PLANNED SCHEDULE COMPRESSION CONCEPT FILE FOR ELECTRICAL CONTRACTORS

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ABSTRACT: Planned schedule compression can be thought of as a reduction of the normal experienced time or optimal time for the type and size project being considered. In contrast to other forms of schedule compression, planned schedule compression is anticipated and provisions are made before the start of the construction phase of the project. This paper presents the development of the planned schedule compression concept file for electrical contractors. Each concept attempts to provide a significant, distinct, and executable objective for enhancing the construction process and minimizing the impacts of schedule compression. Twenty-nine different concepts are presented, categorically subdivided into seven sections including the organization, materials, equipment and tools, information, labor, support services, and construction methods. Each of these concepts can be effectively used during planned schedule compression situations. Seven concepts, one each involving employee incentives, material handling, vendor performance, equipment and tools, constructability, setup crews, and construction methods, have been selected from the concept file and are presented in their entirety.

INTRODUCTION

The necessity for electrical contractors to complete a construction project in a shorter than customary time period is ever increasing. It is not uncommon for electrical contractors to find that they must compress a construction schedule to meet the very basic objectives of the project. One can argue that the necessity for schedule compression is due to a general change in the ideology of society as almost all aspects of life are demanded to move at a faster pace. Clearly, the reasons go far beyond this and are focused on many issues and constraints that are unique to each project. Because of this, electrical contractors, like all contractors, frequently encounter planned and/or unplanned schedule compression.

Schedule compression can be defined as "a reduction from the normal experienced time or optimal time typical for the type and size project being planned within a given set of circumstances" (CII 1990). Supplementing the broad dictionary definition, schedule compression can be thought of as the "squeezing" or "compaction" of the project schedule. Planned schedule compression is defined as schedule compression that was anticipated and planned for before the start of the construction phase of the facility delivery process. This is in contrast to unplanned schedule compression, which was not anticipated and planned for before the start of construction, and is a result of some form of unanticipated change to the originally planned construction schedule.

The nature of the electrical contracting industry is conducive to schedule compression situations. This can be attributed to the following reasons:

1. Electrical contractors often encounter unique scheduling situations, such as in outage work.
2. Delays caused by the general contractor and others are commonly passed on to the electrical contractors and other specialty trades.
3. Outdoor/transmission line electrical contractors typically work in remote areas in which schedule compression is used to minimize travel and accommodation expenses.
4. Many activities commonly completed by electrical contractors are able to be expedited in a compressed schedule that reduces the electrical contractor's overhead costs, especially for large electrical contractors.

The Construction Industry Institute (CII) lists the following as primary reasons to compress the schedule of a construction project (CII 1990):

1. Monetary considerations such as project financing, lost production during construction, or stockholder pressure.
2. The development of a new product or service by the owner organization that needs to get to market as soon as possible due to rising loss-of-opportunity costs.
3. The planning and design phases of the project delivery cycle have fallen behind the required schedule, forcing the construction phase to make up the lost time.

Planned schedule compression for the electrical contractor can also be introduced to a project for the following reasons (Noyce 1995):

1. The owner or electrical contractor requires that the proposed project be completed in a less than normal time frame.
2. Anticipated weather conditions limit the available time for construction, especially for outdoor/transmission work.
3. There are seasonal construction considerations in many parts of the country.
4. Planned utility work requires that the outage to customers be minimized.
5. To minimize the shut-down time to plant operations during maintenance work.
6. To increase contractor's total annual work volume by completing more project within a given time frame.
7. To obtain an incentive or award.
8. To reduce supervision and accommodation costs incurred by traveling contractors by reducing or compressing the schedule.

In spite of these reasons, the project integrity, as originally intended by the project stakeholders, must be maintained.

When planned schedule compression is encountered, project management is faced with the task of selecting a construction method that minimizes the cost and time impacts to the

