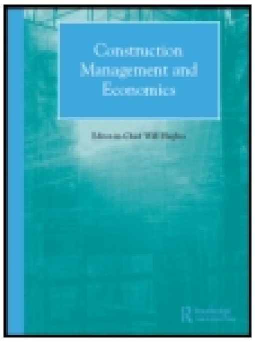

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Phased construction and fast-tracking have received considerable attention in recent years and have been synonymous with the development of new project delivery systems under the professional construction management approach. Many articles and even textbooks have described only the advantages of these popular methods. Despite the differences between the two approaches, outlined in this paper, they are still being referred to interchangeably by construction professionals. Through a case study, this paper also identifies the potential disadvantages of the fast-track technique. Problem areas associated with the implementation of this technique are identified and further ranked with respect to their frequency observed on 28 fast-track construction contracts. A delay analysis shows the impact of this accelerated technique on construction activities. The far-reaching effects of mistakes during the early design/engineering phase in a fast-track programme are usually underrated. Accelerating a project through fast-tracking is a major decision, and construction professionals are often not aware of its implications. Based on the case study examined in this paper and other fast-track constructions previously analysed, 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 unless considerable attention is directed to problem areas, particularly those related to design, such a popular accelerated technique could result in unexpected delays.

Keywords: Fast-tracking, phased construction, professional construction management, design management

Introduction

Management of engineering and construction projects has unquestionably become more complex in recent years. During the 1970s, technical complexity of projects, increased government regulations, spiralling 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. Phased construction and fast-tracking management techniques have been developed as part of the Professional Construction Management (PCM) approach (Barrie and Paulson, 1984) in an effort to meet these challenges. In both approaches the project duration is compressed by overlapping work packages, but fast-tracking further overlaps design and construction as illustrated in Fig. 1. Such overlapping of project phases has been synonymous with the growth of PCM organizations (Gray and Flanagan, 1984). Today, with the uncertainty of inflation and interest costs, and with the competitive business world requiring owners to do their utmost to beat market competitors, these accelerated project delivery approaches are becoming attractive.

