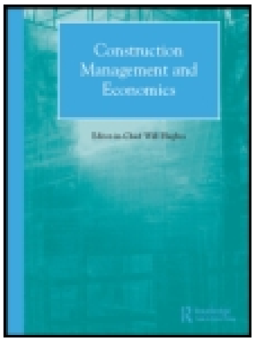

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# An investigation into construction time performance

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A systematic method for measuring construction time performance has been developed. This enables comparisons between individual project performances and best practice worldwide. Four factors affect construction time performance: construction management effectiveness, the sophistication of the client and the client's representative in terms of creating and maintaining positive project team relationships with the construction management and design team, design team effectiveness in communicating with construction management and client's representative teams, and a small number of factors describing project scope and complexity. This research has indicated that construction management team performance plays a pivotal role in determining construction time performance. It also reveals an important relationship between sound client's representative management effectiveness and good construction time performance. Detailed findings provide useful performance indicators that may be used to assist in defining benchmark measures necessary to assess a project's performance relative to a representative population.

*Keywords:* Time, productivity, team management, benchmarking.

## Introduction

Construction time performance has been identified along with cost and quality as one of three crucial success factors for a construction project. The Royal Commission into Productivity in the building industry in New South Wales concludes that 'through improving its productivity, the construction industry can have an important rôle in promoting national competitiveness, and therefore in defending living standards and achieving a satisfactory rate of growth. The benefits from such improvement would include increased attractiveness of Australia as a location for investment in new plants or projects and lower costs to domestic industry. Measures that prevent or slow steps toward improving building and construction industry productivity are, in effect, an attack on the employment prospects and future welfare of Australian workers. Such measures would also be an attack on the potential performance of Australian industry and the economy generally'. (PRD, 1991a, p. 32). This view is shared by construction industry organizations concerned with improved performance. The formation of construction industry development association (CIDA) and its focus in both facilitating and encouraging productivity improvement, reinforces the argument for attention to construction time performance. The argument is also supported by the potential for significant improvement which has been demonstrated by Stoekel and Quirke (1992). Their analysis indicates that a 10% construction industry productivity improvement will lead to a 2.5% increase in Gross Domestic Product.

The first section of this paper provides a brief overview of the literature relating to construction time performance. This is followed by a brief review of benchmarking literature, related to the concepts of continuous improvement and the learning organization. The research methodology adopted for the case study investigation is then discussed and a further section explains the model developed from this research. Results, practical applications and suggestions for further research are given at the end.

This paper contributes to the study of construction time performance improvement by identifying factors that influence construction time performance and demonstrating how this knowledge may be applied within the context of continuous performance improvement and adoption of best practice.

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## Factors affecting construction time performance: scope, complexity and managerial effectiveness

A review of the literature has established that construction time performance is determined by numerous factors. Much of the literature has concentrated upon project scope as a useful predictor of construction time. Bromilow's seminal work (Bromilow *et al.*, 1980; Bromilow and Henderson, 1976) is widely cited and his ideas have been developed and extended by those developing construction time prediction models.

While previous models have explained construction time by project scope measured by construction cost or gross floor area and numbers of floors (Ireland, 1986; Nahapiet and Nahapiet, 1985) there is widespread acceptance that other factors must be considered.

The principal criticism of purely scope-based models is that the management process is too complex to be relegated to the value of a constant conveniently described in a formula, regardless of the correctness of statistical methodology used. The Royal Commission into Productivity in the building industry in New South Wales (PRD, 1992), for example, revealed valuable data regarding the impact of worker attitude and management practices which indicated that both management and workers are responsible for poor productivity.

