*Sixth International Conference on Construction in the 21st Century (CITC-VI)*
*"Construction Challenges in the New Decade"*
*July 5-7 2011, Kuala Lumpur, Malaysia*

# Labor Productivity Improvement in the Industrial Construction Projects based on Effective Factors Utilization

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## Abstract
Poor productivity among construction workers is one of the main causes of cost and time overruns, as well as poor quality and lack of safety in construction projects. Considering that a multitude of factors simultaneously affect labor productivity, the aim of this study is to identify and rank the most influential factors. In this regard, based on the literature, review a practical classification method is presented using a Factor Breakdown Structure which sorts the initial list of 430 factors into 5 levels and 4 main groups: Management, External, Human, and Technical. In an effort to quantify the workers' perspective on labor productivity, a number of structured questionnaires (including 45 factors) were distributed among a group of craft workers, technicians, and engineers. Two different fields of industrial construction were analyzed through the following case studies: 1) Construction jobsite located in South Pars Gas Filed development phase 12, Assaluyeh, Iran; and 2) South Khorasan cement factory, Khorasan, Iran.
The findings revealed that weather, management, motivation and incentives, tools, planning and materials have the greatest impact on labor productivity in South Pars Gas Field. Additional factors were pulled from the second case study. Finally, some guides are presented for improving labor productivity.

## Keywords
Industrial construction, labor productivity, craftsmen, improvement.

## 1. Introduction

The construction industry is dynamic in nature due to the increasing uncertainties in technology, budgets, and development, which have resulted in building projects becoming more and more complex and difficult. Despite this, three main criteria (cost, quality and time) have always been the priority in every project undertaken. A growing consensus among owners and contractors indicates that measuring and monitoring productivity are essential first steps to managing and improving productivity (CII, 1990).

So far, numerous scientific works have been developed by researchers dealing with labor productivity and identifying the factors which influence the productivity of construction workers. For example, different workforce motivations in industrial construction, through different working conditions, are proposed in some references (Borcherding et al. 1981; Maloney et al. 1986). Likewise, activity sampling for investigation of labor productivity was presented by Thomas (Thomas, 1981). Later on, a comprehensive study was carried out introducing a factor model technique for the investigation of labor productivity

(Thomas *et al*., 1990). Similarly, factors that affect the motivation of construction workers were also proposed (Dozzi *et al*., 2000). Other influential parameters on labor productivity and those that are directly related to the workers' efficiency, such as overtime, overstaffing, change of orders, crowding, multiple shifts, working environment and safety are mentioned by the same authors. A few years later, the impact of early material delivery on craft productivity was measured (Diekmann *et al*., 2001), as well as the causes of absenteeism and turnover and their impacts on construction productivity (Sargent *et al*., 2003). In recent times, many researchers have become interested in finding more influential parameters on productivity. Studies by Enshassi *et al*. indicate that the main factors affecting labor productivity in a negative sense include material shortage, lack of labor experience, lack of labor surveillance, misunderstandings between labor and superintendent, and drawings and specification alteration during execution (Enshassi *et al*., 2007). It was also observed that factors involving tools and consumables, materials, engineering drawing management, and construction equipment, have the greatest impact on productivity perspective from the craft workers' point of view (Dai et al., 2009).

As mentioned above, it has been observed in related literature that different studies have been performed to identify, classify or arrange the influencing factors on labor productivity. Various classifications have been presented based on the identification protocols related to different projects. The rankings of the impact factors in these studies were based on the conditions and circumstances under which the survey was performed. In fact, different aspects of the project influence the sequence of affecting factors' ranking. The aim of this study is to present a new practical classification for impacting factors of productivity which was achieved via an investigation of two different industrial construction projects named South Pars Gas Field and South Khorasan Cement Factory. In the next step, the results obtained in each of the projects are gathered and analysed to yield a list of influential factors for the improvement of labor productivity in related projects. In this regard, a practical classification method along with a Factor Breakdown Structure (FBS) is presented to sort the initial list of 430 factors, with 5 levels, into 4 main groups of factors: Management, External, Human, and Technical. In effort to quantify the workers' perspective on labor productivity, a number of structured questionaries (including 45 factors) were distributed among a group of craftworkers, technicians, and engineers. Two different fields of industrial construction were analyzed through the following case studies: 1) Construction jobsite located in South Pars Gas Filed development phase 12, Assaluyeh, Iran; and 2) South Khorasan cement factory, Khorasan, Iran.

