Effects of Schedule Pressure on Construction Performance

Madhav Prasad Nepal[1]; Moonseo Park[2]; and Bosik Son[3]

Abstract: Accelerating a project can be rewarding. The consequences, however, can be troublesome if productivity and quality are sacrificed for the sake of remaining ahead of schedule, such that the actual schedule benefits are often barely worth the effort. The tradeoffs and paths of schedule pressure—and its causes and effects—are often overlooked when schedule decisions are being made. This paper analyzes the effects that schedule pressure has on construction performance, and focuses on tradeoffs in scheduling. A research framework has been developed using a causal diagram to illustrate the cause-and-effect analysis of schedule pressure. An empirical investigation has been performed by using survey data collected from 102 construction practitioners working in 38 construction sites in Singapore. The results of this survey data analysis indicate that advantages of increasing the pace of work—by working under schedule pressure—can be offset by losses in productivity and quality. The negative effects of schedule pressure arise mainly by working out of sequence, generating work defects, cutting corners, and losing the motivation to work. The adverse effects of schedule pressure can be minimized by scheduling construction activities realistically and planning them proactively, motivating workers, and by establishing an effective project coordination and communication mechanism.

DOI: 10.1061/(ASCE)0733-9364(2006)132:2(182)

CE Database subject headings: Construction management; Productivity; Quality control; Scheduling; Labor.

Introduction

Working under schedule pressure and in a stressful environment has become a routine phenomenon at many construction sites. Site managers often schedule activities aggressively to maintain the project on schedule or to recover from a lapsed schedule (CII 1989). Moreover, clients or developers exert pressure on contractors by setting aggressive and ever-changing project objectives and target schedules in an effort to market their products earlier (Michalak 1997).

In the shorter term, contractors can avoid delays by accelerating projects by means of, for example, adding resources, increasing the work week/hours, and exerting schedule pressure on site staff and, consequently, on workers. Although accelerating a project can be rewarding, the consequences can be troublesome (Thomas 2000; Pena-Mora and Park 2001). Not surprisingly, when a project is accelerated, the productivity and quality are often sacrificed for the sake of remaining ahead of schedule, and the actual schedule benefits may not be worth the time saved (Ballard and Howell 1998). It is a fact that when the time available to complete tasks or activities is perceived to be far shorter than that which is reasonably required, the productivity and quality of the work tend to suffer and labor inefficiencies occur (Cooper 1994; Horner and Talhouni 1995; Eden et al. 2000). Thomas (2000) has argued that labor inefficiencies occur when both large and small amounts of work are made available. It is inferred, therefore, that schedule pressure is a key factor that influences the performance of a project.

The term "schedule pressure" may be defined as the induced demand perceived by individuals or work groups to perform their work within a given time frame. It is often conceptualized with respect to some underlying baseline period. The precise operational definitions of the different categories or levels of schedule pressure are presented below. Despite its significant role in construction scheduling, only a limited amount of research has been published on the effects that schedule pressure has on construction performance. In particular, very little empirical research is available on this issue. In addition, there is limited understanding and knowledge on how schedule pressure creates dynamic effects on project performance—and, more importantly, how to counteract the negative aspects of schedule pressure. In an effort to address these issues, we have systematically analyzed the effects that schedule pressure has on construction performance, primarily focusing on tradeoffs in scheduling. This paper first presents a research framework using a causal diagram to illustrate the cause-and-effect analysis of schedule pressure. An empirical investigation founded on a questionnaire-based survey is then presented to determine the effects of schedule pressure. Based on these research results, we suggest some scheduling strategies to help site managers to deal effectively with schedule pressure and to improve project performance.

Research Framework

When there is a delay, construction activities cannot simply be extended because of time constraints. In response to such a situ-

[1]PhD Student, Dept. of Civil Engineering, The Univ. of British Columbia, Vancouver BC, Canada V6T 1Z4. E-mail: mpnepal@civil.ubc.ca

[2]Assistant Professor, Dept. of Architecture, Seoul National Univ., San 56-1 Shinrim-dong, Seoul, Korea. E-mail: mspark@snu.ac.kr

[3]PhD Candidate, Dept. of Architecture, Seoul National Univ., San 56-1 Shinrim-dong, Seoul, Korea. E-mail: bsson1@snu.ac.kr

Note. Discussion open until July 1, 2006. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on June 28, 2004; approved on July 1, 2005. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 132, No. 2, February 1, 2006. ©ASCE, ISSN 0733-9364/2006/2-182–188/$25.00.

