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Identification and Evaluation of Effective Factors on Labor Productivity in Power Plant Construction Projects

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Abstract: Productivity improvement of construction projects, due to labor productivity improvement, has been a major challenge in construction industry for decades. In this regard, construction project performance could be improved by identification, evaluation and improvement of effective factors on labor productivity. The objective of this paper is to identify and evaluate the effective factors on labor productivity in thermal power plant construction projects. To achieve this objective, on the basis of a comprehensive review of literature, an opinion survey is conducted on labor productivity factors which are classified under the following five primary groups: (1) management/supervision; (2) planning; (3) technical; (4) human/labor; (5) external. Survey participants include direct and indirect human resources of thermal power plant construction projects in Iran which are categorized in two classes: (1) site staff; (2) office staff. Finally, effective factors on labor productivity in power plant construction projects are identified and their relative importance indices and ranks are determined by analyzing the results of the questionnaire survey. Findings of this paper are the most important effective factors on labor productivity and their relative importance in power plant construction projects. Since productivity of a construction project is affected both directly and indirectly by the labor productivity, the results of this paper could be used to improve the power plant construction projects performance by labor productivity improvement. Moreover, these results could be utilized in other construction projects in developing countries.

Keywords: Labor productivity, Effective factors, Relative importance, Power plant construction projects.

1 Introduction

Productivity improvement of construction efforts, due to labor productivity improvement, has been a major challenge in construction industry for decades. Construction is a labor-intensive industry, and in most countries, labor cost comprises 30 to 50% of the overall project's cost (Yates and Guhathakurta 1993, Hanna 2001, McTague and Jergeas 2002, Harmon and Cole 2006). Labor is more variable and risky than other project cost components and compared to other project cost components such as material and equipment, labor costs have more opportunity to improve by good management (Hanna et al. 2008). Horner et al. (1989) indicated that a 10% increase in construction labor productivity would yield annual savings of approximately billion to the British economy; a similar conclusion was echoed by Stoekel and Quirke (1992). So, labor productivity performance plays a key role in determining the financial success of a project (Liu and Ballard 2008). According to the aforementioned statements, identification and evaluation of factors affecting labor productivity is not only desirable but also necessary to improve construction labor productivity which mainly affect construction productivity. The first step in finding opportunities for improvement of labor productivity is to identify what factors are affecting it. The second step is to find relative importance of factors. After completing these steps, managers can effectively

dealing with lowering costs and improving schedules, as well as, obtaining a more accurate productivity prediction when estimating construction costs (Borcherding and Alarcón 1991, Edmondson 1974). Utilizing (or amplifing) factors that positively affect productivity and eliminating (or controlling) factors that have a negative effect, will ultimately improve labor productivity.

Due to the increasing demand for energy in recent years, power plant construction projects have been highly put on the agenda in Iran's construction projects. According to different disciplines and labor force engaged in these projects in various stages of construction and installation on one hand, and on the other hand the high volume of investment required for these projects, it is obvious that addressing the issue of labor productivity in the implementation of these projects is very necessary and important.

Therefore, the objective of this paper is to identify and rank the relative importance of effective factors on labor productivity in power plant construction projects in Iran, since productivity of a construction project is affected both directly and indirectly by the labor productivity. The results of this paper can be used to improve the power plant construction projects performance by labor productivity improvement. In addition, the outcomes can be utilized in other construction projects in developing countries.

2 Literature Review

In theory, productivity is defined as output divided by input, where both output and input are usually expressed in cost. In construction, it is more often described as units of production output per personnel-hour input (Neil and Knack 1984, Thomas 2000).

Horner et al. (1989), in a questionnaire survey to a wide section of British constructors, have identified the significant factors as follows: skill of labor, buildability, quality of supervision, method of working, incentive scheme, site layout, complexity of construction information, crew size and composition. Lim and Alum (1995) explored various factors impacting the construction productivity in Singapore and shortlisted the followings as most significant: lack of qualified supervisors, shortage of skilled labor, high rate of labor turnover, labor absenteeism, and communications with foreign laborers. Kaming et al. (1997) studied factors affecting the productivity of craftsmen in Indonesia and concluded that lack of materials, rework, absenteeism of operatives, and lack of suitable tools, are among the most influential.

