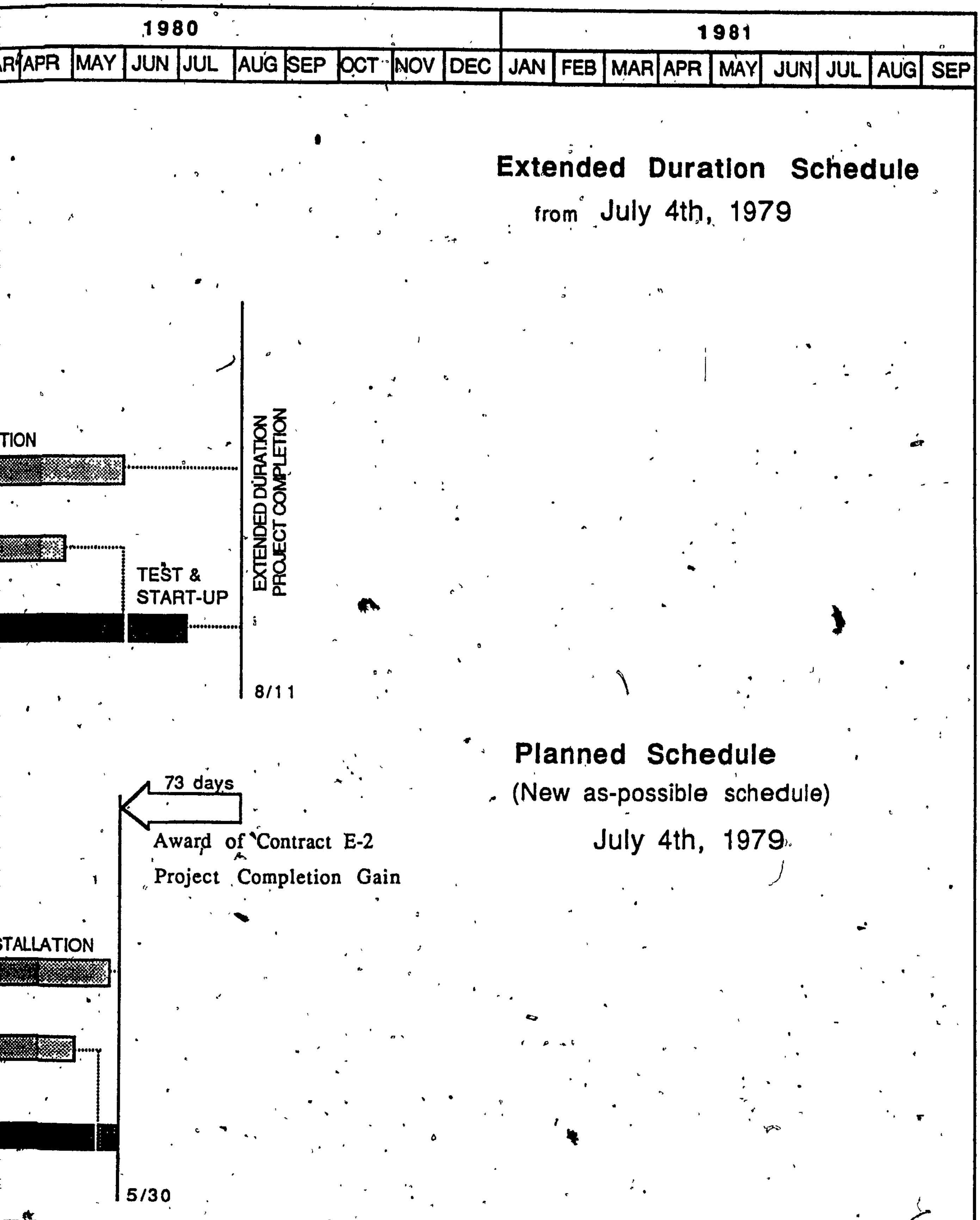
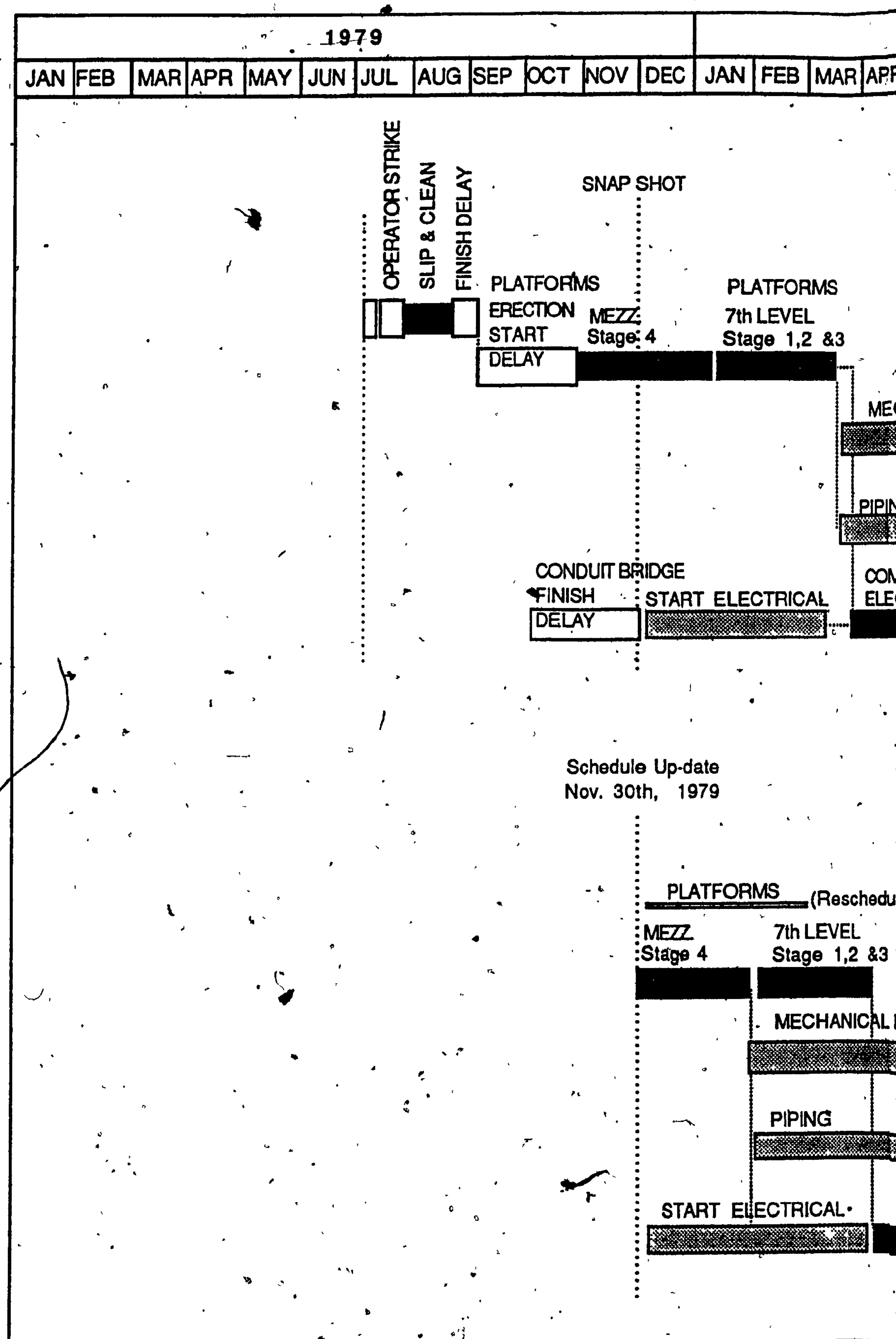
APPENDIX