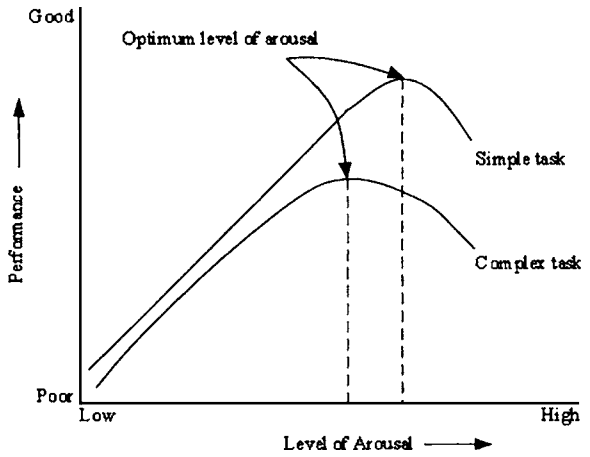

Fig. 1. The Yerkes–Dodson Law (adapted from Wickens and Hollands 2000)

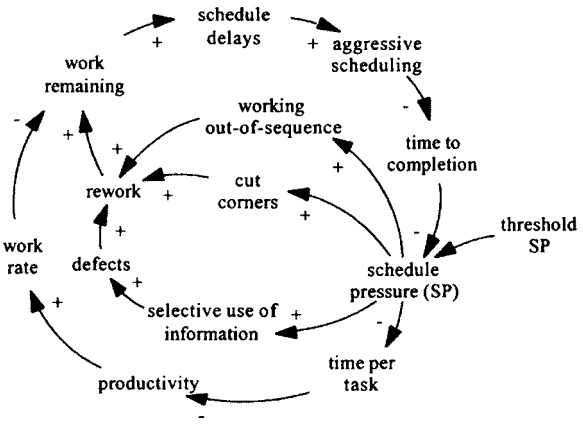

Fig. 2. Dynamics of schedule pressure

ation, a site manager may decide to accelerate the project by aggressively scheduling activities, thereby allowing less time to complete each activity. When workers perceive that the time available to complete certain activities is insufficient, but the imposition of the time limit is obligatory, they experience work pressure (Bronner 1982). The perceived work pressure intensifies as the required time increasingly exceeds the available time (Rastegary and Landy 1991). Indeed, schedule pressure has both its merits and demerits. An appropriate amount of schedule pressure can increase the work rate, but "too much" or "too little" pressure can be detrimental to productivity (Rastegary and Landy 1991; Eden et al. 2000; Bertrand and van Ooijen 2002). We assume that there exists a certain ideal level of schedule pressure at which the performance is optimum. If the schedule pressure deviates from that value, the workers become less efficient. Below, we expand on this assumption by considering the psychological literature.

Research in psychology explains how individual performance is related to arousal. It has been argued that the relationship between arousal and work performance is not linear, but curvilinear. That is, it is best represented by a curvilinear model in which the optimum level of performance is obtained at an intermediate level of arousal (Wickens and Hollands 2000). Such a relationship is modeled as an inverse U-shaped curve, which is known in psychology as the Yerkes–Dodson Law (see Fig. 1). This relationship implies that for a given individual and type of task, there exists an optimum level of arousal at which performance is at a maximum. The performance increases upon increasing the degree of arousal up to a certain point, beyond which the performance decreases.

Arousal is caused by stressors such as threat, crisis, noise, fear, and anxiety. It has been argued that schedule pressure acts as a major stressor to workers and, therefore, causes arousal. As such, the relationship between performance and arousal also holds equally to the relationship between schedule pressure and work performance. When schedule pressure is too low, the performance is affected because of a lack of urgency or awareness or through, for example, boredom. On the other hand, when there is too much pressure, the expected performance may be difficult to achieve as a result of phenomena such as information filtration and omission, adaptation, frustration, and decreased human judgment, and coping strategies tend to be active (Wickens and Hollands 2000; Rastegary and Landy 1991; Svenson and Benson 1991). As a result, a number of events may occur: the workers may lose motivation to finish the work on time, they may try to cut corners, or they may perform their work out-of-sequence.

Based on these concepts, we have developed a framework that is represented by the causal loop diagram in Fig. 2. The arrows in the diagram indicate the direction of causality, whereas the signs on arrowheads ("+" or "−") indicate the polarity of relationships. A + sign indicates that an increase (decrease) in one variable causes a corresponding increase (decrease) in the dependent variable; a − sign indicates that an increase (decrease) in the independent variable causes a corresponding decrease (increase) in the dependent variable (Sterman 2000).