The rest of the paper is organized as follows: Section 2 describes the labor productivity concept. A brief description of case studies is presented in section 3. Data collection procedure is covered in section 4. Finally, Results and discussions are presented in section 5.

## 2. Productivity

According to Bodek, productivity, in general, represents the conscious growth of a society or an organization in its ability to improve the value and quality of its products or its services (Bodek,1985). The success of a company can probably be more clearly measured by its productivity growth than by its growth in profits. However, productivity is theoretically defined as a ratio between output and input. In the context of the construction industry, the output is the structure or facility that is built or some component thereof. The major inputs into the construction process include manpower, materials, equipment, management, energy and capital. Productivity is a frequently discussed topic in the construction industry because productivity improvement translates directly to labor cost savings.

### 2.1. Labor Productivity

Labor productivity is the ratio of output to the input of labor. Where possible, hours worked, rather than the numbers of employees, is used as the measure of labor input. With an increase in part-time employment, hours worked provides the most accurate measure of labor input. In particular, it reflects

more than just the efficiency or productivity of workers. Labor productivity is influenced by many factors that are outside of workers' influence, including the nature and amount of capital equipment that is available, the introduction of new technologies, and management practices (CII, 2006).

### 2.2 Factors affecting labor Productivity

According to industry related literature and scientific articles developed by researchers, there are many factors that affect construction labor productivity. These include a wide range of subjects, such as hours worked per day, equipment, materials, tools, consumables, motivations and etc. In order to improve productivity, a study of the factors affecting it, whether positively or negatively, is necessary. Making use of those factors that positively affect productivity and eliminating (or controlling) factors that have a negative effect, will ultimately improve productivity. If all factors influencing productivity are known, it will also be possible to forecast productivity (Lema, 1995). Despite such intensive investigations, researchers have not agreed on a universal set of factors with significant influence on productivity, nor has any agreement been reached on the classification of these factors. Therefore, this research is based on a survey designed to gather all necessary information in an effective way.

## 3. Case Studies Description

### 3.1. South Pars Gas Development Phase 12, Onshore Project

The South Pars / North Dome field is a natural gas condensate field located in the Persian Gulf. It is the world's largest gas field, shared between Iran and Qatar. This gas field covers an area of 9,700 square kilometers, of which 3,700 square kilometers (South Pars) is in Iranian territorial waters. The National Iranian Oil Company (NIOC) is planning to develop the field in 24 to 30 phases. Phase 12 is dedicated to Petropars (an Iran company) and like other phases consists of two main parts i.e. ONSHORE and OFFSHORE. This phase will receive and treat 3 billion standard cubic feet per day (bscfd) of the reservoir fluids coming from offshore. The ONSHORE of phase 12, which was the target of our study, has been developed by Petropars in three contractual projects including: EPC1 (Camp, non industrial building and storage thanks); EPC2 (Liquid processing and utilities) and EPC3 (Gas processing). In this study, we focused on EPC1 as the initial developed project. Two other projects are in their primary executive stage. EPC1 includes different parts such as Condensate and chemical storage tanks, fire fighting system, and non-technical buildings.

