On Site Performance Improvement Programs

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Abstract: The paper presents the various phases in a comprehensive On Site Performance Improvement Program (OSPIP) of a medium size construction project which includes: problem identification; data collection; data analysis and planning the change content; planning the change process; and measuring and evaluating the results. Methods, techniques, and means to put the various program phases into practice are examined, and the problems likely to be encountered are discussed. An OSPIP case study of a medium size construction project is described in detail. It deals with production rate, safety, and manpower turnover problems, improvement plans to overcome them, and how implementation was realized in each of the problem areas. The paper suggests that OSPIP in medium size projects is not only economically feasible and worthwhile, but highly recommendable.

Introduction

Much interest has been generated during the last decade in on-site performance improvement programs. Publications are mostly limited to describing results of successful programs, but no overall picture can be gained about the methods and phases by which results were attained. Furthermore, nearly all deal with very large construction projects costing $100,000,000 or more (3,6,7,15,16,24,34,41,42). The problems encountered are a function of their very size, expressed in volume of resources, area, duration of execution and organizational structure, concern equipment and tools logistics, and communications. Though the relative share of large-scale projects is growing, the majority is, and will remain, in the smaller categories.

This paper purports to describe, as fully as possible, the steps by which an improvement program in a medium size construction project ($2,000,000–$20,000,000) can be implemented. The experience gained by this writer in the course of initiating and activating such programs, as consultant, researcher and manager in various construction projects in the United States and Israel, forms the basis of the observations. A description of the general scope of a typical OSPIP is followed by details about the stages which must be navigated, emphasizing the difficulties that lie enroute. An On Site Performance Improvement Program (OSPIP) case history concludes the paper.

Nature of OSPIP

Medium size projects addressed in this paper employ 25–100 workers for a duration of 1–2 yr, and cost $2,000,000–$20,000,000 (2). Though OSPIP operations considered here are scaled to this size, most observa-

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tions will apply to larger projects and to some extent, to smaller ones as well. An OSPIP can be divided into two main stages: the study and the implementation stage. The study stage subdivides into:

1. Identification of the problems.
2. Data collection.
3. Data analysis and planning the change.

The implementation state subdivides into:

1. Planning and implementation of the change process.
2. Assessment and measurement of the results.

The study phase in OSPIP is of the action research type which involves the investigation of a problematical situation and its diagnosis with a view towards introducing strategies that will minimize or eliminate the problem. The emphasis in this type of research is on change (9). The change agent often plays different roles, e.g., researcher, consultant or teacher. Whether he can be more effective as an outsider or as a member of the organization is a moot question (5).

During the study stage, data is collected by various methods from:

1. Observations (e.g., work sampling).
2. Survey methods (e.g., questionnaires).
3. Secondary data (e.g., cost records).

OSPIP changes being actioned during construction after major decisions on design and contractual commitments have already been completed, are of necessity, limited in scope. They focus on means, i.e., on actions selected, rather than on end objectives. They use relatively modest resources and their influence is short-lived. Though the firm will barely register the (tactical) changes, their impact on the project is likely to be of a large (strategic) order. The diagnosis will probably include areas beyond the confines of the stimulating problem. The change should be expected to include concurrent attainment of other goals, much as the project itself pursues several subsidiary objectives (e.g., in areas of cost, timetable, quality, and safety), each reciprocally affecting the others. In many instances, change is accomplished by an indirect route in which an aspect is changed (e.g., reducing employee turnover) to affect changes elsewhere (e.g., safety performance and crew productivity) in order to arrive at the ultimate target (e.g., accelerated construction) (4).

OSPIP will naturally turn its particular attention, during the investigation as well as during the implementation stages, to improving worker performance on-site, by training, motivating and improving methods (20,31,45). The reasons for this are as follows:

1. Cost. Manpower which constitutes 25–40% of total construction costs, is almost wholly under the control of site management and, thus, holds the greatest cost reduction potential. Though material costs are comparatively higher, their saving potential is relatively small, as most decisions are either made by outsiders (designers) or by the company

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head office (purchasers). Moreover, improvement of manpower productivity brings with it construction time reduction which, in turn, affects time dependent cost (e.g., site administration cost), which comprises as much as 10–15% of construction costs. Construction time reduction also accelerates the contractor's capital turnover and renders to the owner the utilization of his investment ahead of time.

