THE NEED FOR A PRO-ACTIVE METHODOLOGY TO REDUCE HEALTH AND SAFETY INEFFICIENCIES WITHIN A CONSTRUCTION ORGANISATION

Lucy J. Smith

Centre for Research in the Management of Projects (CRMP), Department of Civil and Structural Engineering, UMIST, Manchester, UK

The construction industry delivers projects that are unpredictable in terms of time, cost and quality, whilst at the same time trying to ensure a zero accident rate. The Author aims to develop a model that will identify inefficiencies within a construction organisation, through an integrated project process, to achieve sustained improvement. This will ultimately increase value for the customer to meet the targets set by Latham and Egan. Methodologies have been used in other industries to identify areas of weakness but none of these are directly applicable in the construction environment. The Total Loss Control theory, originally used for safety analysis, will be adapted to reduce inefficiencies within an organisation, by providing a pro-active and predictive approach. The model which is in the form of a questionnaire, has been field tested with respect to site based activities and it was concluded that, although inefficiencies were highlighted, many questions were not sufficiently targeted to the project. The next stage of the research is therefore to utilise a filtering matrix to obtain a more targeted and accurate response to the questionnaire.

Keywords: continuous improvement, failures, inefficiency, quality, health and safety.

INTRODUCTION

The construction industry is vital to our economy; Egan (1998) states that its output in 1998 was equivalent to approximately 10% of the GDP and it employed around 1.4 million people. However, there is concern that the industry is not functioning at its optimum potential with respect to low and unreliable profitability, and insufficient investment in areas such as research and training. The industry also has an unfortunate reputation of delivering projects that are unpredictable in terms of delivery on time, within budget and to the pre-specified quality.

The health and safety record of construction is also one of the worst in any industry. Most accidents occur when people are either not adequately trained or are working in an unfamiliar environment. The resulting costs may be attributed in terms of lost working days, potential prosecutions and in the extreme, the enforced closure of the construction site. The Health and Safety Executive in its report ‘The costs of accidents at work’ (HSE 1993), states that accidents or unplanned events may result in financial losses of up to 8.5% of an organisation’s annual turnover.

Reports by Sir Michael Latham (1994), and Sir John Egan (1998), suggest that there are significant inefficiencies in the construction industry. The industry however does have the potential for a more systemised and integrated project process, in which waste in all its forms, is significantly reduced, and both quality and efficiency improved. The industry should create a suitable methodology, through which

Smith, L J (2000) The need for a pro-active methodology to reduce health and safety inefficiencies within a construction organization. *In:* Akintoye, A (Ed.), *16th Annual ARCOM Conference*, 6-8 September 2000, Glasgow Caledonian University. Association of Researchers in Construction Management, Vol. 2, 743-52.

sustained improvement would be delivered by the use of tools and techniques for eliminating waste and increasing value for the customer.

The research embraces all aspects of inefficiency, including waste, quality, sustainability and economics, but due to the limit of space, the Author will concentrate on the safety aspect in this paper.

AIMS AND PURPOSE OF THE STUDY

The Building Research Establishment reported at the launch of The Construction Quality Forum, in November 1993, that "*Each year, defects or failures in design and construction, costs members of the construction industry more than £1000 million*".

The construction industry is unique in nature when compared to other industrial sectors, in that construction projects are undertaken on a one-off basis. This research aims to develop and implement a continuous improvement methodology to achieve increased quality and productivity within a typical UK construction company. This can be achieved by reducing the number of non-conformances, failures, losses and accidents, and consequently the overall costs of running a business. The outcome of this study will also enable a construction organisation to identify its underperforming areas, to achieve greater success in its quest for continuous improvement.

REVIEW OF LITERATURE

Technology in all industries is changing at a dramatic speed to keep up with increasing business competition, the internationalisation of the economy and the reduced turn around time from the concept phase of a project, through to its hand over back to the Client. However, the problem concerning how to build a high quality product, cheaply, quickly and yet still safely soon becomes apparent.

