Span of Control of Construction Foreman: Situational Analysis

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Abstract: The function of the crew foreman has not received the degree of attention in research the crucial role in construction deserves. In this study, we investigate aspects of the foreman's role that have strong implications on the productivity of the crew. By enquiring into how the foreman divides workaday time between various functions and activities, how these are affected by the size of the crew, what factors determine the span of control, and what effect the size of the crew has on its performance, the study has come to the conclusion that: (1) The size of the crew and the managerial assistance, if given, affect the mode of daily activities; (2) the size of the crew can vary considerably, depending on circumstances; (3) the size of the crew can affect its performance; and, finally, (4) the size of the crew has to be adapted to prevailing conditions.

Introduction

Span of control (SOC), defined as the number of subordinates reporting to a given supervisor, is a widely researched and discussed subject in management literature outside the construction branch. Particular attention is devoted to SOC efficacy of first-line supervisors (Porter et al. 1975; Ouchi and Dowling 1974; Steiglitz 1962; Woodward 1965; Worthy 1959). These papers stress the importance of limiting the size of a unit under a supervisor, buttressing its advocacy by situational analyses of the factors that govern the unit's healthy performance, such as similarity of tasks, need for its members to confer frequently with the leader, nonsupervisory duties the leader has to discharge, and the managerial support the unit leader gets from lower echelons. Steiner (1972), dwelling on the productivity problem, concludes that increasing the size of the crew reduces the productivity per worker. He argues that, aside from limiting the scope of the unit leader, larger numbers also affect the workers' motivation and cohesion.

Conversely, a narrow SOC (the twin of the tall organizational structure), causes higher management costs and unwieldy vertical flow of information, and stifles the initiative of the individual in the group.

The construction industry gets relatively minor attention in the literature on the question of the optimal size of effectively controlled crews under diverse circumstances.

Borcherding (1972), while interviewing foremen, briefly probed the question of SOC. He found the number of crewmen per foreman varied between 4 and 25. The foremen specified that the SOC depends upon the type of work, how spread out the work is, and the amount of direct supervision required.

Investigating labor management in union and nonunion construction enterprises, Levitt (1977) discovered a significant difference in the SOC prac-

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tices between the two sectors. The nonunion sector employs far more apprentices and helpers, and their journeymen get far less basic, specific training than their union counterparts. As a result, the union foreman can command a crew force of 12 workers, against only 4 of the nonunion foreman. The Business Roundtable ("Contractor" 1982) came to the following conclusion: "Frequently the ratio of first-level foreman to the craft workers they supervise, is determined by a collective bargaining agreement rather than by an employer's decision based upon efficiency, economy and safety." In another report ("Constraints" 1982), the Business Roundtable recommends: "Crew sizes and manning requirements are matters for contractor judgment for each project. They should not be specified in collective bargaining agreements."

Studies regarding management at the crew-size level are uniquely significant for construction. Galbraith (1977), leaning on Stinchombe's classical work (1959), stressed the point that in construction detailed, centralized programming of work processes is replaced by increasing the discretion exercised by lower-level echelons. He illustrates this by comparing manufacturing with construction. In mass production, many work processes are planned in advance: The location at which a particular task will be done; the movement of tools, materials, and people to the workplace and the most efficient arrangements of the workplace characteristics; the particular movements in getting the task done (sometimes); the schedules and time allotment for particular operations; and the inspection criteria for particular operations.

In construction, most of these conditions are difficult to emulate, and problems are dealt with, primarily by the foreman, on a short-term basis.

Research Scope

An elaborate research program has been initiated that focuses on crew management at the construction site. Individual studies deal with questions of organization, planning and control, productivity, safety, worker motivation, and others. The study reported here probes the SOC of the first-line supervisor, the foreman, of a crew of concrete formworking carpenters at the construction site. Before one takes a look into the foreman's SOC, one should first obtain a systematic job description.

