Construction Management & Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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**To cite this article:** Helen Lingard & Steve Rowlinson (1998) Behaviour-based safety management in Hong Kong's construction industry: the results of a field study, Construction Management & Economics, 16:4, 481-488, DOI: 10.1080/014461998372259

**To link to this article:** https://doi.org/10.1080/014461998372259

Published online: 21 Oct 2010.

*Construction Management and Economics* (1998) **16**, 481–488

# Behaviour-based safety management in Hong Kong's construction industry: the results of a field study

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Received 19 August 1996; accepted 2 January 1997

Hong Kong's construction industry has had a poor site safety record for over a decade. Behaviour-based methods of safety management (BSM) have proved successful in other industries and in other countries. Hence, this study aimed to test the effectiveness of BSM by applying goal-setting and feedback interventions to specific areas of safety performance on Hong Kong Housing Authority construction sites. Using a within-group experimental design and with the use of a proportional rating safety measurement instrument, data were collected on the effectiveness of BSM on Hong Kong sites. The data were recognized as time series data; this has been a serious methodological oversight in much previous research. The data were analysed using autoregressive moving averages models, and the results were mixed in that a significant improvement in safety performance occurred in the housekeeping category of intervention but no improvement was observed in the access to heights and bamboo scaffolding categories. Based on these results a goal setting/expectancy theory model of site safety improvement has been synthesized, and the lack of provision of an adequate safety infrastructure has been identified as a serious impediment to improvement.

*Keywords*: Safety, motivation, behaviour-based methods, goal setting, feedback, intervention

## Introduction

Behaviour-based methods of safety management have become increasingly popular in recent years. Motivational techniques, aimed at increasing the incidence of safe behaviour among employees, have been introduced in the construction industries of the UK and Finland, and researchers have concluded that these techniques are effective in these environments (Duff *et al.*, 1994; Matilla and Hyodynmaa, 1988).

The Hong Kong construction industry performs very poorly in the area of site safety. In 1994, an accident rate of 280 accidents per thousand workers was recorded (Hong Kong Government Commissioner for Labour, 1995). 1993 was the worst year on record for construction fatalities with 80 workers losing their lives in the course of their employment. This number represents 87% of all industrial fatalities occurring in Hong Kong during that year. Reasons for this poor performance have been documented elsewhere (Lingard and Rowlinson, 1991, 1994). Given this unenviable record, and the fact that worker motivation is a commonly cited reason for the high accident rate, it was deemed to be useful to assess the effectiveness of behaviour-based safety management methods in the Hong Kong construction industry context.

This paper describes the research methodology that was adopted and emphasizes the importance of employing suitable statistical methods for analysing results. The research results are then presented and discussed with reference to organizational factors which may have limited the effectiveness of the behaviour-based techniques of safety management in Hong Kong. An expectancy/goal setting model of motivation is developed and the research results are discussed in the light of this model.

## Experiment design

Traditional methods of evaluating the effect of an intervention are not appropriate for use in industrial settings as they rely upon the random assignment of subjects into control and experimental groups. This cannot usually be arranged in a work environment and the violation of this assumption, by using existing work teams or departments as control and experimental groups, has been a methodological flaw in previous behavioural safety research (Zohar *et al.*, 1980; Smith *et al.*, 1978).

An alternative to traditional experiment designs involves the drawing of comparisons within the same group of subjects (Barlow and Hersen, 1984). Within-group experimental designs have been used by the majority of researchers assessing the effectiveness of behaviour-based safety techniques in industrial settings. Duff *et al.* (1994) combined the multiple baseline and withdrawal experiment designs in their study of behaviour-based safety techniques in the UK construction industry. This combination was also used in the Hong Kong construction study. Figure 1 is a graphic representation of this experiment design.

Four categories of safety behaviour were identified and measured during the experiment. These were housekeeping, access to heights, bamboo scaffolding, and personal protective equipment (PPE). Housekeeping items related to such aspects of site safety as the storage and stacking of materials and the maintenance of clear access routes. After a period of baseline measurement using a pre-designed measurement instrument (see next section), participative goal setting and performance feedback were introduced to the housekeeping, access to heights and bamboo scaffolding categories at staggered intervals. PPE was maintained as a control category and thus no intervention was introduced in relation to the use of PPE.