2. Ease and speed of study. Problem identification and data collection at the worker level can be accomplished within a much briefer time span than at management level. The time span discretion theory, developed by Jacques, captures this point well. According to this concept, jobs vary tremendously in the time it takes for a person's performance to show up in effectiveness indicators. At the lowest level jobs in an organization, it typically takes only a few hours or days, whereas at the top levels it takes months or years (17).

3. Ease and speed of implementation. Except for principal approval and some policy decisions, the change agent can expect little interference from the head office in his activity on site. Here, site management is his real partner in the planning and implementation of changes. The degree of autonomy with which site management of a medium size project disposes of manpower is nearly complete. However, with regard to its own functioning and ability to introduce changes, site management's independence from the head office will be more restricted. Changing work procedures with subcontractors, for instance, may require corresponding adjustment by the head office (because of possible affect on other sites). Preference will, therefore, quite naturally be given to changes affecting manpower which can be accomplished with relative ease and speed.

It is worth emphasizing that an attack on manpower problems serves chiefly as an expedient entry point into the system (40). In many unhealthy situations, neither workers nor even foremen have much sway, but they are a fertile soil for the collection of important data. The investigation can then be pursued further at site management where remedies can be devised and enacted. The correct timing of changes will often depend on a suitable redisposition at management level, e.g., revised tool distribution procedure—without which little can be done at work crew level to cure, say, delays in work starts, which are due to a cumbersome or faulty tool distribution procedure.

Identifying the Problems

Research in OSPIP arises from the need to diagnose the problem symptoms. The problem identification is a two-step process:

1. Identifying the symptoms.
2. Setting the focus and scope of the diagnostic activity.

In the first step, problem symptoms will be analyzed. Preliminary collection of data may already be deemed expedient at this point, in which documents, records (e.g., cost and schedule) and visual observations can be utilized. The selection of the problems to be addressed will be made

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on the basis of their importance and their savings potential. Usually, only a few critical operations will use up the largest share of the resources (Pareto law). Research and change effort will concentrate on these operations.

In the second step, the question regarding what the possible reasons for the occurrence of symptoms really are, must be asked. What data will best reveal the underlying problems and lead to their understanding? At this stage in the diagnostic process, the change agent, together with site management, must draw heavily on their understanding of construction site performance to insure that all reasonable explanations of the observed symptoms are addressed in the diagnostic. Recognizing these fully will help in selecting data collection methods and setting targets.

Data Collection

It is possible to collect data in numerous ways. The majority can be brought under one of the following headings: survey methods, observations, and secondary data. Methods commonly practiced include:

1. Survey methods (or self report data)—questionnaires and interviews.
2. Observations—unstructured visual observations, structured observations (e.g., work sampling), stopwatch technique, and time-lapse photography.
3. Secondary data—documents (e.g., procedures and specifications) and records (e.g., cost and safety reports).

The type of problem will often suggest the choice of method. Problems concerning training and methods improvement, for instance, will best be handled by observations; motivational problems by interviews and questionnaires; cost, safety, and manpower turnover problems by records. Complementary study methods are sometimes recommended, e.g., in cases of safety problems by observations, and manpower turnover problems by questionnaires.

Moreover, in a given situation, a method may have a distinct advantage and disadvantage. A study comparing, for instance, a Foreman Delay Survey (a type of questionnaire) with work sampling, concluded that the former offers advantages of speed, economy, and absence of adverse relationships, while the latter offers advantages of more detailed information and recognition as an accepted objective measuring system (35). The type of problem always being the overriding consideration, the data collection technique should also be valued according to yield in terms of validity, richness, efficiency (time and cost), flexibility, and ease of analysis and presentation.