The increased competition within the construction industry during the last recession, has meant that only organisations that had a monopoly in their specialist fields could afford to ignore the customer's demand for value for money and satisfaction with the finished product. Construction operates in a dynamic environment and as a result, the primary research into quality within manufacturing, has had to be adapted to take into account factors such as the weather, the extensive supplier chain, and the reality that every project is a prototype. To quote Ashford (1989), '*The products of construction are expensive, complex, immovable and long-lived. They seldom offer scope for repetition, they have to be built where they are needed and, if not designed or built correctly, there is usually little that can be done to put things right at a later stage.*'

Many of the defects associated with construction are the consequence of deficient management in areas such as training and communication, and from commercial pressures which arise from the traditional procurement method of awarding work to the Contractor with the cheapest tender.

Speakers from the panel and the floor of ICE's Towards Zero Defects Event, concluded that quality within the construction industry will never improve while the labour is underpaid and underappreciated; they must therefore be motivated to aim for zero defects. Motivational tools such as money, working conditions and welfare all cost money and unfortunately they are the first things to be cut when contractors are preparing competitive bids. Little regard is given to the workforce and the environment in which they work, even though few appreciate that they have the most impact on the final quality.

Every employee has a responsibility towards health and safety, but for many individuals, this has always been somebody else's responsibility. Unfortunately, this is still a common philosophy today, even from senior managers who believe that that is where the Safety Advisor's role lies. Construction operates in an ever-changing environment, some sites only exist for a couple of days and their associated risks change daily. If a hazardous condition is identified, by the time it is rectified, the working environment has changed, bringing new hazards. The turnover is also higher than in most industries, and consists of a large number of unskilled labour and small contractors who do not have the available funds to employ a Safety Advisor. Consequently, safety awareness and training is not always as up to date, or as good as it should be.

Managers know that accidents cost money, irrespective of whether people are injured, plant and machinery damaged, or material wasted. As a result of this, safety must become an essential factor when considering potential work; it has to be accounted for when pricing contracts and not simply considered as something extra to offer. The potential for large scale adverse events involving all those who come into contact with a construction site, be it the workforce or general public, must enforce the issue that safety is one of the highest priorities for a successful project.

Human error is a contributing factor in up to 90% of all industrial accidents. This statistic gives even more cause for concern due to the increased sophistication, reliability, and safety standards regarding machinery. As the absolute numbers of accidents decrease, the proportion of accidents attributable to human error increases. Groeneweg (1994) suggests that human error is fast becoming the single most important source of failures. Reason (1998) also argues that human errors are a consequence of upstream events and not the prime cause of accidents or incidents, as previously believed. This means therefore that one has to look at why that human error occurred in the first instance. Was it as a result of lack of training or communication, or possibly even further upstream, with failures occurring at an organisational level? Even so, when analysing a failure on a higher level, the cause can still be attributable to an individual's or group of individuals' error.

High health and safety standards are not only ethically desirable, but if pursued as part of a wider strategy of management control, can help reduce an organisation's costs. Commercially successful organisations also demonstrate a progressive improvement in their safety record, since they bring efficient business expertise that influences all aspects of their operations, to health and safety within the organisation.

The construction industry has to overcome its 'rough and tough' image, and the associated philosophy that 'if you aren't prepared to take the risks you shouldn't be in the business', if there is any real hope of improving its safety record to match that of the manufacturing industry.

Quality, which is all too often forfeited for time and money, must also be improved if reliability, lower cost and shorter development time are to be achieved within construction. Performance must also be elevated to a new level, where the emphasis is on prevention of non-conformances, reduction in unreliability, and the elimination of waste.

RESEARCH METHODOLOGY

In order to eliminate any kind of accident, non-conformance, failure or defect that incurs a loss, managers must identify the associated root cause. The Author has therefore utilised the Total Loss Approach in the development of a pro-active tool to identify potential underperforming areas within an organisation.

Total Loss Control

Total Loss Control Theory, developed by Heinrich in 1931, utilises the triangle concept illustrated in Figure 1, to show that by controlling the numerous non-injury accidents, the chance of injuries and fatalities will reduce, and so provide a pro-active control of health and safety.

