Factors affecting safety performance on construction sites

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The factors influencing safety on construction sites are discussed. The impacts of the historical, economical, psychological, technical, procedural, organizational and the environmental issues are considered in terms of how these factors are linked with the level of site safety. The historical factor is assessed by the background and characteristics of the individual, such as age and experience. The economic factor is determined by the monetary values which are associated with safety such as, hazard pay. The psychological factor is assessed by the safety behavior of fellow workers on site including supervisors. The technical and procedural factors are assessed by the provision of training and handling of safety equipment on site. The organizational and environmental factors are assessed by the type of policy that the management adopts to site safety. Information regarding these factors were correlated with accidents' records in a sample of 120 operatives. Results of the factor analysis suggest that variables related to the 'organization policy' are the most dominant group of factors influencing safety performance in the United Kingdom Construction Industry. The top five important issues found to be associated with site safety were: (1) management talk on safety; (2) provision of safety booklets; (3) provision of safety equipment; (4) providing safety environment and (5) appointing a trained safety representative on site.

Introduction

Safety at work is a complex phenomenon, and the subject of safety attitudes and safety performance in the construction industry is even more so. In the construction industry the risk of a fatality is five times more likely than in a manufacturing based industry, whilst the risk of a major injury is two and a half time higher.[1] Each year, up to 120 people are killed on construction sites in the UK and there are about 3000 workers who suffer from a major injury in construction related accidents.[2] Unfortunately, it is not only construction workers who suffer from accidents but, on average, one member of the public, including children, is killed each month, with a further 1200 major injuries reported under RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrence Regulations). Apart from the human cost of suffering an accident, the economic effect can be devastating. Every £1 of an accident cost, that an insurance company has to pay out, could cost the contractor between £5 to £50 in indirect costs. These indirect costs will range from product and material, to legal costs.[3] Furthermore, it has been reported that there are over 370 million lost working days due to classified incapacity at work and over 15 million days are lost due to industrial injuries.[4]

In general, accidents at work occur either due to lack of knowledge or training, a lack of supervision, or a lack of means to carry out the task safely, or alternatively, due to an error of judgment, carelessness, apathy or downright reckless. In addition to these factors, the short term and transitory nature of the construction industry, the lack of a controlled working environment and the complexity and diversity of the size of organizations, all have an effect on safety performance within the industry. In construction, it is suggested that 'unsafe behaviour' is the most significant factor in the cause of site accidents and therefore provides evidence of a poor safety culture.[5] Nevertheless, according to a report by the HSE (cited in[6], nearly 90% of all construction accidents leading to death could (or should) have been prevented, 70% by positive management action.

Despite the evidence which suggested that the construction industry has an unenviable safety record, there appear to be few marked initiatives on the part of the researchers or safety practitioners towards the facilitation of an in-depth study into the attitudinal aspect of safety in the United Kingdom construction industry. Previous literature on the subject of safety had been mainly concerned with the mechanistic aspects of safety, that is to say, they dwell on areas of accident prevention concentrating on guards, machines and methods, as well as accident statistics. Therefore, the specific objectives of this research are: first, to correlate the operatives' background and attitude towards safety with their accident or non accident records. Second, to determine the group of factors that has the most effect on site safety, utilizing the Factor Analysis Technique.

Methodology

This research commenced by reviewing the relevant literature on construction safety published by the Health and Safety Executive as well as Academic Journals. This was followed by exploratory interviews which took place with two operatives, two site managers and one safety officer. The interview discussions were focused on the causes of accidents and the attitude of workers toward safety on site. After the exploratory interviews, a pilot study questionnaire was designed and discussed with twenty personnel (including the five in the exploratory interviews). Lists of names and addresses were obtained from personal contacts; through conferences and seminars; and others through published material, such as list of Top Building Contractors disseminated by the Chartered Institute of Building.