The extent to which the desired yield is obtainable through the different data collection methods can be assessed by referring to a number of sources which deal with this question (5,29,31,39). Interviews, unstructured observations and time-lapse photography (where camera can be positioned) produce rich data yields in comparison with stopwatch technique and most records which produce relatively lean results. Sec-

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ondary data and questionnaires (in large samples) are efficient collection methods, while time-lapse camera and interviews are quite the opposite. It is worth noting that, due to the short duration of operations at a site, timeliness of feedback is of decisive importance. This is particularly relevant in conjunction with method improvements. Validity will be weak with most methods in which data depend on the person furnishing and the person assembling them. Thus, the time-lapse camera gets a high validity rating compared with questionnaires, interviews and stopwatch techniques which are inherently subjective. Interviews and unstructured observations enjoy much flexibility; questionnaires and stopwatch registrations have opposite characteristics. Ease of analysis and presentation are virtual corollaries of questionnaires, work sampling and stopwatch records, while observation and unstructured interviews are difficult to cast into molds of data.

Data Analysis and Planning the Change

To conduct purposeful and effective data analysis, two prerequisites are needed. The first is a conceptual model of the factors influencing site performance (e.g., the type considered in Refs. 12, 15, and 40). Analysis is essentially a process of asking questions of the data. A model will help generate the diagnostic questions which must be put to the data (29). The second prerequisite is in the nature of a tool, namely, analysis techniques. The techniques to be used will depend on the type of problem and on the method of data collection. In the case of method improvement, for instance, the questioning method (8), a variety of graphical presentation practices (e.g., crew balance charts, flow diagram and process charts (28,31), simulation techniques (13,32), and special delay analysis techniques (1,40) can be effective. For the analysis of questionnaires, interviews and work sampling, for instance, statistical tools have been developed.

The next step is to translate diagnostic insights into specific and practical ideas as to how a problem may be solved. There are no hard and fast rules for this stage. A thorough understanding of all work and management aspects of a construction project, buttressed by a sound diagnosis of the situation on hand, form the basis for a good start. Beyond this point, everything depends on the situation. When dealing with method improvements, for instance, this writer had recourse to the quality circles method to generate improvement ideas. A group of 5–10 people, made up of foremen and representatives of site management, participated in tightly controlled brainstorming sessions to thrash out alternative proposals. This technique is often very effective because it is also supportive during implementation. An extensive study is presently under way at the Technion, I.I.T., to examine the conditions under which the technique can be used effectively.

Planners of improvement changes must maintain an overall system perspective in order not to lose sight of the interaction of performance aspects as they reciprocally influence project effectiveness. An operating system, however faulty, functions in a certain balance. A change in one element will upset the equilibrium and will necessitate adjustments in others. The planning phase must include a process of anticipatory testing which involves projecting consequences of envisioned change alternatives. A detailed example of this process is furnished in a study by Laufer and Moore (21) in which the feasibility of financial incentive programs at construction sites is examined. Fifteen different work aspects (e.g., quality of work, safety) are subjected to anticipatory testing to probe the likely results of financial incentives.

Having picked the most promising alternative, it is necessary to define the goals which the improvement should achieve and plan the follow-through steps to ascertain that goals will be reached. The follow-though steps include:

1. Selecting the most attention deserving project performance aspects and setting their targets.
2. Devising measuring methods.
3. Determining frequency of measurements.
4. Making an economic forecast which justifies the improvement (e.g., cost/benefit analysis).

It is important to act upon the preceding follow-through steps while the change preparations are still in progress so that the pre-change conditions can be measured by the same benchmarks as will be applied during and after the change process. Project management should be partners in the change planning and evaluation phases in order to enhance credibility in the success of the change and inspire it with confidence in future change endeavors (5).