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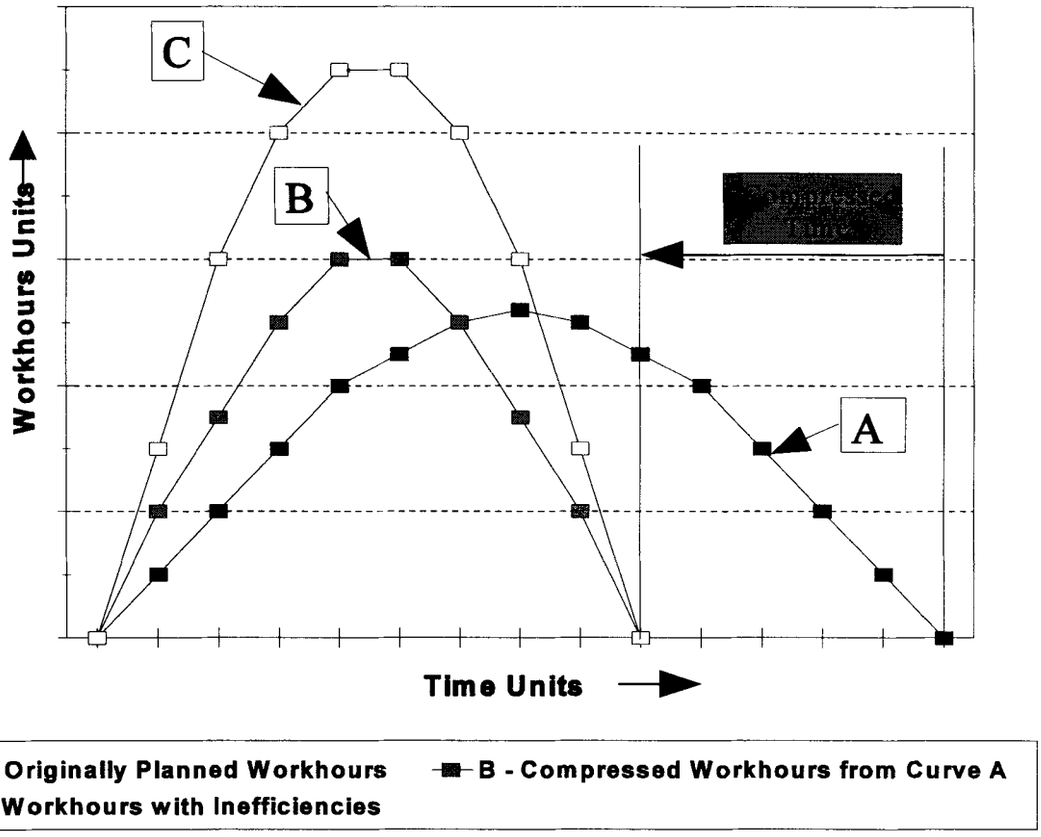

FIG. 1. Effect of Schedule Compression on Time and Workhours (Heather 1989)

project. Work must be completed at a rate greater than what is considered to be normal which leads to inefficiencies and higher than anticipated construction costs to the contractor. Fig. 1 depicts the increasing cost effect of schedule compression in terms of increased workhours. As can be observed, it is likely that both the number and the intensity of work hours will increase. To achieve an economical project compression, the selected method must make effective use of surplus resources and minimize the impact to other components of the project schedule. The most effective and economical way to achieve these requirements must be determined.

This paper presents the development of the planned schedule compression concept file for electrical contractors involved in residential, commercial, industrial, and transmission/line work. The concept file is intended to provide the electrical contractor with methods and concepts that can be employed in a planned compressed schedule situation to minimize the potential for increased costs. Many of the ideas presented are also applicable to other construction trades.

Problem Statement

CII has produced a practical and usable catalog of concepts and methods effectively used in industry to compress a schedule and assist a contractor in analyzing project needs during planned schedule compression. However, the appropriate use of the concepts applicable to the electrical contractor, as well as its associated cost implications, are not presented. There is a need to go beyond this by doing the following:

1. Providing electrical contractors with information about how to effectively compress a schedule
2. Assisting electrical contractors in selecting the best concepts and methods available
3. Minimizing the potential losses in labor productivity and increased project costs

The electrical contractor also needs to make use of data and experiences from other electrical contractors. He or she must understand the applicable resource constraints and apply the appropriate management decisions and associated external factors in the selection of the schedule compression approach or technique that produces the desired outcome. The appropriate decision and method of schedule compression selected by the electrical contractor should be closely correlated to the given set of circumstances and constraints, and minimize the potential of financial losses.

OBJECTIVES

The primary objective of this research is to identify and develop planned schedule compression techniques, in the form of a concept file, that depicts necessary information and can be effectively used in handling organizational issues, labor, materials, equipment, tools, support services, and construction methods while minimizing the impacts to labor productivity. A concept can be considered as a significant, distinct, and executable objective for enhancing construction efforts during schedule compression, abstracted from the analysis of ideas (O'Connor et al. 1987). The concept file should provide alternative response methods for planned schedule compression situations and provide electrical contractors with detailed information about schedule compression techniques.

