Productivity Improvement Tool: Camcorders

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Abstract: This paper describes the use of a video camera for improving productivity on construction projects. The paper presents a step-by-step procedure for the use of the camcorder technique from purchasing the equipment to implementation of productivity improvement program. A case study is presented where a camcorder system was used as a management tool to improve labor productivity during the construction of a state prison. Data were collected for selected major work items including precast units, tilt-up panels, and preengineered metal buildings. The use of camcorders resulted in measurable benefits to the project in terms of improving communication between management and labor, identifying the reasons for productivity problems, and providing irrefutable records of construction activities for training, safety, performance evaluation, and possible legal disputes.

Introduction

Construction productivity has been declining steadily in the last few decades. Along with this decline, the cost of construction labor has been continuously rising. Failure to improve productivity to match the increasing labor wages has pushed construction costs 50% over the inflation rate (Tucker 1986). The complexity of today's projects and the competitiveness of the market have forced the construction industry to study the causes of productivity decline and to search for methods to improve it.

The objective of this paper is to demonstrate the use and benefits of a fairly new technology, camcorders, that has the potential for improving construction productivity. Camcorder is the generic name for video camera recorders (VCR). This study focuses on the application of camcorders to improve site operations and labor productivity on construction projects.

Reasons for Productivity Decline

Productivity improvement has been a challenging task to many researchers and practitioners since the midcentury (Asher 1956; McNally and Havers 1967). The subject has been studied from the viewpoint of human motivation (Jones 1964; Kahn and Katz 1965; Schrader 1972; Samelson and Borcherding 1980), job satisfaction (Borcherding and Oglesby 1974), learning curves (Thomas et al. 1986; Sprinkle 1972), and impact of management on labor productivity (Logcher and Collins 1978). However, the large number of factors involved made the task of increasing construction productivity difficult and created a need for more research.

A comprehensive discussion of the reasons for productivity decline was presented recently by Tucker (1986). In his paper, Tucker suggested the following causes for this decline:

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J. Constr. Eng. Manage., 1990, 116(1): 100-111

1. The drastic increase of communication channels in today's large projects along with the lack of simple reporting methods and clear communication procedures especially at the craft level.

2. The lack of fast feedback systems to accompany the growing tendency toward "fast-track" projects.

3. The increasing percentage of time that management spends in obtaining field data and writing reports that all detract from the attention that could be devoted to actually managing the project.

4. The need for establishing strong "project-team attitude" involving a wide variety of participants to jointly address significant project issues.

5. Overlooking the possible improvement of site operations during construction.

It is apparent that all these factors are under the control of project management teams. The writers believe that camcorders can provide a management tool that directly addresses the causes of productivity decline. Recommendations for the use of the camcorder technique are described in the first part of this paper, and the benefits of using this technique are presented in the latter part through a case study.

Camcorder Technique

Data collection is a major task, especially on a large construction project. Conventional methods involve employing several observers and are usually time consuming. A video camera, being a more accurate and superior data collection method, can take the place of several observers because it captures all concurrent activities. The camcorder technique involves several steps: selection of video equipment, preplanning for the taping process, conducting brainstorming sessions, analysis of recorded data, and development of final recommendations. Each of these steps is briefly described herein.

Selection of Equipment

A variety of camcorder systems are available on the market. The initial cost of the basic equipment (i.e., video camera, editor, video player recorder, and tripod) ranges from about $3,000 to $6,000, depending on the degree of sophistication desired. Two common types of video cameras are currently affordable for on-site analysis, the 8-mm and the 1/2-in. VHS formats. Advantages of the 8-mm system include portability, high resolution, and reduced size in comparison to the 1/2-in. system. On the other hand, the VHS cameras are less expensive and are currently more popular. In selecting a video camera, some of the characteristics that need to be considered are: the weight and feel of the camera, the degree of resolution (number of pixels), versatility of the focusing features, the magnitude of zoom ratio, the ability for characters generation, flexibility of the edit switch, the existence of the time counter, the length of battery life, the existence of frame-by-frame advance capability, and the quality of freeze frame pictures.