1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
PLATFORMS
MEZZ. Stage 4
7th LEVEL Stage 1,2 &3
FDNS.
SLIPFORM
MECHANICAL INSTALLATION
PIPING
TE
ST
ELECTRICAL
SNAP SHOT
FDNS.
FNDS. FINISH DELAY
ASSEMBLE FORMS
DETAIL & FABR. FORMS
EMBED PLATES DELAY
SLIP FORMS
PLATFORMS
MEZZ. Stage 4
7th LEVEL Stage 1,2 &3
MECHANICAL INSTALLATIO
PIPING
ELECTRICAL

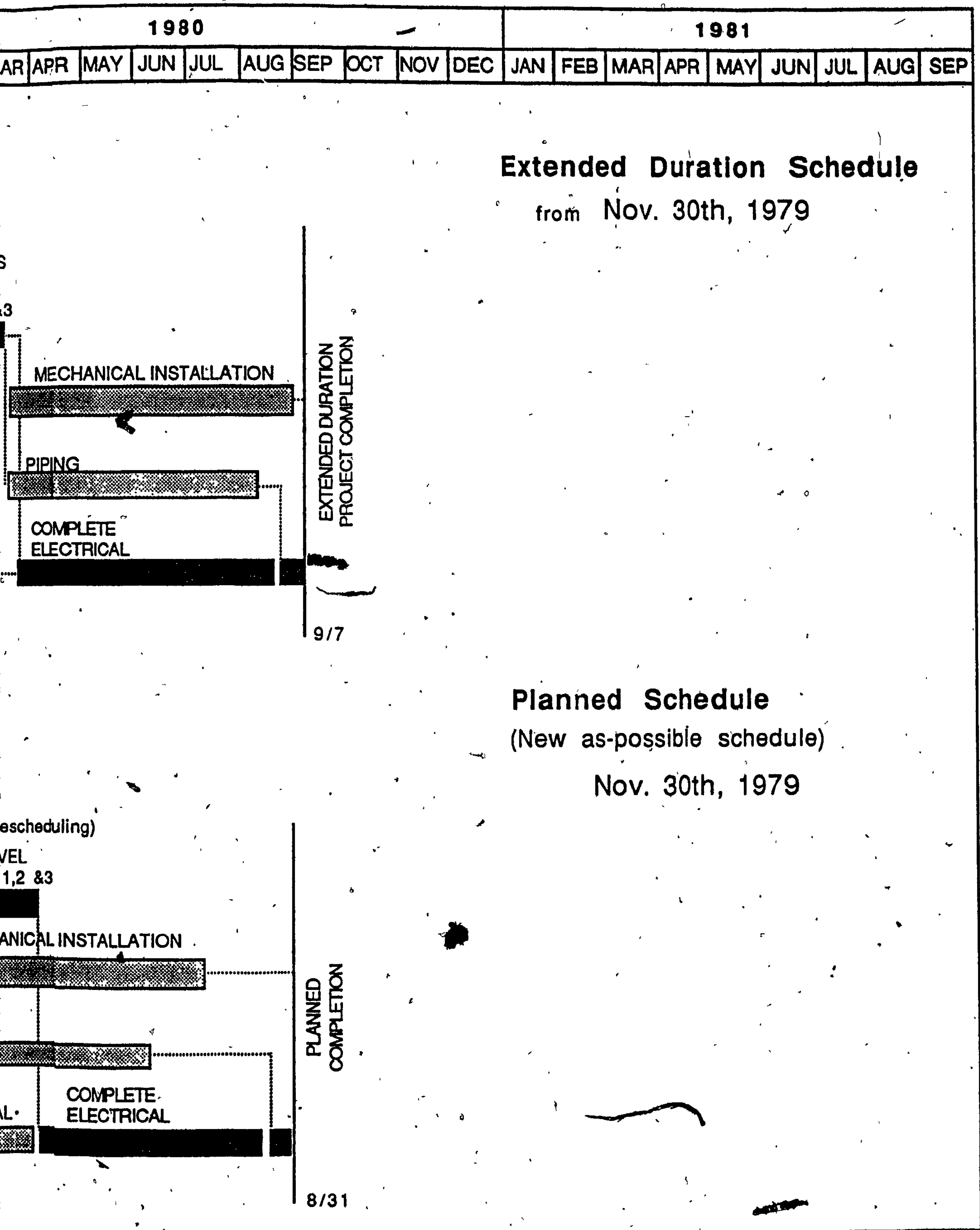

1980
1981
AR APR MAY JUN JUL AUG SEP OCT NOV DEC
JAN FEB MAR APR MAY JUN JUL AUG SEP
As-Planned
Construction Schedule
February 8, 1979
TEST &
START-UP
PLANNED
PROJECT COMPLETION
5/23
Extended duration Schedule
from July 4th, 1979
Projected
Delay
80 days
TION
TEST &
START-UP
EXTENDED DURATION
PROJECT COMPLETION
8/11
Legend
As-built activities
Delays
As-Planned activities
Critical activities
Sub-Critical activities