Makulsawatudom et al. (2004) researched the influence of 23 factors on the productivity of the construction industry in Thailand and deduced that lack of material, incomplete drawings, incompetent supervisors, lack of tools and equipment, labor absenteeism, poor communication, instruction time, poor site layout, inspection delay, and rework, are the most critical. Alinaitwe et al. (2007), further ranked the following five factors as being most significant according to their recognized impacts on the productivity of craftsmen in Uganda: incompetent supervisors, lack of skills, rework, lack of tools/equipment, and poor construction methods. Dai et al. (2009) quantified craft workers' perspective of 83 factors affecting their productivity, in a nationwide survey involving 1,996 craft workers throughout the United States. Factors involving tools and consumables, materials, engineering drawing management and construction equipment were identified as having the greatest impact on productivity from the craft workers' perspective.

Kheirieh and Heravi (2011) distributed a number of structured questionnaires (include 45 factors) among a group of craft workers, technicians, and engineers in construction job site located in South Pars Gas Field development phase 12, Assaluyeh, Iran. Their findings revealed that weather, management, motivation and incentives, tools, planning and materials have the greatest impact on labor productivity in South Pars Gas Field. Jarkas et al. (2012) identified and ranked the relative importance of 45 factors perceived to affect labor productivity on construction sites in Kuwait. Among the factors explored, the subsequent 10 are discerned to be the most significant in their effects on labor productivity: (1) clarity of technical specifications; (2) the extent of variation/change orders during execution; (3) coordination level among design disciplines; (4) lack of labor supervision; (5) proportion of work subcontracted; (6) design complexity level; (7) lack of incentive scheme; (8) lack of construction manager's leadership; (9) stringent inspection by the engineer; and (10) delay in responding to requests for information.

As mentioned above, different studies have been performed to identify, classify or arrange the influencing factors on labor productivity. Despite such intensive investigations, researchers have not agreed on a universal set of factors with significant influence on labor productivity, nor has any agreement been reached on the classification of these factors.

3 Research Methodology and Data Collection

Figure 1 shows the research methodology, which contains three main steps: (1) Identifying and classifying labor productivity factors, (2) Data collection, and (3) Data analysis.