A video editor is needed to combine selected segments from different tapes and to organize the data more efficiently for the analysis and viewing sessions. A 27-in. monitor is appropriate for viewing sessions involving up to 30 people. A recommended tripod would have height adjustment, telescoping secured leg locks, and separate tilt and pan adjustment locks.

Preplanning for Videotaping

Preplanning for a taping session is crucial to the success of this technique. It must be clearly communicated and understood by all workers that the analysis of an operation is used only to identify and document methods of improving workers effectiveness, installation methods, and field operations on the jobsite. It is important to establish that the analysis will not lead to critical evaluation and termination of individuals. The person in charge should emphasize that the camcorder exercise will be used only to study, analyze, and improve jobsite conditions for enhancing the overall productivity and, hence, improving the individual's performance. If a consultant is in charge of this exercise, it is equally important that he/she involves project superintendents and area supervisors in the selection of the operations to be taped and analyzed. Upon confirming the selection, the area foremen and their crews should also be notified.

Videotaping

A stationary video camera should be kept in operation for a period of typically 5–6 hr per day. The camera should be located approximately 100 feet away from the operation, under observation and at an elevation that ensures that equipment and personnel will not obstruct the view. This ensures capturing enough of the observed activities and their surrounding environment for a more complete analysis of the tapes. The rather remote location of the camera also helps to reduce the possible distraction caused by the presence of the video camera and the taping operation. Checking on the camera should be done approximately every 2 hr or when batteries and tapes have to be changed. A hand-held video camera should be used for close-up shots taken from different angles to complement the data gathered by the stationary camera. Critical activities, equipment movements, material handling, craft-machine interference, and travel time of individuals and equipment are typical operations that should be recorded by both cameras.

Analysis of Data

The analysis process starts by organizing the data and extracting only the data most relevant to improving productivity. It is strongly advisable that the function of individual workers in a crew and their effectiveness in performing these functions be closely examined. Superintendents, foremen, craftspersons, and inspectors should be interviewed at convenient times during videotaping of an activity to discuss the logic and details of the operation investigated. These individuals are an excellent source of innovative ideas because of their previous experience and their intimate familiarity with the details of their activities.

The process of organizing the relevant information involves viewing of the videotapes in the fast-forward mode, which takes about 5 min per tape. This step is usually repeated two to three times to give better familiarity with the data recorded. The tape is then rewound and the footage counter is set to zero. The tape is reviewed at normal speed with frequent override with the fast-forward mode. In this manner, the observer is given enough time to note pertinent information, improvement ideas, and cross reference the footage on the counter. Other functions of the cassette deck such as double speed, slow motion, pause, and stop action can be used to help the observer to interpret and document certain conditions and circumstances. The time recorded on the tapes, which is also displayed on the screen, gives more perspective to the actual sequence of the operation. With the aid of the video editing controller, one or more video tapes of 10–15 min duration are developed to combine the most important findings and to reduce the viewing time. Such tapes are used in brainstorming sessions to address operational procedures, equipment movement, crew balance, and safety related issues.

Brainstorming Sessions and Final Recommendations

After the initial analysis is complete, preferably the following day, a meeting is arranged with area superintendents, foremen and lead craftpersons to discuss and analyze the findings and tentative recommendations. A meeting for 30–60 min is considered adequate for these sessions that can be held in the site office trailer. It is also advisable that each participant receives a narrative on the findings and tentative recommendations before the meeting. It is important to establish an environment of open discussion in these meetings so that ideas and opinions are encouraged and freely expressed. Participants should be encouraged to discuss and comment on the findings and the tentative recommendations. Innovative ideas, new alternatives, and individual's perceptions of the operations observed should be prompted. The objective of the first part of a brainstorming session is to encourage the development of new ideas without the fear of negative criticism. In the second part, the ideas that seem more promising are further discussed and detailed. An important benefit from a meeting of this kind is the strong involvement and sense of commitment developed by the workers toward their field operations as well as toward the company in general.

A final report is then prepared, summarizing all findings and final recommendations. The report becomes a project document that is circulated to the project superintendents, engineers, and supervisors. Such a report serves as a formal documentation of field conditions and a planning tool for future operations.