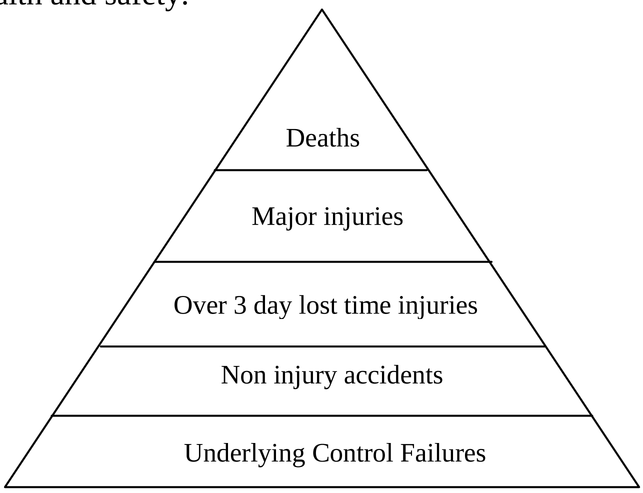

Figure 1: The accident triangle (HSE 1993)

This approach applies control systems at the base of the triangle to eliminate the underlying control failures. In doing so, the number of accidents, injuries and ultimately number of fatalities will also reduce. This view is based on the belief that, although there is a wide range of immediate causes of accidents, the underlying causes are more common. The Total Loss Approach therefore emphasises the need to learn from both accidents and incidents that have occurred, in order to achieve effective control.

The Total Loss Control Theory has its origins in safety management and since effectively an accident is a specific type of failure, the Author has also applied this theory when analysing non-conformances, defects and any kind of loss.

Methodology

The study commenced with a review of the literature in the areas of quality and safety, and the associated tools and techniques used in continuous improvement (Smith et al 1999). The Author researched many of the existing techniques available to investigate and analyse non-conformances, but none of these were directly applicable to the construction industry, since it is such a dynamic environment. The Author undertook a more detailed study into two safety management tools, The Health and Safety Climate model developed by the Health and Safety Executive, and Tripod developed by Shell International. This was undertaken to ascertain their applicability to the construction industry.

One of the main limitations to the HSE Climate model was that it investigated solely the health and safety within an organisation. The 71 questions were intended to probe many of the issues covered in the health and safety management model illustrated in HS(G)65 (HSE 1997). Even though these factors encompass safety management, other potential areas of inefficiency such as quality, waste and the environment are not considered. It was therefore felt that this model, even though utilised by the HSE, would not be effective to holistically analyse an organisation, to identify the areas producing the most inefficiencies.

Tripod was created for the oil exploration and production operations of Shell International Maatschappij and was considered a new approach to researching the accident causation process. This approach utilises the fact that human error is an important contributing cause in up to at least 80% of all business 'mishaps'. The main philosophy behind Tripod is that human error can be more effectively controlled by controlling the working environment. Substandard acts do not just take place but are the direct result of mechanisms within an organisation, known as Basic Risk Factors. There are 11 Basic Risk Factors (BRFs), which are as follows:

1. Organisation
2. Hardware
3. Design
4 Housekeeping
5. Incompatible Goals
6. Training
7. Communication
8. Error Enforcing Conditions
9. Maintenance Management
10. Defences
11. Procedures

Tripod, which is also in the form of a questionnaire, was considered inapplicable to the construction industry because many of the questions suited a production, steady state environment, not the project environment and immense supplier chain, associated with construction. Other limitations to this tool were the actual length of the questionnaire, which comprised 275 questions, and the implementation costs.

The literature review revealed that there was a gap in the construction industry for a pro-active tool such as Tripod, which could be used to highlight inefficiencies within an organisation. The Author is therefore developing such a tool, that has the potential to analyse all aspects of the construction process from feasibility to handover, incorporating quality, safety, environmental and waste factors. It will be innovative in that, unlike Tripod, it is directly applicable to the construction industry and, by redefinition of the BRF, elements inherent to the industry will be addressed. The research instrument will be in the form of a questionnaire and the data obtained will enable management to more accurately target their continuous improvement initiatives, and consequently reduce the overall inefficiencies within the business.