BACKGROUND

To compress a project schedule, the contractor can implement any of a number of methodologies. The most commonly used methods include scheduled overtime, bringing on additional workers (overstaffing), and implementing a second or third shift. There are, however, many other methods or concepts that a contractor can employ throughout the duration of the project. Regardless of which concept is employed in a

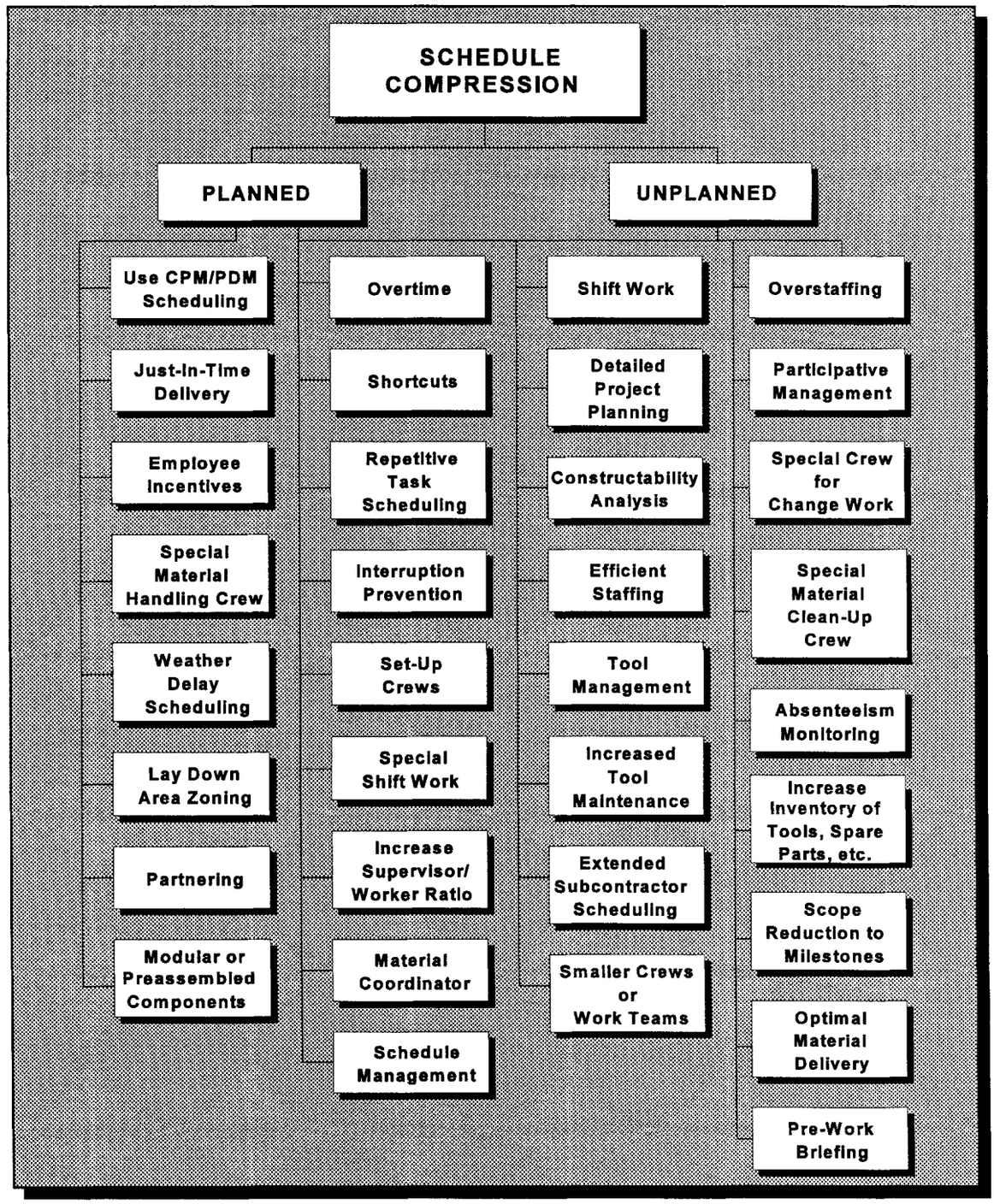

FIG. 2. Schedule Compression Concepts and Methods

planned or unplanned compression situation, the contractor must find a way to increase productive time and, in this way, reduce the project schedule.

Schedule compression is commonly regarded as a time-cost trade-off problem, with the trade-off between the amount of compression and the consequent increase in direct costs due to schedule compression (Yau et al. 1990). This has focused much of the literature written on schedule compression on the applied mathematical methods and optimization components of the problem, in a planned context. Many heuristic methods and models have been developed as a means of mathematically compressing individual activities of a project schedule (Yau et al. 1990; Ritchie 1990; Ritchie 1985; Vrat et al. 1986; Perera 1980; Perera 1982; Coskunoglu 1984; Moselhi 1993; Senouci et al. 1995). The methods and models focus on "crashing" a project schedule, which means reducing the project schedule to the fully expedited or minimum activity durations that are technically possible.