The causal loop diagram suggests that the schedule pressure can result in several direct or indirect consequences on the construction performance. In particular, the diagram maps the dynamics of schedule pressure, which through mediated relationships either can help meet the schedule or cause even further delays. For example, schedule pressure can facilitate construction progress by increasing productivity because less time is spent per task or activity. This situation would occur when schedule pressure boosts output as workers speed up their efforts, cut their breaks, and work longer hours (Sterman 2000). Any apparent short-term progress can be lost, however, as very high schedule pressure is likely to introduce fatigue and stress on construction workers or affect their morale. All of these factors eventually cause productivity to decline.

There are additional harmful effects of schedule pressure. As Fig. 2 indicates, when the schedule pressure continues to increase as a result of an increase in aggressive scheduling it can bring about other negative effects on the work site. First, the higher the schedule pressure the greater will be the amount of work performed out of sequence. Second, workers may intentionally try to cope with schedule pressure by cutting corners. Third, an increase in schedule pressure may increase the number of work defects through the selective use of information, which, unlike the previous effect, can occur unintentionally. This situation is due to the fact that under high-pressure conditions, site staff and workers are likely to engage in activities that make progress even though not all the prerequisite information is available. All these phenomena—working out of sequence, cutting corners, and work defects—are responsible for increasing the amount of rework. The increase in rework on construction sites is arguably a quality problem. Thus, the site manager's efforts to improve construction progress through aggressive scheduling can worsen if multiple feedback loops arise.

From our previous discussion, it appears that schedule pres-

J. Constr. Eng. Manage., 2006, 132(2): 182-188

Table 1. Summary of Project Profiles and Survey Responses

Project type	Number of projects	Number of questionnaires delivered	Number of final respondents
Infrastructure[a]	12	35	17
Institutional building	6	20	15
Codominium	10	76	31
Commercial/office building	7	57	36
Industrial	3	6	3
Total	38	194	102

[a]Includes projects such as roads/highways, mass rapid transit, airports, and depots.

sure often influences construction performance directly or indirectly. It interacts with many factors and introduces dynamic effects to construction performance. We infer from our discussion so far that the core indicative variables pertaining to construction performance that arise from schedule pressure are work rate, quality, and productivity; for the purposes of this research study, we assume these factors to be dependent variables. It might be argued that schedule pressure can have a negative effect on the safety performance of a project—say, through deciding to extend the amount of overtime work. We believe, however, that site safety, in one way or another, is related to work rate, quality, and productivity. Therefore, in this study, we did not examine site safety as a variable.

Empirical Investigations

Data Collection

To investigate the effects of schedule pressure empirically, in this study we adopted the survey questionnaire technique for data collection. This technique enabled us to obtain a large number of samples, and made it possible that the qualitative attributes in the research framework could be assessed subjectively. In addition, the low cost, ease of obtaining information from many industry practitioners, and the possibility of collecting unbiased information boosted our decision to use survey questionnaires as our research method.

We identified a list of 38 construction projects in Singapore through our vigilance, networking, and personal contacts. We visited all of the identified project sites and hand-delivered the survey questionnaires to 194 construction practitioners, including site managers, site/project engineers, project coordinators, and site supervisors representing the general contractor, subcontractors, or trades. In the questionnaire we did not ask respondents for any personal information, such as their sex, age, or experience/background, and maintained the respondents' anonymity. We sought additional research-related information and comments by providing open questions in the questionnaire and also through face-to-face discourse during our site visits. Altogether, 102 practitioners, with representatives from all 38 of the selected projects, responded to our survey. Table 1 summarizes the profiles of the surveyed projects and the distribution of the response.

Definition and Measurement of Variables

We defined four categories of schedule pressure (Table 2), among which the respondents were asked to choose the one that best described their work. Establishing a common basis for our research required that we define a number of other variables. The "work rate" is analogous to the production rate; it determines the speed or pace at which work is being performed. Thus, we defined the work rate as the ratio between output and time. We defined "productivity" as the ratio between the output (number of units installed or quantity of work performed) and the input, i.e., the labor hours used (Halligan et al. 1994). We considered the target work quality to have been achieved if the finished work did not require rework and conformed to the original plans, specifications, code requirements, and the accepted industry standards (Alfeld 1988). The respondents rated these variables—i.e., the work rate, productivity, and quality—on a scale from 1 to 5 (where 1 = "very low" and 5 = "very high").

Table 2. Categories of Schedule Pressure

Schedule pressure	Definition
Low	A perceived situation pertaining to the time available to the site staff in completing activities when the project is ahead of the schedule
Normal	A perceived situation pertaining to the time available by site staff when the project is on schedule
High	The resulting time pressure when a project is behind a schedule or when management decides to revise the deadline to an earlier date
Very high	A perceived time pressure by the site staff when the project is very behind schedule, or when the project's duration is drastically reduced

Data Analysis

We conducted descriptive and statistical analyses of the survey data. The details of these analyses and their results are presented below.