Case Study

A productivity study was conducted during the construction of a major state prison located on the west coast to house 3,000 inmates. The project cost $43,000,000, covered 650 acres, and involved about 1,000 construction workers. The facilities included: 15 housing units of 19,000 sq ft each; 13 steel framed guard towers of a floor area of 97 sq ft each; a concrete tilt-up facility of 28,500 sq ft for central control and visiting activities; two structural steel buildings of 5,300 sq ft each for visitors processing; and a preengineered metal building of 145,000 sq ft serving as a general warehouse. Fig. 1 shows the layout of the project site.

The video equipment used in the case study included an 8-mm video camcorder (Sony CCD-V110), a 1/2-in. VHS camcorder (Panasonic AG-160), an editing controller (Sony RM-E100V), and a cassette deck (Sony 8-mm EV-S700V). One camera was kept stationary on site to capture on-going activities for over a 5–6 hr/day. The other camera was carried around the area under investigation to record specific segments from various angles. Combining the 8-mm and the 1/2-in. VHS equipment was intentionally chosen to test the feasibility of both formats. The two systems proved feasible and their combination gave access to the advantages of both formats.

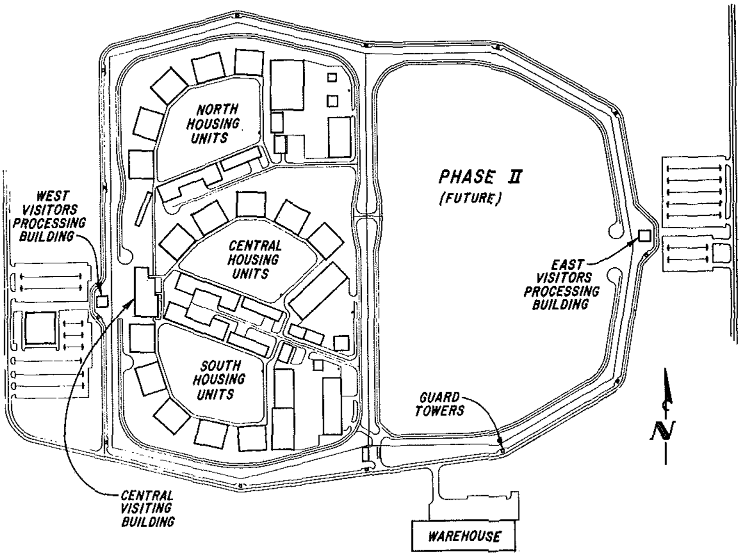

FIG. 1. Project General Layout

The video editing controller made it possible to control the video camera and the 8-mm Sony cassette deck simultaneously. It also provided some useful functions such as automatic assembly editing of up to eight desired segments in any sequence, check on memorized progress before editing, and playback of any memorized program sequence. The video recorder was necessary to allow for advanced editing and convenient features such as pause, frame-by-frame advance, fast forward, fast reverse, slow motion, and double speed.

The actual setting of the video equipment was planned after an operation was selected for analysis. The 8-mm camcorder was attached to a tripod and placed on the top of an adjacent building at 50–150 ft from the operation under investigation. Beyond this distance, picture clarity became a problem. A lens filter (neutral density) was used to compensate for the brightness of outdoors and establish contrast.

Selection of Operations

Several construction operations were selected for the productivity study that took place in the summer of 1987. The study focused on the operations that did not progress at an acceptable rate and on the operations with which the prime contractor did not have previous experience. These operations were identified by consultation with the project superintendent and area supervisors. Erection of tilt-up panels, installation of precast units, and placement of metal studs and drywalls were video taped and examined. The data collection, data analysis, and recommendations made for improving each operation are described below.

J. Constr. Eng. Manage., 1990, 116(1): 100-111

Tilt-Up Panels

In a tilt-up operation, the concrete panels are poured flat on the ground in the vicinity of the final installation site to avoid extra handling. Planning of the layout and number of pours is important to assure efficient use of equipment, reduce the risk of structural damage, and maximize productivity. In the case study, the tilt-up operation was completed in six weeks and involved four major individual pours. Fig. 2 is provided to help the reader to appreciate the need for thorough planning of the various activities involved. This figure shows the area selected for each pour, the layout of the major outside panels, their final location in the building, the preplanned position for the crane to pickup and set each panel, the crane operating radius, and the maximum lifting capacity for each position at the required boom angle. The operation was monitored for a few days and the data taped demonstrated that additional planning of the panel layout, movement of the crane, and labor activities could have eliminated a number of problems and improved productivity. Table 1 summarizes the data collected on several video tapes.