Specifically, the study purports to answer the following questions: (1) What time percentages does the foreman devote to his various functions and activities, and what effect does the size of the crew have on him? (2) What factors demarcate, and to what extent, the foreman's SOC?; (3) What effect does the size of the crew have on performance?

The data reported in this paper were obtained through structured interviews conducted on site in Texas and Israel. The first-line supervising level in the United States coincides generally with the foreman (FM) of a single crew. However, the lowest ranking supervising level in Israel is usually reponsible for a number of trade crews, such as formworkers, ironworkers, and cement masons, although primary attention will always be devoted to the formworkers. The Israeli foreman's greater span of control will generally be compensated by a supervisory assistant, who takes care of the other quite independent trades.

Research Method

The data on the activities of the foreman were collected in interviews with foreman on site. The efficacy of interview as the preferred method has been

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established in earlier research by Kay and Meyer (1962), summarized in the statement, ". . . the questionnaire approach would be the more efficient research method than the direct observational method." Certain operations, such as planning, cannot be tangibly sized up through observation. Direct questioning of the first-line manager can bridge this deficiency (Snyder and Glueck 1980).

Data regarding the various factors affecting the foreman's SOC were likewise obtained in interviews with the foreman. The factors and situations on which questions were to be based were culled from the literature outside construction, mentioned in the introduction to this article, and from construction literature (e.g., Borchering 1977; Hinze and Kuechenmeister 1981; Levitt et al. 1984; Samelson 1977). Another source was test interviews held in a preliminary study conducted in Texas and Israel. Crew performance, measured by work and safety sampling, could only be carried out in Israel, because of limited funding in Texas.

Efforts to ascertain the validity of the data included the following complementary actions.

1. Pilot studies to refine and clarify the questionnaire, define categories, and train the interviewer.
2. In addition to the interviews, prepared observations were carried out on a portion of the samples (eight foremen in Israel). These corroborated the interviews very closely.
3. Care to pick the more advanced construction sites in terms of a progressive quality of management (e.g., operating in an environment of advanced management information, formal planning, and control practices). Interviewees were selected for their ability to articulate and cooperate. Preparatory talks for the undertaking with the site manager and the foreman were also utilized to get background briefing on the company and the project they were working on.

Therefore, while the sample is geographically representative of the two states, from the point of view of the quality of the companies, the sample is deliberately biased, in that it represents, in both states, a population of the more advanced construction companies.

Background Data

Table 1 provides background information about the sampling, crew, and workers studied in the course of the wider research project (Laufer and Shohet 1988). The data were obtained through interviews with site managers and foremen.

The definitions of skill and formal training of workers used in this study are more lenient than those employed in the literature for the union sector (Mills 1971; Northrup 1984). In this study, the ones who have been found acceptable among the foremen are used. Accordingly, a skilled worker is not necessarily one able to "lay out work from blueprints and to supervise his own performance" (Mills 1971), but one able to perform certain tasks under supervision. Similarly, formal training is not necessarily ". . . training which includes some form of supplementary instruction, either theoretical or manipulative or both, away from the workplace" (Northrup 1984). Formal training denotes here a trainee-apprentice (not a helper), whose training comprises planned and progressively more advanced job assignments.

TABLE 1. Characteristics of Sample (Mean Values)

Variable (1)	Texas (2)	Israel (3)
Sample size (sites)	24	32
Project cost (million $)	19.5	5.5
Crew size (workers)	10.9	9.4
% of crew with assistant foreman	70.8	93.7
% of time invested in managerial activity by assistant foreman	40.7	42.7
% of skilled carpenters	67.0	50.0
Experience of skilled carpenters (years)	7.4	8.2
% of formally trained carpenters	41.1	7.6
% of carpenters reading blueprints	17.6	9.8
Experience as foreman (years)	8	14

The findings clearly show a drastic percentage of fall off from skilled workers who do, to those who do not, read blueprints; from 67% to 17.8% in Texas, and from 50% to 9.8% in Israel. The low percentage of formally trained carpenters in Israel indicates that most skilled workers there acquire their skills through on the job experience (8.2 years on the average).