Perceived Schedule Pressure

As indicated in Table 3, the percentages of practitioners who perceived high, very high, normal, and low schedule pressure in their work were 59.1, 21.5, 18.3, and 1.1%, respectively. This evidence suggests that most respondents worked under high or very high schedule pressure. Many respondents expressed the fact that their trades had been given an unreasonably short amount of time to complete their tasks.

Relationship between Schedule Pressure and Aggressive Scheduling

We mentioned earlier that site managers often exercise aggressive scheduling for a variety of reasons. The likelihood of adopting such a scheduling practice increases when the schedule pressure

Table 3. Perceived Level of Schedule Pressure

Perceived schedule pressure	Count	Percent	Mean	SD
Low	1	1.1		
Normal	17	18.3	3.01	0.67
High	55	59.1		
Very high	20	21.5		
Total	93	100.0		
Missing	9			
Grand total	102			

Table 4. Paired Sample t Test

	Paired difference between high and very high schedule pressures					
Variable	Mean	SD	Standard error of the mean	*t*-Value	Degrees of freedom	Significance
Aggressive scheduling	−0.29	0.62	0.08	−3.59	58	0.001

increases, e.g., from high to very high. Using a five-point scale (where 1="never" and 5="always"), we asked respondents to indicate how often they scheduled construction activities aggressively as a result of a high and very high schedule pressure; the calculated mean values were 3.95 [standard deviation (SD)=0.71, N=87] and 4.28 (SD=0.72, N=64), respectively. Thus, there seems to be a positive association between schedule pressure and aggressive scheduling. We further analyzed this result statistically to see if the relationship was significant. Using the scores for high and very high schedule pressure as the first and second pairs, respectively, the results of a paired-sample t-test (Norušis 2002) indicated that there was a significant increase in aggressive scheduling when the schedule pressure increased from high to very high (see Table 4). Having established the causal relationship between the schedule pressure and aggressive scheduling, next we analyzed the effects that the schedule pressure has on construction performance.

Impact of Schedule Pressure on Construction Performance

Earlier, we established the links relating the schedule pressure to productivity, work rate, and quality of work on a project site. The level of productivity on any site indicates the efficiency of the construction operation, which is basically a measure of the cost performance. On the other hand, the work rate level on any site indicates the extent to which a project is on schedule. Thus, productivity, work rate, and quality are good performance indicators for assessing the impact that schedule pressure has on construction performance. The respondents to this survey assessed these performance measures on a five-point Likert scale, where 1 and 5 represent very low and very high, respectively.

Fig. 3 presents the distribution of percentage ratings of the three performance measures. The majority of the respondents (over 50%) rated each performance measure as "satisfactory;" the next most common response was high. None of the respondents

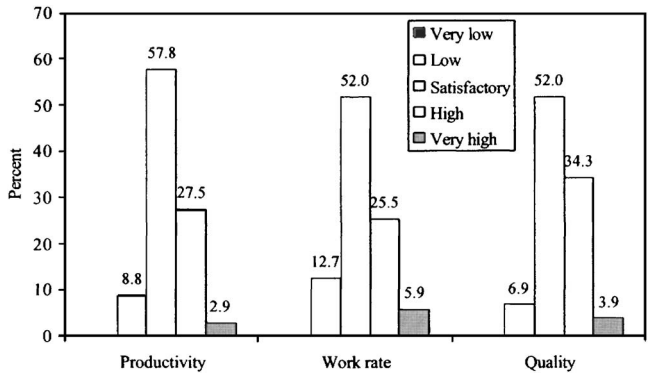

Fig. 3. Patterns of perceived site performance measures

Table 5. ANOVA Test of Performance Measures

Perceived performance measure	Source	Sum of squares	Degrees of freedom	Mean square	*F* value	Significance
Productivity	Between groups	0.34	2	0.17	0.402	0.670
	Within groups	36.60	86	0.43		
	Total	36.94	88			
Work rate	Between groups	0.60	2	0.30	0.543	0.583
	Within groups	47.11	85	0.55		
	Total	47.72	87			
Quality of work	Between groups	2.25	2	1.12	2.545	0.084
	Within groups	37.96	86	0.44		
	Total	40.20	88			

rated the measures as very low. We chose to perform an analysis of variance (ANOVA) test (Norušis 2002) to determine whether there was a significant difference between the perceived performance measures and the various levels of schedule pressure. Because there was only one case of a low schedule pressure, we did not include it in this analysis. Table 5 lists the results of the ANOVA test.