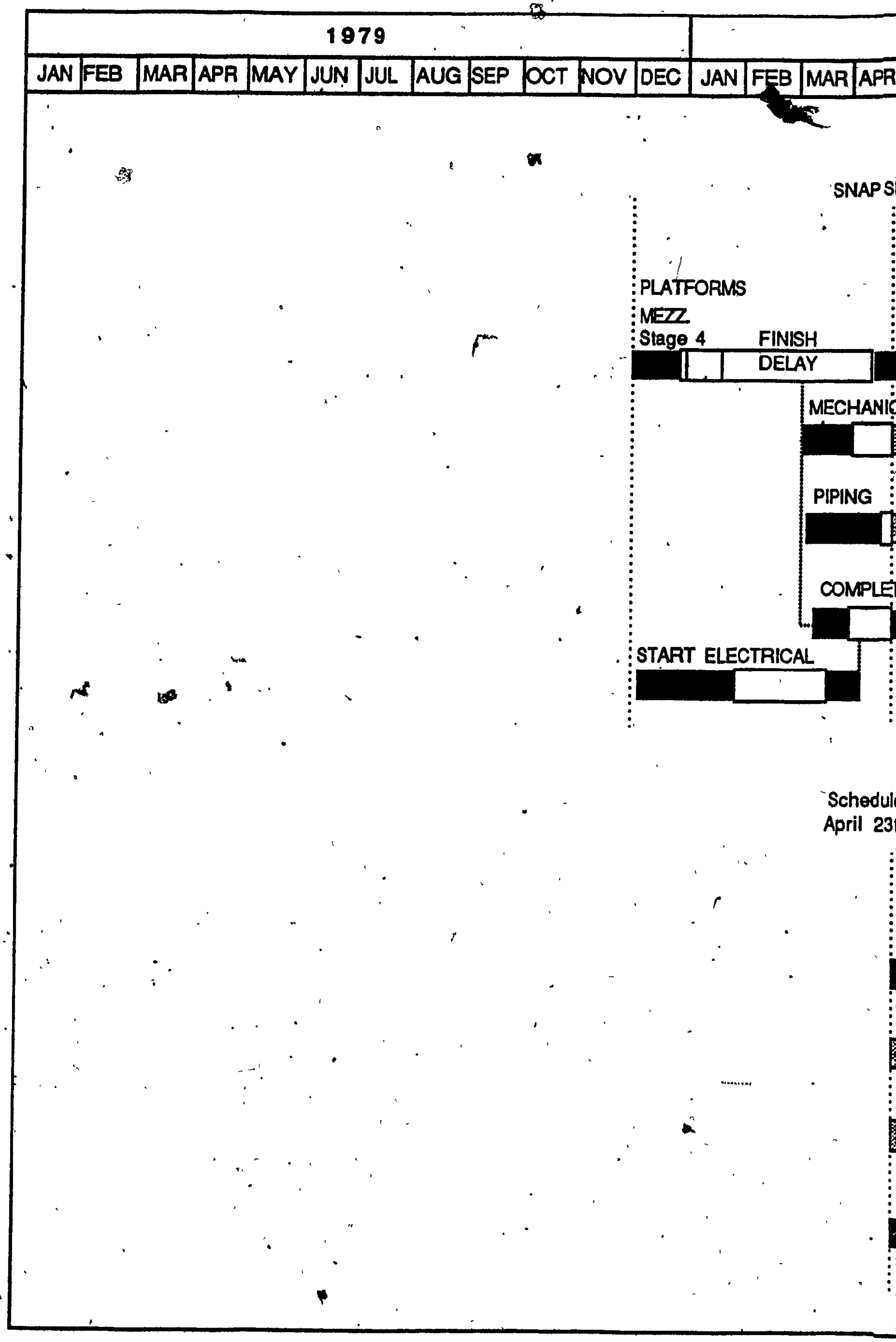

1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
SNAP SHOT
FDNS.
FNDS. FINISH DELAY
ASSEMBLE FORMS
DETAIL & FABR. FORMS
EMBED PLATES DELAY
PLATFORMS
SLIP FORMS
MEZZ. Stage 4
7th LEVEL Stage 1,2 &3
MECHANICAL INSTALLATION
PIPING
ELECTRICAL
Schedule Up-date July 4, 1979
PLATFORMS
SLIP FORMS
MEZZ. Stage 4
7th LEVEL Stage 1,2 &3
PIPING
START ELECTRICAL
COMPLETE ELECTRICAL


1980
R APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
JAN FEB MAR APR MAY JUN JUL AUG SEP
Extended Duration Schedule
from July 4th, 1979
TION
TEST &
START-UP
EXTENDED DURATION
PROJECT COMPLETION
8/11
Planned Schedule
(New as-possible schedule)
July 4th, 1979
73 days
Award of Contract E-2
Project Completion Gain
TALLATION
5/30