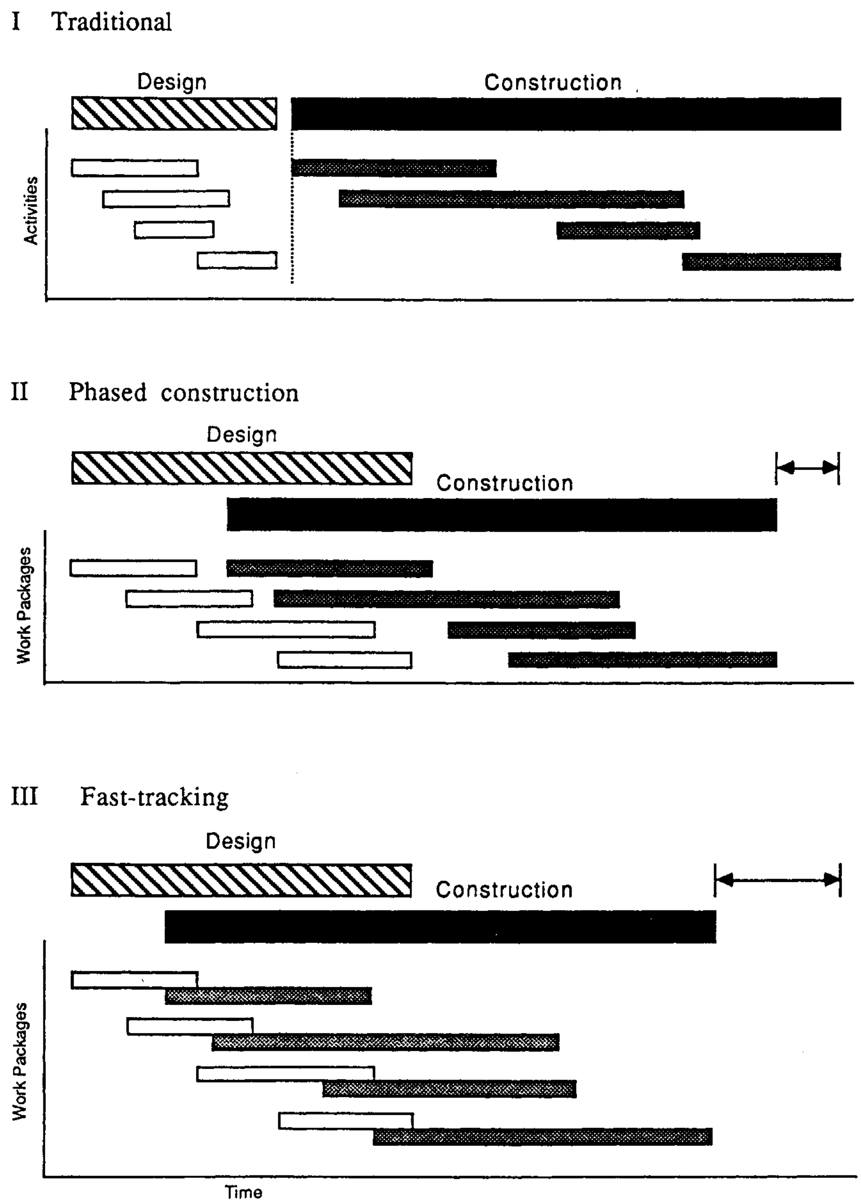

Fig. 1. Traditional, phased construction and fast-tracking approaches.

Phased construction and fast-tracking concepts are being used interchangeably in the literature and by construction professionals. Despite the similarities between the two approaches, the fast-track technique (which could be viewed as an 'accelerated phased construction' as shown in Fig. 1) requires considerably more attention in order to achieve successful project completion. Ruby (1978) and Sidwell (1983) pointed out two major challenges in fast-track construction: coordinating the construction work and providing subcontractors with the information they need for bidding. Clearly defined independent work packages are certainly important for both phased construction and fast-tracking (Schich, 1982), while the latter specifically stresses the need for a flexible design (Trombley, 1985). The importance of effective management during the design phase, stressed in several papers (Ruby, 1978; White, 1980; Schich, 1982), is certainly a prominent factor when fast-tracking a project.

This paper briefly outlines the differences between the fast-tracking technique and the phased construction approach. It further illustrates, through a project study, the impact of compressing and overlapping design activities in a fast-track programme in order to expedite project delivery. An in-depth delay analysis is presented to show the impact of fast-track-related problems on the construction duration. Finally, based on the project study presented in this paper and in reference to other fast-track projects which experienced difficulties, recommendations are made for the effective utilization of this accelerated technique.

Case study

The case study presented here illustrates the critical importance in timing of design activities, and its inevitable impact on overall planning and scheduling of construction work. Design difficulties in putting work packages together and associated construction delays were examined and assessed to reveal coordination problems when activities are overlapped. In the fast-track project examined here, a distinction is made between the contractor's delays, excusable but non-compensative delays, and fast-track delays directly or indirectly related to the approach. The project has been considered to identify typical risks and problem areas, generally encountered on fast-track projects.

In order to investigate the problem areas which have a potential impact on the performance of fast-track construction, an in-depth delay analysis has been performed by comparing the as-planned and as-built schedules. This is a well-established method, used by industry at large in preparing construction claims. This method has been used rather than that described in the work of White (1980), since the latter calls for a number of assumptions required to generate a hypothetical case which when compared with the original case can yield the delays encountered. For the effective utilization of the method selected, the investigation of a project which has experienced difficulties, illustrated by several construction claims, has been considered to depict problem areas associated with fast-tracking. The tight schedule of fast-tracking and the size of the project were considered helpful in identifying the coordination and scheduling problems.

The selected project is a typical fast-track construction of a large industrial plant in the United States with an estimated value of $100 million. The estimate includes all the procurement contracts, major construction packages, and 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 (see Fig. 2). Actually the construction period started 5 months behind schedule, and spanned $26\frac{1}{2}$ months. The plant finally went into operation after a construction delay of $10\frac{3}{4}$ months, extending the planned project duration by 40%.