The results indicate that the productivity and work rate are related negatively to the schedule pressure and there is a significant negative correlation between work quality and schedule pressure (p=0.084, α=0.10). Posthoc comparisons using Tukey's honestly significant difference test (Pallant 2001) indicated that the mean score for "normal" schedule pressure (mean=3.64, SD=0.70) was significantly different from that of very high schedule pressure (mean=3.15, SD=0.68). Fig. 4 displays graphically the variation in performance measures with respect to the schedule pressure. We infer that an excessive schedule pressure can be detrimental to on-site performance. As indicated in the diagram, there is a definite downward trend in productivity, work rate, and quality of work when the schedule pressure increases.

These findings may provide us with some new insight into the dynamics of schedule pressure because the results present the performance of the surveyed construction sites against their schedule pressures. Most respondents in this survey indicated that high-quality completions could not be performed within the shortest period of time. The majority of them also mentioned that a compromise between the quality of the work and a quest to meet the deadline would result in a greater amount of rework or rectification work at the end of the project, thereby reducing the overall site productivity. Some respondents also commented that the schedule pressure in some instances—e.g., when introduced for a short period—could increase the work rate to finish certain tasks or activities. They admitted, however, that a higher work rate is not achievable when schedule pressure continues for a longer period.

To gain additional insight into the effects that schedule pressure has upon construction workers' behavior and performance, we provided a number of hypothesized statements, on the basis of the research framework discussed earlier, and asked the respondents to rank the statements on a five-point scale (where 1="strongly disagree" and 5="strongly agree"). These state-

J. Constr. Eng. Manage., 2006, 132(2): 182-188

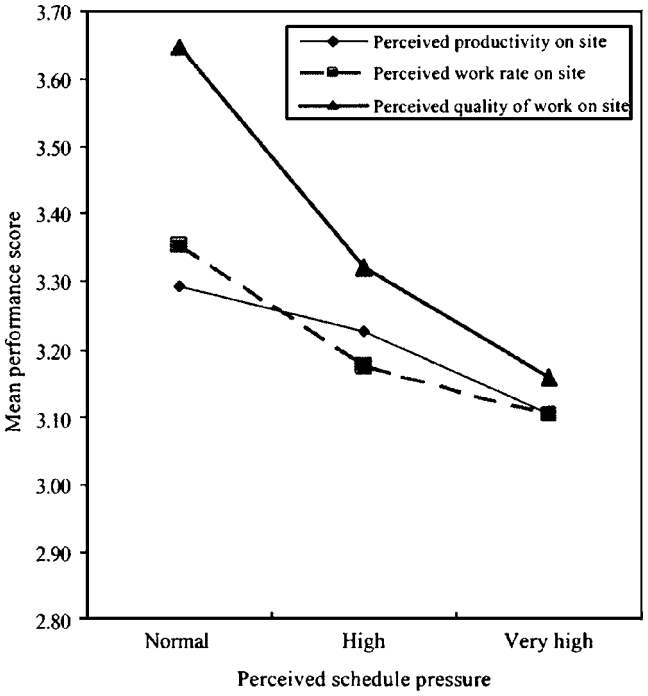

Fig. 4. Variation of site performance measures with respect to schedule pressure

ments are listed in Column 1 of Table 6. In this analysis, we used only the high and very high pressure individuals because we assumed that the hypothetical statements arose from working under high or very high schedule pressure. Table 6 lists the results of the analysis in terms of frequencies, mean, SD, and percentiles.

The majority of the respondents agreed that the schedule pressure does affect workers' work behavior and performance. The most significant negative effects of schedule pressure, as indicated by the practitioners, are the increase in the amount of out-of-sequence work and the number of work defects. The results confirm that workers do cut corners to meet deadlines when they feel pressured. The practitioners also believed that, under high-pressure conditions, workers tend to lose motivation to complete their work on time. This situation normally occurs when workers feel that the schedule is not feasible by any available means. A large proportion of industry participants disagreed or strongly disagreed, however, with Hypotheses c and d, which state that workers cut corners and lose motivation to work as schedule pressure increases (see the percentage values in the Column 3 and the 25 and 50 percentile values in Columns 11 and 12). It is possible that these results reflect the unique characteristics of Singaporean construction workers. The foreign workers who continue to form the bulk of the construction workforce in Singapore are perceived to complain less, to be less willing to communicate potential problems, and to have much lower expectations for their working standards (Loosemore and Lee 2002).

The results of this survey also strongly suggest that schedule pressure, to a certain extent, helps to increase productivity. There is also strong evidence to support the notion that high schedule pressure decreases workers' productivities (see the corresponding percentage and percentile values). The evidence, therefore, suggests that a moderate degree of schedule pressure may be essential to increase the efficiency and effectiveness of the workers, but too much pressure is detrimental to productivity. The decrease in workers' productivity upon increased schedule pressure is understandable because workers may try to cut corners or lose motivation to work in an effort to cope with their work stress. It is possible that the respondents who disagreed with our assumption of the negative effects of schedule pressure are those who had a better management teams that provided better scheduling and coordinating capabilities.