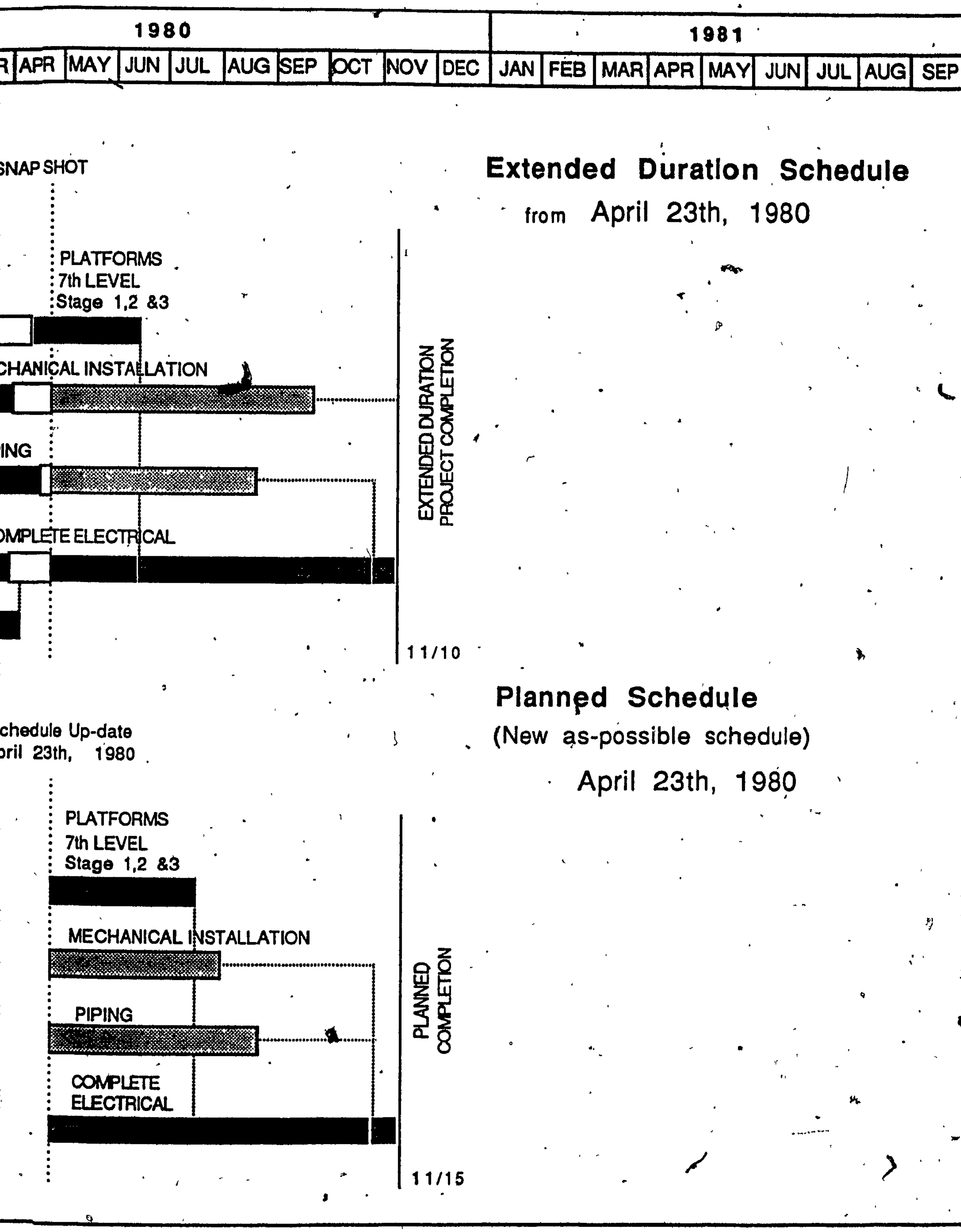


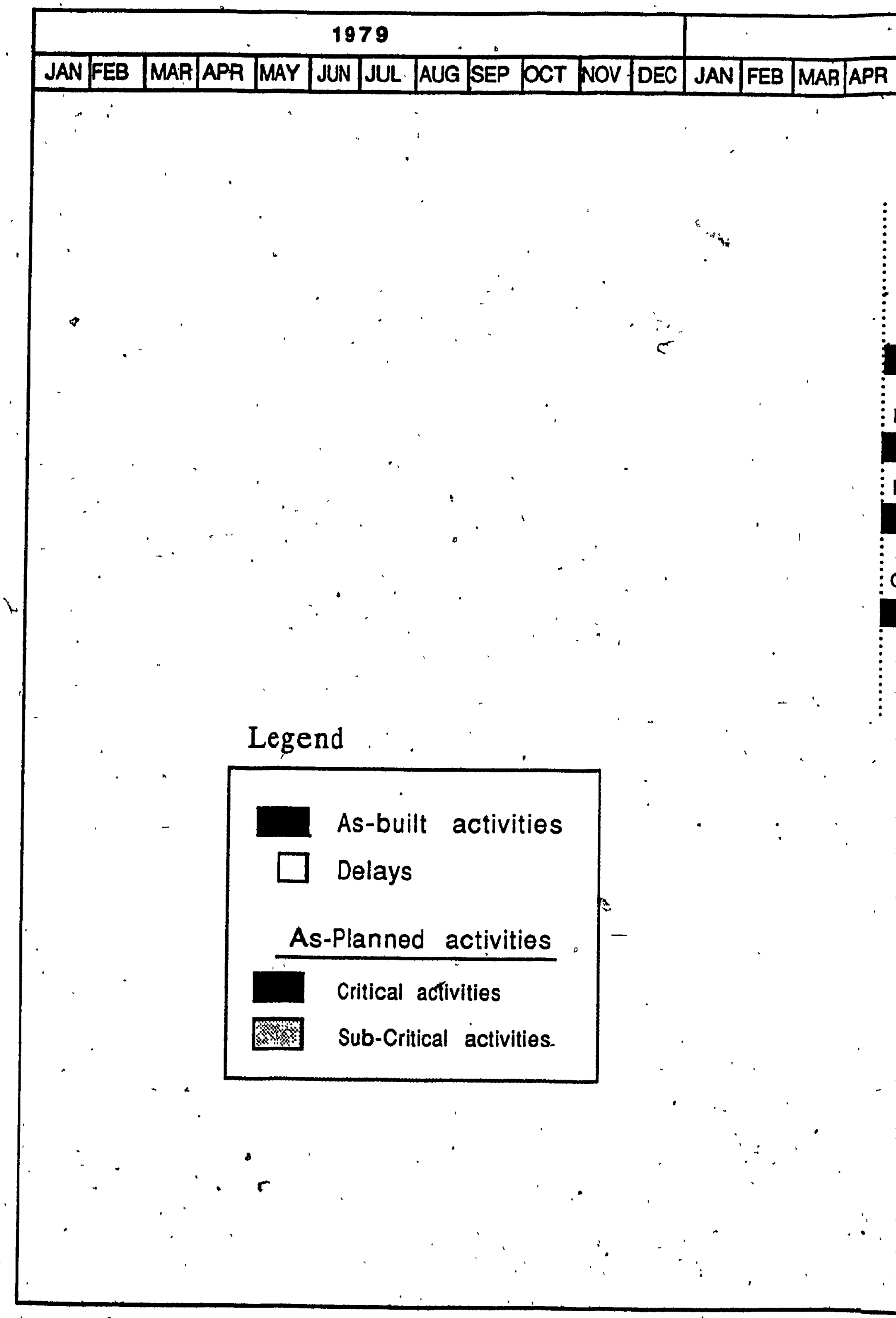
1979
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
OPERATOR STRIKE
SLIP & CLEAN
FINISH DELAY
SNAP SHOT
PLATFORMS ERECTION START
DELAY
MEZZ. Stage 4
PLATFORMS 7th LEVEL Stage 1,2 &3
CONDUIT BRIDGE FINISH
DELAY
START ELECTRICAL
Schedule Up-date Nov. 30th, 1979
PLATFORMS
MEZZ. Stage 4
7th LEVEL Stage 1,2 &3
PIPING
START ELECTRICAL