Design and procurement

An experienced engineering firm took over the design development of the plant after significant preliminary work by the owner. Construction work was separated into several self-contained packages each awarded individually to a different contractor in a multiple prime arrangement. In this study critical work packages were examined in detail, with emphasis on the design phase.

Because of initial difficulties in obtaining the required vendor information and of complications with design coordination, drawings were not completed on time for the scheduled bid dates. As a result, the tendering of the main construction packages was postponed and compressed towards the end of the design period (see Fig. 2). This slippage in bid dates disturbed the original sequence of contract awards, and significantly affected the construction schedule.

Trying to meet the intended date of commercial production, the engineering consultant and the owner did not hesitate to reschedule activities, overlap work, and revise activity durations through compression or acceleration. At that time, planning and coordination of the work were severely affected by the fast-tracking approach adopted for the project. Five main packages have been examined for a schedule comparison of tendering period as illustrated in Fig. 3.

Even during tender periods a large number of drawings were revised, added, or deleted in several contract packages. In some cases up to seven addenda were issued. This resulted, for example, in a slippage of up to 6.5 months in the award of the structural steel package. The bid closing date of this package was delayed three times, 190 drawings were added, and 109 drawings were revised. These figures represent respectively 50% and 28% of the number of drawings on hand at bid opening. These last-minute revisions affected the accuracy of the bids and contributed to low productivity levels in the initial stage. The incomplete design resulted in a large number of drawing revisions being required after contract awards (see Fig. 3).

The civil design man-hours histogram and design packages bar chart presented in Fig. 4 clearly show the considerable amount of engineering design required after tender call and award of the contract packages. Typically, two to three more months after award (21% of the planned design duration) were needed to substantially complete the design.

For the civil work (Fig. 4), over 30% of the design man-hours were spent after award of the last contract package. Similar percentages were established for electrical and mechanical works, not shown here. Awarding civil, electrical, and mechanical work packages with incomplete contract drawings and specifications, has caused an important increase in total man-hours spent by the engineering firm to finalize the project design.

Construction and completion

According to the original schedule, the project completion date was 21 April 1980, including a construction duration of 21 months (see Fig. 2). The initial delay in design activities resulted in a late start of 5 months in construction. Through further fast-tracking

