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Integration of Occupational Safety to Contractors` or Subcontractors` Performance Evaluation in Construction Projects

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Abstract

Several factors should be considered by the owner and general contractor in the process of contractors` and subcontractors` selection and evaluation. The paper reviews the recent models addressed to guide general contractors in subcontractors' selection process and in evaluation of different contractors during the execution of the project. Moreover the paper suggests the impact of different contractors' performance to the overall level of occupational health and safety culture at the sites. It deals with the factors influencing the safety performance of contractors during construction and analyses the methods for assessing the safety performance of construction contractors. The results of contractors' safety performance evaluation could be a useful tool in motivating contractors to achieve better safety outcomes or could have effect on owners` or general contractors' decision making about contractors suitability for future contracting works.

Key words: construction, contractors, subcontractors, contractors' performance, contractors' evaluation

1 Introduction

The construction industry is one of the most diverse and unstable sectors within the economy. It faces fluctuating demand cycles, project-specific product demands, uncertain production conditions, and it combines a diverse range of specific skills within geographically dispersed short term project environments. It is not unusual that general contractors act in construction projects only as construction management agents and subcontract a large volume of their work to subcontractors. Subcontracting has extensively been used in the construction industry, the subcontractors continue for almost the past two decades to play a vital role in executing significant portions of construction work. It mostly refers to an arrangement whereby a contractor authorizes another firm, a subcontractor, to undertake part of work he has secured with the owner. Subcontracting allows general contractors to employ a minimum workforce in construction projects and promotes specialization.

The widespread use of subcontract arrangements in construction follows from the nature and structure of the construction industry. As the industry's workload is highly diversified by type, size, function, form, and method of production, and materials used, the execution of the works equally requires services of many different trades and specialists. Companies of a relatively smaller size carry out activities of a specialist nature, through a subcontract arrangement. As a result, the construction industry is dominated by a large number of small companies that provide subcontracting services to their larger counterparts. According to the report about small and medium-sized enterprises operating as subcontractors in the European Union (EU) [1] the construction sector is the economic sector the most involved in subcontracting activities. It is estimated that around 3.7 million small and medium enterprises (SMEs) in the European Union are engaged as subcontractors. They represent 17% of all SMEs in the EU.

2 The approaches to contractors` selection and evaluation in construction projects

For the construction industry is typical that between owners and general contractors as well as between general contractors and subcontractors the bidding processes occur. During the bidding process is noticeably critical to select the most sufficient contractors for specific works. Owners and general contractors need to be highly careful while selecting the most suitable contractor for a definite part of the work or the entire project and they must be fair and objective in their dealings with the contractors [2].

Contractors' and subcontractors' evaluation plays an important role in construction project. Previous evaluations can help select the most suitable contractors for a new project, during the execution of the project it can provide feedback to the contractors and subcontractors to help them improve their productivity and over time evaluation may promote collaboration those contractors and subcontractors that consistently perform well. Poor selection of subcontractors may result in elimination of qualified subcontractors from business or lead to the lowering of their standards, hence, producing cheap and poor quality work. Moreover, the general contractors may lose time and money by selecting unqualified subcontractors for the relevant works. Generally, the construction companies choose intimate subcontractors that had already done business with them. The benefits of this subcontractors` selection practice involve mainly reduction of search and transaction costs, flexibility, stability and mutual trust. The problem of this practice is represented primarily by uncertain adoption of new technologies. Subcontractors' evaluation that is usually carried out by the general contractor management and is based mainly on intuition and past experience has been recognized as a particularly complex task [3]. The important factor in subcontractors' evaluation is that it should be based on a combined assessment of various criteria.

Contractors' and subcontractors' role in the success of construction projects is eminent and the quality of different contractors is significant. The selection of the contractors is considered the important aspect and critical issue in any construction contract whereas the right choice of contractors increases the overall success of a construction project [4]. Even though, the importance of contractors and subcontractors selection is mostly underestimated and neglected in construction. Selecting contractors and subcontractors only on a basis of the lowest price, as it is usual in construction practice, often results in claims for extensions of

time, for additional fees, less trust between the parties, less investment in training and development, higher capital costs of construction and operation, and a reduced quality in workmanship [5]. Several factors should be considered by the owner and general contractor in the selection process. Among the factors that should be considered by owner or general contractor in the selection process belong performance of relevant previous projects, the quality of production, quality of materials used, efficiency, financial capacity, employment of qualified members, compliance with site safety and environmental requirements, compliance with contract and collaboration with other contractors and subcontractors, reputation of the company, accessibility to the company, completion of the work on time, etc.