Certain modifications were made to the pilot study questionnaire and the final version was then sent to the appropriate personnel (mostly site managers) who then passed them on to their operatives as previously agreed. Each questionnaire consisted of 34 questions which were related to the research variables, namely, historical information (V1), economical (V2), psychological (V3), technical (V4), procedural (V5), organizational (V6) and environmental (V7) (see Table 1 for breakdown of sub-variables). Safety performance (V8) is identified as accident occurrence to a person resulting in various degrees of injury. For this research, this variable will be considered in the light of accident data gathered from the questionnaire over a three-year period. The research variables were consolidated as a result of literature search and interviews, in particular, the work of Cherns,[7] Leather,[8] Accident Prevention Unit Report HSE,[4] Hinze and Gordon,[9] Andriesson,[10] Darwish,[11] Irvine,[12] Shimmin et al.,[13] Socrates[14] and Tarrants.[15]

Outcomes of the exploratory interviews and the pilot study have consolidated the research framework and prepared the ground for the main study. The principal contractors interviewed were asked whether they would be prepared to circulate the main study questionnaire to those operatives who were directly employed by their company. Almost all interviewees showed interest to the subject of investigation and were willing to assist. The final questionnaire was then sent to the appropriate personnel (mostly site managers) who then passed them on to their operatives as previously agreed.

The response to each attitudinal question was measured on a five-point Likert scaling, under categories of ‘strongly agree’, ‘agree’, ‘neither agree nor disagree’, ‘disagree’, ‘strongly disagree’. Respondents were invited to discriminate favorably or unfavourably against statements of opinion, ordered under different headings. For example, the attitudinal statements such as “whether safety training has an influence on safety performance” was assessed by giving a score of 5 to those who strongly agree with the statement and were given a score of 1 to those who strongly disagree. On the other hand, safety performance is viewed within the context of accident occurrence. Therefore, the variable safety performance was measured by the performance group that the respondents (i.e. operatives) fall into. Those operatives with high performing safety record were given a score of 3, those with moderate performance were given 2 and those with low performing safety records were given a score of 1. High, moderate and low performing group were identified by the level of accident/s that each respondent had in the past. Operatives who had no injury in the past were given the score 3, those who had minor injuries were given the score 2, and those who had major injuries were given the score 1. Major injuries were defined as in the report published by RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations). RIDDOR's definition of major injuries included all fractures, amputations, loss of eye sight and injuries resulting in the person being admitted into hospital for 24 hr or more.

The operatives were chosen as the subjects of this study because their positions are more directly related to the construction environment and their positions interact with the organizational policies and practice. The implementation of economical, procedural and organizational policies may vary from company to company and, therefore, influence organizational members differently. For example, individual payment systems, overtime, bonus or profit-sharing, is likely to motivate individuals one way or another in the operation of their duties within the organizational hierarchy. The provision or non-provision of protective safety clothing and equipment, may have some influence on safety performance levels within and between organizations, hence their relevance.

In total, 200 questionnaires were sent of which 120 returned with use. The operatives who completed the questionnaire varied in their trade and they were selected in random. All questions were then coded and each question (i.e. variable) in the questionnaire was given a numeral. For example, the variable age was identified by the age group that each respondent falls into. Age (V1.1) was classified under 5 groups. Those who were under the age of 21 years were given a numeral 1, age 21-28 were given 2, age 28-35 were given 3, age 35-45 were given 4 and those over the age of 45-years were given a numeral 5. The age group was determined as in the work of Vant.[16]

The data was then analyzed utilizing the statistical computing package SPSS (Statistical Package for Social Science). Two statistical techniques were used, namely, Pearson’s Correlation Coefficient (for linearity) and the Factor Analysis (for non-linear groupings). The Pearson’s Correlation measured the strength of the relationship between the research variables and safety performance. For example, whether operatives under the age of 28 also got a high level of accident and whether operatives over the age of 28 were involved in less accidents. The question at issue in this example is whether age and safety performance ‘go’ together or there is no connection between the two variables. Another example is whether the operatives who believe very strongly about safety training also got the highest safety performance level and whether the operatives with the least confidence in training also got the least safety performance level, and so on.

The Pearson correlation coefficient matrix was then evaluated to examine the complex inter-relationships that exist between the research variables. The matrix showed that there are cross-correlation between the variables at a significant level. As a result, the factor analysis technique was applied to reduce the large amount of data to a small number of factors (or components), showing the group of factors that has the most influence on safety performance. The factor analysis technique is too complex to be described here, but can be read in most statistical texts. In short, it takes into account the weighting of the various variables (items), scored by the respondents, and combine them together to form a group of factors.