Planning the Implementation Phase

Improvement in project performance is not attained by merely choosing a change objective and designing the content of the change. Research and practice indicate that the question of how the change is best implemented is of no less importance. Lack of synchronization between content and process issues could stymie, if not neutralize, the change effort (4,5). In approaching the change process, the change agent must make choices regarding the pace of the effort, the amount of preplanning, the involvement of others, and the way to deal with resistance (19). The greater the expected resistance, the slower the change strategy. The agent must identify the person who can furnish the relevant data needed for the detail design of the change and who has the energy to implement it. The more the agent anticipates that he will need information and commitment from others to help design and implement the change, the more the change strategy will slow down. However, the change pace is also influenced by the stakes involved. The greater the potential short-term risk to project performance survival, the faster the change must (and by common consensus, possibly can) be accomplished. Occasionally, a dilemma will dictate a compromise, e.g., when the activity is of short duration (quite typical for construction sites), but the planning of the change calls for the involvement of many people.

When exploring possible sources of resistance, one should not overlook the union sector (21,38). Maloney (25,26) recommends guaranteeing job income and employment security, and utilizing productivity bar-

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gaining in order to reduce union resistance.

The sequence in which the previously mentioned problems should be tackled deserves close attention. Some problems or aspects of a problem need to be worked on before others can be resolved (4). Sometimes it is necessary to first improve methods, prior to introducing motivational programs, in order that an acceptable norm can be attained, before linking higher performance to a bonus. In subsequent stages, when workers have become accustomed to perceiving method improvements as attainable goals, motivation schemes coupled with additional improvement methods are likely to be well-received and to inspire higher performance.

Measuring Change Results

Measurement is the assignment of numerals to objects or events according to rules (36). Measurement of performance serves as the basis for decision-making. The usefulness of measurements must be evaluated in terms of their ability to provide information wich will improve the accuracy and validity of decisions made. Specifically, measurements are employed to: (1) Discover whether, and how well, performance objectives are being achieved; and (2) determine the reasons for success or failure.

The latter, which is diagnostic in nature, is really part of a continuous feedback process—performance measurement, diagnosis, decisions, implementation, and, again, measurement. As can be seen, OSPIP performance measurement is a particular application of data collection. However, while in the case of OSPIP, the data is compiled only once, extensively, under the supervision of a research-oriented expert; regular performance is normally measured periodically under the supervision of the administratively-oriented line people. The routine performance measurements can, therefore, utilize a large number of secondary data which are extracted from the regular control and registration sources. These sources are mostly output oriented and, generally, include data on costing, progress, accidents, absenteeism, manpower turnover, etc. But for OSPIP requirements, the output or events data supplied are not always sufficiently relevant or timely, e.g., the normal data to measure safety performance (i.e., lost time events) will not record events which resulted in slight injuries and property damage or which had some disruptive effect on productivity. The standard safety performance measure records only rare events. This feature stands out particularly in construction projects of medium size with a small manpower force and which are short duration. A single accident can have a drastic effect on the data and distort the perception about the effectiveness of the safety improvement program (37). Because of the inherent weakness of the output-oriented measuring methods, performance measurement concerned with the process and focusing on the activities required to convert input into output (e.g., work sampling) have been developed. Research work concerned with project performance measurement has concluded that both output and process-oriented performance measures are needed for a proper evaluation of project improvement programs (46).

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One method of solving the problem of safety performance measurement on site is by employing a process-oriented technique. This falls under the category of structured observations and will focus on behavior which is deemed important for a high safety level. Evaluating safety practices rather than safety events, will enable management to anticipate problematical situations and avoid accidents. A measure based on performance rating will include criteria, e.g., safety behavior, housekeeping, protection devices, and mechanical hazard elimination (33).

Questionnaires and interviews are not widely practiced in performance measurements at construction sites, but their use should not be ruled out when examining such aspects as worker motivation (22).