Some researchers investigated the issue of contractors' selection and proposed few models that address the important decision making issue that is exercised by general contractors, eventually by owner multiple times on every single project. Alarcon and Mourgues [6] suggested a contractor selection system incorporating the contractor`s performance prediction as one of the criteria for selection. They developed a conceptual model of a project that depicts a causal structure of the variables, risks, and interactions that affect a contractor's performance for a specific project from the owner's point of view. The conceptual model helps to identify information needed for a comprehensive evaluation. Some information can be readily available from historical records, while other can be unavailable and can be replaced by estimates based on experience. A mathematical component of the model can generate predictions of multiple project performance outcomes for each contractor under evaluation. These predictions and contractors' bid prices are then used for contractor evaluation purposes. From more recent, Ko and al. [7] developed a Subcontractor Performance Evaluation model based on an Evolutionary Fuzzy Neural Inference Model that is a synergism of generic algorithms, fuzzy logic and neural networks. The authors consider enhancing subcontractor performance evaluation as crucial one in terms of providing to general contractors information on historical contractor performance essential to guiding a selection of appropriate subcontractors for a specific current or future subcontracting need. Their study identified 12 significant factors to assess subcontractor performance: construction technique, duration control abilities, cooperative managers, material wastage, services provided after work completion, collaboration with other subcontractors, safe working environment, self-owned tools, clean working environment, effective management capabilities, manager personality, and financial condition. Arslan and al. [8] proposed a web-based subcontractor evaluation system where subcontractors can be evaluated according to the sets of evaluation criterion which are grouped under these headings: cost, quality, time and adequacy. Each of these main criteria is divided into sub-criteria. For instance, the quality criterion is divided into sub-criteria as quality of production, standard of workmanship, team efficiency, quality of materials used, experience in similar works, experience in the construction industry, job safety, personnel training, and number of qualified personnel. Each sub-criterion is scored on a 1 to 10 scale, 1 being unsatisfactory and 10 being satisfactory. Then, the subcontractors` score is calculated as a weighted sum of ratings over all sub-criteria, i.e., multiplication of each sub-criterion by their weights. A fair and objective assessment is provided by this system. It eliminates the dependence on lowest bid price by considering a combined criterion. El –Mashaleh [9] established a Data Envelopment Analysis (DEA) model to guide general contractors in their subcontractor selection decisions. The DEA is a non-parametric linear programming approach that is designed to compare and evaluate the relative efficiency of a number of Decision Making Units (DMUs). The DEA makes use of linear

programming to determine which of the set of DMUs under study form an envelopment surface. This envelopment surface is called the efficient frontier. The DMUs that lie below the efficient frontier are considered inefficient compared to the DMUs that "determine" that frontier. The model combines subcontractors` bid price along with any related subjective criteria that is reputed important by the decision maker resulting in one holistic subcontractor evaluation. Eleven variables such as: amount of bid proposal, performance of relevant previous projects, financial capacity, completion of job within time, prompt payment to labor, quality of production, standard of workmanship, quality of materials used, compliance with contract, compliance with site safety requirements and collaboration with other subcontractors are considered in the model. Bid proposals are measured in monetary terms and other variables are evaluated by management for the subcontractor in question based on a scale of 1, meaning the lowest, to 10, meaning the highest.

The benefits of the mentioned systems for contractors' evaluation imply particularly competitive bid proposal, faster selection of the most appropriate subcontractor with the systematic approach, subjectivity elimination in evaluation, costs reduction compared to traditional selection methods, user friendliness of the system.

3 The contractors evaluation in construction projects based on safety performance

Construction is almost all the world over a very hazardous industry in which fatal and non-fatal occupational injuries occur most frequently than in other industries. It is caused by many reasons: high – risk nature of construction work, low knowledge and a lack of trade risk awareness of tradesmen, building terms decreasing, high proportions of unskilled and temporary workers, complicated contractor system with big amount of subcontractors, absence or malfunction of safety management system especially in small construction companies and tradesmen, etc.

The highest percentage (60 – 70%) of work accident reasons falls in the group where the reasons of the health damage are the defects of personal assumptions for a full-quality professional performance, absent physical assumptions, flaws of the sensory system, negative personal traits and immediate psychic and physiological states such as using the dangerous methods or processes of work, an unauthorized behavior against an order or instructions, eventually keeping to stay in a dangerous space [10].