Foreman's Activities

This part of the study is based on interviews with foremen concerned with their on-site activities—24 in Texas and 32 in Israel. The time distribution of the foreman's activities was gleaned from answers to a closed question to estimate ". . . the percentage of time he invests in each of the following activities:" (1) Read blueprints; (2) participate in meetings; (3) plan work (task planning, scheduling and layout); (4) give instructions; (5) control work pace and quality; (6) fill reports; (7) fetch and distribute materials; (8) talk on the telephone; (9) work with hands; and (10) travel away from site.

Table 2 depicts the mean breakdown of time between the various activities of the foremen.

The following four activities occupy the center stage with the American foreman.

TABLE 2. Breakdown of Foremen's Time (in Percentages)

Activity (1)	Texas (2)	Israel (3)
Control work pace and quality	18.0	33.7
Give instructions	17.1	21.2
Read blueprints	16.8	9.8
Plan work	14.7	8.9
Work with hands	10.6	3.1
Complete records	6.0	4.5
Fetch and distribute material	5.9	4.0
Participate in meetings	5.4	8.4
Talk on telephone	3.9	3.8
Travel away from site	0.9	2.6
Other activities	0.7	0.0

TABLE 3. Foreman Activity by Crew Size (Texas; Percent of Time)

Activity (1)	Small crews (2)	Large crews (3)
Control work	13.3	23.6
Work with hands	15.1	5.3

1. Control work pace and quality—18.0% of the time.
2. Give instructions—17.1% of the time.
3. Read blueprints—16.8% of the time.
4. Plan work—14.7% of the time.

The American foreman also spends an average of 10.6% of his time on manual tasks.

Mean breakdown of the Israeli foreman's time reveals, also in descending order, the following five items in significantly different percentages.

1. Control work pace and quality—33.7% of the time.
2. Give instructions—21.2% of the time.
3. Read blueprints—9.8% of the time.
4. Plan work—8.9% of the time.
5. Participate in meetings—8.4% of the time.

The data were analyzed to reveal if the time distribution of the foreman was influenced by context variables (e.g., type of construction, size of project, percent completion of skeleton). Two factors were found to have such effect: crew size and the percentage of time the assistant foreman spent on supervision. This was particularly evident in the case of the American foreman, as shown in Tables 3 and 4.

To analyze the influence of crew size on the foreman's activities, the sampling was divided into two categories, small crews of eight or fewer formworkers, and large crews of nine or more. Foremen in charge of small crews engaged 13.3% of their time in control, while foremen with a larger SOC spent 23.6%. Manual work was another item showing a marked difference between the two categories. Foremen of small crews spent 15.1%, against foremen of large crews devoting 5.3% to manual work.

To establish context variables related to supervision, the sampling was divided into two distinct categories of foremen.

1. Those with assistants who spend more than 75% of their time on supervisory functions, hereafter called "supervisory assistant."

TABLE 4. Foreman Activity by Assistant Foreman's Function (Texas; Percent of Time)

Activity (1)	Supervisory assistants (2)	Working assistants (3)
Plan work	25.3	11.1
Give instructions	9.1	19.9

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2. Those with assistants who spend more than 75% of their time on manual work, hereafter called "working assistant."

Consequently, this analysis excludes foremen whose assistants are engaged in manual tasks in 25% to 75% of their time.

Foremen with "working assistants" under their command spend 11.1% of their time on planning, compared with foremen with "supervisory assistants," who spend 25.3% on planning. This difference has a significance of $\alpha < 0.05$ by the T-test (where α = the level of significance of the difference).

The effect on the percentage of time allocated to "giving instructions" was likewise significant under this division. Foremen with supervisory assistants overseeing the formworkers spent 9.1%, while those with working assistants spent 19.9% of their time directing workers. This difference, too, has a significance of $\alpha < 0.05$.

In conclusion, the foreman's ability to direct a worker can be enhanced by either reducing the SOC, that is, decreasing the size of his crew, or by assigning an assistant to him.