Research findings

Discussion of the research findings was based on results of the correlation coefficient and the factor analysis technique which are shown in Table 1 and Table 2.

Table 1. Significant level of factors influencing safety performance

	Variable	Significant level *P* <
1	*Historical factors*	
V1.1	Operative's age	0.01
V1.2	Operative's job experience	0.05
V1.3	Operative's trade	Not significant
V1.4	Operative's background safety training	Not significant
2	*Economical factors*	
V2.1	Danger money	0.001
V2.2	Banksman training	Not significant
V2.3	Productivity bonus payment	0.001
V2.4	Safety bonus payment	0.001
3	*Psychological factors*	
V3.1	Personal care for safety	0.001
V3.2	Impact of H and S act	0.001
V3.3	Ongoing safety training on site	0.02
V3.4	Supervisor's safety behavior	0.001
V3.5	Workmates' safety behavior	Not significant
4	*Technical factors*	
V4.1	Asbestos awareness	0.002
V4.2	Asbestos handling	Not significant
V4.3	Use of ladders	0.01
V4.4	Scaffolding fixing and inspection	0.001
V4.5	Steel erection	0.01
V4.6	Plant driving skills	0.01
5	*Procedural factors*	
V5.1	Provision of safety clothing and equipment	Not significant
V5.2	Training on use of safety clothing	0.001
V5.3	Training on use of safety equipment	0.001
V5.4	Issue of safety booklet	0.05
6	*Organizational factors*	
V6.1	Worker-management relationship	0.001
V6.2	Trade union involvement	Not significant
V6.3	Control on sub-contract's safety behavior	0.02
V6.4	Site safety representative	0.01
V6.5	Management-worker co-operation on safety	0.02
V6.6	Safety committee policy	0.01
V6.7	Talk by management on safety	0.01
V6.8	Safety poster display	0.01

7	*Environmental factors*	
V7.1	Tidy site	0.02
V7.2	Company COSHH information	Not significant
V7.3	Planned and organized site (layout)	0.001

Safety performance and historical variables
The correlation coefficients in Table 1 suggest that there is a strong relationship between the age and experience of operatives and their level of safety performance. Analysis of the result showed that operatives between the age of 16-20 were more subjected to accidents than others. Further analysis of the data suggests that the level of accidents tends to decline steadily after the age of 28 to reach a low point in the mid forties. This result suggests that the older the operative gets the more experienced he/she becomes, hence, being more aware of safety requirements. Cherns[7] explained this phenomenon by contending that, as aging is a slow process, one can adjust to one's continually changing powers. Therefore, while one may continue to undertake the same work as one did when was younger, one tends to do it in a different way. Thus, because of this ability to adjust, one can continue with a highly skilled activity which makes considerable demands on the perceptual and central mechanism well beyond the age at which we could ever hope to acquire such a skill from start.

Safety performance and economical variables
Analysis of the data showed that there is a high correlation between safety performance and hazard payment (significant at $P = 0.001$). This indicates that tasks where operatives are paid hazard money are subject to higher risk of accidents. This is tantamount to an inducement to task risks, and that such an inducement ran counter to aims of safety promotion on site, and in the construction industry generally. The result also showed that there was a strong relationship between productivity bonus pay and safety performance. Bonus payments can lead operatives to achieve higher production through performing unsafely at the site level. It is therefore an incentive to work faster than is usually the case, and in the process, unsafe methods of work by chance-taking become the norm, and hence accidents result. People tend to commit unsafe acts because they have been rewarded in the past for doing so; that is, operatives received bonus payments for extra productivity that may have been achieved by performing insanely. A similar finding was evident in the work of Leather[8] who concluded that “management was indeed concerned with the problem of bonus. A staggering 67% of foremen, and 43% of housing managers in the Public Sector Group did consider bonus targets to be a major contributing cause of risk-taking and corner-cutting by the direct labor operatives”. Rather than paying productivity bonuses as an incentive for higher productivity without due regard to safety, safety bonus should be paid instead as it combines productivity and safety performance as a goal for reward. Hinze and Parker[17] concluded that “good safety performance and high productivity are compatible and they should not be sacrificed with one another. Good safety performance is also related to the management style and that applying excessive pressure by any means to the workmen resulted in increased injuries”.