Due to diversification of activities large number of subcontractors is common within the construction site whereas most subcontractors are specialist trades people performing a limited range of activities. In the site, different tradesmen and workers from different companies have to work close together within limited spaces and share workplace. With higher numbers of subcontracting the chances of accidents occurrence become more frequent. The construction participants at the lower end of the supply chain concentrate exclusively on completing projects to the required quality standard with the minimum time and cost. Safety is, therefore, regarded as an inessential concern. As well, tradesmen and workers from small subcontracting firms usually have no interest in safety matters because most of them believe that safety should be the exclusive responsibility of the general contractor. Their improvement in occupational safety could be helped by continuous monitoring and review of their safety

performance from general contractor side as well as from owner side. Furthermore, as it was mentioned before, several factors should be considered by owners and general contractor in contractors' selection process. The selection-for-safety practice may eliminate contractors with the lowest bid and who do not have satisfactory safety records. Contractors and subcontractor selection is the first step in the process of being sure that different contractors contribute to the safety performance of the project rather than sabotage it. This requires attention during the processes of qualifying contractors for bidding work and selecting contractors for a contract award. A prospective contractor with a history of good safety performance is more likely to perform safely in the future than a contractor with a poor, or less than average safety record. Therefore, the owners or general contractors can help themselves in evaluating and selecting safe contractors or subcontractors by investigating contractors` or subcontractors' safety attitudes and practices. Past practice indicates that contractors are seldom awarded contracts on the basis of anticipated safety performance.

3.1 The safety performance factors in the construction sites

The study investigating the safety among small construction firms supported by Construction Industry Institute in USA [11] found that on large projects subcontractors` safety was influenced by the quality of the scheduling and coordination effort of the general contractor (GC) or construction manager (CM) and the degree of emphasis placed on safety by the GC or CM. Better safety performances were noted when the GC or CM provided a full-time project safety director, discussed safety at coordination meetings and pre-job conferences, monitored project safety performance, insisted on full compliance with the safety regulations, and had top management involvement in project safety. On medium-sized projects, the safety performance of subcontractors was found to be most influenced by keeping project pressures (primarily related to cost and schedule) under control and by providing effective project coordination. In addition, but to a lesser extent, it was found that subcontractor safety was influenced by the general contractor's emphasis on safety, the concern about the workers, and compliance with the safety regulations. The study concluded that subcontractor safety, as a general rule, appeared to be influenced more by the GCs than by the subcontractors themselves. This highlighted the importance of the role played by GCs and CM firms in the safety performance of subcontractors.

Enshassi and al. [12] introduced the study of which objective was to identify, evaluate and rank factors that influence the safety performance of subcontractors according to their relative importance, as perceived by respondents. The research was based on qualitative and quantitative approaches. Qualitatively, 30 factors that influence safety performances of subcontractors have been identified based on the knowledge obtained from literature review and consultation with key local experts; and quantitatively, 60 questionnaires were distributed to randomly selected subcontractors to get their opinion about the influence of the identified factors on their safety performance on a five- point Likert scale. To determine the ranking of the different factors that influence safety performance of subcontractors, the "Relative Importance Index" (RII) was adopted. The factors leading to a decrease and increase in the injury rate amongst subcontractors are presented in Table 1.

Table 1: Ranking of factors that decrease and increase the Injury Rate for subcontractors [12]

