PHYSICAL FACTORS AFFECTING PRODUCTIVITY OF TURKISH CONSTRUCTION WORKERS

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This survey investigates the current situation of labour productivity in the Turkish construction industry from physical viewpoint. In this research, it is aimed that the physical factors influencing worker performance are determined, defined, and evaluated in detail. For this purpose, a survey of 82 large scale construction companies in Turkey was carried out. The survey used a questionnaire applied to managers, engineers, and architects of the firms with one-to-one technique. The results were evaluated by means of the relative importance index method. The research findings pointed out that working at similar activities, design complexity, and error tolerance were ranked as the three most influential physical factors on worker performance.

Keywords: labour, physical factors, productivity, Turkey.

INTRODUCTION

In today's competitive market, labour represents one of the most significant risks to contractors. In other words, project risks cover uncertainties due to labour. Construction industries in many developed and developing countries suffer from delays and cost overruns due to poor labour productivity (Odeh and Battaineh 2002), as was in Turkey (Arditi *et al.* 1985).

Construction workers are not machines, always behaving the same way under the same conditions. Even under apparently identical work conditions, different productivity values might be obtained. That is, the productivity for the same work item is not constant throughout the construction period, and varies at different stages of the production. As a conclusion, variability is shown to be a key factor in the behaviour of construction labour productivity. Meanwhile, the effect of the factors on productivity may vary from task to task. Although some factors could have similar influences on productivity of a number of tasks, their rate of impact on productivity may be different (Kazaz and Ulubeyli 2004).

Several factors, of course, have potential to impact worker productivity such as organizational, economic, and socio-psychological. Physical factors are one of them, and this type of factors always affects construction workforce productivity with serious indications. On the other hand, any survey, which investigates physical factors in terms of labour productivity, does not exist in the construction management literature. Some researchers such as Sonmez and Rowings (1998) and Ng *et al.* (2004)

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examined some factors influencing manpower productivity without any classification. Rojas and Aramvareekul (2003), which is the exceptional study in this regard, shortly considered very limited factors although classified. Therefore, in the present study it is aimed that physical factors are formed and evaluated thoroughly. Thus, it will be possible to create more concrete criteria for these factors. Moreover, there is a lack of common reference point in establishing these factors, and this study is a proposition in this regard. Consequently, today's position of construction productivity of Turkish labour will be divulged from the physical perspective.

RESEARCH METHODOLOGY

A detailed questionnaire comprised of 16 questions was first formed to obtain the data required for the study (Ulubeyli 2004). Turkish Employers' Association of Construction Industries (TEACI) and Turkish Contractors Association (TCA) were then contacted. 187 construction firms are available in these associations. The telephone interviews explaining the content of this survey were conducted with the top directors of 187 firms, and hence, 82 of them (43.85%) positively responded. As can be seen from Figure 1, a large amount of them (78.05%) comprises medium and large scale organizations.

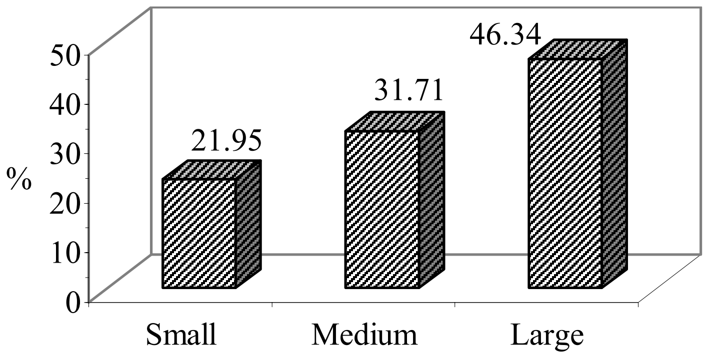

Figure 1: Firms' scales according to their annual turnovers

In terms of working fields in the sector, these 82 companies have undertaken almost every type of construction projects to date (see Figure 2), i.e. building (residential, commercial, educational, touristic, etc.), engineering (highway, bridge, dam, harbour, infrastructure, etc.), and industrial (power plant, pipe line, refinery, etc.).