It was expected, if the interventions were effective, that performance in a given category would improve only when the intervention was introduced with respect to that category. Thus, with reference to Figure 1, housekeeping should improve on all sites after week 18, access to heights should improve after week 22 and bamboo scaffolding should improve after week 26. No

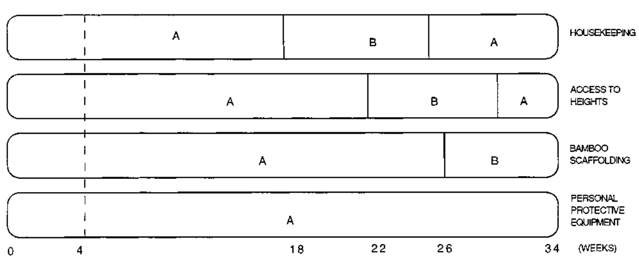


**Figure 1** Design of experiment

improvement in PPE should be observed. Measurements in all four categories continued until week 34 of the experiment and this enabled a comparison to be made between performance during the intervention and performance following the removal of the performance feedback in the categories of housekeeping and access to heights. A deterioration in performance following the removal of performance feedback would lend further weight to the argument that any improvement could be attributed to the implementation of goal setting with feedback.

## Measurement

A proportional safety measurement instrument was developed for use in the research. The proportional measurement of safety performance was developed by Phillips (1992) and used by Duff *et al.* (1994). It was found to possess a high degree of inter-rater reliability. The measure was modified slightly for use in the Hong Kong setting to account for the use of traditional construction methods such as bamboo scaffolding. Items were selected for inclusion in the safety performance measure on the basis of detailed statistical analysis of past accidents on Hong Kong Housing Authority building construction sites (Lingard and Rowlinson, 1994)

Measurement was carried out by a trained and appropriately qualified observer with relevant site experience. The observer was not informed as to the purpose of the measurement so as to reduce the possibility of observer-induced bias. Each item was scored proportionally; for example, the observer would record the number of unsecured ladders which he observed in use as a proportion of the total number of ladders in use on the site. Items were rated on a scale from zero to ten. Zero indicated full compliance and ten indicated total non-compliance with pre-established safety standards.

Measurement was carried out twice weekly on all seven sites. Sites were visited on different days of the week and at different times of day each week and site staff were never forewarned as to when a site visit was to be made. Reliability was assessed 18 times during the course of the experiment. Assessments involved the observer and the researcher independently and simultaneously measuring a site's safety performance. In ten of the 18 instances, the agreement was 80% or greater. However, owing to one low agreement score (29%) in week five of the experiment, the average percentage agreement between observers was 78%. This low score was followed by an observer re-training session and agreement improved rapidly and remained high for the rest of the experiment. The overall average of 78% is deemed to be an acceptably high level of agreement.

## The sample

All of the experimental sites were Hong Kong Housing Authority (HKHA) building construction sites. These sites were an ideal environment in which to experiment with behaviour-based safety management techniques. HKHA sites represent a reasonably homogeneous sample as construction design and specifications vary little from site to site. Client-based safety management activities, which have been found to have a considerable impact upon construction safety performance (Levitt and Samelson, 1987), also are uniform. HKHA building construction sites have a lower rate of accident occurrence than the Hong Kong construction industry average. This may be attributable to the HKHA's prequalification system under which tendering opportunities are linked to safety performance on past projects. In addition to this, HKHA have an internal safety committee and HKHA design staff carry out monthly safety audits on all sites. HKHA sites were therefore considered to be an ideal environment within which to test behaviour-based safety management methods as it could be expected that contractors engaged in these works would represent the industry's better performing firms.

## Time series data

Data generated during behavioural safety field experiments are in the form of temporally ordered scores or time series data. Time series data often possess characteristics which violate the assumptions underlying standard statistical methods such as analyses of variance or *t*-tests. Time series data should be analysed using specially designed statistical methods but, more often than not, researchers investigating the effectiveness of behavioural safety management programmes have failed to account for the peculiar characteristics of time series data and have applied inappropriate statistical methods.

## Statistical methods previously employed

Early studies in the behavioural safety field involved little statistical analysis. Visual inspection of graphical data was the means by which the effect of an intervention was measured (Sulzer-Acaroff, 1978). The problems associated with a reliance on visual inspection of data are numerous. Where high variability within and across experimental phases or where baseline data reflect an improving trend prior to the introduction of the intervention, it is difficult to judge with accuracy the effect of any intervention (Hartmann *et al*, 1980).