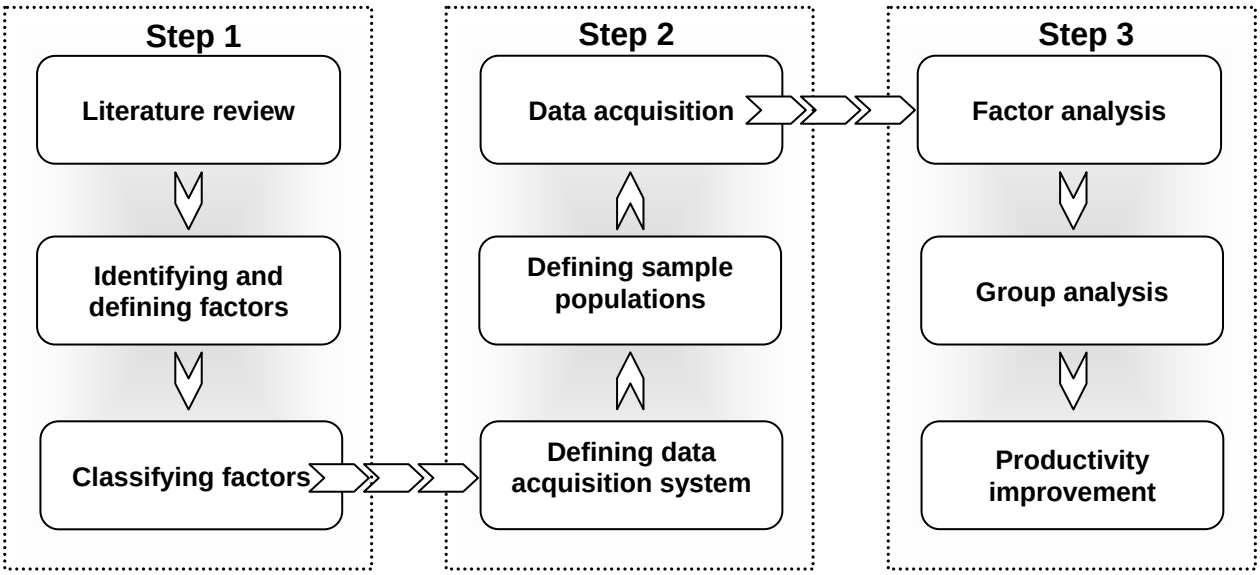

Figure 1: Framework of research methology

The relevant data to this investigation are collected by a structured, closed-ended questionnaire survey which is distributed among the representative sample of the population. On the basis of related previous researches on labor productivity, by a more general review of effective factors compared to previous studies, and expert judgment, 15 factors are identified and classified to five primary groups: (1) management/supervision; (2) planning; (3) technical; (4) human/labor; and (5) external (table 1).

Thermal power plant construction projects (consisting of gas, heater, and combined cycle power plants) are the most common types of power plants in Iran which are labor-intensive, and thus appropriate choices for labor productivity investigation. So, The population of this study are selected from human resources of thermal power plant construction projects, include two classes of people whose perspectives can be determinant and different about effective factors on labor productivity:

- **Site staff:** This group includes different people who are directly associated with on-site works such as foremen, supervisors, coordinators, HSE staff, quality control staff, and project control staff. A good understanding of the factors affecting labor productivity can be obtained by those directly related with on-site production in construction projects. This can also enable site managers to make decisions more effectively to improve labor productivity (Dai et al. 2009).

- **Office staff:** This group includes those who work in central offices of construction companies of power plant projects which consists of administrators and different experts such as: human resource, mechanical, electrical, construction and installation experts. Their opinion can be very efficient because of their access to different projects and construction progress data.

Table 1: Factors affecting labor productivity along with groups, and subfactors

Group	Factor	Subfactor
Management/supervision	**Supervision**	Sufficient labor supervision; Supervisor's competence; Supervisor's positive characteristic and behavior; Fair/just performance reviews by supervisor; Hinder late arrival, early quit, and frequent unscheduled breaks of labor; Avoid interruption and disruption; Avoid Changing, turnover and absenteeism of worker or superior
	Proper Coordination	Coordination between the trades; Consider proper sequence of work assignments; Prevent Interference and congestion
	Effective Communication	Constructive communication between site management and labor; Interaction of technical office and executive committee
	Poor Decision Making	Slow decisions; Delay in work permit; Delay in responding to requests for information (RFI); Delay in responding to questions with drawings
Planning	**Proper Planning**	Proper and realistic scheduling; Proper crew size and composition; Proper resource allocation
	Proper HSE Program	Site safety program and performance for prevention of accidents; Site health program and performance for prevention of labor injuries; Safety and health Training
	Schedule Compression	Working overtime; Shift work; Overmanning; Extra work
Technical	**Technical Excellence**	Designs, drawings and technical specifications (in terms of availability, errorless, clarity & legibility); Proper construction method, technology and Engineering
	Suitable Site Layout	Site restricted access; Suitability of storage location; Sufficient size of material storage area
	Frequent Change Order	Change of designs, plans, scheduling, sequence of works and etc.
	Materials, Tools and Equipment Deficiency	Material damage and defect; Deficiency of tools and equipment; Lack of repairman for tools and equipment; Materials, Tools and equipment poor maintenance
Human/labor	**Labor Competence**	Skill of labor; Experience of labor; Education; Skill Training of labor
	Sufficient Facilities and Accommodation	Suitable rest area offered to labor on site; Providing labor with ample transportation
	Motivation of Labor	Respect for worker; Craftsmen's incentive scheme; Avoid delay in payments
External	**Unfavorable External Condition**	Bad weather conditions (High/low temperature, Rain, snow and etc.); Environmental factors (noise, dust, poor lighting & ventilation); Political, Social, Cultural & Economical poor conditions