The suitability of a measure for a given performance aspect should be determined on the basis of a number of criteria. The criteria can be divided into two groups: administrative and psychometric. The first group will include feasibility, understandability and acceptability, adaptability and efficiency (time and cost). The second group will include validity, reliability and sensitivity (27,37). It is difficult to find a measure which answers all criteria and, as in other situations, it is best to devise a number of methods to measure the same performance element. A high degree of convergence of different techniques will yield more confidence in the validity of the data. If all measures point to differences between before and after the improvement program, the evidence can be accepted that the OSPIP has been effective (10). If the measures indicate that the planned goals have not been attained, the measurement data should be utilized in a repeat diagnosis and study to locate the cause of deviation, to devise appropriate changes and to implement them. The measurement data should be periodically used in the preparation of economic evaluations, e.g., cost-benefit ratios, for presentation to management.

OSPIP Case Study

The performance improvement program described here involved this writer as consultant. The construction project was executed by a medium size open shop firm which generally handles 5–10 projects simultaneously, and whose turnover ranges from $1,000,000–$10,000,000 each. The firm has been operating for a considerable number of years and specializes in civil engineering and concrete work projects. The following description concentrates on the project, the research phase, planning of the changes, the results and program evaluation.

Construction Project

150 apartments, approximately 800 sq ft each, in rows of houses 4 stories high, were being erected. The construction area was rocky and very hilly bordering on steep gradients, which was the reason why the buildings were laid out at odd angles. Architectural considerations further aggravated both external and internal building design, severely limiting uniformity. External stone cladding, a building code requirement for the area, was executed by a relatively new method in which the 1 in. thick stone slabs were premounted inside steel forms. The slabs

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were laid during the assembly of the wall forms. After slab tie-down, the steel reinforcement was installed and the inner insulation was laid on. The inner wall form completed the assembly. Small stone pieces, stuck to the rear side of the stone slabs, anchored them to the poured concrete wall. In order to minimize finishing work, the interior walls and ceilings were also poured in steel forms after the various conduits, pipes, recesses, etc., were laid out. Concrete pouring was done in 4 apartment entities. Construction site equipment comprised a stationary concrete mixing plant, a transit mixer, and a truck mounted concrete pump. Because of the difficult terrain, the crane shovel was crawler mounted. The building skeleton was put up by the prime contractor who employed 30 workers. Finishing work, which comprised of a single layer of plaster on the inner walls, floor tiling, carpentry, whitewash painting and various complementary jobs, were carried out by subcontractors. Management consisted of a site manager, field engineer, skeleton construction general foreman and a finishing work supervisor.

Study Findings

The writer was engaged 3 months after the work on the structure had begun, in order to suggest ways to shorten construction time. This was important for two reasons: (1) The contract provided for compensation of inflation only if the timetable pre-set for each construction stage was met; (2) strong winds prevailing at the site during the winter would make moving of forms nearly impossible. It was, therefore, necessary to complete concrete casing before the onset of the following winter. The research lasted approximately one month and employed various "tools," among which were the study of records and documents; interviews; questionnaires; work sampling; stopwatch technique; observation of safety practices; and quality circles. The findings pointed in the direction of three aspects in the skeleton construction process which merited attention: schedule delays, safety level, and manpower turnover. The diagnosis of the research data indicated that the chief causes for poor performance were:

Lagging Production Rate and Timetable

1. Low production rate due to decisions that had been taken before construction started. The irregular architecture of the building and of the apartments slowed down the learning progress which had been calculated to past experience on regularly shaped apartment buildings. The decision to cast all interior walls caused heavy congestion during assembly and disassembly of the forms which impeded movement and communication within the work crew, with the foreman and the crew supplying the steel forms. The holdups were particularly vexatious during the assembly of forms in the last stage of completing a floor, which lasted twice as long as at the beginning of a floor.

2. Slow progress during crane operations, expecially when lowering forms into assembly locations (no eye contact with crane operator whose control position was below the assembly point), and delays caused by

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waiting for crane services (the slowness of its operation and problems in storage of forms).

3. Slow progress resulting from high manpower turnover (conforming with Refs. 44, 45).

4. Holdups occasioned by faulty planning and organization of construction site layout (e.g., off-loading and storing procedures).