Scheduling Strategies

Many managers believe that "if you don't set the target high enough, workers won't deliver their best efforts" (Hopp and Spearman 1996). This notion is also common in construction projects. At one extreme, project clients often press hard to squeeze project schedules as much as they can. At the other extreme, site managers exercise an aggressive scheduling practice because of over optimism, or to recover a lagging schedule. As we discussed in the previous sections, however, schedule pressure invites many negative ripple effects on a construction workers' performance that ultimately reduce the rate, productivity, and quality of their work. It is, therefore, important to counteract and/or minimize the effects of schedule pressure on construction

Table 6. Sample Statistics for Effects of Schedule Pressure

		Extent of agreement								Percentiles		
Hypothesized statement	Frequency	1	2	3	4	5	Total	Mean	SD	25	50	75
(a) Out-of-sequence work increases as schedule pressure increases	Count	0	9	16	33	14	72	3.7	0.9			
	Percent	0	13	22	46	19	100			3.0	4.0	4.0
(b) Very high schedule pressure generates more defects in a project	Count	1	0	23	30	18	72	3.9	0.8			
	Percent	1	0	32	42	25	100			3.0	4.0	4.8
(c) Workers cut corners as schedule pressure increases	Count	12	16	22	18	4	72	2.8	1.1			
	Percent	17	22	31	25	6	100			2.0	3.0	4.0
(d) With greater pressure workers lose motivation to work	Count	7	17	30	14	3	71	2.8	1.0			
	Percent	10	24	42	20	4	100			2.0	3.0	3.0
(e) Schedule pressure to a certain extent increases productivity	Count	2	2	11	52	6	73	3.8	0.7			
	Percent	3	3	15	71	8	100			4.0	4.0	4.0
(f) High schedule pressure decreases workers' productivity	Count	6	11	30	20	5	72	3.1	1.0			
	Percent	8	15	42	28	7	100			3.0	3.0	4.0

Note: 1=strongly disagree; 2=disagree; 3=slightly agree; 4=agree; and 5=strongly agree.

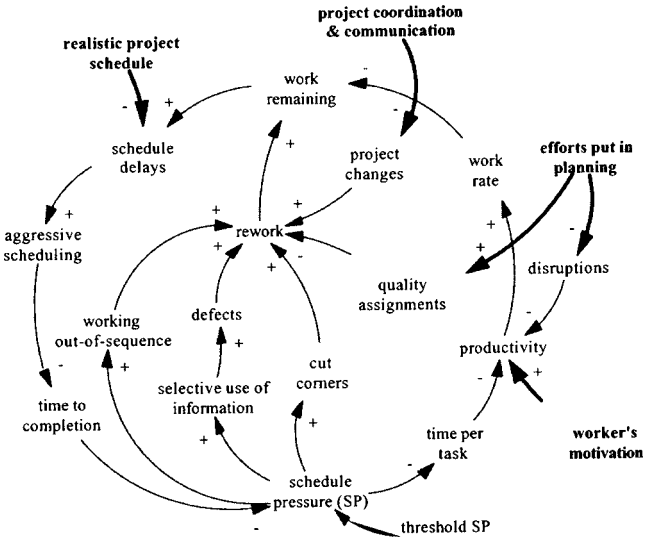

Fig. 5. Cause-and-effect analysis of scheduling strategies

performance by adopting sound and proper strategies. Based on our findings in this study, we have highlighted a number of strategies by incorporating them in the causal loop diagram presented in Fig. 5. In the following we discuss each of them briefly.