The only significant literature found on planned or unplanned schedule compression applicable to this investigation is the CII publication on schedule compression (CII 1990). CII has identified 94 concepts and methods of compressing or accelerating a schedule applicable throughout all phases of the facility delivery cycle. In some cases, the concepts and methods presented are essentially emergency techniques that are most commonly considered only when the advantages (or ne-

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cessity) of reducing the schedule outweigh the potential drawbacks of implementation. This is quite often the case in unplanned schedule compression situations. In other cases, the concepts and methods provide an ingenious and unique way not commonly thought of by most contractors to minimize the impacts of a compressed schedule, such as a better utilization of resources. Still other concepts and methods can be thought of as standard business practices and applicable to every project.

Fig. 2 contains 34 concepts and methods that were determined too most directly apply to the construction phase of electrical construction. These concepts were derived, either directly or indirectly, from the 94 concepts presented by CII (CII 1990). The concepts were then associated with either planned or unplanned schedule compression, based on their attributes and potential effectiveness in each situation. All 34 concepts identified were determined to be applicable to planned schedule compression and provided an initial set of concepts to be explored and evaluated as part of the research investigation. Twenty-six of these same concepts were also considered to be applicable to unplanned schedule compression situations and described elsewhere (Noyce 1995).

METHODOLOGY

Twenty-three separate interviews were conducted with management personnel of National Electrical Contractors Association (NECA) member electrical contractors throughout the United States. These participants included residential, commercial, industrial and manufacturing, and outdoor/transmission line electrical contractors. The primary objective of the interview process was to determine the electrical contractor's experience with planned schedule compression. Discourse was initiated during the interview process to determine the electrical contractor's familiarity with the 34 concepts initially selected, if they did or did not use any of the concepts, or if there were other concepts not included that may be applicable to planned schedule compression situations. Essentially, it was an attempt to confirm and/or validate the 34 concepts initially selected by the writers. The information obtained from the interviews was used to form the database necessary for the development of a questionnaire survey. The questionnaire survey was sent to 1,250 randomly selected NECA members. Two forms of the questionnaire survey were developed; one pertaining to unplanned schedule compression and the other pertaining to planned schedule compression. The survey forms were essentially identical except for the exchange of the word unplanned for planned at the appropriate locations.

The surveys provided the initial list of concepts for the respondent to evaluate, and provided ample space for the respondent to add other concepts or methods that he or she currently used. Of the 1,250 surveys sent, 625 were of the planned schedule compression form. A total of 72 electrical contractors returned the plan form of the questionnaire survey, yielding a response rate of 11.5%. A detailed description of the survey methods, questions, responses, statistical analysis, and results is provided elsewhere (Noyce 1995).

A number of electrical contractors were contacted and asked to submit examples of successful and unsuccessful concepts and methodologies employed in a planned compressed schedule situation. This was an attempt to quantify the concept effects in terms of the impact on labor productivity. Although a number of very detailed project data sources were received, the impacts of planned schedule compression methods were in all cases confounded with other factors such that the actual cost impact on labor productivity could not be determined. Thus, it was impossible to determine the cost of a specific amount of schedule compression or the cost of implementing a specific concept. Related information that could be derived from the analysis of project data was incorporated into the concept file database.

SCHEDULE COMPRESSION CONCEPT FILE

The concept file provides the initial step in fulfilling the needs identified in the problem statement. The initial list of 34 concepts, identified as applicable to planned schedule compression situations, was reduced to 28 based on the results of the interview and questionnaire survey investigation. The six concepts eliminated were determined through the investigation process to be either worthy of a standard alone document (partnering), a subset of another concept (increased tool maintenance, special crew for change work, optimal material delivery, smaller crews or work teams), or more appropriately applied to unplanned schedule compression situations (absenteeism monitoring). A concept related to improving vendor performance and the associated vendor management system was not included in the initial list but was identified during the interview process and added to the concept file. Thus, a total of 29 concepts was presented.

The development and results of the concept file for planned schedule compression were categorized into seven project areas including the organization, materials, equipment and tools, information, labor, support services, and construction methods. Table 1 provides a complete list of the concepts contained in the planned schedule compression concept file. The presentation format of each concept within each project area comprises seven sections: (1) description; (2) additional details; (3) when to apply; (4) conditions for successful application; (5) cautions; (6) cost implications; and (7) illustrations and examples.