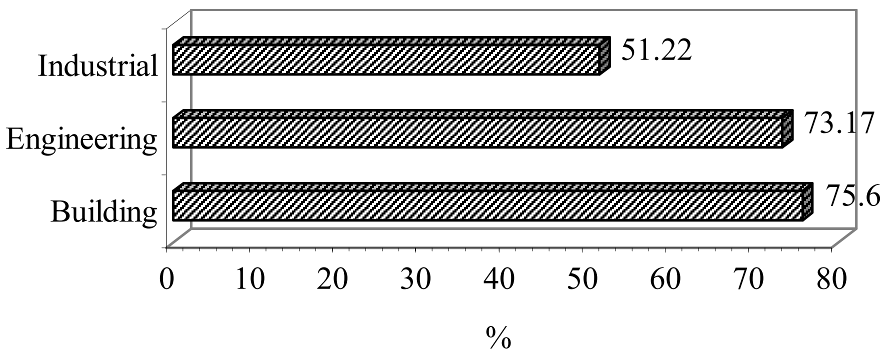

Figure 2: Type of contractors

The questionnaire was applied to technical staff of the firms by the one-to-one technique. 10 firms that could not be contacted were interviewed by e-mail. As shown in Figure 3, most of the firms and respondents have extensive experience in the construction industry.

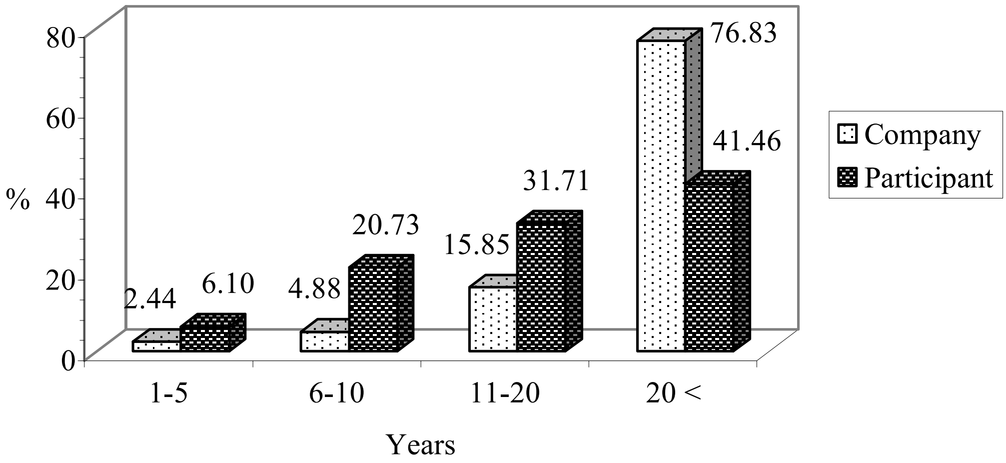

Figure 3: Experience of the firms and respondents

To analyze the data provided by the questionnaire, a Relative Importance Index (RII) was calculated. To this aim, a rating scale of 1 to 5 was used with 1 representing the lowest level of effect and 5 representing the highest level of effect. The RII was calculated by means of the following formula (1):

$$RII = \frac{\sum_{i=1}^{5} W_i X_i}{\sum_{i=1}^{5} X_i}, \quad (1 \le RII \le 5), \qquad (1)$$

W_i, is the rating given to each factor by the participants ranging from 1 to 5, with 1 representing 'not significant' and 5 representing 'extremely significant'; X_i, is the percentage of participants scoring; and i, is the order number of participants. The numerical values evaluated by the above equation were then differently classified since a single point or number changing from 1 to 5 in questions no longer symbolizes each verbal scaling expression in the evaluation phase. In contrast, these five expressions are defined by the intervals of 0.8 as the following,

- 1.00 ≤ not significant (NS) ≤ 1.80
- 1.80 < somewhat significant (SS) ≤ 2.60
- 2.60 < significant (S) ≤ 3.40
- 3.40 < very significant (VS) ≤ 4.20
- 4.20 < extremely significant (ES) ≤ 5.00

The percentages of participants scoring 2 or fewer, 3, and 4 or more, on the significance scale were also calculated for the factors to rank them in which relative importance indices were the same.