1. We suggested that the construction schedule be attainable and set realistically. Adequate time allocated for various activities would ensure that the specified quality standards would be achieved optimally. Owners and developers need to realize that by setting an unrealistic project duration they would have to compromise quality by allowing hidden defects into the constructed facility. The contractor would also lose money because schedule acceleration always turns out to be costly.
2. Motivating workers intrinsically or extrinsically can be an effective means of dealing with their working under schedule pressure, because losses in productivity are generally attributed to a decrease in worker motivation (Halligan et al. 1994). Therefore, to the extent that site management can keep workers motivated, it should be possible to minimize the impact of schedule pressure. Worker motivation can also help to reduce the amount of rework by lowering the workers' tendencies to cut corners. In addition, goal-setting, which is one of the strongest extrinsic motivational forces, can provide directions for operatives (Locke and Latham 1984). Indeed, goals must be set through active participation of both the site supervisors and the workers. This situation ensures that site staff and workers are not penalized for not attaining unrealistic targets. Care should be taken, however, when setting such goals because previous research has indicated that short-term goals are more effective than are long-term ones (Hadavi and Krizek 1993). The capacity of workers to work effectively in a given project environment, along with their personal and cultural values, must be taken into account when making schedule-related decisions. In addition, site managers should provide an equal amount of attention toward fulfilling the expectations and basic needs of their workers while still acting within the boundaries of their managerial and project constraints.
3. Site managers must act proactively to avoid the ripple and dynamic effects of schedule pressure through proper and/or rigorous planning of construction activities. Efficient site planning measures—such as material procurement and inspection, proper site layout and workspace design, adequate resource commitment (labor, materials, tools, and equipment) and site support facilities, and early design and drawing reviews—will minimize work disruptions and interruptions that are endemic to many construction sites. An increased amount of effort placed into planning helps to ensure the higher quality of work assigned to construction crews and ultimately reduces the amount of rework required. It should be emphasized, however, that site managers must be vigilant of the progress in the construction through constant schedule monitoring to ensure that the resources are used optimally and project milestones are met.
4. At the project level, establishing extensive levels of coordination and communication from the beginning of the project with suppliers, subcontractors/trades, and designers is a key to minimizing any possible negative effects of schedule pressure. Careful consideration should also be given to the overall work schedule of the project and its integration with the individual trades. In this survey, most of the subcontractors' site engineers and supervisors who reported that they were being worked under schedule pressure criticized the main contractor for failing to provide up-to-date, detailed information and on-time approval of submittals. Many of them also argued that the lack of coordination and design changes affected their normal schedule. As argued by Howes (2000), it appears that teamwork and the establishment of effective coordination and communication mechanisms are decisive factors in the construction process because they can provide a boost to the workers to help meet project deadlines or milestones without sacrificing their productivity or quality of work.

Conclusions

Aggressive project schedules or targets and the reactive response of the construction site manger to delays often invite undesirable consequences on a project's cost and schedule as a result of the dynamic nature of schedule pressure. This situation is due mainly to a lack of understanding of the tradeoffs and the cause-and-effect relationships of schedule pressure. If site managers do not understand these factors, unintended sacrifices in productivity and quality may occur in a quest to meet construction deadlines. Nevertheless, only a limited amount of attention has been paid to determine the significance of schedule pressure, and very little empirical research has been undertaken on this matter. In this paper we address this issue by analyzing the effects that schedule pressure has on construction performance, focusing on the tradeoffs in scheduling policies and the workers' responses against them.

Our research results suggest that a strategy of acceleration may cause more error-prone performance. We have demonstrated that the productivity, rate, and quality of work tend to decline as the schedule pressure increases above its normal level. This study indicates that while a moderate degree of schedule pressure may help to increase productivity—possibly by increasing worker alertness and attention—schedule pressure above a certain level leads to workers cutting corners, increases the amount of out-of-sequence work and the number of defects, and causes workers to lose their motivation to work productively. Our findings have important implications on the approaches taken by contractors because all of these factors contribute to increasing the amount of

J. Constr. Eng. Manage., 2006, 132(2): 182-188

rework, which ultimately lowers the overall site productivity.

The findings of this research study may contribute positively to many aspects of the construction process. Through cause-and-effect analysis, our results provide an insight for construction site managers on how schedule pressure can induce negative effects on construction performance. In particular, this study provides a good understanding of the tradeoffs of schedule pressure and, thus, could assist construction practitioners in the selection and implementation of appropriate scheduling strategies. Further, the method we describe in this paper is a useful analytical tool for assessing the effects that schedule pressure has at the construction operative level; it incorporates multiple interactions and feedback processes, which are often difficult to capture through mental models. We hope that construction practitioners will implement sound strategies and contingency plans in an effort to mitigate the adverse effects of working under schedule pressure. Our research has demonstrated that a greater degree of schedule pressure slows down the construction progress by lowering the quality of work. Allocating an optimum amount of schedule pressure at the operative level is, therefore, a key to achieving a maximum level of labor output and, consequently, to providing greater savings to contractors.

Research on the effects of schedule pressure is relevant because labor costs in construction constitute a significant fraction of the overall project cost and because construction productivity depends greatly upon the performance of its workers (Laufer and Jenkins 1982). The research insights and the strategies suggested in this paper will be useful for site managers as a step toward improving labor efficiency, on-site productivity, and work quality. In addition, estimators can take into account the effects of schedule pressure into the project cost and schedule estimates; this approach may, subsequently, provide better project control and monitoring.