TABLE 1. Concepts Included in Planned Schedule Compression Concept File

Project category (1)	Concept (2)
Organization	Provide employees with incentives
	Staff the project with the most efficient crews
	Avoid interrupting crews during peak productivity times
	Provide proactive schedule management during compression periods
	Participative management
	Detailed project planning
	Reduction of task scope to milestone activities
	Increase the supervisor to worker ratio
	Use CPM scheduling techniques for project control
	Include anticipated weather delays in work schedule
Materials	Employ a just-in-time material delivery plan
	Establish a special material handling crew for the project
	Establish a special material cleanup crew for the project
	Assign a material coordinator to the project
	Establish a clear zone in the material lay-down area
	Improve vendor performance by establishing a vendor management
Equipment and tools	Develop a project tool management program
	Increase the inventory of spare parts, tools, and so on
Information	Complete a constructability analysis of the plans prior to construction
Labor	Place the crew on overtime
	Add additional staff to the project
	Add a second shift
	Change to special shifts
Support services	Use a setup crew
Construction methods	Schedule tasks in repetition
	Create more detailed subcontractor schedules
	Look for short cuts in the process
	Plan for and use modular and preassembled components
	Brief the crew prior to work operations

The first six sections were primarily derived from the results of this investigation. The illustrations and examples provide citations from the literature that directly applied to concept and include related information obtained from electrical contractors through the questionnaire survey process.

As previously discussed, the results of this investigation did not provide quantifiable cost data that would show the potential saving related to the implementation of a specific concept or how much a construction schedule could be compressed for a given cost. Clearly, these values are quite variable and would likely differ for each project and each electrical contractor. The cost implications section of the concept file is intended to provide the electrical contractor with methods and ideas that can be used to improve the cost performance of the specific concept implemented.

To provide the reader with an example of the contents of the planned schedule compression concept file, the following section presents seven concept files in their entirety. Due to the large size of the concept file document, it is impossible to present all of the 29 concepts identified. The concepts selected are concepts that were shown to be very effective in planned schedule compression situations and may not be as commonly thought of or as well understood as some of the other concepts. These concepts were not selected because they were perceived to be any more or less significant than the other 22 concepts for a given planned schedule compression situation. At least one concept file has been selected from each of the categories listed except for concepts related to labor. Labor concepts have been documented in the literature and are generally well understood. The following concept files are presented:

1. Provide employees with incentives
2. Establish a special material handling crew for the project
3. Improve vendor performance by establishing a vendor management system
4. Increase the inventory of spare parts, tools, and so on
5. Complete a constructability analysis of the plans prior to construction
6. Use a setup crew
7. Look for short cuts in the process

Provide Employees with Incentives

Description

This concept is developed around the idea that incentives have proven to motivate stronger performance in work crews if fairly administered. Incentives range from pats on the back to letters, lunches, and/or significant cash bonuses. Incentives can also be used with suppliers and vendors. Incentives based on difficult but attainable goals may increase worker performance.

Additional Details

Work groups tend to develop performance norms that are related to performance incentives they face individually and collectively.

The most common types of incentive programs provide cash rewards or the availability of additional work hours if goals, such as a predetermined productivity level, are achieved. This allows the crew members to increase their number of hours worked and thus increase their weekly income. Financial incentive programs are commonly used in European countries with successful results (see *Illustrations and Examples*).

When to Apply

Incentives can be applied in both short-term and long-term schedule compressions when the achievement of specific goals are essential to the success of the project.

Conditions for Successful Application

- The crew foreman must believe in the benefit of the incentive provided to him or her and the crew. The foreman must motivate the crew members to meet the prescribed goals to achieve the incentive.
- The incentive program must be easy to understand and measure performance on a crew basis. The program should be implemented at the beginning of a project.
- Crew members should be involved in the initial design of the incentive program if at all possible.
- The reward should be tied to several performance criteria. Specifically, the program should heed quality and safety as well as productivity.
- Performance should be measured over a short time duration, usually on a weekly basis, and the awards should be distributed accordingly.
- Hourly base rates must be guaranteed and the goals should not be altered during the course of the incentive program without mutual consent.
- Crew members must desire the incentive being offered.
- The incentive program should be extended to as many of the crews on the project as possible.
- The incentive pay should be in direct proportion to the increased output (savings should be shared with the workers).
- The incentive scheme should be self-financing.
- Open communication must exist between the foreman and project management as well as the foreman and craft persons. Expectations must be clearly understood and feedback from all individuals encouraged.

Cautions

- Some crew members may not be motivated by nonincome producing incentives.
- Incentive programs are much more difficult to administer when some or all of the crew members are hired from the union hall and are not permanent employees of the electrical contractor.
- What might be a successful incentive program for one electrical contractor may, for an array of reasons, be an ineffective program for another.
- The effectiveness of the incentive program depends on such factors as the size of the electrical contractor, the type of work being performed, the organizational climate, and many other potential factors.
- Crews tend to develop performance norms that are related to the performance incentives they are faced with individually and collectively. If the electrical contractor provides no incentives for individual or group performance, then work crews tend to establish lower standards of performance for the group as a whole.
- Rewards that are valued by the workers must be based upon the crew's performance. High performers must receive more rewards than low performers.