RESULTS

In this study, nine physical factors were investigated: working at similar activities, design complexity, error tolerance, weather conditions, disruptions, schedule compression, overtime, shift, and site congestion. These are clarified in descending order below. Statistical results of the RII technique can be seen in Table 1. The survey results exposed that working at similar activities, design complexity, and error tolerance were ranked by the respondents as the three most influential motivators with the 'very significant' effect. On the other hand, site congestion was calculated as the least predominant factor with the index of 2.83, showing a 'significant' effect. Six of nine factors have 'very significant' effects on productivity while it is 'significant' for the rest of them. The average index of the whole factors was determined as 3.46. This effect level points out that labour performance is 'very significantly' impacted by physical factors.

Table 1: Relative importance index results

Rank	Physical factors	RII	Effect level	Percentage of respondents scoring		
				≥ 4	3	≤ 2
1	Working at similar activities	4.04	VS	87.18	8.97	3.85
2	Design complexity	3.68	VS	60.53	28.95	10.53
3	Error tolerance	3.64	VS	65.33	24.00	10.67
4	Weather conditions	3.53	VS	54.66	34.67	10.67
5	Disruptions	3.50	VS	48.68	36.84	14.47
6	Schedule compression	3.43	VS	44.00	48.00	8.00
7	Overtime	3.26	S	44.73	35.53	19.74
8	Shift	3.25	S	36.36	45.45	18.18
9	Site congestion	2.83	S	21.06	48.68	30.26
	Average	3.46	VS			

DISCUSSION AND RECOMMENDATIONS

Working at similar activities

Working constantly at the same or similar activities in the construction sector is one of the key elements guaranteeing the work to be performed in a definite standard. Experience is the warranty of success and productivity in any job. If experienced labour is known to be available, supervisors do not have to explain details of how to perform the tasks to experienced workers. In addition, estimator can foresee that the learning curve will not be significant, and productivity and quality of work will be better than those of a new worker. As the skill level and experience of fellow workers increase, job-site safety and health concerns are also likely to decline. This in turn may reduce workers' compensation and insurance costs in the industry. As a result, sustainability of the productivity level of construction workers today depends completely on specializing in a specific craft. On the other hand, experience and seniority concepts do not necessarily go hand in hand because the number of years that someone has been working in an industry may not be as relevant as the specific activities performed. Namely, the quality and diversity of the work performed is far more important than the number of years in a particular position.

Design complexity

As the work content increases or the design becomes more complex, the productivity worsens. Complex products in the construction industry usually prevent productivity from reaching higher values. In this point, the importance of communication between project designers and technical staff who put the project into practice in site appears. The only condition providing that the project is not influenced negatively in case of lack of communication is that project designers have perfect site experience.

Error tolerance
The required quality of finished work is a main factor affecting workforce productivity. Too limited error tolerances in production decrease labour productivity. However, this factor can create an adverse effect, making the required quality specifications closer since it increases labour's care.