Safety

1. Safety problems stemming from absence of eye contact between crane operator and the crew accepting the forms.

2. Safety problems due to poor planning of the work; and deficiencies in protective and safety devices, e.g., railings, ladders, and warning signs.

3. Safety problems resulting from high manpower turnover (conforming with Ref. 14).

4. Safety problems arising from excessive overtime (similar to Ref. 31).

Manpower Turnover

1. High turnover, particularly of unskilled labor because of worker discontent (conforming with Ref. 23).

2. High turnover brought on by low safety level (conforming with Ref. 18).

Performance Improvement Plan

In discussions between the consultant, site and head office management, above findings were conceded and an improvement and performance measurement program was hammered out as follows:

1. Erection cycle of a skeleton section was to be cut to 6 days. During an intermediary stage, a reduction from 10 to 8 working days would be achieved by method improvements. In the last stage, the reduction to 6 days would be achieved primarily through a financial incentive scheme in which the 8-day performance was to be taken as the norm. Measurements would be made by monthly performance (observations), by work sampling once every 3 months and by periodic stopwatch timing of selected operations.

2. Improvement of safety target was set to 25 annual injury rate—a reduction from 44.8 (obtained by extrapolating a 3 months measurement). Achievement would be established by follow-up of the monthly injury rate, as obtained from a log kept by site management and by a 3-monthly evaluation of safety practices to be conducted by the company engineer or the consultant. The measure would be performance rating on a scale of 0–100, with a target of doubling the rating during a period of 6 months, i.e., from a starting position of 35, prior to introduction of improvement, to 70, at the end of the period.

3. Reduction of a quarterly separation rate from 50% to 25%, measured at 3 month intervals (number of terminations per quarter divided by the average number of workers).

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4. Maintaining manpower and material costs. Manpower cost would be followed up through monthly worker attendance records. Overtime and temporary help, which was not included in the incentive program, but whose work, though not charged to skeleton erection, was in fact contributory to it, were to be given special attention. Checking of material costs would be done through job cost reports, watching waste of concrete and stone.

5. Quality level maintenance of the finished product would concentrate mainly on the surface quality of the inner and outer walls. The need for more than one layer of plaster (check of subcontractor's bills) and the amount of stone slab repair after form dismantling (mainly by observation) would be monitored.

The implementation plan for changes which should achieve the goals proposed by the consultant and the quality circle, as adopted in joint sessions with management representatives, included the following steps:

1. Training the site management in short term planning. The instruction sessions were conducted on site. Ways and methods to achieve uninterrupted work flow were emphasized.

2. Methods improvement. The crawler crane to be exchanged by a tower crane; preparation of a detailed wall form assembly plan for each floor, each form being identified by name, precise location, sequential order of erection—all mapped out on a layout plan; pre-assembly of forms, where possible, while in storage, to reduce assembly work on the erection floor; installation of an elevated supervisor's platform; miscellaneous modifications on passages to ease movement of manpower and material at floor level; procedure modification for storage and forms cleaning.

3. Safety improvement through work planning and process modifications (as previously detailed); installation of additional railings and warning signs; changes in loading, tying and off-loading procedures; reduction of manpower turnover and overtime.

4. Reduction of manpower turnover by raising work force satisfaction and by reducing work accidents; changing management attitudes that frequent replacement of temporary workers had only marginal effect on productivity. As a result of this change, site management could be more selective in hiring higher paid workers with a better chance of staying on the job.

5. Improving worker performance and satisfaction by a bonus scheme tied to performance (11). Through interviews designed to determine the degree of importance workers attach to various job rewards (e.g., pay, skill development, supervisor praise, peer acceptance, job security); to what extent workers are satisfied with current level of reward; and to what extent higher performance would lead to more reward. A detailed example of a motivational questionnaire is illustrated in Ref. 22.