Cost Implications

- The incentive programs will require additional management time in administering the program and collecting the data required to determine if the goals are achieved.
- The cost of the incentive for the crews is most often offset by the savings made in having the crew meet the goal.
- In some cases, the additional opportunities and/or profits achieved far outweigh the incentives provided. This makes incentives a more desirable concept for both the electrical contractor and the crew members.

- The electrical contractor should also consider the other hidden benefits and associated costs of the incentives such as improved employee morale, improved customer satisfaction, more repeat business, and more cohesive and productive work crews.
- Monitoring the incentive program will produce significant data useful to the electrical contractor. This information may benefit the electrical contractor in future planning and bidding situations; however, the contractor may subsequently need to revise the incentive program based on bidding margins.

Illustrations and Examples

One electrical contractor reported the use of overtime as an incentive/bonus for their crews. If the crew meets predetermined productivity goals, the crew is allowed to work up to 10 hours per week of overtime. The amount of overtime the crew works, up to the maximum allowed, is their decision. The incentive lies with the additional income achieved in the overtime hours and the freedom to choose when and how much overtime to take. The electrical contractor benefits from this incentive program by motivating workers to exceed planned productivity rates, and when this happens, also receiving productive work completion during the bonus hours of overtime. The program has proven to be an effective motivator and cost effective for the electrical contractor (Doll, personal communication, 1994). Other examples of incentive programs are more limited, such as providing gift certificates and/or cash bonuses to foremen only for meeting production goals and milestone dates. This motivates foremen to maximize the profitability of the project such that they can share in the returns.

A number of studies highlight the success exhibited in the construction industry of certain foreign countries when financial incentive programs were employed (Entwistle et al. 1958; Great Britain Department of the Environment 1974; Advisory Service for the Building Industry 1969; Marriott 1961). Laufer and Borcherding (1981), in a study on incentives associated within the U.S. construction industry, indicated that "financial incentive programs for the construction industry labor force is not only feasible, but that they would also materially raise productivity, lower production costs, shorten construction time, and increase the earnings of workers." Laufer and Moore (1983) provide additional discussion and results of attitudes toward productivity related incentive programs.

Establish a Special Material Handling Crew for Project

Description

This concept requires a special crew or shift to assemble and deliver required materials to the work areas for use by the production shifts. This allows the production shifts and crews to begin work immediately on a specific task and not lose time in locating and assembling required material.

Additional Details

Material is generally required at a faster rate during schedule compression situations. Material should be delivered only in short duration quantities since changes are likely during schedule compression. Excess material on the project site will lead to double handling of the material and additional costs. All bundled and palletized materials should be clearly marked and include an itemized inventory for the foreman.

This concept should lead to better organization of storage areas, minimizing the multiple handling of materials and improving material sorting and marking.

When to Apply

This concept is applicable under any project situation.

Conditions for Successful Applications

- A well planned location for material storage that is safe and clean must exist on the project site.
- Communication between the warehouse or material supplier and the project site must be constant such that materials are delivered consistent with the needs of the production crews.
- Containerized material packaging provides an excellent means of delivering and storing the materials needed for specific tasks.
- Access to the site must be available during nighttime and weekend hours for delivery.
- Careful planning of logistics is important to the success of this concept.

Cautions

- This concept will commonly require nighttime and weekend work for material packaging to keep pace with the production crews on the project.
- Communication is essential to avoid material handling problems.

Cost Implications

- There will be an additional cost in adding the material handling crew and will probably require overtime work to maintain the required material delivery schedule.
- The cost of material loss, due to theft and on-site mishaps, can be reduced due to the increased awareness in material management and on-time delivery.
- These costs should be offset by the productivity improvements of the crews and the reduction in material handling costs on the project site.

Illustrations and Examples

A survey of NECA member contractors concurred with the items listed under cost implications (Noyce 1995). Establishing a special material handling crew was reported to increase project costs, most often due to additional labor and overtime costs, while simultaneously reducing material loss and improving the projects overall labor productivity.

Studies by Muehlhausen (1991), Thomas et al. (1989), Bell et al. (1987), and Borcherding et al. (1980) have shown that as much as 40% of a crew member's productive time can be idle or nonproductive because materials are unavailable.

Improve Vendor Performance by Establishing a Vendor Management System

Description

This concept involves the development of a vendor management system. This includes meeting and working with project vendors, on both an informal and formal basis, in an effort to gain their commitment to optimum performance on the project. Vendor commitment means that their on-time delivery record is maintained at 100%, quality of materials is maintained, financing and transportation costs are minimized, and the vendor provides the lowest cost possible.