Weather conditions
High speed winds, hot and freezing temperatures, snowfall accumulation, high and low air pressures because of altitude, high relative humidity rates, rain showers, or any combination of these parameters are common examples of dominant parameters for adverse weather conditions. In this context, clothing can also be accepted among these parameters due to affecting the heat transfer between the body and the environment. The U.S. Army Corps of Engineers and most sophisticated owners consider the weather 'adverse' on days during which precipitation reaches or exceeds 25 cm and/or where the temperature is 0 degrees Celsius or colder (White paper 2004). Bilhaif (1990) concluded that whilst construction workers' productivity is generally influenced by temperature variations, there is no consistent relationship between these two parameters. However, some studies (Srinavin and Mohamed 2003) that establish a proper thermal temperature-worker productivity relationship by modelling are available in construction. The loss of efficiency due to adverse weather events has been investigated in some studies in detail. These can also be accepted as the researches suggesting optimum weather conditions for high productivity levels. Thomas *et al.* (1999) found out that the daily output of the crew was reduced to a loss of efficiency of 35-41% when snow occurred, and 30-32% when temperatures were less than -7^0C. In the study of Thomas *et al.* (1992), it was observed that significant losses of 65% in productivity was due to rainfall, and cold temperatures also had an effect, resulting in a loss of efficiency of about 30%. NECA (1987) estimated that for a relative humidity of 30-50% and temperatures of -12^0C, the loss of efficiency was in the range of 12-14%. Another article (Thomas and Yiakoumis 1987) asserted that productivity decreased when the temperature deviated from 13^0C or when relative humidity was above 80%. Grimm and Wagner (1974) established a relationship between productivity and a combination of two climatic parameters (i.e. temperature and relative humidity), and observed the highest productivity level at 24^0C and 60% relative humidity. Similarly, another study (NECA 1974) examined the impact of temperature and humidity on productivity for a non-physically demanding task, and it was seen that productivity declined at temperature levels above 27^0C and below 4^0C and at relative humidity rates above 80% especially at high temperature levels. A comprehensive study (Oglesby *et al.* 1989) found that productivity reached its peak in a human thermal comfort zone where temperatures range from about 10^0C to 21^0C under wide variations in relative humidity.

Disruptions
According to Thomas and Napolitan (1995), the ripple effect based on work changes result in a daily loss of labour productivity in the range of 25-50%. Thomas *et al.* (1999) found that disruptions resulted in a reduction of crew performance of 22-25% while Thomas and Raynar (1997) determined that the efficiency on days when disruptions occurred was reduced to an average of 73% of what it would have been if

there had been no disruption. Changes may also possibly impact the worker morale by causing interruptions, adjustments in crew makeup, and requiring rework. The key variable affecting labour efficiency is believed to be the timing of the change. Changes issued later in the projects tend to have a more negative impact on productivity than those when the project is below 50% complete due to the factors such as less time to perform the changed work, large amount of material procured and installed, and crew interruptions. The random variability in daily productivity values in case of the absence of disruptions is about twice the productivity. Values exceeding this limit are almost always the result of assignable causes, i.e. disruptions because of the loss of learning (Thomas *et al.* 2003). Labour inefficiencies also occur when both larger and smaller amounts of work than estimated or planned are made available. The reasons of discontinuity of work include weather and related topographical conditions, equipment and material based problems, work accidents, engineering and design errors, managerial problems, out-of-sequence work due to changes, and rework.

To achieve successful construction projects, the planned activities in a work schedule have to be continuous because out-of-sequence works, disruptions, and discontinuous repetition of tasks produce loss of rhythm due to the forgetting effect. That is, crews need to stop working on their present assignments and reorganize for the new work. The increase in change orders and loss of productivity has a negative impact on worker morale, and increase the amount of absenteeism and turnover. This then becomes a cycle in which increases in absenteeism and turnover will decrease productivity even further.

The industry's agreement is that construction workers have to learn task details, and be accustomed to managers and workmates at the beginning of each project. Poor productivity and high cost due to the learning curve effect just in the initial stages of production in the manufacturing industry appear in almost every project in the construction industry. It is obvious that repetitive operations offer better opportunities than one-off activities to achieve higher productivity. It is widely recognized that as the number of repetitions increases or more units are produced; additional experience and practice are gained, the time and effort expended to complete repetitive construction activities decrease, and hence, work progresses at a faster rate. According to Ballard and Howell (1994), productivity performance for crews with a PPC (the percentage of planned tasks completed) above 50% is 35% better than that of crews with a PPC below 50%. However, the decrease in the schedule duration and production quantity results in lower productivity and higher budget. Larger projects, accordingly, have a higher capacity for absorbing loss of efficiency caused by change order work. The effect of production quantity on labour productivity due to the use of repetitive elements is not linear. As the amount of quantities of a product completed for the task significantly increases, the production rates improve and the cumulative average man-hours decline since learning is fulfilled.