A number of researchers have linked non-scope factors to construction time performance. Ireland (1983) investigated the impact of managerial action upon cost, time and quality performance in building and Sidwell (1982) investigated the impact of client decision-making upon the construction process and project success. Both identified influences upon project time performance from inception to completion and concluded that client experience, form of building procurement, and project organizational structure are elements of a complex causal model of project time performance. Sidwell (1982) states 'when the building team and project procedures are appropriate to client and project procedures, higher levels of success will be attained.' (p. 88). He also identifies managerial control as a key element of achieving project success linking this to project complexity. Ireland's work (1983) supports Sidwell's conclusions and indicates that non-traditional procurement methods are likely to lead to better construction performance than traditional ones. In reporting results from a study of 69 projects, Naoum (1991) concludes that 'the major factors that affect cost and time overruns are the procurement method adopted and the designer's experience ...', (p. 31), however, Bresnen *et al.* (1990) in a study of 138 projects concludes that there was only a slight association between type of client or type of project, and construction time performance. Insignificant association was found between contract type and construction time performance. They also found that new work was built quicker than refurbishment projects. Chauhan and Chiang (1989) undertook a survey of 100 building and civil engineering projects in Hong Kong, India, Korea, Singapore, Taiwan and Thailand. Their survey results led them to believe that the performance of a construction management team is influenced by internal and external factors which they classify as: project, environment and management related.

## Benchmarking, continual performance improvement and best practice

If the goal of organizations is to improve performance to maintain competitiveness and to increase profits, then a methodology needs to be developed that allows performance to be compared against that of competitors. Two separate but allied concepts have evolved which permit this. The Japanese have developed the concept of kaizen or continuous improvement. Kaizen means continual improvement involving all levels of management and the workforce (Imai, 1986). It embraces quality management within a framework of incremental improvement based on critical analysis of work and management practices. For productivity improvement to be achieved it is necessary that a company's performance relative to its competitors be measured so that adverse variance can be identified in order that strategies can be implemented to assure productivity improvement.

Spendolini (1992) provides a useful way of understanding the connection between benchmarking and best practice. After analysing 49 definitions of benchmarking he established the 'benchmarking menu' as a method of conceptualizing the techniques and terms surrounding benchmarking. This is reproduced in Figure 1. Users can select an appropriate word in each box together with the link-words provided to define the term in the user's own context.

A recent study (Macneil *et al.*, 1993) using data from the top 500 enterprises in Australia reveals that benchmarking in general is widespread and growing, however, much of the activity is at a low level of intensity. The utilities business sector reported the highest level of awareness with approximately 60% practising benchmarking and the remainder intending to. This was closely followed by the manufacturing sector with just under 50% practising and just under 30% intending to benchmark. The construction sector was not included in this study as an identifiable group, however, in the 'other services' sector only 25% were practising benchmarkers and a further 25% intending to. In a pilot study (Macneil *et al.*, 1994) project specific best-practices were identified for three projects from a benchmark study which revealed more general principles according with the 33 study project reported upon (Walker, 1994). It was interesting to note that qualitative measures were used rather than quantitative measures which highlights the usefulness of the research results reported in this paper. The benchmarking self-help manual produced by the National Industry Extension Service (NIES, 1993) advises against the use of a wide number of metrics. It recommends that only key measures should be used that reflect the critical issues affecting productivity. It is also recommended that 'Key performance indicators should not be investigated in depth or decided upon before the analysis of the process has enabled people to understand what are the critical aspects of performance of the process itself'.

The usefulness of performance indicators is well appreciated. Holt *et al.* (1994) have established a technique for evaluating performance in the selection of construction contractors based on a multi-attribute decision matrix tool that at its heart uses weighted factors which represent benchmark metrics. Others (Alto and Garavelli, 1994) have adopted a similar approach for rating subcontractors for construction projects in which performance measures are required to be used in a multi-attribute evaluation model. These examples firmly place the need for benchmarking as an important input to an evaluation process that can be used for contract selection, continuous improvement and analysis of past performance.

Jashapara (1993) stresses the importance of organizations establishing an environment where they learn from their mistakes, learn from others and learn from themselves. His view of performance enhancement is predicated upon behavioural changes which facilitate this level of learning throughout the organization. Loosemore (1993) has also stressed the importance of group and individual behaviour as an important element of both inter-personal and inter-organization communication and problem solving. Benchmarking which leads to improvement also facilitates the development of learning organizations. The research presented in this paper has established strong links between management competence, specifically communication and problem solving, and sound construction time performance.