Additional Details

Vendor performance has been observed to be a problem on many projects. Most projects find that on-time vendor delivery

records are less than 100%. In fact, some electrical contractors have reported that vendors were meeting promised delivery dates less than half the time. When vendor performance deteriorates, the potential for achieving benefits in the area of improved labor productivity, reduced material surplus, and reduced management manpower decreases accordingly. Vendor performance can be improved by including vendors in project preplanning and planning meetings as well as in partnering agreements.

When to Apply

The relationships with vendors must be established before the project begins. Once the relationship is established, it will carry from project to project.

Conditions for Successful Application

- Management must be committed to working with the vendors to improve performance.
- Once a successful relationship is established with a vendor, it must be maintained unless performance deteriorates.
- This commitment to the vendor must be made clear before the contractor can expect that the vendor will meet the goals of the vendor management system.

Cautions

- Selecting a vendor based on a low bid without establishing a relationship or reviewing his or her performance record can lead to cost increases associated with late deliveries and poor quality.
- Breaking a relationship established with a vendor for no justified reason can lead to unfavorable vendor performance in the future.

Cost Implications

- A vendor management program can reduce the number of expediting personnel required, reducing labor costs.
- Additional management time and costs will be incurred in meeting with each vendor and developing the commitments before each project.
- The material costs with established vendors may be slightly more. However, this cost will be greatly outweighed by the cost savings involved with on-time deliveries, quality materials, reduced uncertainty, and tighter bidding margins.
- The use of computer generated spreadsheets listing all bid items for vendor quotations can reduce material costs.

Illustrations and Examples

Bell and Stukhart (1987) reported that a contractor who uses a vendor management system had three out of four of his vendors maintaining a 100% on-time delivery schedule. The success was due to a formal rating program that included an annual meeting with the vendor. This management system allowed this contractor to cut his expediting staff in half. This contractor also found that he saved up to 10% over low-bid quotations through a formal "purchase improvements and savings program." The contractor works closely with vendors to explore alternative specifications, alternative financing, improved transportation methods, award combinations, and other scenarios that reduce costs without penalizing the vendor.

Other contractors attribute good success with vendors to an increased emphasis on carefully written vendor contracts (Bell and Stukhart 1987). Liquidated damages that are imposed on the contractor are passed along to the vendor whenever possible.

Increase Inventory of Spare Parts, Tools, and so on

Description

This concept involves increasing inventories to keep pace with accelerated maintenance and repair efforts. The absence of spare parts or tools necessary to complete the work effort can bring the project to a halt, destroying the planned productivity goals of the project.

Additional Details

The electrical contractor must evaluate the tool and equipment needs for the entire project to assure that the parts are present. The tendency is to look only at current needs and omit a review of future needs.

When to Apply

This concept can be applied to any project in all situations.

Conditions for Successful Application

- An inventory storage area for the tools and parts must be available.
- The contractor may work with local suppliers in developing proactive way of improving and storing inventory stock.

Caution

- The volume of parts and tools on hand may become excessive on a large project.
- The additional inventory will require proactive management techniques to maintain organization.

Cost Implications

- Additional up-front costs will be required to develop and maintain the tool and part inventory.
- Storage space will be required for this material.

Illustrations and Examples

In a survey of NECA member contractors, this concept was shown to improve the labor productivity of the project without affecting project costs (Noyce 1995). This increase in productivity was reportedly due to a reduction in down time waiting for new or replacement tools.

Complete a Constructability Analysis of Plans Prior to Construction

Description

This concept provides a review of the engineering design prior to initiation of construction activities by experienced construction personnel. This will insure that the design approach promotes the most expeditious and cost-effective methods of construction.

Additional Details

Requests for additional information, plan errors, requested changes, and specification questions should be resolved prior to the start of construction. Any changes to the plans should be coordinated with the project management. Plan changes during construction have been shown to be a major contributor

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to project delay. The original design can often be improved from the perspective of construction efficiency at no cost to the project.

Constructability analysis is especially important on fast-track projects and compressed schedule projects where new design information is not completed at the time of contracting. Scheduled constructability review dates should be determined.

When to Apply

This concept is applicable to all projects. This concept may be more difficult on fast-track projects where little time exists between the completion of the design plans and the start of construction.

Conditions for Successful Application

- Design engineers and project management must be willing to work with the electrical contractor's staff in this process.
- Time between plan completion and start of construction must be enough to complete this process.

Cautions

- Coordination with the other trades is required when plan changes are made.
- Adversarial relationships can develop between the engineer and electrical contractor during the constructability review, especially if changes are recommended.
- The time available to complete the constructability analysis may be very limited.

Cost Implications

- The application of this technique can reduce delays and interruptions when plans and specifications are clearly understood and have been reviewed for errors and nonconstructable components.