As shown in Table 1, the crane traveled a total of 1 hr and 45 min in a 6 hr and 38 min work session. In other words, the crane was not engaged in actual installation during 26% of the total time. This traveling time included 1 hr and 7 min (i.e., 17% of the total time) in which the crane traveled empty between lifts. Better planning of casting locations and sequence of erection would have saved unnecessary traveling and improved productivity. It should be noted, however, that the number of recessed slabs, utility and structural inserts, and site congestion made the casting and handling of the panels quite challenging.

Analysis of the video tapes revealed a number of problem areas and led to the development of the following recommendations:

1. Panel layout and erection sequence should have been analyzed more closely. A cardboard model was recommended to facilitate the planning of casting and handling each panel and visualizing the positioning of the crane to minimize its movements. Using the model not only would increase productivity, but would also improve communication throughout the operation by clearly displaying the immediate and future work sequence.

2. Grout pads should have been used instead of the Teflon adjusting plates. The Teflon adjusting plates were shifting during panel placement, making final positioning of the panels more difficult and time consuming.

3. An air drill should have been used to reduce the time required for drilling holes for the temporary bracing. The air compressor should also be used to expedite the cleaning of these holes and the pickup points.

3. Modification to the rigging operation was necessary. The holes in the spreader bar and location of the pickup points did not match on a variety of panels. It was evident from the viewing of the tapes that lifting cables of varying lengths were needed in rigging the different panels. Having fixed length cables resulted in lifting some panels from fewer pickup points than specified in the design. Reducing the number of pickup points could damage the panels, grade slab, and equipment.

5. Use of a larger-size connecting angle, at the base of the panel, was recommended to facilitate final alignment and welding of adjacent panels. This recommendation became evident from a close-up view of the welding activities using the hand-held camera.