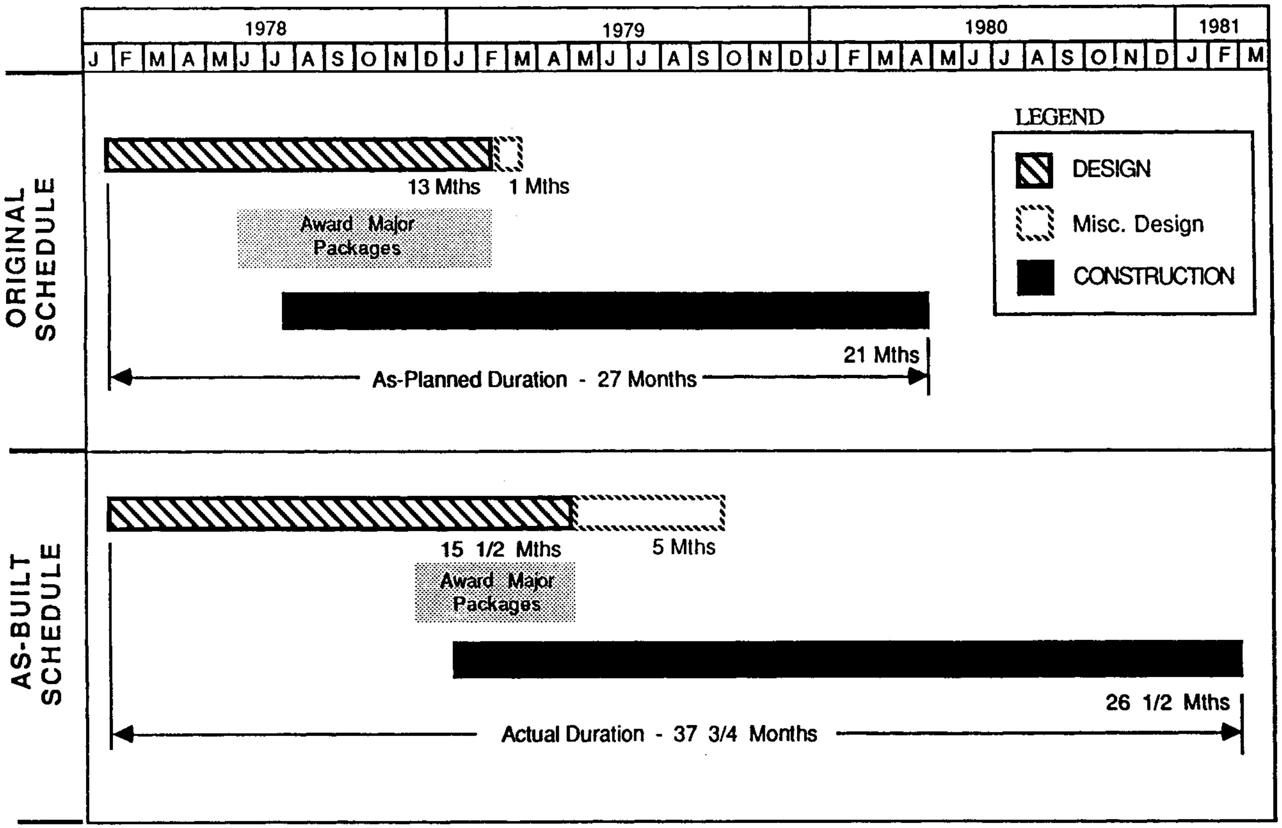

Fig. 2. Summary schedule comparison.