To date, the main body of the research has comprised a pilot study, in the form of a self-administered questionnaire. The questionnaire consisted of 110 factual questions, of which, 10 questions were designed to probe each BRF. Examples of such questions and the format utilised are shown in Table 1

Table 1: Format of questions

	YES	**NO**	**N/A**
In the past week have you been reminded by a work colleague to put your hard hat on whilst out on site?			
Has the Contract you are working on got a waste disposal strategy?			

The initial pilot study was aimed at site level, to analyse the actual construction process, with the intention of using the tool throughout the project lifecycle, once the methodology has been refined and its reliability tested. Due to the length of the questionnaire, the Author designed the questions in a closed format, for speed and ease of answering. The questions once written, were reviewed by a Business Manager and Contracts Manager from a construction organisation, to ensure that the language was appropriate to everyone on site. This also reduced the ambiguity of the questions, and hence increased the questionnaire's overall reliability to identify inefficiencies within an organisation.

In total, 100 questionnaires were distributed between 5 sites. The sites were chosen by the Business Manager as a sample of the type of work that the organisation undertakes, by exhibiting a reasonable range of parameters, in terms of type, size, contract conditions and project place within the life cycle. Another reason for their choice was their accessibility, and the ability to ensure a prompt and effective response to the study. The questionnaires were given out to everyone on site and the respondents were assured confidentiality in the answers they gave. However, they were asked to complete a demographics section to establish which organisation they were employed by; their job position was also logged to aid in the statistical analysis of the results.

STATEMENT OF RESULTS AND ANALYSIS

Results

Due to the pilot study being a self-administered questionnaire, the response rate of 94% was very high. Three sets of results were not used because a substantial number of questions had been left unanswered. Three questionnaires that had been completed by Clients also had to be deemed void because over half of the questions were not applicable to their roles and responsibilities, and would have biased the overall results. In total 28 questionnaires were completed by Managers, 13 by Supervisors and 53 from the workforce.

Once the questionnaires had been analysed, the results from the individual questions were weighted and categorised under each BRF. One advantage of the methodology used in Tripod is that the answers are weighted when being analysed. The Author will utilise a weighting system that considers the average successful answer rate for a particular question. For example, if the two questions previously highlighted to illustrate the format of the research instrument, were to be given to 10 respondents, they would be analysed as follows:

All 10 respondents should answer Question 1 by ticking the 'NO' box. If all 10 answered in this way, there would be a 100% successful response rate, which would give a weighting of 0. This calculation is illustrated below:

Successful response Rate:	(10 'NO' responses/ possible 10 questions)*100
	(10/10) * 100 = 100%
Weighting:	1 – (10/10) = 0

In contrast, consider the weighting system for Question 2. If 3 out of the 10 respondents were to answer 'YES', this would mean that the question would have a 30% successful answer rate, giving a weighting of 0.7. This calculation is illustrated below:

Successful response Rate: (3 'YES' responses/ possible 10 questions)*100

(3/10) * 100 = 30%

Weighting: 1 – (3/10) = 0.7

This system enables the respondents to credited for harder issues and over a period of time, as a practice becomes the 'norm' as in the example of Question 1, the associated question would be phased out since it would obtain a 100% successful answer rate. The higher the weighting of a particular question, the more effort needs to be directed in that area because what is perceived to be best practice is not being undertaken or followed.

The weighting system was applied to each of the 110 questions and bar charts were then produced for each site, showing the weighted number of adverse responses for each BRF, compared to the average value for the study.

Analysis of Results

Statistical analysis of the results from the pilot study was undertaken using the Chi-Square Test for each BRF. This test is one of the most popular non parametric tests of significance and is used to make comparisons between 2 or more samples, essentially using the expected and obtained frequencies from a population. The hypothesis to which this analysis was tested against was:

> *'There is no relationship between an individual's job position on site, and the number of adverse responses they give to 110 questions in the survey.'*

Two variables are present in this hypothesis, job position and the response given to the question. Three job positions were identified in the research, Manager, Supervisor and Workforce. The possible responses given to a question were adverse, non-adverse and not applicable. In experimental research the conditions that the investigator manipulates are identified as the independent variables, and the observations that the investigator gathers from each subject are known as the dependant variables (Spence et al 1992). For purposes of this research, the independent variable is the job position of the respondent and the dependant variable is the response that they are likely to give to any one question. The demographic details (excluding job position) of the respondents are considered as intervening or subject variables (Farrell andGale 1999).