J. Constr. Eng. Manage., 1990, 116(1): 100-111

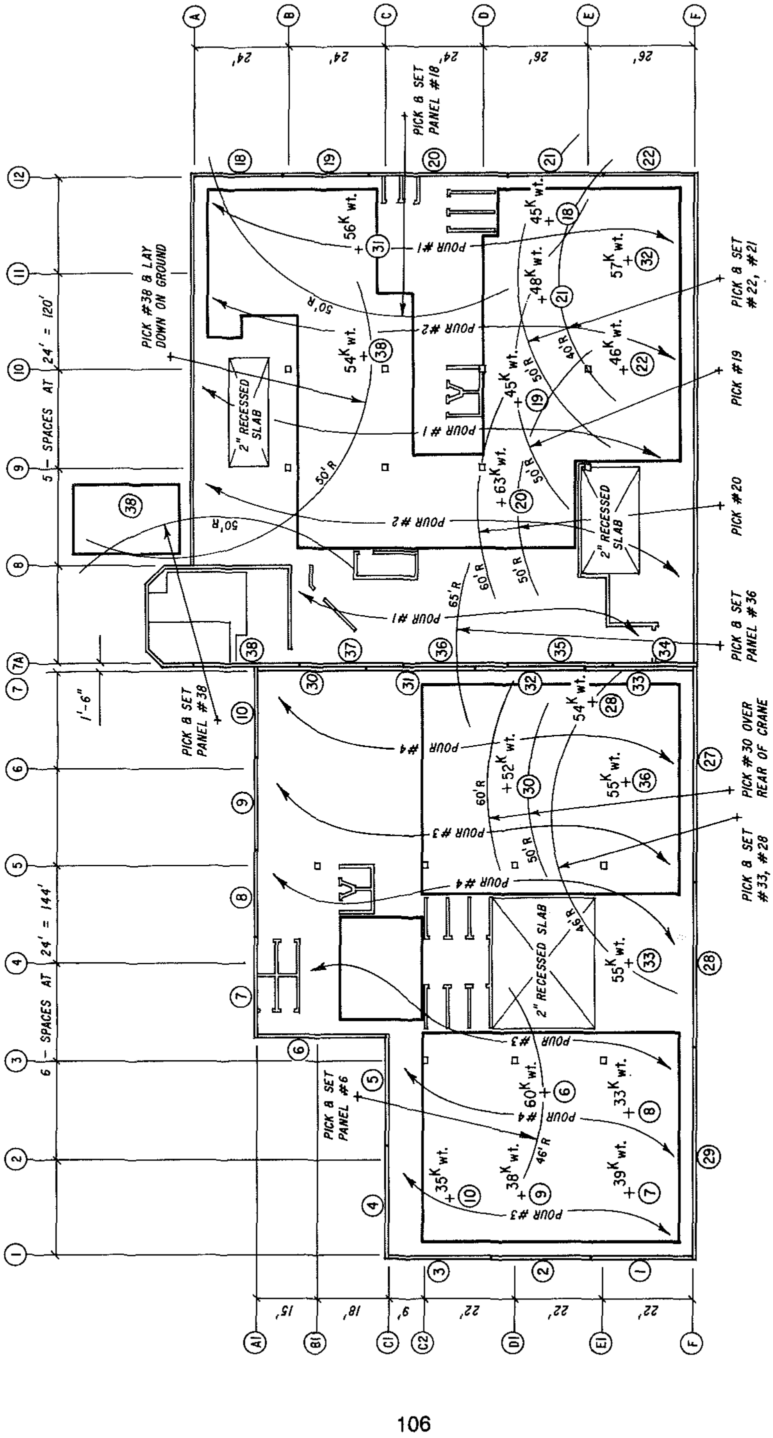

FIG. 2. Layout of Tilt-Up Panels

TABLE 1. Time Analysis of Crane Movement

Slab number (1)	Moving empty (min) (2)	Rigging and lifting (min) (3)	Moving loaded (min) (4)	Placement and adjustment (min) (5)	Total time (min) (6)
18	5	5	2	19	31
19	2	3	2	18	25
20	10	8	6	34	68
21	3	5	1	17	26
28	5	6	6	20	37
32	15	35	7	13	55
22	2	5	3	7	17
31	11	5	2	16	34
30	5	7	3	10	25
38	9	13	3	49	74
Total	1 hr-7 min	1 hr-33 min	1 hr-28 min	3 hr-20 min	6 hr-45 min

6. Development of a systematic list of activities, assigning specific tasks to each crew member during the placement of a panel, was recommended. This was necessary to make each crew member aware of what was expected, when duties were expected to be done, and what other crew members were responsible for. The need for this recommendation became clear after viewing several tapes that showed inconsistency in the functions carried by the different crew members.

Taping the operation after implementing the above recommendations would have produced a valuable training video tape; a tape to be reviewed periodically by the installation crew, used for training new crew members, used for training on future projects, and used in safety programs.

Precast Units

Installation of the precast units was completed in 17 weeks. It involved handling, positioning, and grouting of 5,565 precast units of 12 different configurations. The work was accomplished by three crews working consecutively. An erection crew was responsible for the unloading, initial erection, and temporary bracing of the units. An alignment crew was responsible for plumbing, connecting, and welding the units. A grouting crew followed to confirm final alignment, grout connections, and cleanup.

The operation was allowed three weeks to reach its steady state on the learning curve before starting the productivity analysis. The learning-curve effect was observed as the production rate increased from 24 units per week to over 50 units per week. This production rate, however, was still unacceptable to the contractor who decided to include this operation in the productivity study.