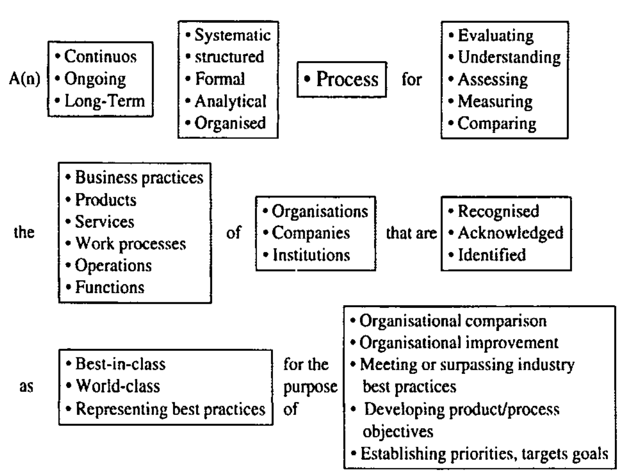


**Figure 1** The benchmark menu (Spendolini, 1992)

## The research methodology

Walker (1994) used a survey to investigate a sufficiently large sample size of projects to enable statistical analysis of data groups to be undertaken. Adequate sample size should allow reliability of results so that the investigation can be repeated with consistent results. Methods of measurement of variables should be consistent between case studies and able to be repeated using the same measurement technique and only appropriate variables used for testing hypotheses.

In examining links between government clients and poor productivity, for example, many instances of government client and poor construction time performance may reveal a significant association. The causal link, however, may lie in team relationships and accountability constraints imposed upon public sector clients rather than the client being from the government or private enterprise sector. This example highlights the need for a research approach that investigates causal links rather than merely testing for associations.

Marsh (1982) understands a survey to be an investigation where systematic measurements are made over a series of cases yielding a rectangle of data, variables in the matrix are then analysed to see if they reveal patterns of meaning. This approach can be contrasted to an experiment where a situation is established, an intervention is introduced and the researcher investigates what the effect of the intervention has on the result. Experiments involving human behaviour in investigating productivity are very complex as the number of possible variables is usually extensive and difficult to effectively model and test. It is for this reason that the survey method was adopted.

A pilot study was undertaken after considerable review of the literature. The pilot study, undertaken with 100 managers of Australian construction projects taken from Melbourne, Sydney, Canberra and Geelong, revealed further issues requiring consideration. Insights from the pilot study, together with additional review of the literature including significant Australian investigations undertaken during the late 1980s and early 1990s (PRD, 1991; PRD, 1991a; PRD, 1992) helped frame the structure of the questionnaire used in the study of 33 projects constructed during Australia's most recent boom-bust cycle of 1987 to 1993. The study used a sample size of 33 projects varying in contract value from approximately Australian $4 million to $45 million. A sample size of greater than 30 was advised as the nature of the question asked was 'is the within sample mean significantly different from the among sample mean, e.g. does the construction time performance index value vary for a low, medium, high or very high rating of a studied variable'. This question can be answered using the analysis of variance (ANOVA) statistical test which requires a sample size of greater than 30 cases (Levin, 1987).

The Australian Bureau of Statistics provided statistics for the sample group in the sample target area and reports that 235 projects in this cost range were commenced in the metropolitan area during the study period. The study's sample of projects represents 14% of all projects constructed during the study period. This represents a stratified representative sample of the population and projects were selected to avoid selection of either a biased sample of weakly or strongly performing group of projects. Representation of the sample as part of all projects constructed during the study period is demonstrated by the following:

*Business sector client*:
15 Public
18 Private

*Procurement method*:
21 Traditional
7 Direct construction management
2 Agency construction management + project management
3 Design and construct

*Type of construction*:
20 New works
5 Refurbishment
5 Mixed new and refurbishment
3 Fit-out

*Percentage designed at construction start*:
4 Less than 25%
1 Between 25% and 50%
4 Between 50% and 75%
22 Between 75% and 100%
2 Redesigned after construction start

*Building end-use*:
12 Office Buildings
5 Industrial Buildings
9 Education Related
1 Hospital
2 Hotels
1 Transport Facility
1 Entertainment Facility