Researchers who have presented statistical analysis of intervention effects often have limited their analysis to a simple comparison between baseline and intervention performance rates (Smith *et al.*, 1978; Sulzer-Azaroff and De Santamaria, 1980). Other researchers have adopted statistical methods which compare the performance means prior to and after the introduction of an intervention (Matilla and Hyodynmaa, 1988; Duff *et al.*, 1994; Marsh, 1995). Glass *et al.* (1975) identify problems associated with comparing pre- and post-intervention mean scores as a method of assessing the effectiveness of an intervention. Time series data which drift steadily upwards obviously would possess different pre- and post-intervention means, but this difference does not necessarily reflect that a significant intervention effect has occurred. Likewise, if an intervention reversed a downward drift in a time series, and led to increasing performance scores in the intervention phase, a comparison of mean scores for each phase could show no significant difference despite the fact that a downward trend had been reversed.

## Standard statistical tests

Regression analyses and *t*-tests have been used widely to assess the impact of behavioural safety interventions (Zohar *et al.*, 1980; Haynes *et al.*, 1982). More recently, Cooper *et al.* (1994) tested the significance of a safety intervention using a one way analysis of variance (ANOVA). Excepting Cooper *et al.* (1994), no authors mention the problems associated with analysing time series data using conventional statistical tests.

## Systematic error

Serial dependency is a common property of 'single subject' behavioural scores, and relates to the extent to which a subject's performance at a given time can be predicted from performance at one or more earlier points in time. Serial dependency is measured by assessing the correlation between scores obtained at points in a time series separated by a given time increment (lag). This correlation is termed autocorrelation. The existence of serial dependency violates the assumption of random error which underlies the application of standard statistical tests. Furthermore serial dependency is very common in time series data representing behavioural scores. Jones *et al.* (1977) found that, in 83% of selected graphs from the *Journal of Applied Behavior Analysis*, data were serially dependent.

The consequences of using standard statistical tests to analyse time series data in conditions of serial dependency can be serious. Scheffe (1959) found that positive autocorrelation gives traditional tests a liberal bias. Since positive autocorrelation is very common in time series data, the result of applying standard statistical tests is that 'far too many interventions are found to be statistically significant when no real effect exists' (Hartmann *et al.*, 1980). In only two of the behaviour-based safety studies discovered, did researchers statistically account for the systematic error in their time series data (Komaki *et al.*, 1982; Chokkar and Wallin, 1984).

Those behaviour-based safety studies in which inappropriate statistical methods were adopted must be read and interpreted with great caution, as failure to account for systematic errors in time series data could lead to the generation of misleading statistical results.

## Time series analysis

Box and Jenkins (1976) developed a series of models known as autoregressive-integrated-moving averages (ARIMA) models, which can be applied to time series data and are designed to account for the systematic error present in a time series. ARIMA models are characterized by three structural parameters ($p$, $d$, $q$), each reflecting a different component of a time series process. Appropriate model selection, for a given time series, involves determining the value of the model parameters. Parameters are identified using a set of rules. For a detailed description of the ARIMA model selection process, see McCleary and Hay (1980). Box and Tiao (1975) developed a method of statistically assessing the impact of an intervention in time series data. This method involves four stages: (i) developing an ARIMA model for the portion of the time series representing the baseline period; (ii) adding one or more dummy, or predictor, variables that represent the timing of the intervention; (iii) re-estimating the model, including the new dummy variables; and (iv) interpreting the coefficients of dummy variables as measures of the effect of the intervention.

## Data analysis

Box and Tiao's assessment technique was applied to the experiment results. The 'Trends' module of the SPSS software package was employed to carry out the analysis. Data from each category and from each site were examined for any change at the observations representing four identifiable points in the series. These were: (a) the point at which goal setting and feedback were introduced in housekeeping; (b) the point at which the housekeeping feedback charts were removed from each site; (c) the point at which goal setting and feedback were introduced in the access to heights category; and (d) the point at which goal setting and feedback were introduced in the bamboo scaffolding performance category.

In each analysis a B-value was calculated. B-values represent the overall change in performance, occurring at a given point in the time series. Since safety scores represent the proportion of unsafe behaviour, a negative B-value indicates an improvement in safety performance and a positive B-value indicates a deterioration in safety performance.