Illustrations and Examples

Numerous examples of the effective use of constructability programs have been documented (CII 1993). One of the examples cited involved of a project where a constructability coordinator was appointed. Design and construction was coordinated both for ease of construction and for timely release of drawings. The net cost of the constructability program was estimated to be approximately $32,000 while estimated savings during construction were approximately $340,000. The constructability program represented a 10 to 1 benefit-to-cost ratio for the project.

Laufer and Cohenca (1990) report that incomplete design has been shown to be one of the most frequent items identified by managers of the largest construction organizations as the primary source of schedule delay.

Electrical contractors have reported the successful use of partnering concepts to overcome the potential adverse relationships that develop between the contractor and engineer when contractors review plans prior to construction. The savings, benefits, and liabilities are shared among the partnered organizations such that everyone benefits from the improvements.

Use a Setup Crew

Description

This concept involves the use of a reduced sized specialty crew, working on a second shift or weekend hours basis, to setup critical tasks for the full crew on the following work day.

Additional Details

Setup crews can be used for special tasks to maintain project continuity. Setup crews can also be used effectively on a second shift to setup the activities for the full production crews on the following work day.

When to Apply

Setup crews are suited for short-term accelerations and compressions; for specialized tasks such as material deliveries, change work, and cleanup; and also for projects where extensive scaffolding or other specialized equipment is needed.

Conditions for Successful Application

- Best used when project tasks can be broken out into definable, short duration subtasks.
- Allows the highly skilled full crew to maintain the highest levels of productivity possible on the critical path by having others complete the setup work.

Cautions

- The setup crew must have a full understanding of the work and what needs to be completed.
- If setup work is completed improperly, additional labor hours are lost in rework.

Cost Implications

- Productivity in setup crews tends to improve since this work is generally completed after hours and on weekends when there is little congestion and few interruptions while others are not working.
- Setup crews can include apprentices and journeymen at lower rates such that the average crew rate is approximately equivalent to the normal crew rates even with the overtime premium hours.
- The use of setup crews can add costs to the project if the setup crew does not complete the required tasks on time or completes the required tasks improperly. This will lead to nonproductive (delay) and rework activities for the full crew.

Illustrations and Examples

The setup crew concept can be used as a bonus type operation (Noyce 1995). Workers tend to want overtime on occasion for the extra income. This incentive tends to counteract the anticipated loss of productivity with overtime. The electrical contractor can rotate electricians into the setup crews, which will improve productivity and increase employee moral.

A survey of NECA member contractors found that the use of setup crews was a sparsely used concept as less than 32% of the respondents indicated that they had used setup crews (Noyce 1995). The respondents who used setup crews reported an increase in the projects overall level of labor productivity by using this concept. This concept may be even more effective in unplanned schedule compression or acceleration situations.

Look for Short Cuts in Process

Description

This concept involves the evaluation of activities and review of precedence relationships. Natural precedence relationships

are unalterable, however, other relationships may provide for ways to reduce the number of steps in an activity.

Additional Details

Typical shortcuts include selecting alternate materials that may be obtained more quickly and are easier to install, reducing the level of design detail to expedite bid packages, selecting components based on delivery time instead of the specifications, reducing equipment test time, limiting procurements to one source, and waiving the owner approval process.

When to Apply

This concept should be common operating procedure for all electrical contractors. This concept can be applied on compressed schedule projects where creative methods of expediting the construction process are required.

Conditions for Successful Application

- The owner, architect, and engineer of the project must be willing to work with the contractor and accept alternate plans outside the original project scope.
- The project owner or representative must have confidence in the work and the shortcut recommendations of the contractor.

Cautions

- Schedule alterations need to be evaluated for incremental cost increases and additional risk.
- Selecting inferior materials may lead to maintenance problems in the future.

Cost Implications

- The material costs will likely increase due to premiums paid for alternate materials. However, the length of construction time will be reduced, decreasing direct costs.

Illustrations and Examples

In a survey of NECA member contractors, this concept was identified as one of the most effective methods of reducing project costs, reducing the schedule duration, and maintaining labor productivity (Noyce 1995).

CONCLUSIONS

This paper presented the background and development of the planned schedule compression concept file for electrical contractors. These concepts provide additional information to the electrical contractor and identify ways in which the impacts of compressed schedule situations can be minimized. An understanding of the most appropriate concepts and methods to implement in a planned or unplanned compressed schedule situation can mean the difference between financial success or financial failure for the electrical contractor.

This research was conducted to determine which concepts and methods of schedule compression provide the least impact to labor productivity. By collecting data through the various methods described, this investigation combined technical information with electrical contractor experiences and has led to a series of concepts and methods that will aid an electrical contractor in minimizing the financial impact of a planned compressed schedule situation. Additional research is required to quantify the effects of planned schedule compression.

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