By taping the installation procedure, conducting brainstorming sessions, and performing productivity analysis similar to that described for the tilt-up operation, several productivity-related problems were identified. The analysis showed that unnecessary extra handling occurred because the precast units were delivered in the wrong order and frequently the units were loaded

J. Constr. Eng. Manage., 1990, 116(1): 100-111

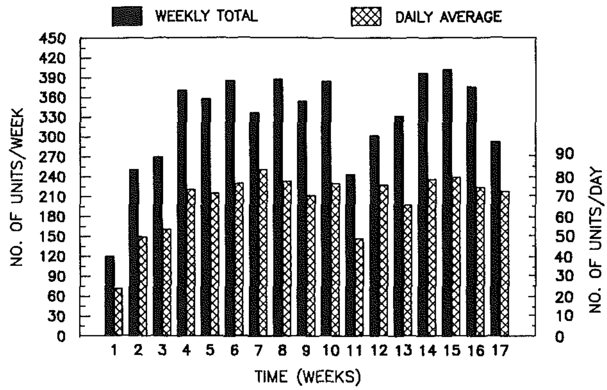

FIG. 3. Production Rate of Precast Units

upside down. It was also evident in the viewing sessions that more welders could be added to increase production without causing congestion of the work area. The analysis of the video tapes and the discussions in the brainstorming sessions confirmed that a foreman with more seniority could also be added to improve the coordination and motivation of the large installation crew.

These problems were resolved by contacting the fabricator regarding the loading of the panels and by adding a senior foreman to the crew. Fig. 3 shows the impact of this analysis on the daily and weekly production. This figure shows that production increased from an average of 50 units per day to over 70 units per week for several weeks. An unfortunate accident took place on the 11th week causing the production to drop that week. Production, however, increased gradually to its maximum again.

Metal Studs and Drywalls

Low productivity of the metal stud and drywall installation became a management concern because it involved a large amount of work in several buildings on the jobsite. Because of the tight construction schedule, the installation of studs and drywalls were integrated with a number of other operations including interior and exterior construction. For example, placement of overhead joists, installation of strapping above and below the roof joists, placement and welding of supporting brackets, and installation of hand rails were all taking place simultaneously in the same area. This integration made it difficult for an observer to focus just on the problems in the installation of the metal studs and drywalls. However, by analyzing several hours of recorded activities, an overall effectiveness factor of only 55% was calculated by work sampling analysis. The tapes showed that the installation of the metal studs in the warehouse building involved the following activities: (1) Placing of top and bottom plates (channels) to receive the vertically placed studs; (2) installing overhead bracing to accommodate and support partition walls; (3) measuring and cutting studs to a variety of lengths ranging from 8 to 25 ft; (4) using a laser setter to ensure that walls were appropriately placed and plumbed; and (5) utilizing a scissor lift throughout the operation.

J. Constr. Eng. Manage., 1990, 116(1): 100-111

It was evident from the video tapes that productivity suffered as a result of the following:

1. Lack of supervision: The installation crew had no supervision except a few short visits by the superintendent. No foreman was assigned to this crew.
2. Absence of a full set of Drawings: Not all work stations had a set of drawings from which workers could confirm measurements. As a result, one tape recorded some rework as a result of installing a header and a sill at the wrong height.
3. Lack of understanding of individual's functions: Some workers appeared idle a significant amount of time and often inefficient when engaged in work. Other workers were in violation of safety regulations since they were not wearing hard hats. Although this infraction may seem unrelated to productivity, safety violations could affect the operation's productivity because of the accident potential.

By isolating the activities related to the installation of metal studs on the video tapes, the following steps were observed as part of the lengthy installation procedure: (1) Measure stud length; (2) put tape measure back in belt; (3) pick up stud; (4) place stud near saw; (5) kneel down; (6) pull out tape measure; (7) measure stud length; (8) mark stud; (9) place stud in vice; (10) cut off to the desired length; (11) release stud from vice; (12) stand up; (13) bend over; (14) pick up stud; and (15) place in final location.

After the analysis and brainstorming sessions the following was recommended to reduce the installation procedure and improve productivity:

1. Stronger guidance and supervision were needed to eliminate the apparent hesitancy and lack of workers organization.
2. Development and communication of designated tasks and job assignments for each crew member to improve labor utilization.
3. Placement of more motivated and skilled workers on activities for which only minimum supervision could be afforded to compensate for the reduced level of supervision.
4. Assurance of at least one set of drawings assigned to each work site to reduce dependency on personnel stationed at different sites.
5. Mounting of a metal stud saw and a measuring tape, with its zero mark lined up with the saw's blade, on a waist-high table and installing a supporting guide to reduce labor intensity during the cutting operation.
6. Development of a procedure to encourage workers to identify efficient installation techniques and effective devices, and to provide feedback from crafts to supervisory personnel.