## Statistical significance

Each impact analysis generates both a B-value, representing the extent to which scores prior to a given point were higher or lower than scores after that point, and the probability associated with obtaining that B-value purely by chance. The statistical significance of the impact analysis results was determined by these probabilities as follows: (1) a probability of 0.001 or less was taken to be a very highly significant result; (2) a probability greater than 0.001 but less than or equal to 0.01 was taken to be a highly significant result; (3) a probability of greater than 0.01 but less than or equal to 0.05 was taken to be a significant result; and (4) any probability greater than 0.05 was regarded as not significant.

## Results

The results of the impact analyses are presented below on a category by category basis.

### Housekeeping

Table 1 shows the results of the impact analyses carried out to test for a change in housekeeping performance at the point at which goal setting and feedback were introduced in the housekeeping performance category. A one way analysis of variance was applied to housekeeping data from site 3 as no systematic error was detected in these data. The analysis of variance indicated that site 3's mean score in the housekeeping category was 3.303 (67% safe) during the baseline period. The mean score for housekeeping improved to 2.268 (77% safe) following the introduction of the housekeeping goal setting and feedback. An $F$-ratio of 14.131 ($p = 0.000$) indicates that this improvement was statistically highly significant.

Performance in housekeeping was found to improve on all seven sites, following the introduction of goal set-

**Table 1** Housekeeping performance results when tested for a change with the introduction of goal setting and feedback to the housekeeping category

| Site | ARIMA model parameters | Change | B-value | Probability |
|---|---|---|---|---|
| 1 | (1,0,0) | Improvement | –1.500 | 0.003 |
| 2 | (1,1,0) | Improvement | –0.139 | 0.788 |
| 4 | (1,0,0) | Improvement | –1.300 | 0.000 |
| 5 | (1,0,0) | Improvement | –1.990 | 0.000 |
| 6 | (1,0,0) | Improvement | –2.190 | 0.000 |
| 7 | (1,1,0) | Improvement | –0.138 | 0.808 |

ting with feedback. On five of these sites (1, 3, 4, 5, 6), this improvement was statistically highly significant.

Analysis of data relating to other categories of performance indicated that on no site was there a general improvement of safety performance (e.g. improvement in all performance categories) when the housekeeping intervention was introduced. This finding lends weight to the argument that the improvement in housekeeping was due to the intervention.

### Withdrawal effect

Table 2 shows the results of the impact analyses carried out to test for a change in housekeeping performance at the point at which the performance feedback charts were removed from the sites. Site 3's mean housekeeping score following the removal of the housekeeping feedback chart was 72% safe. This represents a deterioration from the mean score during the intervention period (77% safe). As discussed above, housekeeping data from site 3 did not exhibit serial dependency or non-stationarity, and it was therefore appropriate to analyse these data using a standard one way analysis of variance (ANOVA). The *F*-ratio generated by the ANOVA indicated that the deterioration in site 3's housekeeping score was significant at a 0.05 probability level.

**Table 2** Housekeeping performance results when tested for a change with the removal of performance feedback in the housekeeping category

| Site | ARIMA model parameters | Change | B-value | Probability |
|---|---|---|---|---|
| 1 | (1,0,0) | Deterioration | 1.215 | 0.000 |
| 2 | (1,1,0) | Improvement | –0.044 | 0.906 |
| 4 | (1,0,0) | Deterioration | 0.167 | 0.117 |
| 5 | (1,0,0) | Deterioration | 0.479 | 0.008 |
| 6 | (1,0,0) | Deterioration | 1.007 | 0.000 |
| 7 | (1,1,0) | Deterioration | 0.180 | 0.635 |

These results show that on all but one site (site 2), housekeeping performance deteriorated with the removal of the housekeeping feedback charts. On four of these sites (1, 3, 5, 6) this deterioration was statistically significant. These findings strengthen further the argument that the observed improvements in housekeeping, when goal setting and feedback were introduced, can be attributed to the intervention.

### Access to heights

Table 3 shows the results of the impact analyses carried out to test for a change in access to heights performance at the point at which goal setting and feedback were introduced in the access to heights category. As Table 3 indicates, the results of the access to heights intervention were mixed. Safety performance in access to heights was found to improve on five of the sites with the introduction of goal setting and feedback in the category, but on only two of the sites was the improvement found to be statistically significant (sites 1 and 2). On site 4, there was found to be a highly significant deterioration in safety performance relating to access to heights at this time.