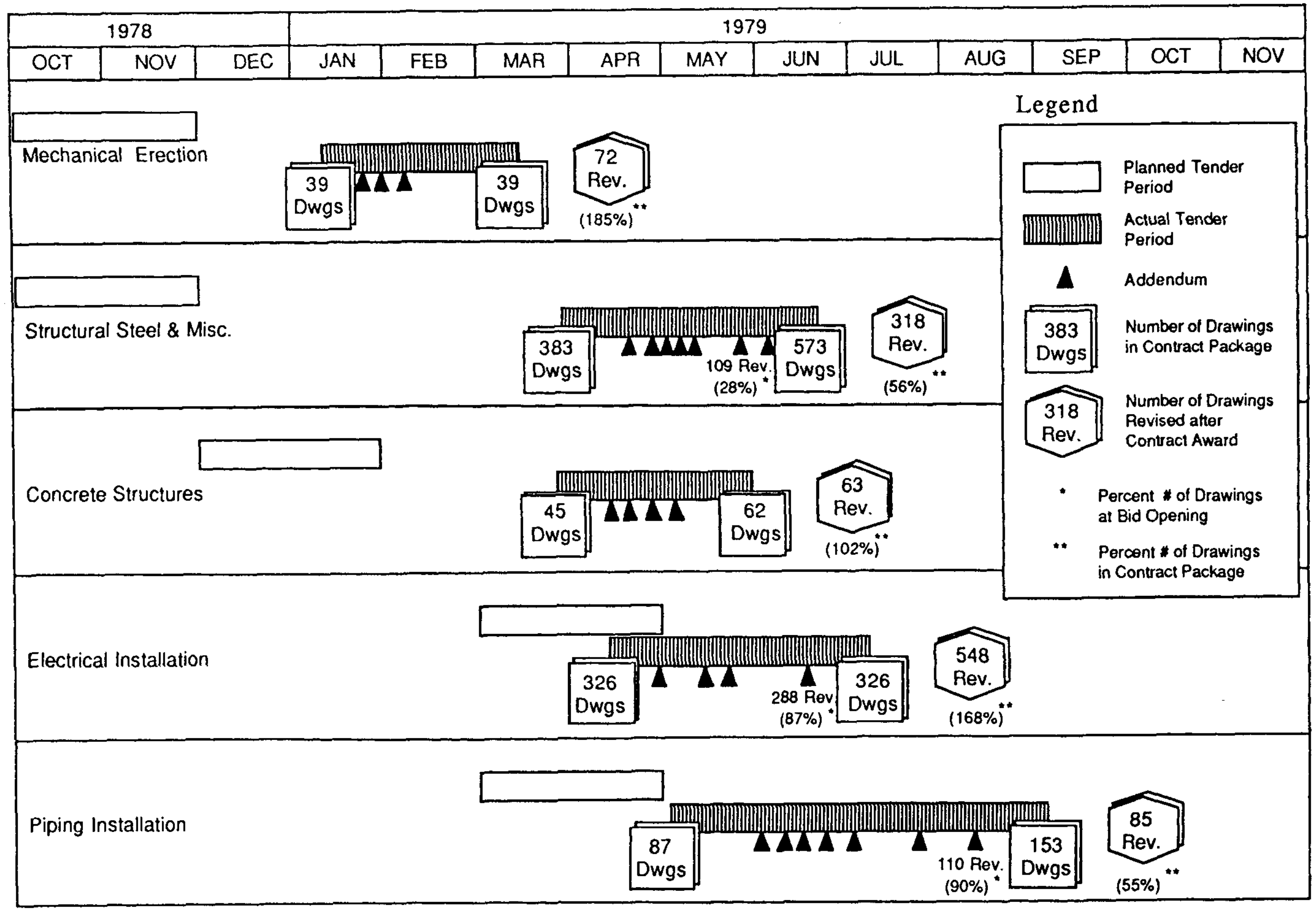

Fig. 3. Schedule comparison of tendering period.