Ranking of Factors Decreasing the Injury Rate		Rank	RII
The injury rate decreases among subcontractors and their workers	if new workers are trained well on the work site and informed about dangerous places	1	0,89
	if a workable safety plan is well pre-planned	2	0,86
	if a safety officer is hired	3	0,85
	if new workers are trained with other experienced colleagues on the work site	3	0,85
	when safety and health is included in general contractor`s priorities	5	0,82
	if supervisors and foremen are well trained	5	0,82
	if official inspection is applied	7	0,81
	if the contract between the general contractor and the employer stipulates a specific amount for safety during bidding	7	0,81
	if the general contractor is deprived of contracts for a limited period for being negligent in applying safety and health regulation and rules	7	0,81
	if strict laws and penalties, such as dismissal and discount, are applied against illegal workers and specialist contractors	7	0,81
	if general contractor gives the work to professional specialist contractors with clean record of safety	7	0,81
	due to motivation based on compliance with safety regulation and rules	12	0,80
	when safety and health is included in owner priorities	13	0,79
	if safety guidance and orientation facilities are spread among workers and specialist contractors	14	0,76
	when their presence on site is scheduled so as to avoid creating any build up on site	15	0,69
Ranking of Factors Increasing the Injury Rate		**Rank**	**RII**
The injury rate increases among subcontractors and their workers	when using old, unsafe equipment	1	0,85
	when there is complexity or difficulty appear on site	2	0,78
	due to depression and hard economical situations	3	0,77
	on large, complex projects, which require big numbers of subcontractors	4	0,76
	due to accumulation of subcontractors in different specialisations	4	0,76
	when the award is to the low bidder	6	0,72
	if experienced familiar workers are replaced by subcontractors with new experienced workers	6	0,72
	if their workers are unfamiliar with the work site and dangerous positions	8	0,71
	due to bad weather	9	0,68
	when owner or employer is private firm	10	0,64
	due to acceleration to implement project on time	10	0,64
	due to safety expenditure and cost	12	0,63
	if a subcontractor is replaced by another one of the same specialisation at same project	13	0,60
	if owner is governmental semi-official firm	14	0,53
	when project is over budget	15	0,49

The research project that explored attitudes to occupational health and safety held by subcontractors in Australian domestic building industry [13] found that the construction workplace culture influences the work practices of the subcontractors. Subcontractors want to be safe at work, but working safely is compromised by such competing forces as time and money pressures, the nature of the work, the power and position of the general contractor and the interrelationships between the trades. The aim of the project was to talk to and listen to subcontractors from the domestic housing industry with the objective of finding out what they think, feel and do about safety at work to deconstruct subcontractors' subjective experiences and how they give meaning to their own situation. As it is presented in the Figure 1, in response to the open-ended oral survey question "How did you learn to work safely?" the most often cited response was "Common sense".

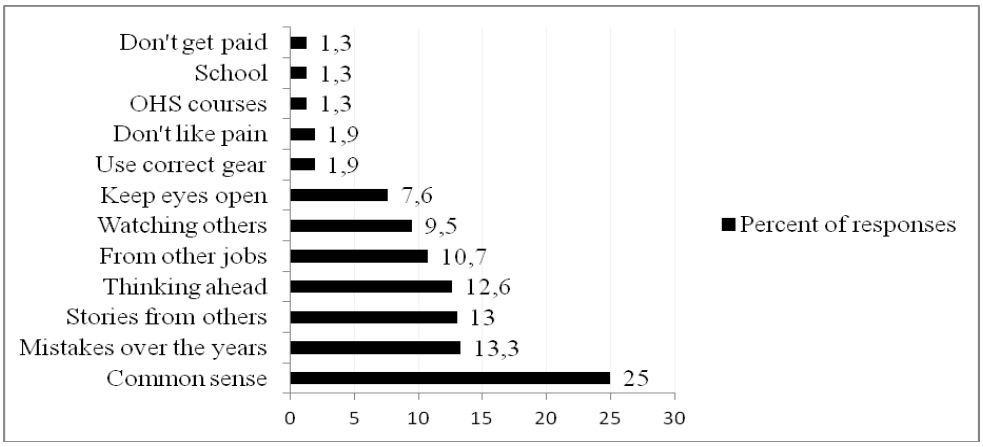

Figure 1: Responses to the question: "How did you learn to work safely?" [13]

If an owner or general contractor employs contractors and subcontractors with a history of poor safety performance, should require the individual contractors to operate in accordance with acceptable construction industry safety practices. All the participants (owner, general contractor and subcontractors) could reap cost savings from better safety performance. Owners and general contractors can take measures to achieve better safety performance of contractors such as: i) provide safety and health guidelines that the contractors and subcontractors must follow, ii) require prompt reporting and full investigation of working injuries, iii) conduct safety audits during construction, iv) discuss safety at owner-general contractor and general contractor-subcontractors meetings and v) require the use of permit systems for potentially hazardous activities.

3.2 Assessment the safety performance of construction contractors

The four of the most commonly used indicators for assessing safety performance of construction contractors are:

i. Accident rate (AR)
ii. Incidence rates for recordable injuries (IR)
iii. Experience modification rates (EMR) for workers` compensation insurance
iv. Contractor safety attitudes and practices

The mentioned sources of information provide ways for owners or general contractors to evaluate the probable safety performance of prospective contractors.