### Bamboo scaffolding

Owing to the fact that, by week 25 of the experiment, bamboo scaffolding was present on only four of the experimental sites, the bamboo scaffolding intervention could be introduced only on these four sites. Table 4 shows the results of the impact analyses carried out to test for a change in performance relating to the use of bamboo scaffolding at the point at which goal setting and feedback were introduced in the bamboo scaffolding category. As Table 4 indicates, no significant improvement in safety performance, relating to the use of bamboo scaffolding, was observed on any of the four sites at which goal setting and feedback were introduced in the bamboo scaffolding category.

**Table 3** Access to heights performance results when tested for a change with the introduction of goal setting with performance feedback in the access to heights category

| Site | ARIMA model parameters | Change | B-value | Probability |
|---|---|---|---|---|
| 1 | (1,1,0) | Improvement | –3.001 | 0.027 |
| 2 | (0,1,1) | Improvement | –2.240 | 0.036 |
| 3 | (2,1,0) | Improvement | –1.535 | 0.340 |
| 4 | (1,1,0) | Deterioration | 3.778 | 0.000 |
| 5 | (0,1,1) | Deterioration | 0.268 | 0.764 |
| 6 | (0,1,1) | Improvement | –0.503 | 0.586 |
| 7 | (0,1,1) | Improvement | –0.555 | 0.456 |

**Table 4** Bamboo scaffolding performance results when tested for a change with the introduction of goal setting with performance feedback in the bamboo scaffolding category

| Site | ARIMA model parameters | Change | B-value | Probability |
|---|---|---|---|---|
| 1 | (0,1,0) | Improvement | –0.021 | 0.988 |
| 3 | (2,1,0) | Improvement | –0.492 | 0.561 |
| 5 | (0,1,1) | Deterioration | 0.909 | 0.274 |
| 6 | (0,1,1) | Deterioration | 0.092 | 0.907 |

## Discussion

The results of the experiment were mixed. The highly significant improvements observed in site housekeeping with the introduction of the intervention, coupled with the significant deteriorations observed following removal of the housekeeping charts, indicate that the observed improvements during the housekeeping intervention stage were attributable to the intervention. The combination of goal setting and feedback were effective when applied to the housekeeping category. In contrast to these results, the access to heights and bamboo scaffolding interventions did not, in general, result in significant improvements in these areas.

Housekeeping is a very different aspect of site safety than access to heights or bamboo scaffolding. Generally speaking, improvement can be made in housekeeping without the deployment of additional material or equipment. Everyone on site can contribute to the improvement of site housekeeping. In contrast to this, access to heights and bamboo scaffolding items related to the work of a few specialist trades. Many of the items would require that additional materials be provided and, most significantly, that an increased time period was allowed for the job at hand. For example, if a bamboo scaffold is to be fitted with adequate, closely boarded working platforms, guard rails and toe boards, it requires that good quality timber is available to fit as platforms and toe boards. More significantly, the time required to construct a scaffold with these features is much greater than the time required to construct a bamboo scaffold without these features.

Bamboo scaffolding typically is erected by a specialist sub-contractor, and the extent to which this sub-contractor will incorporate working platforms, guard rails or toe boards into the scaffold will depend upon the specifications and cost agreed between the main contractor and the scaffolding sub-contractor. Unlike housekeeping, improvements in bamboo scaffolding safety cannot be made by every person on the site. Furthermore, the extent to which a safe scaffold is provided for use is pre-determined by an agreement, often verbal, between the main contractor and scaffolding firm. Under these circumstances, it is not within the control of the majority of operatives on site to make improvements in this area.

A highly significant deterioration in access to heights performance occurred on one site (site 4) following the introduction of the goal setting and feedback. This finding may be due to the fact that the project was close to completion and there were large numbers of finishing workers such as painters and plasterers present on site. These trades use a great deal of equipment relevant to the access to heights measurement items, including ladders, trestles and tower scaffolds. Site 4 was also running several weeks behind schedule so these finishing workers would probably have been under pressure to complete work speedily. This pressure may have encouraged bad practices and 'corner-cutting' which would, in turn, be reflected by poor access to heights scores.