150 questionnaires were sent out, and a total of 106 feedbacks which provided suitable data for the research were returned. The overall return rate for the survey is therefore 66%. Considering the Cochran Formula for calculating the sample size for large populations (George and Mallery 2006), based on 90%

confidence level and 10% margin of error, the sample size of 68 is adequate. Survey sample composition is shown in Table 2.

Table 2: Survey sample composition

Site staff (Number: 49; Percent: 46.2%)			Office staff (Number: 57; Percent: 53.8%)		
Position	**Number**	**Percent**	**Position**	**Number**	**Percent**
Supervisor	12	11.3%	administrator	8	7.5%
Foreman	7	6.6%	Human resource expert	5	4.7%
Coordinator	9	8.5%	Mechanical expert	13	12.3%
Project controller	10	9.4%	Electrical expert	11	10.4%
Quality controller	7	6.6%	Construction expert	11	10.4%
HSE staff	4	3.8%	Installation expert	9	8.5%

The questionnaire survey comprised an ordinal measurement scale (Likert scale) ranking the effect level of each factor in an ascending order from 1 (no influence) to 5 (most influential) regardless of the positive or negative impact of the factor. Subfactors as the explanations of factors were considered in the questionnaire which help respondents to rank the factors with perfect view and clear understanding of them.

The data collected were analyzed using the relative importance index technique. The relative importance index was calculated by the formula shown in Eq. (1):

$$[1] \qquad \text{Relative importance Index (\%)} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1}{5\left(n_5 + n_4 + n_3 + n_2 + n_1\right)} \times 100$$

Where n_1, n_2, n_3, n_4, and n_5 = the number of respondents who selected: 1, for no effect; 2, for little effect; 3, for moderate effect; 4, for strong effect; and 5, for very strong effect, respectively. The relative importance index was used to determine the rank of each factor explored. The rank of each group was established by quantifying the average value of the importance indices for all factors within; the higher the average value, the stronger the effect of the group.

To measure the internal consistency or reliability of the questionnaire, the Cronbach's alpha method is applied. The Cronbach's alphas for "total", "site staff", and "office staff" classes, are calculated as 0.78, 0.81, and 0.77, respectively. The desirable value is 0.7 or more (George and Mallery, 2006).

4 Results and Discussion

After processing the information from the questionnaires, the relative importance indices and ranks of the factors are determined within each of population classes separately and also within the total population (Table 3). The most significant factors are presented and compared to previous research studies. The group importance indices are, furthermore, quantified, and therefore a comparison among their relevant importance within the total population and each of population classes is carried out (table 4).

4.1 Relative importance of individual factors

With an overview of the relative importance of considered factors it is observable that relative importance indices of all factors in both of the classes and total, have scores higher than 50% except schedule compression which has scores of 48.11%, 43.67% and 51.93% in total, site staff and office staff views, respectively. Furthermore, the most of relative importance indices are higher than 60%. This indicates that all considered factors have significant influence on labor productivity, and their selection procedure, with perfect literature review and expert judgment was valid.

Table 3: Relative importance indices and ranks of productivity factors surveyed within the site staff, office staff and total perspectives