Schedule compression

Construction labour productivity impacted broadly by deviations from the normal flow of work planned before in the projects causes schedule compression. The efficiency level that has been reduced automatically due to uneven flow of work decreases one more time because of this acceleration. Noyce and Hanna (1998) examined the effect of shortening the estimated duration on workers during project. The results of that study indicated that planned or unplanned schedule compression causes losses in labour performance. Thomas (2000) similarly found out that the economic consequences of schedule acceleration to the contractor relative to labour productivity were quite severe, with estimated losses of labour efficiency easily within the range of 20 to 45% on an average of 25% on account of time pressure.

Overtime
As practiced in many countries, the overtime concept in construction is originally used to catch up with schedule when the project is behind schedule. Operatives are forced to initiate overtime working without hiring additional workers, which can lead to several problems such as site congestion. There is little doubt that scheduled overtime creates an adverse effect on the motivation and physical strength of workers. It results in a rise of absenteeism and a loss of productive output of labour due to fatigue or poor mental attitude. But in reality, the vital aspect of this subject is that the more prolonged the period of overtime for working, the greater the loss in productivity. Thomas (1992) reported that a 12% reduction in efficiency could be expected for every 10 hours of overtime worked. Thomas and Raynar (1997) observed that average productivity losses due to overtime were between about 10 and 15% as short-term overtime effects, i.e. during 3 to 4 weeks and less. Horner and Talhouni (1995) proved a linear relationship showing increases in working overtime of 5 hours per week from 40-hours standard week, as causing 5% productivity loss. Conclusions drawn by that paper are in line with the findings of BRT (1980), reporting that where a work schedule of 60 or more hours per week continued for longer than 2 months, the cumulative effect of decreased productivity caused a delay in the completion date beyond that which could have been realized with the same crew size on a 40-hours week. BRT (1991) similarly claimed that work schedules that extend beyond 40-hours per week reduce labour productivity and create excessive inflation of construction labour costs without material benefit to the completion schedule. An overtime schedule, however, when applied for particular purposes and short periods can be beneficial and help to achieve desired performance. In some instances, overtime is required by labour, and it is arranged to motivate workers by allowing extra income because the wage for overtime hours is 50-100% higher than the regular earnings.

Shift
Working in relays is not a productive working style indeed. All of the managers interviewed in this survey have asserted that they prefer overtime to shift since labour might slow down or shirk due to darkness. Another drawback of the factor suffered is that a comprehensive coordination with other trades and shifts is certainly needed.

Site congestion
Over-staffing and inadequate working areas at the work place likely result in delivery problems, disruptions, and serious cost implications. It impairs construction productivity because of undesired working conditions, and provides increased opportunities for unnecessary worker interface. Some physical plant congestion regarding labour density is inevitable although feelings of constriction and frustration are frequently felt. According to Smith (1987), as working space decreases from 30 m^2, which is the standard working space, to 10 m^2 per operative, it incurs about a 40% productivity loss. Rad (1980) also estimated an average weekly loss of 5 hours per man, resulting from the overmanning problem on nuclear power station sites. The relationship between the number of labour and the total output of them says that as more and more of workers are used in a construction site, there will come a point when total output will fall. In fact, this top point represents the most desired situation, i.e. maximum output and optimum number of employees.

CONCLUSIONS

In this study, physical factors influencing construction manpower performance was determined and evaluated by taking the industrial conditions of a developing country into consideration. The comprehensive explanations about the factors can be seen both as a baseline leading to future works for academicians, who may find interesting similarities between their countries and Turkey about productivity-related issues, and as an original point of view for professionals. Despite the fact that all of the factors should be paid attention in detail, the research results pointed out that the respondents ranked the followings as the three most influential physical factors on worker productivity,

- working at similar activities,
- design complexity, and
- error tolerance.

The rank order of the 'working at similar activities' factor is actually not an interesting or surprising outcome for the sector. If the low levels of education and training of construction labour in Turkey, it is a usual practice that the quality and productivity of activities carried out by workers is based entirely on experience. On an average, it was also found out that labour performance in Turkey is 'very significantly' impacted by physical factors. This is the proof of that physical issues established in the present research are perceived as one of the main productivity drivers in construction.

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