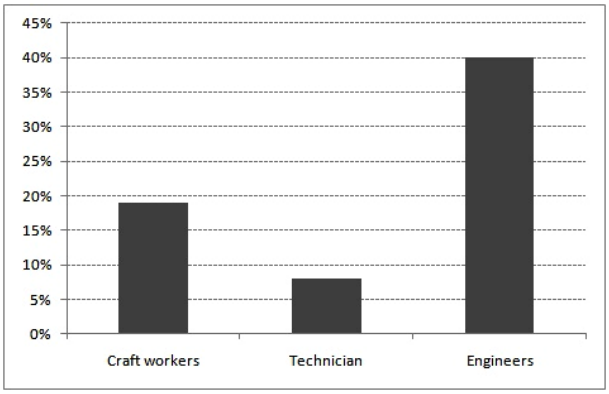
### 3.2 Khorasan Cement Factory

The Khorasan cement factory is the largest cement factory in the east of Iran, located 125 kilometres from the South Khorasan state capital of Birjand. This job site location includes an area of 100 acres to be developed during 2 working phases. The physical progress of the project is estimated at about 85% up until now. The factory is expected to produce an amount of 3,500 tonnes of clinker per day. It should be noted that the entire job site, including the workers, craft workers, technicians and engineers in various trades, is considered in this part of study and involved in our scope of investigations.

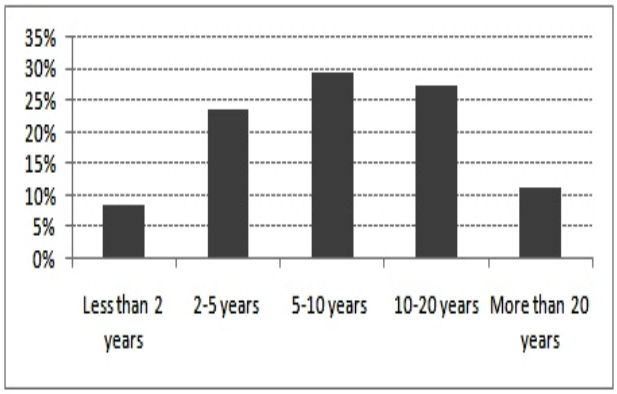
## 4. Data Collection

Data collection is considered the most important stage in gathering all required information regarding the main objectives of the study. Basically, the main or primary data was collected from two different information sources including questionnaires and interviews. The structured questionnaire survey was selected to be the main study instrument, as it provided the needed information, quickly and relatively cheaply. The first part of the questionnaire asked for general information about the craftsmen and their organizations. In the last part, the respondents were asked to provided their opinion about the factor

influencing labor productivity, by ranking their opinion on a 5-point Likert scale from 1 (no influence) to 5 (most influential). These values were normalized to show the issues that obtained the highest rating in the survey as having a value of 100. Furthermore, respondents were welcome to add and rate factors that they believed to have an effect on labor productivity, apart from those included in the questionnaire. All the questionnaires were distributed evenly among different site and trades such as mechanical, electrical, piping, installation, concrete and sheet metal works. The general information of interviewers is also shown in Fig. 1 for better illustration.




a) Survey sample composition




b) Job experience

Fig 1. General information of Interviewers

To obtain a set of comprehensive factors affecting labor productivity and gain a better insight into the influential parameters, a study of related scientific literature was conducted. Based on the literature review, an initial list of candidates was created. reSince the preliminary list includes numerous parameters which have similar concepts in some cases, a Factor Breakdown Structure (FBS) was applied to shorten the list in a meaningful manner. To reach the goal, the initial list of factors including 430 elements is classified into four major groups using a five-level procedure and applying a filtering mechanism. These groups are mainly described as: external, management, human, and technical. To establish an optimal scheme along with a practical framework for doing research, expert judgment was sought. In this regard, a set of factors from level 3 were applied and stated in a typical questionnaire. To create an applicable interview based upon the special situation of the case studies, the 45 factors present within Level 3 that meet the requisit criteria were used.

## 5. Results and Discussion

In this study, 45 factors affecting labor productivity have been identified and ranked according to their relative importance as shown in Table 1. It was observed that factors such as management, weather, motivation and incentives, tools and planning having the greatest impact on labor productivity in South Pars gas development, phase 12-onshore while other factors such as management, planning, design and drawings, qualification of people, team-spirit of the crew and a distinct goal for workers rank the highest in terms of importance in the second case study.