Situational Analysis of SOC

Structure of Questionnaire

The second part of the interview researched nine salient factors that affect the SOC of the foreman. Each factor was posed in antipodal alternatives of either fostering or impeding the extension of the foreman's span of control. Here the same 56 foremen (24 in Texas and 32 in Israel) were requested not to relate to their present site, but to their accumulated experience. The following factors were presented to the interviewee.

1. Carpenters' motivation: Fostering—A group unsupervised for 2 hr will continue to perform well. Impeding—A group unsupervised for 15 min will loaf.
2. Carpenters' training: Fostering—Formally trained, read blueprints. Impeding—No formal training.
3. Carpenters' experience: Fostering—5 years or more working in the trade. Impeding—Fewer than 5 years.
4. Foreman's managerial training and experience as foreman: Fostering—Formal training with 5 years experience. Impeding—No training, less than 1 year as foreman.
5. Foreman's managerial style: Fostering—Candid relations between foreman and his subordinates; he is "people" oriented. Impeding—Formal relations between foreman and his subordinates; he is "task" oriented.
6. Foreman's assistant: Fostering—Appointed and participates manually less than 50% of the time. Impeding—No assistant appointed.
7. Quality of information provided to foreman: Fostering—Blueprints and construction plans are detailed, complete, and on time. Impeding—Blueprints and construction plans are general, incomplete, and late.
8. Work complexity: Fostering—Very common project with simple and routine operations. Impeding—Nonrepetitive, many trades, complex operations.
9. Dispersal of work locations between crew members: Fostering—Less than 30 yards apart. Impeding—Distances greater than 60 yards.

TABLE 5. Span of Control in Fostering Situations

Factor (1)	Texas (2)	Israel (3)
Carpenters' motivation	11.7	17.1
Carpenters' training	14.0	17.4
Carpenters' experience	16.2	16.7
Foreman's training	18.8	19.2
Foreman's managerial style	17.1	16.1
Foreman's assistantship	21.1	20.5
Quality of information	15.2	15.4
Work complexity	19.1	17.5
Dispersal of work locations	15.5	15.6
Overall mean	16.5	17.3

The position halfway between the two extremes was termed the middle situation.

The pilot study, during which the factors and situations were formulated, served to select situations as realistically as possible, to permit gauging their effect as practical contingency choices.

The interviewees were asked 18 questions (Appendix I). In each question, they were requested to assess the maximum SOC in which a single factor was in an extreme position, while all other eight factors were in the middle. The maximum SOC was defined as the number of workers that, if exceeded in given circumstances, would diminish the control effectiveness of the foreman.

The analysis of the findings regarding the effect of the factors follows in the presence of three variables: maximum SOC, a situational range, and a situational multiplier.

Maximum SOC

Table 5 presents the largest SOC under favorable (fostering) situations. Outstanding findings include the following.

1. The three factors allowing the largest SOC in Texas are supervisory assistance for the foreman, 21.1; project simplicity, 19.1; and managerial training of the foreman, 18.8 workers.
2. In Israel, the same three factors emerged, though in a somewhat different order: supervisory assistance for the foreman, 20.5; managerial training of the foreman, 19.2; and project simplicity, 17.5 workers.
3. Two large disparities show up in workers' motivation (in Israel 11.7 and in Texas 17.1, significant at $\alpha < 0.05$), and in workers' training (in Israel 14.0 and in Texas 17.4). A suggested explanation for these differences will be offered later.
4. The maximum SOC for the remaining four factors are similar in both states.

Situational Ranges and Multipliers

The situational range (SR) is the mean difference between the large and small SOC, assessed by the interviewees in respect of the two opposite situations. Graphically, the SR is shown as a connecting line between the large and small SOC.

Another variable was developed to express the quantitative effect of each factor, the situational multiplier (SM), defined as the mean ratio of the SOC of the fostering (F) to the impeding (I) situation. The formula for calculating SM is

$$SM = \frac{\sum_{j=1}^{n} \frac{SOC(F)_j}{SOC(I)_j}}{n} \qquad (1)$$

where SOC(F) and SOC(I) are the SOC in fostering and impeding situations, respectively, as assessed by FM (foremen) J; and n is the number of responses.