Analysis of the interviews indicated worker preference for bonus money and foreman recognition in return for higher productivity. A simple incentive scheme in which a bonus was linked to the quantity of apartment skeletons per month, was introduced. Through indoctrination and

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verbal instructions by site management, it was ascertained that appropriate foreman praise would reach the workers.

Special efforts were devoted in the planning of the change process to lowering expected resistance. The steps taken, among others, were:

1. The first changes aimed mainly at ameliorating working conditions by making available better tools and improved means of access (ladders, steps, and platforms).
2. The change agent attended to personal problems of key people (e.g., to secure deserving promotions).
3. Co-opting site managment and work supervisors in the planning stages.
4. At the point when the beneficial effects of method improvements began to be widely appreciated and before the generated zeal would tend to dissipate, financial incentives were introduced.
5. Site staff was briefed, throughout, by talks and circulars about the progress and the upcoming steps in the improvement project.

Program Results

Figs. 1 and 2 show the performance improvement which was made throughout the program.

During the research period and introduction of the improvement program, average production time of walls for a 4-apartment section fell

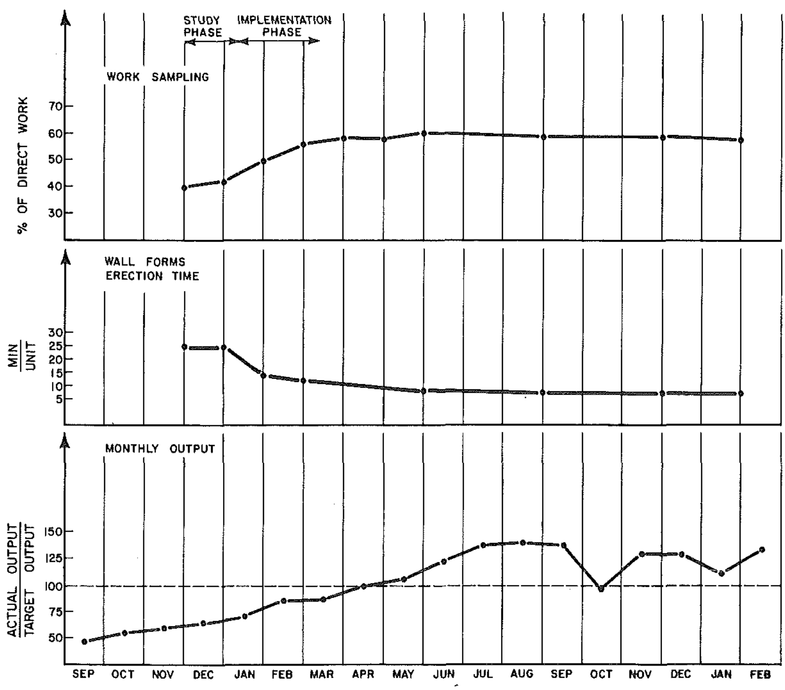

FIG. 1.—Improvement of Production Rate and Activity Level

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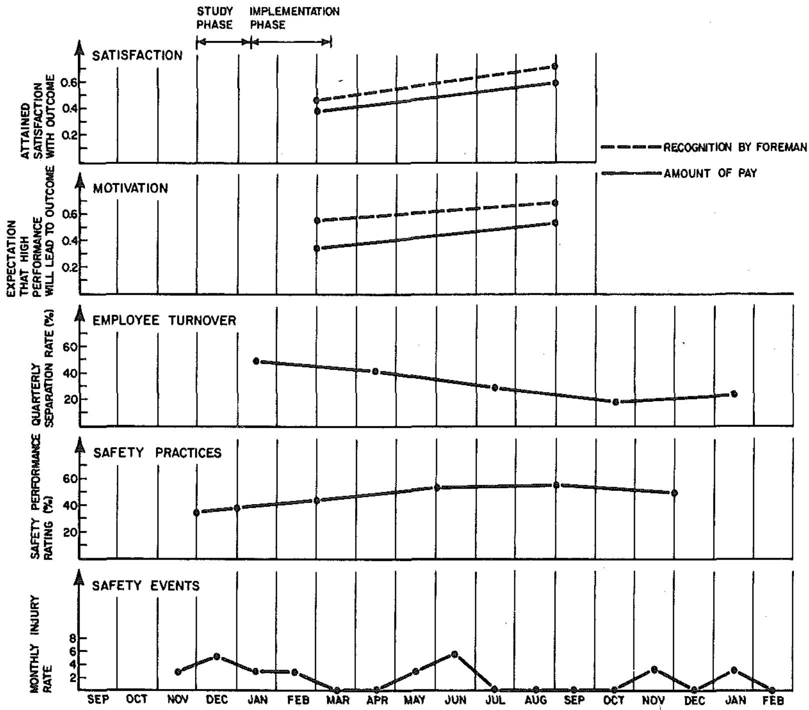