A structured survey was used to gather data in both the pilot study and 33 case study investigations. The format of questions followed a logical structure in gathering data about the projects from hypothesized factors affecting construction time performance. The structure ensures consistency of approach as questions were asked in the same order and the questions asked were identical. The questionnaire was completed face-to-face with the interviewer so that respondents could, if necessary, fully probe the meaning of questions and reflect upon the nature of answers they gave. This approach also allows general discussion and peripheral comments to be noted to add supporting contextual evidence. This approach was adopted by Ireland (1983) and Sidwell (1982). The construction team manager was interviewed in each case study project using a structured questionnaire of 172 questions which took, on average, 2.5 hours to complete. Projects were drawn from a population of non-residential, non-engineering sector of the construction industry. Canvassing the views of other project team leaders – the client's representative, design team and key-subcontractors was considered but this approach presented difficulties that could hinder progress in understanding the issues addressed by this work. The construction team leader has unique insight into what happens on-site and is well placed to judge the effect of actions and circumstances that affect construction time performance, thus, the study started from the point of view of the construction team leader as this was considered as the most effective repository of knowledge about projects studied.

## Data analysis

The methodological approach adopted was to establish a model to predict construction duration based on the data sample. Data gathered from the research questionnaire was used as input into a multiple regression model. This provided a predicted construction time which could be measured against actual construction time to produce a construction time performance index.

The ANOVA results from the best-fit run of a multiple regression analysis, gave all variables in the model a '$p$' value less than 0.05 and a plot of residuals indicated that they were random and normally distributed. The model (with a 0.9987 $R^2$ value) predicts construction time in workdays (actual days worked) from the following variables: end_val (construction cost in $000s indexed to January 1990 taken at the mid-point of construction period), eot_act (the ratio of extensions of time granted to actual construction period), work_type = 'fit' (applicable if the project is a fit-out), obj_qual (the case study's data for the client's representative's objective for high quality of workmanship on a 7 point scale where 1 = very low and 7 = very high), cr_people (the case study's data for the client's representative's people-orientated management style measured on a 1 to 7 point scale where 1 = very low and 7 = very high), cm_des_com (the case study's data for the communications management for decision making between the construction and design team measured on a 1 to 7 point scale where 1 = very low and 7 = very high), and cm_IT_use (the case study's data for the effective use of information technologies by the construction management team measured on a 1 to 7 point scale where 1 = very low and 7 = very high).

| | Variable | Coefficient | Significance level |
|---|---|---|---|
| log workdays = | log end.val $000s | 0.481294 | 0.0000 |
| | eot_act | 1.187976 | 0.0002 |
| | work_type = 'fit' | −0.488867 | 0.0011 |
| | obj_qual | 0.105097 | 0.0126 |
| | cr_people | −0.125269 | 0.0011 |
| | cm_des_com | 0.079837 | 0.0278 |
| | cm_IT_use | 0.104343 | 0.0204 |

The formula can be transformed from log form as follows:

$$\text{WORKDAYS} = \text{Construction cost in } \$000\text{s}^{0.481294*} \exp [(1.187976 * \text{eot act}) - (0.488867 \text{ if it is a fit-out project}) + (0.105097 * \text{obj qual}) - (0.125269 * \text{cr people}) + (0.079837 * \text{cm des com}) + (0.104343 * \text{cm IT use})]$$

Coefficients provide some indication of importance weighting for variables. The model indicates that principal factors affecting construction time performance are management and client related. Fit-out projects appear to be quicker to construct than non-fit-out projects. The client's representative contributes to the granting of extension of time from scope changes. The client's representative's quality expectations are significant and the degree of people-orientation to management style also has an impact in a negative direction indicating that a high people-orientation reduces the factor and therefore the time. The construction management team also have a strong influence upon construction time with their ability to work effectively with the design team to get decisions made and acted upon one important factor and their effective use of IT as another factor.

An interesting result emerging from the regression analysis is that construction duration increases as the client's quality objective, the communications management between the construction manager and design team and the construction manager's use of IT increases. Thus an improvement in communications between construction manager and design team results in a deteriorating construction duration. It is unclear at this stage why this may be so, and more analysis and follow-up questioning needs to be undertaken to answer this question. A number of possibilities spring to mind, learning effect, use of mutually incompatible or poorly integrated software etc. which indicate how increased IT use can prove detrimental to construction time performance. Quality of IT use should have been better defined in the question to obtain a more useful measure of this variable.