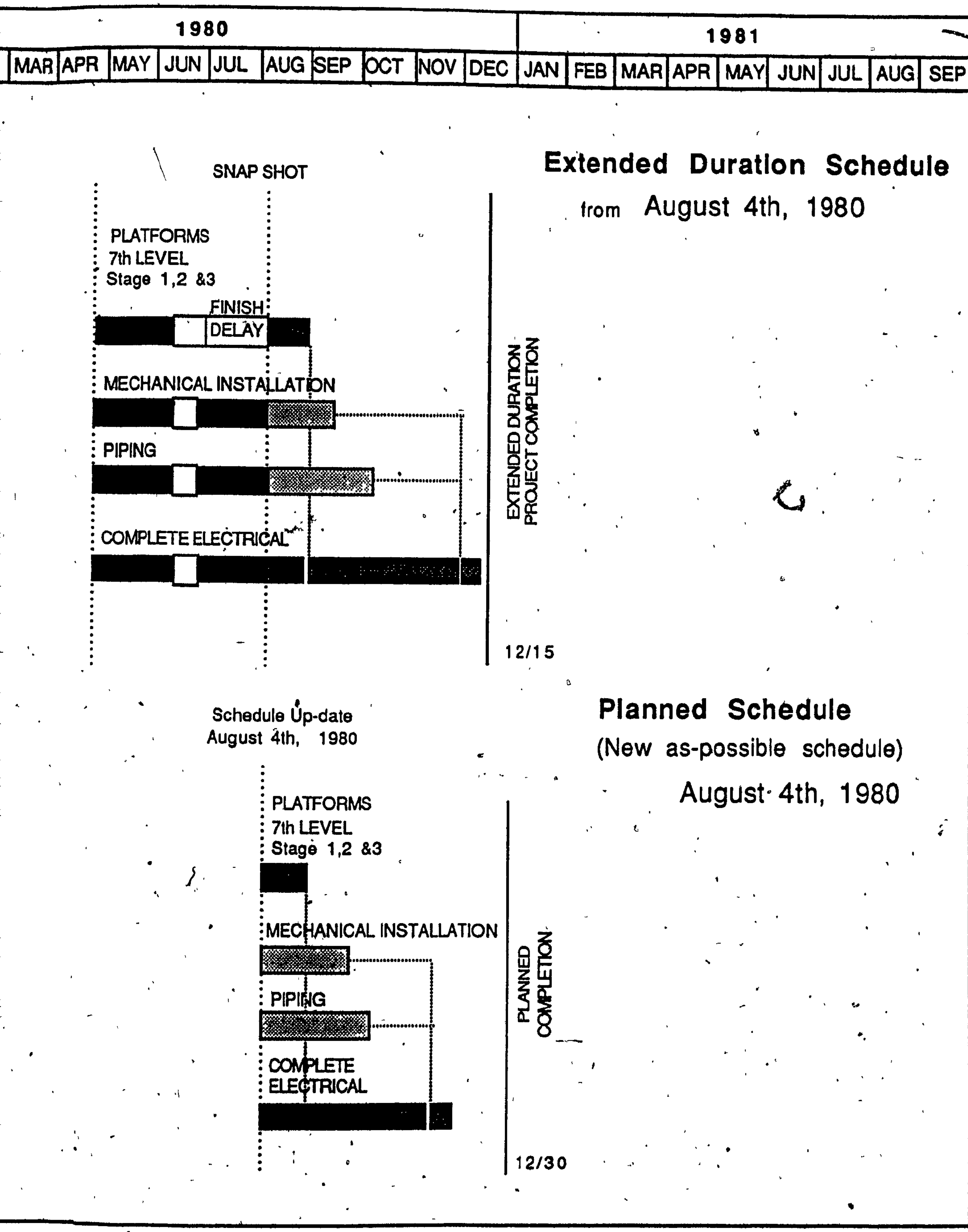

1980
AR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
JAN FEB MAR APR MAY JUN JUL AUG SEP
Extended Duration Schedule
from Nov. 30th, 1979
S
3
MECHANICAL INSTALLATION
PIPING
COMPLETE ELECTRICAL
EXTENDED DURATION PROJECT COMPLETION
9/7
Planned Schedule
(New as-possible schedule)
Nov. 30th, 1979
escheduling)
VEL
1,2 &3
ANICAL INSTALLATION
L·
COMPLETE ELECTRICAL
PLANNED COMPLETION
8/31