FIG. 2.—Improvement of Safety, Employee Turnover, Motivation and Satisfaction

from 14.5 to 9.7 days. After all improvement changes and the incentive bonus were fully in operation, the average time shrunk to 6.6 days. Average assembly time for wall forms decreased from 25 to 8 min/unit; and direct work category in work sampling increased from 40% to, approximately, 60%. A marked safety improvement showed up in the annual injury rate which fell from 44.8 to 16.8; while the safety performance rating rose from 35% to 55%. Manpower turnover measured in quarterly separation rate decreased from 50% to 23%.

Worker belief that higher performance will lead to higher pay and to foreman recognition showed an increase from 0.34 to 0.55, and from 0.56 to 0.7, respectively, measured on a scale of 0–1. Similarly, satisfaction with pay and praise from the foreman rose from 0.41 to 0.6, and from 0.48 to 0.72, respectively.

No significant changes occurred in areas in which performance was to be maintained to the pre-change level. There were slight deviations of actual hour input from hours budgeted. Overtime did not increase to a significant extent. Material costs could not be ascertained with sufficient accuracy because concrete was also being supplied to subcontractors. Quality of inner walls remained constant, but stone cladding repairs rose slightly.

Evaluation of Results

Construction time was reduced by 3–5 months as a direct result of the changes and bonus scheme, making due allowance of performance betterment which would have accrued from experience [the lower figure corresponds to an optimistic estimate of the learning curve gain (30,43)]. Performance measurements indicated that shortening of the schedule was mainly achieved by eliminating the numerous major delays lasting half an hour or more, which stemmed mostly from poor detail planning. Site management training, on one hand, and worker pressure because of the financial incentive program, on the other, deserve the credit for eliminating at least part of these delays. Percentage increase of direct work detected in work samplings were largely traced to the replacement of the crawler crane and the reduction of essential contribution work, e.g., study of drawings and consultation between workers. The latter feature is also a reflection of reduced manpower turnover, since veteran employees need less consultation. A group incentive plan has, of course, only limited motivational effect on the individual worker. This incentive plan, however, being simple in design, easily understood, administered and followed up, promoted coorperation between workers. A benefit/cost ratio calculation of the direct and immediate gains (mainly due to reduction of time dependent cost) was found to be 4:1. If one includes less quantifiable benefits and the long-term gains, the ratio becomes even more favorable.

Following are examples of indirect benefits which resulted from the implementation of the OSPIP:

1. In future projects, the firm's engineers will become more intimately involved in the physical design and engineering process.
2. Functioning of site management will improve in future construction projects, having gained confidence in its ability to influence site productivity.
3. Increased safety and reduced manpower turnover brought savings beyond their direct effect on performance and schedule.
4. Higher working norms will be established in future projects.

Conclusions

This paper presented the various phases in a comprehensive OSPIP of a medium size construction project which included: problem identification; data collection; data analysis and planning of the change content; planning of the change process and its implementation; and measuring and evaluation of the results.

While inferences and generalization from a single case study are inadmissible, the results presented combined with experience gained by the writer in other less well documented OSPIP projects, suggest that OSPIP in medium size projects is not only economically feasible, but highly recommendable.

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