The model of determining construction time was exhaustively verified. Two available models of predicted construction time were tested together with an area based model, however, the model described above proved the best fit with a tight fit around the line equating predicted to actual time and a very high $R^2$ value of 0.9987 which indicates that the predicted time model can be used with confidence.

Having established a predicted construction time, given project scope and individual characteristics, a performance index was constructed for each project. This index provides a measure of construction time performance for a project relative to the sample population which is also representative of the greater population of projects constructed in the target area during the period studied. Each case study project was given a construction time performance index value based on the ratio of predicted to actual time. Thus project one has a predicted duration of 262.183 workdays but an actual observed duration of 273 workdays. The construction time performance index for project one is, therefore, 0.960376. This statistic indicates that project one's construction time performance is 96.04% of trend, i.e. below trend. Project two with a predicted construction duration of 238.488 workdays and an observed duration of 184 workdays performs above trend at a construction time performance index of 1.29613 or 129.61% of trend. In this way a picture emerges of the relative construction time performance of projects so that inferences can be made and statistical analysis and hypothesis testing can be undertaken based on comparing construction time performance of projects.

Once an index was developed to compare the data sample, comparison of projects and suspected factors could be undertaken using one-way analysis of variance (ANOVA). Correlation analysis (Pearson's product moment and Spearman Rank order) was also used to test hypotheses and develop models. Most of the data gathered is ordinal and interval data has been transformed into ordinal categories which has allowed the use of Spearman Rank Correlation to construct a 102 by 102 correlation matrix using a PC-based software package (STATGRAPHICS) for data analysis. The ANOVA results were used to determine, at the 95% confidence level, factors which affect construction time performance and correlation analysis to identify the correlation between variables in the 102 by 102 matrix. This provides details of factors contributing to each hypothesis tested and the degree of association with the question data under analysis.

The thesis tested by this research was that 'variance between actual performance and trend line performance can be substantially explained by managerial effectiveness of the project team in response to challenges posed by factors outside the control of the construction management team.'

More specifically, four principal hypotheses are tested by this work:

client's representative team's management effectiveness –

$P_1$–$H_0$ that construction time performance IS NOT significantly affected by the management effectiveness of the client's representative;

$P_1$–$H_1$ that construction time performance IS significantly affected by the management effectiveness of the client's representative;

construction management team's effectiveness –

$P_2$–$H_0$ that construction time performance IS NOT significantly affected by the management effectiveness of construction management teams;

$P_2$–$H_1$ that construction time performance IS significantly affected by the management effectiveness of construction management teams;

design teams' effectiveness –

$P_3$–$H_0$ that construction time performance IS NOT significantly affected by design team management effectiveness;

$P_3$–$H_1$ that construction time performance IS significantly affected by design team management effectiveness;

project challenges –

$P_4$–$H_0$ that construction time performance IS NOT significantly affected by a small number of challenges posed by factors outside the control of the construction management team;

$P_4$–$H_1$ that construction time performance IS significantly affected by a small number of challenges posed by factors outside the control of the construction management team.

Investigation of evidence to support or reject the principal hypotheses involved testing 102 sub-hypotheses because the principal aim of this work was to investigate the reason why some projects are built more quickly than others by establishing a 'league table' of factors for the sample group to also indicate the strength of each factor tested.

Results were analysed and a model of construction time performance was produced which describes the major grouping of construction time performance causal factors with indications of the influence of other factors upon the construction manager's performance. For example, the construction manager's ability to manage is affected to a large extent by the client's representative team's effectiveness which means that the construction manager finds it difficult to overcome problems of this kind. However the construction manager finds it easier to overcome environmental challenges of a physical and economic nature and problems emanating from communication breakdowns between the design team and the client's representative and construction manager. In conclusion, it is apparent that good construction time performance is primarily dependent upon the construction manager's aptitude in overcoming the above problems. Of secondary importance is the capability of the design team and client's representative. The implication is that in relation to construction time performance, the construction manager is the 'king pin' within the project organization. A proficient construction manager provides a safety net by being able to overcome many of the problems fed down by poor consultants. In contrast, the problems generated by an ineffective construction manager have no safety net and construction time performance is directly affected. Figure 2 illustrates the model.