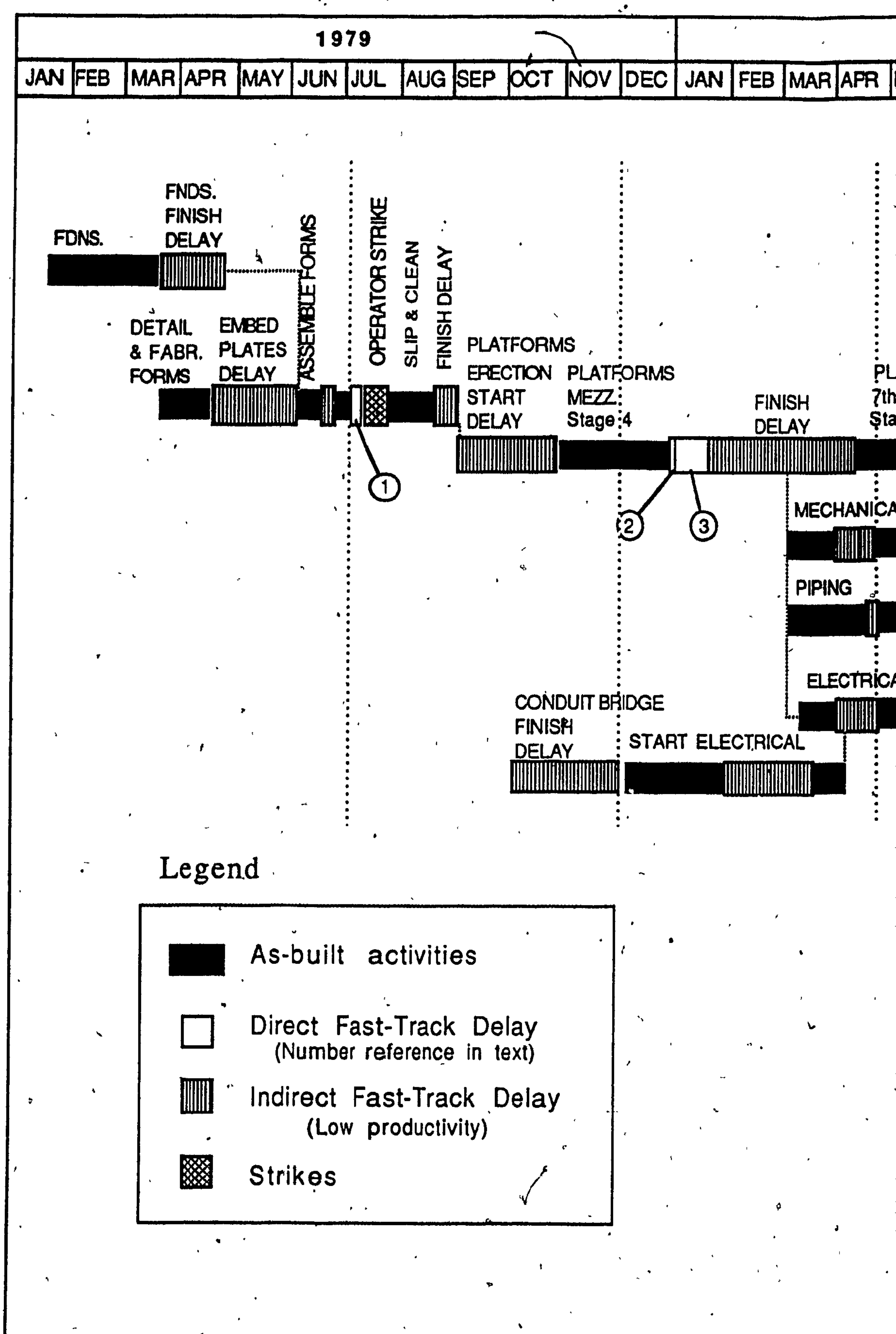
1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR
SNAP
PLATFORMS
MEZZ.
Stage 4
FINISH
DELAY
PIPING
START ELECTRICAL
April