Implementation of these recommendations improved production to a satisfactory level and reduced the installation procedure from the aforementioned 15 steps to the following eight steps: (1) Measure stud length; (2) put tape measure in belt; (3) pick up stud; (4) place stud on the cutting table; (5) line up stud with the measuring tape fixed on the table; (6) cut off stud to the required length; (7) pick up stud; and (8) put stud in place.

The installation of drywalls was analyzed in a similar manner. It was identified from the tapes that most of the installation problems were encountered in placing the top portion of the walls where the drywall sheets had to be

J. Constr. Eng. Manage., 1990, 116(1): 100-111

cut to fit around the roof trusses. The installation procedure for this work involved the following: (1) One worker measured the location of the component parts of the truss rafter where the drywall fitted up against the studs and met the metal decking; and (2) this worker then called out the measurements to another worker who placed these measurements on the drywall and cut according to these marks. This procedure resulted in many misfits and reworks. To resolve this problem, a template was made to speed up the cutting operation. The template marked where the drywall passed around the truss rafters. The use of the template improved the fitting around the trusses, reduced rework, and minimized the need for wide sealant joints at the interfaces between the roof trusses and the drywall.

Analysis and Interpretation

The use of camcorders improved productivity on the investigated project. This technique addressed the causes of productivity decline outlined by Tucker (1986). In particular, the following productivity improvement concepts were addressed.

Providing Clear Communication and Simple Reporting System at Craft Level

Because "one picture is worth a thousand words," a well-prepared video tape is an excellent communication technique. The combined sight-and-sound features of the current video technology cast information in an easily usable format. Precise verbal instructions accompanying a video tape offer the simplest effective reporting system understood at the craft level. The interaction between the audience in the brainstorming sessions is a critical element that makes this technique a superior communication and reporting method.

Obtaining Fast Feedback

Camcorders allow instantaneous capturing of data, analysis, and feedback while an operation is still active. Since no time is required for processing a video tape, recommendations can be implemented while they can result in actual and immediate benefits. With this technique, management is always dealing with current pertinent information throughout the construction phase.

More Effective Use of Management Time

The superiority of a video camera, in collecting data without being attended, reduced the data collection efforts to a minimum. In the technique described, only one individual (who can be an independent consultant) is responsible for recording data and coordinating analysis sessions. With preliminary analysis and tentative recommendations prepared before the brainstorming sessions, management time can be spent most effectively in selecting best alternatives and evaluating new ideas instead of collecting data and writing reports. The discussion of a well-defined problem, in a controlled environment (air conditioned office) by individuals who possess the know-how and are responsible for carrying on the work, results in the optimal use of management time.

Establishment of Project-Team Attitude

The fact that all the members of a crew are present on the monitor screen during the viewing sessions, are addressed as a team, and are asked to func-

J. Constr. Eng. Manage., 1990, 116(1): 100-111

tion as one unit promotes the team attitude among workers. Equally important, to establishing this attitude and a high level of commitment, is the encouragement each member receives when contributing to the success of an operation or the development of a solution for a problem.

Improvement of Site Operation and Erection Procedures

Constructability, methods of erection, and effective use of labor and equipment are the main subjects discussed in the viewing sessions. These subjects are the heart of site operation improvement. With this technique, attention is always focused on providing workers with instructions, tools, material, and equipment to improve site operation and erection procedures.

Conclusions

The intent herein was not to claim that camcorders are the solution to all productivity problems. However, this technique has distinct advantages that can be used to increase construction productivity. The camcorder technique offers a means to identify productivity problems and provides a systematic procedure to resolve them. Video tapes provide complete and permanent irrefutable records of construction activities that can be used for personnel training, safety programs, performance evaluation, and possible legal disputes. Measurable benefits were realized in the case study by using camcorders. The tapes provided clear and simple communication method between management and labor. The brainstorming sessions provided a systematic procedure for exploring innovative ideas that may not be otherwise surfaced. The team attitude established among workers made it feasible to cooperate in implementing recommendations and improving productivity.

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J. Constr. Eng. Manage., 1990, 116(1): 100-111