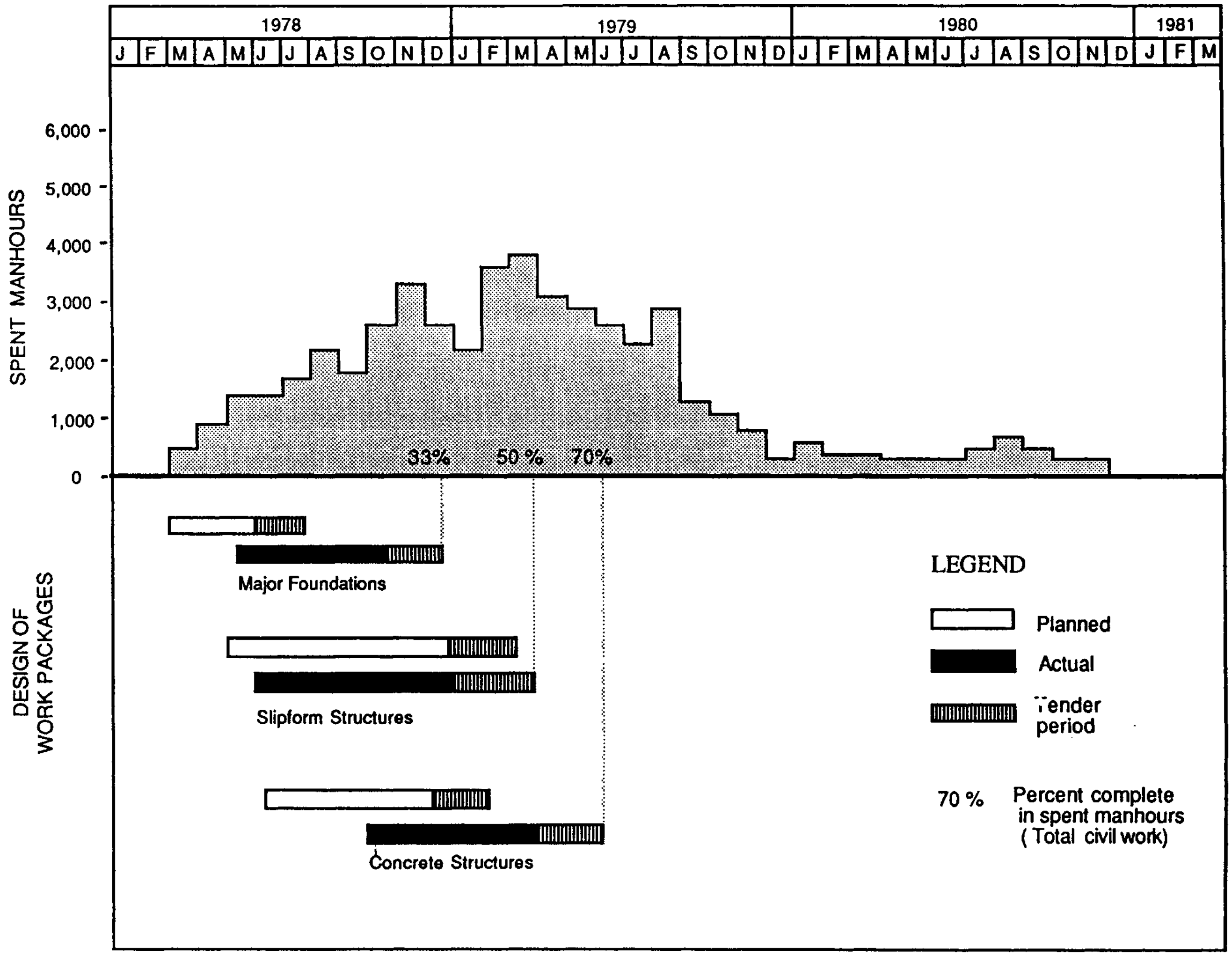

Fig. 4. Civil design man-hours and contract packages.

compression the owner and construction manager were able to reduce this delay to 1 month only.

However, during the construction period, the project suffered an additional $9\frac{3}{4}$ months' delay. This slippage occurred despite an acceleration in the work of both mechanical and electrical contractors through formal orders by the owner.

A detailed schedule analysis has been carried out on the critical activities of the whole project. In determining the critical path several schedule updates have been examined, each having somewhat different critical paths. It is through this 'snapshot' progression of the work that the cause and effect relationship of the delays has been identified. Individual delays have been examined and classified according to their origin.

Parallel critical paths were present throughout the construction period. In determining delays, several factors have been accounted for in order to ensure 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 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 construction start, design errors and omissions resulting from poor coordination between work packages, and design changes attributed to the accelerated approach. Individual delays directly and indirectly related to the fast-track concept have been identified and allocated according to the schedule analysis performed and with reference to claim reports of the project. Table 1 shows delays which have been linked directly to the fast-track approach.

Delays indirectly caused by fast-tracking include trade interferences, work disruptions and productivity losses. In a recent study commissioned by the Canadian Construction Industry Development Council (1984), the management of construction phase was ranked to be second or third out of seven factors impairing construction productivity. This factor would certainly become more pronounced in a fast-track construction due to the additional management effort required in the coordination of work packages and the design and construction overlapping phases. This is clear from Fig. 5 where 25 out of the 28 fast-track construction contracts analysed (Théberge, 1987) experienced inadequate scheduling pertaining to design/construction coordination. It has also been illustrated in the case study

Table 1. Direct fast-track delays.

Nature of delay	Days
Award of main electrical package	7
Additional steel	5
Elevator shaft interference	18
Additional steel	15
Design error – Interference	1
Electrical design changes	33.5
Revised burner system	22
Total	101.5

and in other studies (Linthicum, 1982) where it was pointed out that the construction manager has to exploit his management skills to a greater limit to integrate and coordinate design and construction overlapping.

Loss of labour productivity usually reflects the contractor's difficulty in planning adequately because of the numerous revisions of drawings and the required extra work. From the schedule analysis, individual delays resulting in productivity losses and disruptions have been summarized in Table 2.

In summary, on the project's critical path a total of 213.5 days out of the 324-day delay period can be attributed directly or indirectly to the fast-tracking approach; representing 66% of the total project delay. Two and three-quarters months were identified as excusable delays (rain, strikes, etc.), owner-caused delays and labour shortage. The total delay of 10.75 months (324 days) represents 40% of the planned project duration (10.75 out of 27 months), while the delay caused by fast-tracking amounts to 26%.

Summary

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

In light of the design difficulties and the data presented in Figs 2, 3 and 4, the impact stemming from drawing revisions can be grouped into: (1) delaying call for tenders, (2) extending the tender periods, (3) affecting the contractor's ability to plan and execute his work efficiently, and (4) additional work through change orders.