With this presentation, one can project the possibility of enlarging the crew, with improvement of the situation, without detrimental effect on the foreman's ability to control. For example, if the multiplier for supervisory assistance to the foremen is 2.0, the addition of an assistant enables doubling the SOC of the foreman (i.e., twice as many workers) without impeding crew performance.

These two analyses variables complement each other. While SM focuses on the independent variables (the situational factors), SR focuses on the dependent variable (SOC). The main advantage of the SM is that it enables a comparison between the relative influence of the various factors. SR, on the other hand, gains the edge in that it is not too sensitive to the value fluctuations of the affected variable in an impeding situation. In general, SM is more useful for research in answering the questions that are the more powerful situational factors, while SR is suitable for practical applications to show to what extent SOC can be increased, by affecting any particular factor. That's why both variables are shown.

The main findings include the following.

1. The highest SM and SR in Texas and in Israel is for managerial training of the foreman: in Texas, SM = 3.5, SR = 11.5; in Israel, SM = 2.4, SR = 10.3.
2. The lowest SM rating in both countries represents dispersal of work locations, in Texas 0.8, in Israel 1.3. The value below 1.0 for Texas signifies that the fostering condition of 30 years distance, as originally conceived, produces a negative result in the form a lower SOC than under the inhibiting condition of 60 yards. It appears that as long as formworkers operate in open space that allows some overview from a distance, spreading workers is rated by foremen to be of greater value to productivity than short distance, with its attendant condition of congestion.
3. As a general rule, SMs in Texas are higher than in Israel. The overall mean of SM of all nine factors reaches 2.5 in Texas, against 1.9 in Israel.
4. The overall mean of the SR of all nine factors shares in both states a fairly similar value, 7.0 in Israel to 8.0 in Texas.
5. The overall mean SOC (the mean of all nine middle points between maximum and minimum SOC) is 12.5 in Texas and 13.5 in Israel.
6. Figs. 1 and 2 reveal an asymmetrical relationship between the SRs of some factors to the overall mean SOC. The effect of the addition of an assistant to

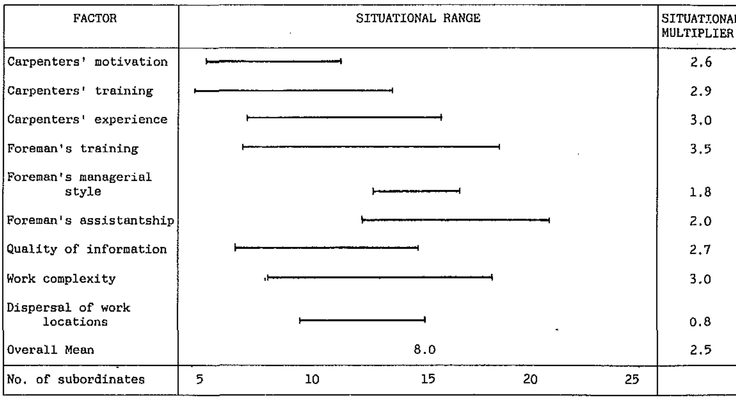

FIG. 1. Situational Analysis of Span of Control (Texas)

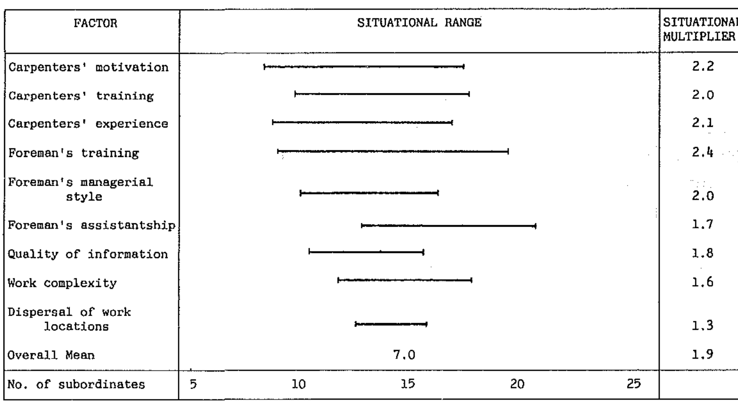

FIG. 2. Situational Analysis of Span of Control (Israel)