The survey samples used in this research study were drawn from heterogeneous projects and individuals and, thus, the results provide a good representation of the attitudes in the construction industry. This research was performed in the context of the Singaporean construction industry and, thus, further empirical research needs to be undertaken in more diverse construction settings and environments to validate these findings. Further, additional research is needed on the relationship between project performance and schedule pressure, and its variations over the period in which the pressure exists, particularly with reference to project cost and schedule data. More in-depth studies are required to better understand the effects that schedule pressure has upon the construction process.

Acknowledgments

This research was sponsored by the Department of Building, National University of Singapore (Academic Research Grant No. R-296-000-081-112). The support obtained from Mr. Sangjin Han, Project Manager, Samsung Corporation Singapore, is gratefully acknowledged. The writers acknowledge the assistance of the two anonymous reviewers for their insightful, thorough, and constructive comments and suggestions. Finally, they thank all of the respondents who participated in their survey.

References

Alfeld, L. E. (1988). *Construction productivity: On-site measurement and management*, McGraw-Hill, New York.

Ballard, G., and Howell, G. (1998). "Shielding production: Essential step in production control." *J. Constr. Eng. Manage.*, 124(1), 11–17.

Bertrand, J. W. M., and Van Ooijen, H. P. G. (2002). "Workload based order release and productivity: A missing link." *Prod. Plan. Control*, 13(7), 665–678.

Bronner, R. (1982). *Decision making under time pressure*, Lexington Books, Lexington, Mass.

Construction Industry Institute (CII). (1989). "Concepts and methods of schedule compression." *Construction Industry Institute Publication No. 6-7*, The University of Texas at Austin, Austin, Tex.

Cooper, K. G. (1994). "The $2,000 hour: How managers influence project performance through the rework cycle." *IEEE Eng. Manage. Rev.*, 22(4), 12–23.

Eden, C., Williams, T., and Howick, S. (2000). "The role of feedback dynamics in disruption and delay on the nature of disruption and delay in major projects." *J. Oper. Res. Soc.*, 51(3), 291–300.

Hadavi, A., and Krizek, R. J. (1993). "Short-term goal setting for construction." *J. Constr. Eng. Manage.*, 119(3), 622–630.

Halligan, D. W., Demsetz, L. A., Brown, J. D., and Pace, C. B. (1994). "Action-response model and loss of productivity in construction." *J. Constr. Eng. Manage.*, 120(1), 47–64.

Hopp, W. J., and Spearman, M. L. (1996). *Factory physics: Foundations of manufacturing management*, Irwin, Chicago.

Horner, R. M. W., and Talhouni, B. T. (1995). *Effects of accelerated working, delays and disruption on labor productivity*, The Chartered Institute of Building, Ascot, U.K.

Howes, R. (2000). "Making governance mechanisms effective in a coordinated industry: The case of construction in the United Kingdom." *Int. J. Technol. Manage.*, 20(1), 194–213.

Laufer, A., and Jenkins, D. G. (1982). "Motivating construction workers." *J. Constr. Div., Am. Soc. Civ. Eng.*, 108(4), 531–545.

Locke, E. A., and Latham, G. P. (1984). *Goal setting for individuals, groups, and organizations*, Science, Research Associates, Chicago.

Loosemore, M., and Lee, P. (2002). "Communication problems with ethnic minorities in the construction industry." *Int. J. Proj. Manage.* 20(7), 517–524.

Michalak, C. F. (1997). "The cost of chasing unrealistic project schedules." *Transactions of the American Association of Cost Engineers*, PC.02.1–PC.02.6.

Norušis, M. J. (2002). *SPSS 11.0 guide to data analysis*, Prentice Hall, Upper Saddle River, N.J.

Pallant, J. (2001). *SPSS survival manual: A step by step guide to data analysis using SPSS for Windows (version 10)*, Open University Press, Buckingham, U.K.

Pena-Mora, F., and Park, M. (2001). "Dynamic planning for fast-tracking building construction projects." *J. Constr. Eng. Manage.*, 127(6), 445–456.

Rastegary, H., and Landy, F. J. (1991). "The interactions among time urgency, uncertainty, and time pressure." *Time pressure and stress in human judgment and decision making*, O. Svenson and A. J. Maule, eds., Plenum, New York, 217–239.

Sterman, J. (2000). *Business dynamics: System thinking and modeling for a complex world*, McGraw-Hill, New York.

Svenson, O., and Benson, L. (1991). "On experimental instructions and the inducement of time pressure behavior." *Time pressure and stress in human judgment and decision making*, O. Svenson and A. J. Maule, eds., Plenum, New York, 157–165.

Thomas, H. R. (2000). "Schedule acceleration, work flow, and labor productivity." *J. Constr. Eng. Manage.*, 126(4), 261–267.

Wickens, C. D., and Hollands, J. G. (2000). *Engineering psychology and human performance*, 3rd Ed., Prentice Hall, Upper Saddle River, N.J.