Safety performance and psychological variables
Table 1 indicates that a there is a strong correlation between care for personal safety and safety performance (significant at $P = 0.001$). This means that, operatives that showed concern for personal safety and reflected this concern in their approach to their work, had a better safety record than those who neglected their personal safety in the course of their work.

A strong correlation between knowledge of the 1974 Health and Safety Act and safety performance was also established ($P < 0.001$). Top management's attitudes towards safety is also a significant factor ($P < 0.002$). Previous researchers in other industries have reached similar findings such as Davies and Stachi[18] and Andriesson.[10] Davies and Stachi[18] found that “frequent daily contact between workers and supervisors on safety and other job matters, is most important to accident control efforts”. Andriesson[10] also concluded that “workers will work more safely with a supervisor who is seen as someone who respects their workers and their contribution, and who is stimulated by a distinct company policy on safety. Because they see that their supervisor regards safety equally important as production, they can also expect operatives to react positively, when they work safely”. However, this research did not provide enough evidence to reject this notion in relation to variable (V3.5), i.e. the results did not indicate a strong relationship between Workmates' safety behavior and safety performance on site.

Safety performance and technical factors
The statistical analysis of the data showed a significant relationship between asbestos awareness and safety performance in terms of exposure to asbestos (significant at $P = 0.001$). However, despite the awareness of

asbestos as a source of health hazards (expressed by 98%) of the operatives, only 55% felt confident that they would recognize its exposure on site. Ladders and scaffolding were similarly found to be a great source of accidents in the construction industry. Eighty-four percent of the operatives believed that certain criteria such as good technical skill, training and experience should be considered as highly important to certify those who handle ladders and scaffolding. A similar view was indicated for steel erectors.

The operation and use of mechanical plant and equipment were also found to be a major source of accidents on site. Ninety-two percent of operatives reported that they have been asked to operate machinery without adequate training. The same opinion was expressed about operating site transport. Some form of certification is considered necessary before workers operate or drive a dumper or other mobile vehicle on site.

Safety performance and procedural factors

Analysis of the result has shown that safety performance is not so much related to providing safety kits but rather on how operatives are trained on how to use them. Training operatives on the use of protective clothing and equipment was also found significant in the work of Hale[19] and Du et al.[20] However, whilst workers are reluctant to wear safety protective clothing, Pirani and Reynolds[21] found that safety awareness has far more to do with personal attitudes than anything else. He suggested that the only way to counter such individual negative attitudes was to persuade people to wear safety clothing through the use of a 'poster campaign' or 'fear techniques' (see organizational factor V6.8). This point was supported by some operatives who commented that the failure to wear/use safety clothing and equipment ought to be a punishable offense through sanctions imposed on the offender. They suggested that such a sanction should be written into Contracts of Employment. This study showed that management did not give enough importance to the training of operatives on how and where to use protective safety equipment and clothing. Rather, whilst they were good at the provision of their use, operatives were left to use their own direction most of the time.

Safety performance and organizational factors

The correlation coefficients in Table 1 stress the importance of management's viability and participation in achieving successful safety performance. Those variables which require management involvement such as safety policy, relationship with workers, safety representative, talk on safety, etc., were all found to be linked safety performance. This finding adds further support to earlier research on health and safety such as Andriessan's study[10] on "safety behavior and safety motivation" and Peterson[22] work on Techniques of Safety Management. Both of these studies agreed on the role that management's support, involvement and commitment have on the efficiency and success of any safety performance scheme. covered the role and perceptions of supervisors on safety performance.

A guidance by CONIAC suggests the following,[6]

1. The responsibilities for health and safety on each project should be clearly defined and reflected in contractual arrangements.
2. The management of health and safety should be an integral part of the management of the work, and whoever is responsible for co-ordinating the activities of others on site should ensure that health and safety are effectively managed.
3. Hazards should be anticipated, suitable plant and equipment identified and someone made responsible for its provision and maintenance. Appropriate working method statements are invaluable, providing proactive commitment and understanding.
4. The design team should identify major factors which could affect health and safety and inform prospective contractors of them.
5. Prospective contractors should not be selected or placed on tender lists unless they can show competence in the management of Health and safety.
6. Common, priceable items which are necessary for health and safety should be considered for inclusion in the contract documents.
7. The organization of site safety should be planned in detail, rules established and performance monitored routinely and by special safety audits where appropriate.