One criticism of this conclusion may be that this result would be expected because the data were collected exclusively from the construction manager and consequently it would be inevitable that they would perceive themselves to be of pivotal importance to construction time performance. To prevent this criticism construction managers were not asked to identify their perceived influences upon construction time performance but merely to give information about project characteristics and interpersonal relationships. This data were then correlated with construction time performance. It is acknowledged however that these perceptions may not be representative of those within the project as a whole.

Table 1 contains a list of factors significantly affecting construction time performance, threshold values are

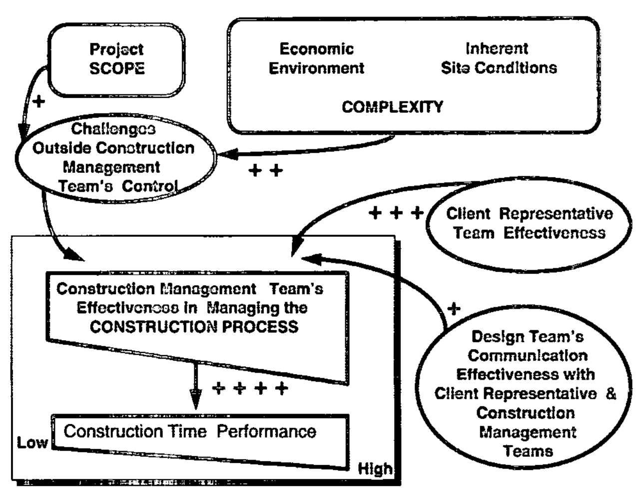


**Figure 2** Model of construction time performance causal factors

indicated in the sub-hypothesis short-hand description column. These indicate the point or level at which the factor become significant. SH+ means slightly high and better, AVG+ means average and better, HI+ means high and better. Variables used in the derivation of the construction time performance index have also been included in Table 1 and appear in the shaded rows. Table 2 is also very interesting as it contains a list of factors found to have not significantly affected construction time performance.

All correlation between the factor investigated under each sub-hypothesis and each other factor was analysed and correlations greater than 0.45 was provided. An example for sub-hypothesis 60 is reproduced in Table 3.