Measuring safety performance simply by the number of accidents could be regarded as an unsound basis for comparison in contractors' selection process. Contractors intensively reporting and investigating accidents might be disadvantaged in comparison with less scrupulous contractors who under-report accident occurrence. Although it is likely that self-reporting of accidents result in under-reporting of accidents, it is often argued that the use of self-reported measures of involvement in accidents is a reliable method measuring safety outcomes. The IR can be computed according to the number of lost time cases (lost time IR), number of days lost for all lost time cases (severity rate or lost workday rate), and number of fatalities, injuries and illnesses with or without lost workdays (recordable IR). Similar to the AR, the accuracy of IR depends on how honest a contractor is in revealing the reportable accidents, illnesses, fatalities and injuries. Also, as some construction workers are not aware of their OHS rights, they may not be in a position to claim for compensations. The EMR reflects the cost that companies have to pay for workers' compensation insurance. It is essentially the ratio between actual claims filed and expected claims for a particular type of construction. It dictates the contractor premium of the workers compensation insurance. Rating is based on comparison of companies doing similar types of work, and the employer is rated against the average expected performance in each work classification. The insurance industry has developed experience rating systems as an equitable means of determining premiums for workers compensation insurance. The EMR formula is criticized for its complexity and because of the existence of different versions in practice. The experience modification rate could be used as indicator of a contractor past safety performance. Owners and general contractors should request from prospective contractors and subcontractors The EMRs for the recent years, which will show the firm`s trend in safety performance. The safety attitudes and practices of a contractor are helpful in evaluating his safety and health capabilities. Owners and general contractors should look mainly for: management accountability, a qualified staff, written safety and health programs, regular orientation of foremen and new workers, and management commitment.

Beriha et al. in their distinguished study [14] proposed the fuzzy logic approach to predict accidents in three types of industries as construction, refractory and steel. Assimilating past data, subjective judgment and site inspections, types of accident are designated. The methodology may serve as a robust control system for continuous assessment and improvement of safety performance. Prediction of different types of accidents is vital to develop a strategic framework to improve safety performance. The mentioned study attempts to use a fuzzy logic approach for accurate prediction of accident rate in uncertain environment when sufficient data are not available.

Thomas Ng and al. [15] developed a safety performance evaluation (SPE) framework for evaluating contractor's safety performance. The range of organization-related and project-related SPE factors was identified, presented in Table 2. Based on a survey conducted with clients, contractors and consultants, the researchers assigned the weights to the different SPE factors to calculate a weighted average safety performance score for each contractor. Generally, it is well-accepted that weighted average scores have an inherent weakness due to the biases introduced in the development of the weights and the additive assumptions utilized in the computations of the weighted score average. Having reviewed different existing SPE

methods, a more comprehensive framework for evaluating construction safety performance was developed. This provides a comprehensive analysis approach on contractor's safety performance at both organisational and project levels that are not found in any existing systems. The safety performance scores can be used to form a league table of contractors' safety performance. This benchmarking system could be applied at tendering stage, or for determining insurance premium and award in order to enhance contractor's motivation and awareness in construction site safety.

Table 2: Safety factors in organisation level and in project level [15]

Organization-related safety factors		**Project –related safety factors**	
Factors	**Sub-factors**	**Factors**	**Sub-factors**
Safety and health training	accident happened	Emergency procedures	emergency plan and procedures
Accident record	resources for training; organizational safety plan	Project management commitment	safety responsibility; safety committee
Administrative and management commitment	safety policy; safety rules; safety organization; safety responsibility; safety management system	Implementation	safety inspection; safe system of work; plant and equipment; safe working environment; safety offices
Selection and control of subcontractor	selection of subcontractors; safety induction and performance monitoring	Safety review	safety audit; site safety policy review; safety hazard review
Safety review	organizational safety policy review; safety audit	Information, training and promotion	safety promotion; updated safety information; safety promotion
Legislation, codes and standards	compliance with legislation	Recording, reporting and investigation	accident investigation and analysis; accident recording and reporting