Sample size Total:106; Site staff: 49; Office staff: 57	**Relative importance index% (RII)**			**Rank**		
Factor	**Site staff**	**Office staff**	**Total**	**Site staff**	**Office staff**	**Total**
Supervision	77.55	87.37	82.83	5	2	3
Proper Coordination	70.61	80.00	75.66	7	6	6
Effective Communication	59.59	74.38	67.55	12	7	9
Poor Decision Making	58.78	68.77	64.15	13	9	11
Proper Planning	77.14	82.10	79.81	6	5	5
Proper HSE Program	62.04	55.09	58.30	10	14	14
Schedule Compression	43.67	51.93	48.11	15	15	15
Technical Excellence	79.18	82.46	80.94	4	4	4
Suitable Site Layout	61.22	60.35	60.75	11	13	12
Frequent Change Order	55.10	64.56	60.19	14	11	13
Materials, Tools and Equipment Deficiency	82.86	65.26	73.40	3	10	7
Labor Competence	89.80	83.86	86.60	1	3	2
Sufficient Facilities and Accommodation	64.49	72.28	68.68	9	8	8
Motivation of Labor	84.49	89.12	86.98	2	1	1
Unfavorable External Condition	69.80	62.10	65.66	8	12	10

On the basis of above opinion survey, as depicted in Table 3, the most effective factors on labor productivity are as follow:

- **Motivation of labor (Rank 1):** This factor, as an effective factor on labor productivity, is studied in several researches such as: Hazeltine (1976); Borcherding et al. (1980); Horner et al. (1989); Enshassi et al. (2007); Kheirieh and Heravi (2011), and Jarkas et al.(2012).

- **Labor competence (Rank 2):** Horner et al. (1989); Lim and Alum (1995); Heizer and Render (1996); Alinaitweet al. (2007), and Enshassi et al. (2007) are some of researches that have studied this factor as an effective factor on labor productivity.

- **Supervision (Rank 3):** The related influence of this factor is in agreement with the findings of Lim and Alum (1995); Makulsawatudom et al. (2004); Alinaitwe et al. (2007); Enshassi et al. (2007), and Jarkas et al. (2012), whose research asserted the importance of this factor to labor productivity.

- **Technical excellence (Rank 4):** This outcome supports the findings reported by Horner et al. (1989); Makulsawatudom et al. (2004); Alinaitwe et al. (2007), and Jarkas et al. (2012), whose investigations identified this factor among the most significant factors impacting labor productivity.

- **Proper planning (Rank 5):** The perceived effect of this factor is in agreement with the results obtained by Horner et al. (1989), and Kheirieh and Heravi (2011).

4.2 Relative importance of groups of factors

Table 4 shows ranking of the five primary groups, under which the corresponding factors affecting labor productivity are classified, within the total, site staff and office staff perspectives. With a high average relative importance index (ARII) of 80.75%, the human/labor group, asserting the significant positive impacts of motivation and competence of labor, earns a top spot. The comparison of total average relative importance indices of groups demonstrate that management/supervision group ranks second over technical, external and planning groups, which rank third, fourth and fifth, respectively. As Table 4 shows, human/labor group is the first rank in both site staff and office staff perspectives.

Tangible discrepancy between the site staff and office staff perspectives about management/supervision group and external group is comprehensible. The rank of management/supervision group is forth within the site staff population and second within office staff population. Adverse condition is perceptible for external group.

Table 4: Overall average relative importance indices and ranks of productivity groups

Sample size Total:106; Site staff: 49; Office staff: 57	**Average Relative importance index% (ARII)**			**Rank**		
Groups	**Site staff**	**Office staff**	**Total**	**Site staff**	**Office staff**	**Total**
Management/Supervision	66.63	77.63	72.55	4	2	2
Planning	60.95	63.04	62.07	5	4	5
Technical	69.59	68.16	68.82	3	3	3
Human/Labor	79.59	81.75	80.75	1	1	1
External	69.79	62.10	65.66	2	5	4

5 Labor Productivity Improvement

Recognition of the most important labor productivity factors in previous sections, leads to classify the most effective endeavors of labor productivity improvement in the following main groups:

- Respect, incentive scheme, and avoidance of delay in payments cause **motivation of labors.** As result labors carry out their duties with more potency, accuracy, and speed. Majority of these laborers comprise of persons who basically share a common goal to make and save money as much as possible. Thus, avoid delay in payments and monetary incentive schemes further promotes the objective of labor forces and creates a high level of motivation and satisfaction among them; as a result, higher efficiency is achieved on sites.