As observed from the numerical results, it was concluded that there are both similarities and differences between the influential factors on labor productivity within the case studies. For example, factors such as management, planning, respect for workers, materials, design & drawings and qualification of people are identified as the influential indices with relatively close ranking in both projects. Some other factors like

weather, HSE and sense of responsibility are mentioned as important ones with different ranking, e.g., HSE gets the rank 6 in South Pars gas development, phase 12-onshore while it ranks 22nd in the second project.

**Table 1. Ranking of the factor affecting labor productivity within the case studies**

| South Pars Gas Development Phase 12, Onshore Project | | | | Khorasan Cement Factory | | | |
|---|---|---|---|---|---|---|---|
| **Group** | **Rank** | **Factors affecting labor productivity** | **Normalized Score** | **Group** | **Rank** | **Factors affecting labor productivity** | **Normalized Score** |
| M* | 1 | Management | 2.546 | M | 1 | Management | 2.743 |
| E* | 2 | Weather | 2.529 | M | 2 | Planning | 2.686 |
| H* | 3 | Motivation and incentive | 2.529 | T | 3 | Designs & drawings | 2.657 |
| T* | 4 | Tools(In terms of availability, quality and maintenance) | 2.495 | H | 4 | Qualification of people(skills, experience) | 2.657 |
| M | 5 | Planning | 2.462 | E | 5 | Team-spirit of the crew & distinct goal for workers | 2.570 |
| M | 6 | HSE | 2.445 | H | 6 | Sense of responsibility | 2.570 |
| E | 7 | Respect for worker | 2.428 | M | 7 | Interaction of technical office and executive committee | 2.541 |
| T | 8 | Materials(In terms of availability, kind, quality and management) | 2.411 | E | 8 | Respect for worker | 2.483 |
| E | 9 | Job security | 2.394 | E | 9 | Discrimination in working situation | 2.483 |
| T | 10 | Designs & drawings | 2.394 | M | 10 | Coordination | 2.483 |
| H | 11 | Qualification of people(skills, experience) | 2.394 | T | 11 | Tools(In terms of availability, quality and maintenance) | 2.483 |
| E | 12 | Team-spirit of the crew & distinct goal for workers | 2.377 | H | 12 | Motivation and incentive | 2.483 |
| E | 13 | Discrimination in working situation | 2.377 | E | 13 | Shift work | 2.455 |
| E | 14 | Delay in work permit, inspection and supervisors | 2.360 | T | 14 | Materials(In terms of availability, kind, quality and management) | 2.455 |
| H | 15 | Training & learning | 2.344 | E | 15 | Weather | 2.368 |
| E | 16 | Interference | 2.327 | E | 16 | Competition | 2.368 |
| M | 17 | Quality control | 2.327 | E | 17 | Delay in work permit, inspection and supervisors | 2.339 |
| H | 18 | Sense of responsibility | 2.327 | E | 18 | Rework | 2.310 |
| E | 19 | Rework | 2.310 | E | 19 | Misunderstanding | 2.310 |
| E | 20 | Site condition | 2.293 | M | 20 | Quality control | 2.310 |
| M | 21 | Changing and turnover of worker | 2.293 | E | 21 | Owner and client characteristic | 2.281 |
| E | 22 | Supervisor's characteristic and behavior | 2.276 | M | 22 | HSE | 2.281 |
| M | 23 | Coordination | 2.276 | E | 23 | Job security | 2.252 |
| E | 24 | Interruption and disruption | 2.242 | E | 24 | Supervisor's characteristic and behavior | 2.252 |
| E | 25 | Misunderstanding | 2.242 | H | 25 | Training & learning | 2.252 |
| E | 26 | Shift work | 2.226 | E | 26 | Latitude for doing work | 2.224 |