Chockalingam and Sornakumar [16] introduced the Key Safety Performance Indicator (KSPI) approach, as the effective tool to monitor the subcontractors safety performance, it is useful in identifying the unsafe conditions in construction site and for reducing the overall accident rate, improve the communication between the general contractor and subcontractors. The technique is based on a traditional regular workplace inspection method with appropriate checklist. The file of fifteen categories to measure the performance of the construction site is developed based on past accident statistic in country. It includes: excavation, blasting, piling,

scaffolds, concreting, work at height, material handling, grinding, welding and gas cutting, plant and machinery, electrical safety, fire protection, housekeeping, personal protective equipment, working inside tunnel and shaft. The criteria, against which each category can be measured, are framed to satisfy the requirement of statutory body. The average score of each zone and grand total can be obtained on the basis of determined categories and developed criteria. Measurement is conducted by dividing a workplace into different areas or zone, where the persons conducting the measurement can stand and observe the workplace conditions. For example, if each worker in an area uses all the relevant safety equipments required for the task, there is not taking any obvious risk then they score the "Maximum" mark. If the workers were not using the personal protective equipments (PPE), the score is "Minimum". The KSPI score for a workplace as a whole is calculated by adding the total number of Marks got in each category. One of the prime goals of KSPI is to report what is right, no wrong. The approach is intended to provide positive feedback to the workplace and involve personnel in the method of measurement and the development of strategies aimed at improvement. This can be done for example by displaying the score at a workplace in prominent locations by using posters. In the Table 3 is outlined a lot of unsafe act/conditions existing in the construction site examined by the researchers in their case study. The feedback regarding the specific safety performance of individual trades could be a useful tool in motivating subcontractors to achieve better safety outcomes.

Table 3: Subcontractors wise break up of unsafe act/condition [16]

Subcontractors	Scaffold	Work at height	Material handling	Grinding	Welding	Gas cutting	Electrical	Fire protection	House keeping	PPE	Barricading	TOTAL
Subcontractor nr.1	2	5	1			1			3	4	1	17
Subcontractor nr.2	1	12		1	1		2	1	1	2		21
Subcontractor nr.3		2	1		3			4	1	2	3	16
Subcontractor nr.4	2	5	1			1	1		3		1	14
Subcontractor nr.5	1			1		1	1	1		4		9
Subcontractor nr.6	1	5	1	1	1	2		1				12
Subcontractor nr.7	3	2	1	1	1	1	1	1	3	5	4	23
Subcontractor nr.8	8		3		5				3			19
Subcontractor nr.9	1	2		2		4			1	5	1	16
Subcontractor nr.10		9	4		2		1	4			1	21
Subcontractor nr.11	9		4		4		1			7		25
Subcontractor nr.12	1	3	2		1		1		1	8	1	18
Subcontractor nr.13	5	6		1		1		1		1		15
TOTAL	34	51	18	7	18	11	8	13	16	38	12	226

Teo and Ling [17] introduced a model to measure the effectiveness of safety management systems of construction sites. The authors utilized surveys and experts' interviews and

workshops to collect the important factors affecting safety. The analytic hierarchy process and factor analysis are used to identify the most crucial factors and attributes affecting safety. Using the model, a construction safety index can be calculated. The data envelopment analysis (DEA), mentioned in second chapter of this paper, can be properly utilised to benchmark safety performance of construction contractors. Allowing, the approach of El-Mashaleh [18] was deployed based on empirical data collected from 45 construction contractors. On a scale of 0 – 1,0 DEA assesses the relative efficiency of every contractor relative to the rest of the contractors in terms of safety performance. The DEA approach measures the efficiency of construction contractors in utilizing their expenses on safety to minimize the number of suffered accidents. It relates resources expended on safety to safety performance. Similarly Dou and Zheng [19] with a project of four contractors for case study confirmed that the method of contractors' safety performance through DEA model is objective and reasonable.

4 Conclusion

Most owners or general contractors rely closely on contractors` or subcontractors` bid proposal in contractors'/subcontractors' selection process. The lowest bid price is usually the key determinant factor; in most selection processes the bid cost is over emphasized. It is not unusual that this contributes in project delays, cost overruns, non-confirmation on quality, lost time accident, increase number of claims, litigation and contractual issues and failure to comply with local authority and construction specification. Many researchers suggest replacing the current practice of awarding the contract to the lowest bidder. The tender price should be assessed with other special criteria including, but not limited to safety management system, safety records, safety organization, safety training methodology, monitoring the safety performance and budget for safety implementation in project. The expected standards and safety requirements should be listed onto the subcontract documents as detailed as possible, and to correlate subcontractors past safety performance with tendering opportunity.

Nowadays construction industry requirements are that subcontractors and their workers must change their attitudes towards safety behaviour and site conditions whereas all construction participants have a responsibility for improving safety performance on site. It is regarded as absolutely beneficial when owners or general contractors are keeping full details of the safety records of contractors as this should have impact on their suitability for future subcontracting works.

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