the foreman can be termed a "constructive" factor. An assistant substantially increases the foreman's SOC, while the lack of one brings the SOC down to 12.7 in both states, which is close to the overall mean.

7. Worker motivation in Texas is primarily regarded as a "hygiene" factor. With motivation lacking, the SOC falls off sharply to 5.7 workers, but with its improvement the SOC will only increase to 11.7–close to the overall mean. In Israel, on the other hand, motivation is a very powerful factor with a wide range of variability, the second SM in order of magnitude.

Formworker training is a factor of similar, though somewhat milder, impact. Table 1 shows the Israeli sampling to be sorely deficient in training by comparison with American tradesmen. This seems to indicate that, with regard to motivation, the drift in Texas also surpasses that of Israel [an interpretation supported by other findings of the more encompassing research of Laufer and Shohet (1988)]. Improved motivation, as a fostering situation, will therefore bring about a merely moderate increase of SOC, only slightly greater than the mean size of the crews observed in the interview sampling (10.9). Substantiation for this explanation can also be derived from the findings of the foreman's activities. The Texas foreman, it will be recalled, spends only one-third of his time on direct supervision ("control work" and "give instruction"), compared with his Israeli peer who, facing a crew with low motivation and poor skills, gives more than half his time to related activities.

The underlying assumption to the questions on the variability of SOC is that the size of the crew affects the performance level. This assumption is examined next.

Effect of Crew Size on Performance

So far, SOC has been dealt with as a dependent variable. The following section discusses the influence of SOC (in this case the size of the crew) on crew performance, i.e., SOC is an independent variable. The crew performance measurement was performed only in Israel, employing two process-oriented yardsticks; work sampling and safety sampling.

Work Sampling

Work sampling has given reliable productivity indications (Handa and Abdalla 1989; Thomas et al. 1984). Four hundred observations were collected at each site within one day. The observations were made at fixed intervals. Many studies concluded that, since all construction operations are stochastic in nature, sampling at fixed intervals is a valid technique (e.g., Flowerdew and Malin 1963). Some scholars claim that fixed intervals are superior to random sampling (e.g., Peer 1986). Thomas and Daily (1983) state that the fixed interval approach (intervals ranging from 30 sec to 3 min) is particularly adaptable to the study of short-cycle, highly repetitive group operations.

A total of 40 samples was taken, each included 10 observations of the formworkers at 2 min intervals. The observations were spread over the day in four sessions, two before and two after lunch. To eliminate the effect of the day of the week, measurements were not made on the first and last days of the week.

The work samples were classified in three categories, according to Parker and Oglesby (1972): Effective work, essential contributory work, and ineffective work. The mean values obtained for all sites of the three categories were: Effective work—30.3%; essential contributory work—30.8%; ineffective work—38.9%.

Safety Sampling

The standard safety performance measure (e.g., lost-day cases) records only rare events (Tarrants 1980). This is particularly characteristic of construction projects of medium size with a small manpower force working for short durations (similar to the sites included in the current study). A single accident can have a drastic effect on the statistical picture and distort the perception about safety performance. In a sample as small as the one taken here (a group comprising approximately 10 workers), the process-oriented measures have an inherent advantage because the sample of the phenomenon measured (e.g., unsafe acts) is large even in a small group of workers work-

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ing for short durations. The phenomenon measured is, thus, no longer a rare event.

Safety sampling followed a similar pattern to work sampling, except that the observed work was classifed in work safety categories. This method has been found to be dependable outside the construction industry (Pollina 1970; Rockwell 1970), and is considered by construction safety experts to be credible. It is also endowed with a rich diagnostic potential (Laufer and Ledbetter 1986).