Table 1. *(continued)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| M | 27 | Interaction of technical office and executive committee | 2.226 | T | 27 | Construction technology & Engineering | 2.195 |
| M | 28 | Instruction for doing work | 2.226 | H | 28 | Labor personal problems | 2.195 |
| E | 29 | Latitude for doing work | 2.175 | E | 29 | Interruption and disruption | 2.166 |
| E | 30 | Absenteeism of worker or superior | 2.175 | M | 30 | Instruction for doing work | 2.166 |
| H | 31 | Labor personal problems | 2.158 | E | 31 | Absenteeism of worker or superior | 2.137 |
| E | 32 | Extra work | 2.091 | E | 32 | Environmental factors(noise, dust, lighting & ventilation) | 2.079 |
| E | 33 | Size & Composition of crew | 2.091 | E | 33 | Size & Composition of crew | 2.079 |
| E | 34 | Environmental factors(noise, dust, lighting & ventilation) | 2.074 | H | 34 | Education | 2.050 |
| M | 35 | Change order | 2.074 | E | 35 | Site condition | 1.992 |
| M | 36 | Structure of Organization | 2.040 | E | 36 | Extra work | 1.992 |
| T | 37 | Construction technology & Engineering | 2.023 | E | 37 | Interference | 1.992 |
| E | 38 | Competition | 2.006 | M | 38 | Change order | 1.992 |
| H | 39 | Education | 1.973 | E | 39 | Location of project | 1.992 |
| E | 40 | Owner and client characteristic | 1.956 | M | 40 | Changing and turnover of worker | 1.877 |
| E | 41 | Political, Social, Cultural & Economical consideration | 1.939 | M | 41 | Type & situation of project's contract | 1.848 |
| E | 42 | Location of project | 1.922 | E | 42 | Political, Social, Cultural & Economical consideration | 1.848 |
| T | 43 | Information technology | 1.787 | M | 43 | Structure of Organization | 1.588 |
| M | 44 | Type & situation of project's contract | 1.753 | M | 44 | Research and development | 1.328 |
| M | 45 | Research and development | 1.686 | T | 45 | Information technology | 1.184 |

*M: Management factors, E: External factors, H: Human factors, T: Technical factors.

It was also observed that “management” had the greatest impact on labor productivity among both projects and the numerical results confirm the claim. According to experienced engineers and craft workers, management is a key factor and has a direct effect on all aspects of any organization from top to down. This affect includes applying management strategies with impressive communications results, raising the sense of responsibility among workers, and reaching to high levels of productivity as well. The surveyed respondents in the first case study ranked “weather” as the second position, while “planning” has been shown as the next important factor. In a similar manner, Thomas *et al.* supported this result in their study of factors affecting productivity in the United States (Thomas and Sanders, 1991). However, adverse winter weather condition such as wind and rain reduce labor productivity; particularly external work such as formwork, steel work, concrete casting, external plastering, external painting, and external tiling. Adverse weather sometimes leads to stopped work. It should be noted that, generally, absenteeism among workers or superiors is the by-product of such weather conditions. The alteration of “designs and drawings” during execution is the most important factor in the supervision factors group, and is ranked within the 10 most important factors affecting labor productivity. This result is supported by Thomas, who stated there is a 30 % loss of efficiency when work changes are being performed (Thomas, 1999). The interviewed respondents identified that incomplete drawings can have a high impact on productivity, causing delayed for revision or clarification of drawings and specifications. Therefore, it was ranked third amongst the most crucial factors in the Khorasan cement factory. The main cause is that clients provide limited time and budget for a designer to complete the design in order to expedite the bidding process. As a result, drawings are often incomplete, unclear, impractical, and contain conflicts. In regards to potential for improvement, the survey disclosed that incomplete drawing have high potential. Additionally, from the workers’ prospective, “HSE” ranked 6$^{th}$ amongst the critical factors mentioned in the above list. It mainly pertains to the restrictive manner of the refinery industrial site and it’s mutual high risk. Another important factor can be regarded as “respect for workers”. If this factor is lacking, sense of responsibility