The above grouping illustrates the possible impact of compressing and overlapping design activities. As a result, the design effort for major contract packages in this plant spanned a period of 15.5 months instead of the 13 months specified in the contractual arrangement (see Fig. 2)

Table 2. Indirect fast-tracking delays.

Nature of delay	Days
Late start of platform erection	34
Loss of productivity	52
Fabrication errors and rework	26
Total delay	112

Table 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 (including manpower shortage and excusable delays)	84.5	2.75
Total project delay	324	10.75

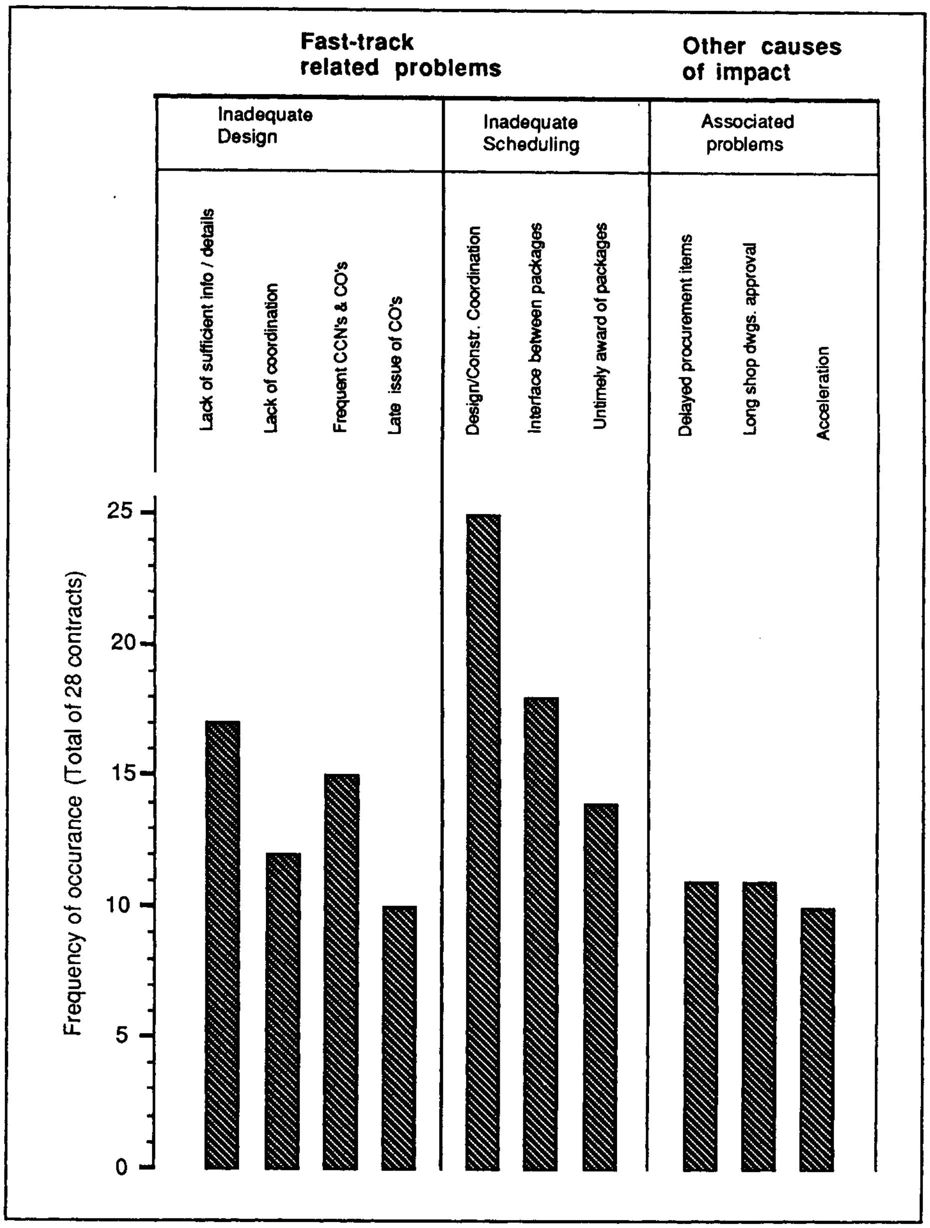

Fig. 5. Relative importance of fast-track-related problems.