Safety performance and the working environment factors

Results of the correlation coefficient provided support to the notion that sites which are tidy and well planned (layout) are more likely to provide a high level of safety performance (significant at $P < 0.025$ and $P < 0.001$ respectively). These results support the early investigation by Hill and Trist[23] who suggested that "accidents are considered to involve the quality of the relationship between employees and their place of work". They concluded that "the level of accidents in any working organization has been held to depend on the interaction of two major groups of factors. On the one hand, are what may be called 'opportunities' for accidents - the actual risks and hazards of the job; on the other, the propensities of individual to take these opportunities, that is, to have accidents". Under the issue of risk and site working conditions, Shimmin et al.[13] stated that “managers should realize that they must make every effort to ensure that safe working conditions begin at the design stage and are not jeopardized by poor site co-ordination. They also need to give full safety training to all employees so that they develop an accurate subjective risk model. To this end supervisors need to press more forcibly for safe working conditions rather than acquiescing in bribery to take risks”.

Factor analysis

The factor analysis technique was utilized to help identifying the underlying cluster of factors that dominate safety performance. The authors have applied the factor analysis on the 32 safety factors and Table 2 shows the factor matrix. Test of factorability was performed on SPSS for windows using Kasier-Meyer-Olkin's measure of sampling adequacy. In order to give meaning to the results of the factor analysis and to relate them to the research framework, it is necessary to assign an identifiable name to the group of factors of high correlation coefficients. This is because the factors are an aggregation of individual variables. It has to be stressed here that the given name is totally subjective and other readers might give a different name.

Table 2 Results of the factor analysis

	Variable	Correlation coefficient of factor analysis	Correlation Order
V1.1	Operatives' age	-0.12346	No order
V1.2	Operatives' job experience	0.15278	No order
V1.3	Operatives' trade	0.2766	No order
V1.4	Operatives' training	0.01079	No order
V2.1	Danger money	-0.12659	No order
V2.2	Banksman training	-0.06157	No order
V2.3	Productivity bonus	0.05479	No order
V2.4	Safety bonus	0.14237	No order
V3.1	Personal care for safety	0.20786	No order
V3.2	Impact of H and S act	0.35663	No order
V3.3	Safety training on site	0.51302	11
V3.4	Supervisor safety behavior	0.07668	No order
V3.5	Workmate safety behavior	0.02376	No order
V4.1	Asbestos handling	0.29024	No order
V4.2	Asbestos awareness	0.0691	No order
V4.3	Scaffold fixing	0.54183	10
V4.4	Steel erection	-0.19451	No order
V4.5	Proper operation of plants	0.56187	7
V5.1	Provision of safety clothing	0.59082	5
V5.2	Proper use of safety cloths	-0.22404	No order
V5.3	Using safety equipment	0.68687	3
V5.4	Issue of safety booklets	0.71314	2
V6.1	Worker-management relation	0.26517	No order
V6.2	Trade union involvement	0.27734	No order
V6.3	Subcontract safety behavior	0.40461	No order
V6.4	Site safety representative	0.58229	6
V6.5	Management-worker cooperation	0.49376	No order
V6.6	Safety committee policy	0.54582	9
V6.7	Management talk on safety	0.73257	1
V6.8	Safety poster display	0.43874	No order
V7.1	Tidy site	0.59277	4
V7.2	Company COSHH Info.	-0.17226	No order
V7.3	Planned and organized site	0.55836	8

Note: No order means the variable showed low correlation in the Factor Analysis Matrix and therefore excluded from the analysis and discussion.