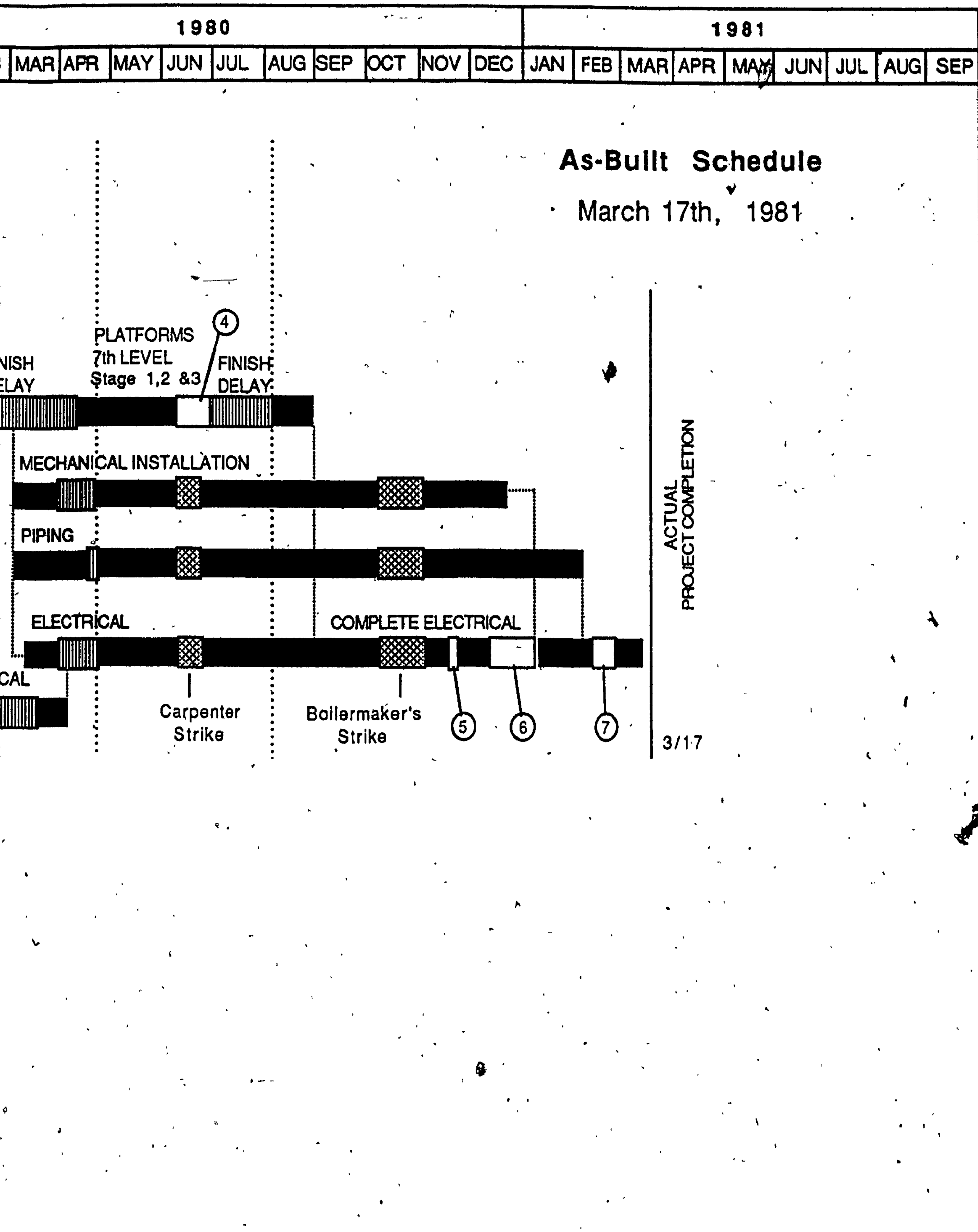

1980
R APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
JAN FEB MAR APR MAY JUN JUL AUG SEP
SNAP SHOT
Extended Duration Schedule
from April 23th, 1980
PLATFORMS
7th LEVEL
Stage 1,2 &3
CHANICAL INSTALLATION
ING
OMPLETE ELECTRICAL
EXTENDED DURATION
PROJECT COMPLETION
11/10
Planned Schedule
(New as-possible schedule)
April 23th, 1980
chedule Up-date
pril 23th, 1980
PLATFORMS
7th LEVEL
Stage 1,2 &3
MECHANICAL INSTALLATION
PIPING
COMPLETE
ELECTRICAL
PLANNED
COMPLETION
11/15


1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR
Legend
As-built activities
Delays
As-Planned activities
Critical activities
Sub-Critical activities



1980
1981
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
SNAP SHOT
Extended Duration Schedule
from August 4th, 1980
PLATFORMS
7th LEVEL
Stage 1,2 &3
FINISH
DELAY
MECHANICAL INSTALLATION
PIPING
COMPLETE ELECTRICAL
EXTENDED DURATION
PROJECT COMPLETION
12/15
Schedule Up-date
August 4th, 1980
Planned Schedule
(New as-possible schedule)
August 4th, 1980
PLATFORMS
7th LEVEL
Stage 1,2 &3
MECHANICAL INSTALLATION
PIPING
COMPLETE
ELECTRICAL
PLANNED
COMPLETION
12/30


1979
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR
FDNS.
FNDS. FINISH DELAY
DETAIL & FABR. FORMS
EMBED PLATES DELAY
ASSEMBLE FORMS
OPERATOR STRIKE
SLIP & CLEAN
FINISH DELAY
PLATFORMS ERECTION START DELAY
PLATFORMS MEZZ. Stage 4
FINISH DELAY
MECHANICA
PIPING
ELECTRICA
CONDUIT BRIDGE FINISH DELAY
START ELECTRICAL
1
2
3
Legend
As-built activities
Direct Fast-Track Delay
(Number reference in text)
Indirect Fast-Track Delay
(Low productivity)
Strikes


1980
MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981
JAN FEB MAR APR MAY JUN JUL AUG SEP
As-Built Schedule
March 17th, 1981
PLATFORMS
7th LEVEL
Stage 1,2 &3
FINISH
DELAY
NISH
ELAY
MECHANICAL INSTALLATION
PIPING
ELECTRICAL
COMPLETE ELECTRICAL
CAL
Carpenter
Strike
Boilermaker's
Strike
4
5
6
7
ACTUAL
PROJECT COMPLETION
3/17