### Goal setting and expectancy theory

A goal setting theory of work motivation was developed by Locke (1968) and Locke *et al.* (1981). Locke's model cites an individual's intentions *vis à vis* a given task as being the most important determinant of effort or choice. The theory holds that when an individual has made a conscious decision to pursue a goal, effort will be directed towards the outcome represented by that goal. Locke *et al.* stress that goals serve to motivate individuals only to the extent that the goals are accepted by those individuals. Locke and his associates do not address directly the question of what factors may lead individuals to accept or to reject goals. Other theorists have suggested that Vroom's expectancy theory of motivation may provide an insight into an individual's choice to reject or to accept and pursue a goal (Landy, 1989; Mento *et al.*, 1980; Matsui *et al.*, 1981; Lingard, 1995). Under the expectancy model, an individual's behaviour is determined by his/her beliefs in three areas. These are: the extent to which increased effort will lead to improved performance (expectancy); the extent to which improved performance will lead to a specified outcome (instrumentality); and the extent to which that outcome is valued by the individual (valence). It is possible that an individual's beliefs regarding expectancies, instrumentalities and valences determine whether a goal is accepted or rejected. Thus, the greater an individual's expectancy that increased effort will lead to goal attainment, the more that goal attainment is perceived to be instrumental in leading to a certain outcome, and the greater the individual values that outcome, the more likely he/she will be to accept and pursue a goal.

The results of the behavioural safety interventions may be interpreted in the light of this model in that housekeeping represents an area of safety performance in which improvements can be made relatively easily. The expectancy that increased effort will lead to improved performance and a specified outcome, i.e. goal attainment, would be high. The value associated with that goal attainment also may be reasonably high and, under the goal setting and expectancy model described above, the goal would be accepted and operatives would be sufficiently motivated to attain the goal.

In contrast to this situation, organizational constraints such as inadequate resourcing and/or time performance pressures may impose upon operatives an inability to perform work safely in the areas of access to heights or bamboo scaffolding. This can be seen as a failure by management to provide an adequate 'safety infrastructure' on site, e.g. inadequate equipment, plant and personal protective equipment. Works Branch of Hong Kong Government has recognized this as a problem and has attempted to ameliorate the situation with a 'pay for safety' tendering system. Hence under these circumstances, operatives may perceive that it is not in their power to improve their performance through increased effort, and goal attainment would therefore not be achieved if they did exert more effort; a negative expectancy exists. This perception may cancel out any value which operatives place on the outcome of goal attainment, the goal would be rejected and enhanced motivation would not occur.

### Reward structures

Another factor which may affect the goal setting/expectancy mechanism described above is the reward structure within which site operatives are working. It is common for Hong Kong construction tradesmen to be paid on a piece-rate basis. Where this is not the case, a main contractor may agree on a fixed price which is to be paid to a sub-contractor on completion of a given task. In some instances bonuses may be paid for work completed ahead of schedule. In any of these scenarios, it will be rewarding for work to be carried out as quickly as possible. If operatives perceive the value associated with the outcome of completing work quickly to be higher than the value associated with the outcome of attaining a safety performance goal then, under the model, it is likely that goal rejection will occur.

The explanatory goal setting/expectancy model described above is hypothetical and the extent to which the model usefully can explain the process of goal acceptance or rejection and the consequent effectiveness of behavioural safety techniques has not been investigated. Future research should be carried out to assess the validity of the model. Another intervening variable identified was commitment to employer by site workers. An exploratory study of commitment revealed that little or none existed on Hong Kong sites, suggesting that goal setting/expectancy models may be hampered by this organizational culture factor (Lingard, 1995).

## Conclusion

The validity of results obtained by previous researchers in the behavioural safety field through the use of inappropriate statistical methods should be critically evaluated. The adoption of statistical methods which rely on simple comparisons between pre- and post-intervention mean scores, *t*-tests or analyses of variance could lead to highly misleading results. Indeed, conclusions as to the overwhelming effectiveness of behavioural safety techniques which have been drawn on the basis of inappropriate statistical analysis of time series data should be questioned. Where possible, results should be re-analysed using techniques suited to the time series data under examination. This will enable firmer conclusions to be drawn concerning the effectiveness of behavioural safety management methods.

Behavioural safety management techniques were found not to be universally effective when applied to the Hong Kong building construction industry, and their role in the overall management of health and safety in the construction industry should not be overemphasized. Employers' responsibilities for providing adequate resources to ensure that construction work can be carried out without risk to health or safety of operatives must be stressed. Unless construction employers accept this responsibility and, in tendering for work, account realistically for the costs associated with ensuring a safe and healthy work site, then a behavioural approach to safety management will not be highly effective.

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