- Lack of training, skill and experience of labor is detrimental to the productivity of the construction process. Unskilled and poorly trained operatives' outputs are commonly low and faulty. Their outputs are usually rejected, either in whole or in part, by the inspection engineer, resulting in extensive and expensive rework, rectifications, or repairs. On the contrary, **competent labors** possess high technical skills, perfect experience, intellectual abilities, and practical solutions to encountered obstacles, all of which lead to higher productivity, lower cost of labor, and better quality of finished outputs (Jarkas et al. 2012).

- Lack of labor **supervision** encourages operatives to engage in unproductive activities, take frequent unscheduled breaks, wait idle, or even leave the job sites during working hours to attend to personal matters. Inadequate instruction provided by supervisors lead to the unavailability of necessary data for craft workers. Direct and continuous supervision of labor is required to avoid

faulty and nonconforming work to contractual specifications, minimize the expensive incidents of rework and the associated delays to activities at hand, and thus optimize the productive input.

- Two main aspects of **technical excellence** which troubleshooting and modifying them lead to improvement in labor productivity, are: (1) design and drawings; and (2) construction method and technology. Complete or clear designs, drawings and technical specifications eliminate continuous requests for clarifications, hence consecutive interruptions and/or disruptions to work progress. On the other hand, Technology improvements have dramatically changed the process of construction, as well as the quality of construction output (Goodrum et al. 2009). Previous research indicated that many of the productivity improvements at the microlevel were related to development in technology (Koch and Moavenzadeh 1979; Goodrum and Haas 2002; Goodrum and Haas 2004). O'Connor and Yang (2004) investigated the reason for the construction industry's reluctance to implement new technologies. They indicated that a lack of information and understanding regarding technological benefits had contributed to the industry's apparent technical stagnation. Using new and advanced materials, tools, equipments and construction methods certainly facilitate labors' operations and enhance their productivity. In this regard, it is notable that training labors to adapt new construction methods, and work with advanced tools and equipment are very influential, which support the perceived effect of labor competence.

- The concept of **proper planning** in this study contains proper and realistic scheduling, balanced crew size and composition, and proper resource allocation, all of which eliminates overcrowding, interference, overtime, uneasiness, hastiness, extra physical fatigue to laborers and unproductive labor input. Labor interference and congestion which is mainly caused by poor scheduling and planning has a high negative impact on labor productivity, because there is evidence to suggest that a labor density greater than one person per 30 m^2 would lead to decrease in labor efficiency (Kaming et al. 1998; Hinze 1999).

6 Conclusions

The improvement of labor productivity in construction industry has been a major challenge for decades, since productivity of a construction project is affected both directly and indirectly by labor productivity. In this regard to find opportunities for improvement of labor productivity, 15 factors affecting labor productivity in thermal power plant construction projects of Iran have been identified and ranked. The explored factors were classified under the following five primary groups: (1) management/supervision; (2) planning; (3) technical; (4) human/labor; and (5) external (table 1). The major conclusions of this study could be summarized as follows:

- The relative importance indices of all considered factors demonstrate that they have significant influence on labor productivity, thus this study focused on major factors affecting labor productivity.

- A high agreement between the perspectives of population classes is known about the top five factors. The only tangible difference between site staff and office staff perspectives was about the factor of materials, tools and equipment deficiency. A high dissension like this is quite logical due to their different job position.

- As a result of the study, the top five ranked factors affecting labor productivity in thermal power plant construction projects of Iran are as follows: (1) motivation of labor; (2) labor competence; (3) supervision; (4) technical excellence; and (5) proper planning.

- The human/labor group, asserting the significant positive impacts of motivation and competence of labor, earned the first rank in groups ranking within both site staff and office staff perspectives and as result within total population perspectives.

- With a general overview on subgroups of management/supervision group it is perceived that they all got lower scores within site staff perspectives in comparison with office staff views, and this discrepancy is certainly perceptible in groups ranking. Adverse condition is perceptible for external group.

The results of this paper can be used to improve performance of power plant construction projects and also other construction projects in developing countries by labor productivity improvement.

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