To reject the Null Hypothesis at the $p \leq 0.05$ level of confidence, with 4 degrees of freedom, the calculated Chi-square values would have to be 9.488 or greater. Table 2 illustrates a three sample Chi-Square Test for the BRF Communication; this test was repeated for each BRF. A total of 11 tests were undertaken on the results from the pilot study and in 3 cases the null hypothesis had to be rejected. It can therefore be concluded that for the BRFs Communication, Organisation, Hardware, Defences, Incompatible Goals, Error Enforcing Conditions, Procedures and Design, an individual's job position does have an effect on the responses they give to the questions in the pilot study.

RECOMMENDATIONS FOR THE NEXT STAGE OF RESEARCH

The pilot study was undertaken to increase the reliability and validity of the questions used in the Author's predictive tool for highlighting inefficiencies within an organisation. The large sample size of the initial study, together with the collaboration of a construction organisation and its senior managers, increase the overall reliability of the questionnaire (Litwin 1995). To utilise the results from the initial study, the collaborating organisation held workshops to discuss the findings and develop initiatives to improve the areas highlighted by the model as being underperforming. The large sample size of the pilot study was chosen so that the results could also be used as a benchmark for the next stage of the research, to identify if any improvements have been made as a result of the continuous improvement workshops.

Table 2: A 3 * 3 table showing the obtained and (*expected*) frequencies given for the BRF communication.

	Non-adverse	*Adverse*	*N/A*	
Managers	192 (*148.6*)	77 (*117.4*)	11 (*14.0*)	280
Supervisors	79 (*69.0*)	48 (*54.5*)	3 (*6.5*)	130
Workforce	228 (*281.4*)	269 (*222.2*)	33 (*26.5*)	940
	499	394	47	N = 880

It was evident from the pilot study that many of the questions were not applicable to specific trades and job positions on site. In particular, to the organisation the respondents worked for, be it the Client, Sub Contractor or main Contractor, or to the managers or workforce. To review the applicability of the questions on a different level, the Author together with the Business Manager of the collaborating organisation analysed each question with respect to its applicability to the respondent. Factors such as the respondent’s job position, length of time that the respondent has worked on the site (new starter), organisation the respondent worked for, contract type, project itself (duration, week number at time of study and the type of work involved), were taken into account. Discussions then took place as to whether the respondent would have been able to answer a particular question, taking into consideration the above factors.

It was concluded that by undertaking a comparison between the original and re-analysed data, taking into account project specific and demographical information, there is evidence of a substantial difference in the results. From the findings of the pilot study, the Author is currently developing a matrix to filter the questions in the model, to target them more effectively, and hence increase the accuracy of the model when analysing a construction organisation. Senior managers and Agents are also reviewing the questions, to reduce their ambiguity and increase their validity with respect to the time scales imposed.

CONCLUSIONS

The pilot study was a valuable piece of research, both as a means of field testing the model and also as a benchmarking tool for the next stage of the research. The results of the Chi-Square test prove that with respect to 8 BRFs, an individual’s job position does influence the way in which they respond to certain questions. The main difference highlighted was that between Managers and the Workforce, that is, those who are office based on site and those ‘on the tools’. This suggests that there is a significant contrariety in what mangers perceive to be taking place and what is actually occurring out on site. These results contravene what constitutes a good safety culture, as quoted from the Third Report by the Health and Safety Commission Advisory Committee on the Safety of Nuclear Installations, Human Factors, Study Group (1993): ‘*Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety, and by the confidence in the efficacy of preventative measures*.’