The construction start was delayed because 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 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 extra rescheduling efforts required by project personnel to limit the consequences of this fast-track approach were overridden by the severity of the problems. Additional work and some rework are common in most construction projects, but in this case the fast-track approach seriously amplified the impact of those disruptions as evidenced by their frequency and severity (see Fig. 2). 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 workers.

On this particular project, 66% of the total delays were attributed directly or indirectly to fast-tracking. Spending only a couple more months (21% of planned design period) on the detailing of design packages before awarding the contract (refer to Fig. 4), would have eliminated a major portion of the fast-track-related delays (a maximum of 7 months in this case). Ideally, there would be far fewer design errors and omissions. Without the revisions and extra work and subsequent acceleration, the productivity loss could have been significantly reduced since the contractors would have had the information necessary for proper performance. Trade interferences would also have been reduced to a level where they would not impact the programme.

Observations and recommendations

As long as the uncertainty of inflation and high interest costs persists, schedule and cost benefits will continue to dictate the use of accelerated construction programmes. In theory shortening the construction period ought to result in lower financing risk and reduction of 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 characteristics of these projects may satisfy the following conditions:

(1) Financial considerations:
Important cost reductions and higher overall project profitability can be achieved by shortening the project duration.

(2) Project complexity:
It is advantageous to award separate early 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.

(4) Market conditions:
There are distinct advantages for industrial buildings to be in production while the competition is still designing or building. This condition is particularly important.

In light of the above study and other studies conducted on fast-track construction jobs which experienced difficulties with this approach (Théberge, 1987), trouble areas have been identified. Fast-tracking a project often results in unexpected extra costs and, as observed in this project, does not necessarily lead to a shorter project duration. For the approach to be profitable, particular attention must be paid to the following.

Design errors and omissions

Fast-tracking construction necessarily means a rearrangement in the design procedures and sequences. With this new approach, design work often ends up being done on a rushed basis. Inevitably accelerated drawings and specifications are often prepared hurriedly, leaving room for a greater margin of errors and omissions.

Design changes

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 design changes, at that stage, without causing delay and increased cost in the field. The increased intolerance of design changes imposes a stringent demand on the performance of design professionals.

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.

Coordination between work packages

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 would inevitably increase the problem of coordinating work between the various contractors in the field.

The above observations reinforce the statement that managing the interface between design and construction proves to be 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. Several recommendations may be made in an effort to reduce these risks.

Spend more effort during the design phase

The far-reaching effect of mistakes during the early design/engineering phase in a fast-track programme 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 package interface areas. Early in the design phase, decisions which will limit future flexibility in the design should be highlighted and their impact evaluated. 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.

Develop an effective design review system

The rushed delivery of drawings combined with an overlapping of work packages will contribute, 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. This precaution would ensure fast and effective review of drawings and would also provide a good interaction between design and on-site activities.

Increase information input from the field work

Proper timing in awarding different work packages is critical in fast-track construction. A package issued too late or too early might delay or interfere with another work package. Once construction has started, the award of subsequent work packages must be more sensitive to the ongoing 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 into the plans and specifications of the subsequent work packages. This can also considerably reduce revisions after contract award and minimize possible interferences.

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 'cooperation'. Contractors should be brought in 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 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 responsibility and authority. This would eliminate the adversarial conditions associated with conventional projects, avoid conflicts, and favour a better exchange of information through well-defined communication channels.

Conclusion

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 construction projects indicated that despite the apparent advantages, few projects lend themselves to a successful application of the fast-track approach. Adequate precautions must be taken with respect to the previously identified trouble areas, which are basically design-related, in order to reduce the overall project duration. The experience of the management team and the team's scale of priorities play an important role in applying the approach correctly. The project team has to be flexible and expeditious in response to complications stemming from a combination of incomplete designs, and from the overlapping of design and construction. Then, even with the high construction costs frequently associated with fast-tracking, overall project profitability could be achieved.

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