At the present state of the art, the routine procedure of safety sampling is still beset with difficulties, both in the data collection and analysis phases. In an unpublished, empirical study, at the Building Research Station of the Technion in Israel, it was found that: (1) Repetitive safety sampling made under similar circumstances by the same observer yielded similar results; and (2) safety sampling made at different sites by the same observer showed close correlation with product-oriented safety measurements (e.g., lost-day cases). The study concluded that a rigorously conducted safety sampling, if implemented by a trained observer and confined to similar trades, yields reliable, valid results.

Based on the aforementioned endorsement, a safety sampling study was initiated alongside the work sampling. For the sake of simplicity, and to easily quantify the time during which the worker is exposed to danger or creates a dangerous situation, only two work safety categories were singled out.

1. Unsafe act or situation. Describes hazardous use of tools or equipment, or hasty execution of work in an unsafe place or under unsafe conditions. The mean score of the sampling was 6%.
2. Safe act or situation. Worker performs job without risk of hazard to himself or others, and surroundings are considered safe. The mean score of the sampling was 95%.

Analysis

For the analysis of the work sampling, the sample was divided into small size crews of up to eight workers and large crews from nine workers and more. Small crews registered a 33% and large crews a 27% share of effective work. T-test showed that this difference is significant at $\alpha < 0.05$.

An effective work percentage rating of 33% is indeed high. Oglesby, Parker and Howell (1989) reported good productivity ratings of different construction trades, among them carpenters which are quoted at 29% effective work.

To analyze safety performance, 12 very small crews comprising up to 6 workers, were compared with 7 large crews of 15 workers or more. The percentage of unsafe acts/situations of the small crews rated 3%, the large crews 7.6%, which represents a very noteworthy difference at $\alpha < 0.05$.

It is not intended to convey the impression that crew size is the exclusive factor accounting for these results. Clearly, other factors, such as the quality of the site or crew management, characteristics of the workers, as well as many other job context variables, can have much influence on crew performance. Nonetheless, the magnitude of the correlation in a sampling taken at random of 32 crews (randomly relative to quality of management and crew characteristics), between size of crew and productivity/safety performance,

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imparts an unmistakable message regarding the effect of crew size on performance.

CONCLUSIONS AND IMPLICATIONS

This study does not resolve the long-standing question if the decisive issue in determining the organizational structure of the crew is SOC (Pfiffner and Sherwood 1960), span of management (Koontz et al. 1982), unit size (Mintzberg 1979), or span of responsibility (Drucker 1986).

What can be derived from this research, however, is that:

1. The size of the crew and the managerial assistance given to the foreman affect the way the foreman divides his workday time.
2. The range of variability of the crew size of carpenters is quite considerable, depending on the circumstances.
3. The size of the crew affects its performance.
4. Crew size has to be adapted to prevailing conditions.

In practice, like in research, when calculating the productivity of manpower (e.g., in cost estimating or in schedule planning), one cannot ignore the effect on productivity arising from the size of the crew and other situational factors. An example of an incomplete treatment of this aspect can be found in the work of Gates and Scarpa (1978). They developed an advanced quantitative model that calculates the optimal size of crews, without taking into account the influence of crew size on productivity. One of the factors, with practical consequences to the size of the crew, is the scope of the work sector. In many projects, particularly in buildings, the sector is fairly well set by the building plan. In single-story housing structures of identical design, for instance, the formwork of the ceiling of one house comprises a natural sector for a crew, as would be the ceiling of one floor in a multistory building. In other words, the activity of the crew is determined by size of the sector and the allotted time, which does not leave much latitude to vary the size of the crew. In numerous instances, however, given work sectors can be split into subsectors. These would warrant a systematic evaluation of alternative composition of crews along the following lines:

1. A single large crew; large SOC with correspondingly lower productivity.
2. Subdividing sector into two segments, each manned by a smaller crew with its own foreman. The expected productivity will be high, duration of work short, but managerial overhead expense will be greater. There will also be need for coordination between the two foremen.
3. Two crews, each supervised by an assistant foreman (who participates approximately 50% of the time in the manual work of his crew), both crews overseen by a foreman. The result would be similar to alternative two with respect to managerial overhead costs and productivity, but with better intercrew coordination.
4. Dividing the sector into two segments to be worked on by a single compact crew. Productivity will increase substantially, also because the repeat operations by the same crew cash in on the extended learning curve. The elapsed time of execution will, of course, grow markedly, and, if the crew is on the critical path, the cost factors tied up with the duration of the project can put the alternative into jeopardy.

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The findings of the study also bear upon crew-size calculations for small sectors. Computations resulting, for example, in fractional manpower, will often end in upward adjusted number of workers. The findings have shown that downward adjustments should also be made when, for example, training or experience of workers or foreman justify it.

Real-life circumstances rarely produce a single factor in an extreme situation, with all the others in the average position. Further study is therefore in order, to investigate the combined influence of a number of extreme situations acting simultaneously.

Summary

This study is breaking new ground on the subject of the span of control over a construction crew. More field studies will be needed to verify the evidence and expand the data. Nonetheless, the preparations made prior to the commencement of the research by way of pilot study, the corroboration of the evidence on the foreman's activity acquired by structured observations, and, lastly, the affinity of results emerging from the comparison between the two countries, reinforce the justification to accept in the interim the practical lessons contained in this research.

An explicit diagnostic phase examining context variables affecting the SOC of the foreman should precede construction planning. Only then should crew size be determined and estimates of manpower productivity be adjusted to the various situational characteristics.

Acknowledgments

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Appendix I. Span of Control Interview Schedule

You are requested to assess the maximum span of control (SOC). The maximum SOC is that number of workers which, if exceeded in given circumstances, would diminish the effective control of the foreman.

You are requested to assess the SOC for nine different factors, each being classified in diametrically opposed situations of either fostering or impeding the extension of the foreman's SOC. The situation in which all nine factors are in the middle between the fostering and impeding situation is termed the average situation.

In each of the following 18 questions, you should assess the maximum SOC in which a single factor is in an extreme position while all other eight factors are in the middle.

List of Situations

Average Situation Except for Workers' Motivation

1. Fostering: A group left for 2 hr will continue to perform well.
2. Impeding: A group left for 15 min will loaf.

Average Situation Except for Workers' Training

3. Fostering: Trained formally, can read blueprints.
4. Impeding: No formal training.

Average Situation Except for Workers' Experience

5. Fostering: More than 5 years.
6. Impeding: Less than 1 year.

Average Situation Except for Foreman's Training and Experience

7. Fostering: Formal training and five years of experience as foreman.
8. Impeding: No training, less than 1 year of experience as foreman.

Average Situation Except for Foreman's Managerial Style

9. Fostering: Open relations between foreman and his subordinates. Foreman is people oriented.
10. Impeding: Formal relations between foreman and his subordinates. Foreman is task oriented.

Average Situation Except for Foreman's Assistance

11. Fostering: Exists, assistants work with hands less than 50% of time.
12. Impeding: Nonexistent.

Average Situation Except for Information Quality

13. Fostering: Blueprints and construction plans are detailed.
14. Impeding: Blueprint and construction plans are general, incomplete, and late.

Average Situation Except for Work Complexity

15. Fostering: Very common project with simple, routine operations.
16. Impeding: Nonrepetitive, many trades, complicated operations.

Average Situation Except for Geographical Dispersal

17. Fostering: Distance among workers less than 30 yards.
18. Impeding: Distance among workers more than 60 yards.

Appendix II. References

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Appendix III. Notation

The following symbols are used in this paper:

n = number of participants;
SM = situational multiplier;
SOC(F) = span of control in fostering situations;
SOC(I) = span of control in impeding situations; and
SR = situational range.

Subscripts
j = participant.

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