The results from the next stage of the research will again be used to highlight inefficiencies, but also as a means of benchmarking the sites to see if any improvements have been made over time. The sites can also be compared with each other and good practice imported and exported. Statistical analyses will also be undertaken, using the demographics of the respondents, to see for example, whether the answer which is given is dependant on the organisation which a respondent is employed by, their trade, or whether they are a new starter on a particular site or to the industry itself.

There are limitations to a study of this kind, especially when utilising a questionnaire. Even though confidentiality is assured, many respondents still answer with what they perceive the 'correct' answer to be. Assurances must be given at the outset that a questionnaire can not be traced back to an individual and that, if they want their work environment and welfare conditions to improve, they must respond as honestly as they can. The only way an organisation can improve is to identify how the business is running at all levels, from those at Head Office to those at the sharp end, undertaking the actual construction work. The pilot study was used to analyse the actual process of construction, but future work will utilise the model at all stages of construction, from procurement through to hand over, to identify potential failures at all levels of a business. A database will therefore have to be developed to ensure that there are sufficient questions to cover these areas.

It is the intention of the Author to use the predictive tool described previously to pro-actively manage a business. This methodology is different to the existing tools used within construction, in that it encompasses all aspects of a business, from quality, safety, environment, and waste, to general productivity issues. By utilising a filtering matrix to target the questions more effectively to the demographics of a respondent and to the project specific information, it will be possible to reduce the number of not applicable responses given, hence, increasing the reliability and validity of the tool. By utilising the successful response rate weighting system, questions about practices which become the norm can be phased out over time.

This methodology, together with regular internal workshops, will allow the identification and analysis of the root causes of an organisation's inefficiencies, not just the symptoms. Organisations will then be able to target their continuous improvement initiatives more efficiently, based on real evidence which highlights the under performing areas. This approach to management within the construction industry is more pro-active than other investigation or improvement methods, since the underlying causal factors can be identified and rectified, thus preventing future failures, as opposed to the reactive process of mitigating against a failure once it has already occurred. Management should ensure that their organisation is stable and inherently safer and more productive at every level.

Good health and safety management is something to which organisations should aspire, just as they do commercially successful companies. It is also a legal requirement, if not a moral and ethical obligation. Construction companies must become more productive, yet at the same time enhance the quality of their products and improve their safety record, in line with Sir John Egan's recommendations in the report, Rethinking Construction.

AKNOWLEDGEMENT

The Author of this paper would like to acknowledge Ian Jones, Business Manager from the Collaborating Organisation who helped develop and promote the research within the collaborating construction organisation and Ian Vickridge, CRMP, Department of Civil and Structural Engineering, UMIST who edited the paper.

REFERENCES

Egan, J. (1998) *Rethinking Construction.* The Report of the Construction Task Force, Department of the Environment, Transports and the Regions

HSE. (1993) *The Costs of Accidents at Work.* HMSO, HS (G) 96, London

Latham, M. (1994). *Constructing the Team*, Final Report, HMSO

Ashford, J.L. (1989) *Management of Quality in Construction.* E & F.N. Spon

Groeneweg, Jop. (1994) *Controlling the Controllable.* DSWO Press, Leiden University, Leiden

Reason, J. (1998) *Managing the Risks of Organisational Accidents.* Ashgate Publishing Company, England

HSE. (1997) *Successful Health and Safety Management*. HS (G) 65, HMSO

Smith, L.J., Vickridge, I. And Jones, I.D. (1999) Increasing Construction Productivity through Total Loss Control. *COBRA 99 RICS Conference Proceedings*. Editors: Baldry, D. and Ruddock, L. 2: 266-275

Farrell, P. and Gale, A. (1999) The need to remove ambiguity from the role of construction site managers. *COBRA 99 RICS Conference Proceedings*. Editors: Baldry, D. and Ruddock, L. 2:194-203

Litwin, M. (1995) *How to Measure Survey Reliability and Validity*. The Survey Kit, Sage Publications, London

Health and Safety Commission (1993) *Advisory Committee on the Safety of Nuclear Installations, Human Factors, Study Group, Third Report* – 'Organising for Safety', HSE Books

Spence *et al.* (1992) *Elementary Statistics.* Prentice-Hall Inc., New Jersey