The authors named the group of factors as ‘Organizational policy’ because most of the significant variables are related to an organization's procedure and practice. The variables are: committee; equipment; operation; plan; protection; safebook; scaffold; talk; tidysite; training; mechan; and have a score ranging between 0.50 to 0.73. The results can be ranked as follows:

1. *Talk* (0.73257): This confirms that in order to have a better safety outcome, site managers and supervisors should engage in regular talks with operatives on site.
2. *Safebook* (0.71314): This confirms the importance of providing operatives a safety booklet or manual when joining a company, as company policy. It shows that a brief safety induction to every new recruit on their first week will positively influence safety on site.
3. *Equip* (0.68687): This indicates that the provision and use of the correct type of equipment for a job, and the provision and use of protective clothing and equipment are pre-requisite for improving safety performance. They should be trained in correct usage.
4. *TidSite* (0.59277): This highlights the importance of clean and tidy sites for improving safety performance. It is part of improving the job condition to minimize the risk of accidents in the physical environment (for example by guarding machinery or prohibiting access to certain areas).
5. *Protect* (0.59082): This result confirms the significance of operatives wearing protective clothing and equipment on site. It also agrees with the suggestion that operatives who refuse to wear them should be punished somehow by management. The company should provide them to maintain standards and affective usage.
6. *SafetyRep* (0.58229): The result indicates that having a well-trained safety representative on site can improve safety performance by undertaking fault spotting and insist on corrective action being taken.
7. *Operate* (0.56687): Companies should have a clear policy of using trained plant operators to operate plants on site and operatives without suitable training should have the right to refuse instructions to do so, as part of safety policy.
8. *Plan* (0.55836): The result indicates that sites which are properly planned are more likely to improve safety performance by reducing the causes of accidents on site.
9. *Committee* (0.54582): Companies with affective safety committees are more likely to take steps that improve safety performance than those companies without. This means that safety committees can play a positive role in the improvement of safety performance.
10. *Scaffold* (0.54183): The result indicates that a single contractor should be responsible for scaffolding on a multi-contract site and that a regular inspection and spot check are imperative for good safety performance. It also confirms that scaffolding erectors should be trained and that common-sense alone is not sufficient.
11. *Training* (0.51302): The result confirms that good training of operatives and site supervisors are relevant to good safety awareness and that those can lead to improved safety on site.

Conclusions

This research studied seven group of factors that can have an influence on the performance of safety on con-struction sites. The factors studied were (1) historical; economical; (3) psychological; (4) technical; (5) procedural; (6) organizational and (7) the working environment. Analysis of the Correlation Coefficients suggests the following conclusions:

1. The historical variables as a whole did have an impact on the level of safety performance, in particular, age of the operatives.
2. The most prominent indicators in the economical factor were shown to be attitudes towards risk taking induced by the offer of payment of ‘hazard pay’ and the ‘incentive bonous pay system’ in order to increase productivity.
3. Results of the psychological factor indicated that a strong relationship exists between ‘personal care for own safety’ and safety performance. Operatives who showed concern for personal safety had a better safety record than those who neglected safety in the course of their work. Additionally, “operative's expectation of their supervisor's safety attitude was relatively high and they see their superintendent's attitude towards safety as being a major source of influence upon their behavior on site”.
4. The most significant variables in the technical factor were awareness of the hazardous materials rather than their handling. Ladders, scaffoldings and operating machinery were also found to be associated with accidents. Operatives believe that lack of training and skill in using machinery are the main cause of accidents.
5. Analysis of the procedural factor has shown that safety performance is not so much related to providing safety kits but rather on how operatives are trained to use them.
6. One of the vital conclusions from the study is that safety performance appears to be significantly influenced by the ‘organizational’ factors. As such, this finding has serious implications for all members of the building team especially, those who have responsibility for the co-ordination of sub-contractor’ work. It is important to promote the essence of safety via the group, including the supervisor, with discussions playing a vital part. The construction industry needs to regularly review their safety training programs and update the health and safety acts via in-company and on-site safety communication.

This finding was further supported by results of the Factor Analysis which indicated that the most influential factor driving safety performance in the construction industry is the ‘organization policy towards safety’.

Some of the significant issues included in first factor were: Talk of Management about Safety; Provision of Safety Booklets; Provision of Safety Equipment; Assuring a Tidy Site; Appointing Safety Representative; and training of operatives on safety.

Outcome of this research seems to underpin the earlier report by the HSE (cited by Coleman[6]). The HSE report recommended that all contractors employing five or more people must have a written safety policy. Ensuring the proper management of health and safety on construction projects should never be seen as burden or something rigidly to be separated from other aspects of management, or worse, something to be ignored! A well-planned and well-run project will be both safe and efficient. It will save lives, injury, ill-health and money.

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