will decrease among the workers and lead to a decline in labor productivity. Disrespect on a construction site could also lead to job site damages. “Job security” is also mentioned as another vital factor. From the craft workers’ point of view, having a high level of job security, despite the potential for low wages, provides the worker with a reason to be satisfied in times of work. “Materials”, in terms of availability, kind, quality and management, was ranked as one of the important factors, which is understandable, as work cannot be accomplished without necessary materials. As an example, the South Pars gas development phase 12 is situated in a place with high relative humidity and temperatures while the other one is located in an arid place suffering from extreme temperature fluxuations and high penetration of wind through the job sites. Likewise, from a cultural point of view, the South Pars gas development project consists of workers from different nationalities, while in the second there are only native workers. It’s also worthy of note that in many cases craft worker not only have a good understanding of the factors that have an impact on productivity, but also can provide an insight into the root causes. An evidenced by the data, factors within the control of the project management team are viewed by craft workers as major sources of impact to their daily productivity. Craft workers indicated that the major areas affecting their productivity were the site management of materials, construction equipment, tools and technical support rather than their procurement on the site (CII, 2006).

Now to address the issues that negatively affect labor productivity and those strategies needed to improve the efficiency of labor on industrial projects. There are multiple ways which these issues are investigated by researches. One strategy, the buffer strategy, stresses the importance of providing large stockpiles (buffers) of design, material, and construction equipment to craft workers. Large buffers provide flexibility to a production system by allowing worker to shift from one task to another when material shortages, design defects, or other impediments are encountered. The second strategy, the production planning strategy, provides effective craft production by ensuring that all necessary productive resources are available for craft workers. The production planning strategy encompasses all jobsite activities that directly support craft labor. Production planning is the domain of project material expeditors, field planners, and field engineers who ensure that craft workers have the materials and information needed for production activities. Based on the previously mentioned studies, the observed data and the statistical results, and regarding the different situations dominated at each job site, we would like to add several guidelines for improving labor productivity within the target systems. These guidelines include: first a backup operator must be assigned in case of a primary operators’ absence. Second, a partnership agreement between assigned trades should be used to allow easier sharing of materials. Third, work schedules must be staggered to spread the need for lifting equipment. On the other hand, to handle an errors in drawing (in terms of availability, completion and constructability), one may use an engineering firm with field experience to help avoid drawing errors. Using an increased margin of time for design completion and construction on fast-track jobs can be regarded as another treatment for the mentioned deficiency. To improve the use and availability of consumables (tools), the next steps can be followed: allot consumable items to the work crew, not individuals, and allow for a larger supply of consumable to reduce re-supply delays. In addition, allow a reasonable quantity of consumables to leave the supply area, maintain the supply area closer to the work force, use multiple vendors for high demand items, do not rely on one source, ensure that the supply of necessary tools matches manpower levels before a task begins, increase tool supply with labor increases, establish and enforce responsibility for tools checked out/in, confirm a tool is operational before it is checked out, teach proper care of tools and have foremen enforce their rule. Another cause of labor productivity decrease is delay in work permits. There was an ongoing effort with the project owner to improve the timeliness of issuing permits. Also, the site sent supervisors earlier to acquire the permits in a more timely fashion.

## 6. Conclusion

Productivity is considered the main value-adding function within the construction sector. The aim of this research was to identify factors affecting labor productivity in industrial projects, and to rank these according to their relative importance from the labors’ viewpoint within two different case studies. A total

of 45 factors were identified in this study, with the identification of factors influencing labor productivity based on a careful review of literature and suggestions from local experts in the industrial construction field. Moreover, labor productivity improvement will not be achieved without considering that there are numerous factors affecting productivity; besides, the necessity to locate the most influential ones should be considered. The results reveal that the most important factors affecting labor productivity which were divided in four main groups (external, management, human and technical), are slightly different among the two case studies, although the important ones were the same in most cases such as management, weather, planning, motivation and incentives, design & drawings, tools, qualification of people and HSE. Having identified the influential parameters, several guidelines based on available potentials considering each project situation were presented to improve labor productivity.

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