**Table 1** Factors significantly affecting construction time performance (in rank order)

| HY | Question | Group | Sub-hypothesis (short-hand) description – in significance order | Sig. |
|---|---|---|---|---|
| 62 | 14.1 | CM | HI+ CM's organizational structure to manage risk | 0.0010 |
| 58 | 13.3.6 | CM | HI+ CM's planning – responding to problems or opportunities | 0.0016 |
| 59 | 13.3.7 | CM | SH+ CM's effectively coordinating resources | 0.0028 |
| 60 | 13.3.8 | CM | SH+ CM's developing an organizational structure to maintain workflow | 0.0032 |
| 30 | 2.7.1 | CR | SH+ the project design team's confidence in the client's representative contribution | 0.0040 |
| 88 | 16.2.1 | CR/CM | SH+ client's representative and CM team communication effectiveness for decision making | 0.0043 |
| 93 | 16.3.3 | CM | HI+ decision making communication within the CM team | 0.0094 |
| 96 | 16.4.3 | CM | SH+ CM decision making, communicating and actioning | 0.0113 |
| 17 | 2.4.2 | CR | HI+ client/client's representative's time minimization objective | 0.0136 |
| 28 | 2.6.5 | CR | SH+ ability of the client's representative to contribute ideas to the design process | 0.0137 |
| 32 | 2.7.3 | CR | HI+ the construction team's confidence in the client's representative's contribution | 0.0142 |
| 18 | 2.4.3 | CR | client/client's representative's quality performance objective | 0.0151 |
| 84 | 15.3 | KEY S-C | SH+ key sub-contractor's task-oriented management style | 0.0156 |
| 9 | 1.11 | CM | 5% (Est. + EOT) workdays being within 5% of actual duration | 0.0161 |
| 38 | 3.1 | PROJ | inherent site conditions | 0.0173 |
| 45 | 9.1 | PROJ | economic environmental complexity | 0.0177 |
| 56 | 13.3.1-4 | CM | SH+ CM's forecasting planning data | 0.0188 |
| 89 | 16.2.2 | CR/DES | SH+ client's representative and design team communication effectiveness for decision making | 0.0237 |
| 87 | 16.1 | CM | SH+ CM's communication management to facilitate decision making | 0.0258 |
| 36 | 2.7.7 | CR | AVG+ client's representative's willingness to contribute effective and positive ideas | 0.0267 |
| 61 | 13.3.5-8 | CM | HI+ effectiveness of the construction team's monitoring and control | 0.0269 |
| 1 | 1.1 | PROJ | construction cost being greater than $20 million (January 1990 dollars) | 0.0272 |
| 100 | 17.1 | CM | HI+ effectiveness of the CM team in managing the construction process | 0.0273 |
| 52 | 13.3.1 | CM | SH+ CM's forecasting planning data | 0.0275 |
| 57 | 13.3.5 | CM | HI+ CM's monitoring and updating plans to reflect work status | 0.0305 |
| 53 | 13.3.2 | CM | AVG+ CM's analysing construction methods | 0.0315 |
| 90 | 16.2.3 | CM/DES | SH+ CM and design team communication effectiveness for decision making | 0.0448 |
| 99 | 16.6 | CM | AVG+ CM's effective use of information technologies | 0.0452 |
| 49 | 12.1 | CR/CM | SH+ impact of client's representative/CM working relationship | 0.0468 |
| 29 | 2.6.6 | CR | SH+ ability of the client's representative to contribute ideas to the construction process | 0.0489 |
| | | | From the regression model (but accepting the null sub-hypothesis) | Sig. |
| | | PROJ | log of: construction cost | 0.0000 |
| 10 | 1.12 | PROJ/CR | ratio of EOT:actual construction time | 0.0002 |
| 5 | 1.6 | PROJ | type of work = 'fit-out' | 0.0011 |
| 70 | 15.3 | CR | client's representative's people-oriented management style | 0.0011 |

CR = client's representative, CM = construction management, DES = design team, PROJ = project factors, KEY S-C = key subcontractors, HY = Sub-Hypothesis, Sig. = significance.

**Table 2** Factors NOT significantly affecting construction time performance (in rank order)

| HY | Question | Group | Sub-hypothesis (short-hand) description – in significance order | Sig. |
|---|---|---|---|---|
| 75 | 15.3 | DES | design team's people-orientated management style | 0.0573 |
| 54 | 13.3.3 | CM | CM's analysing resource movement | 0.0659 |
| 6 | 1.7.1 | CR | project procurement method | 0.0681 |
| 78 | 15.2 | CM | flexibility of the CM's management style | 0.0711 |
| 19 | 2.4.4 | CR | stability of client/client's representative objectives | 0.1033 |
| 42 | 7.1 | PROJ | access to and within site | 0.1053 |
| 66 | 15.1 | CM | CM's effectiveness in team management to achieve synergy | 0.1240 |
| 71 | 15.4 | CR | direct use of power in the client's representative's management style | 0.1382 |
| 23 | 2.5.2 | CR | complexity of client's representative's influence upon the project's management | 0.1596 |
| 41 | 6.1 | PROJ | quality management procedures used on-site | 0.1654 |
| 101 | 15.5.3 | CM | Motivation – job security | 0.2457 |
| 7 | 1.7.2 | DES | design development stage at start of construction | 0.2469 |
| 39 | 4.1 | PROJ | design buildability complexity | 0.2669 |
| 16 | 2.4.1 | CR | client/client's representative's cost minimization objective | 0.2907 |
| 26 | 2.6.3 | CR | client's representative's ability to effectively brief the design team | 0.3140 |
| 12 | 2.2.2 | CR | client company size | 0.3275 |
| 50 | 12.2 | CM | CM's effectiveness in influencing the client's representative decision making process | 0.3338 |
| 55 | 13.3.4 | CM | CM's analysing work sequencing to achieve and maintain workflow | 0.3503 |
| 51 | 13.1 | CM | CM management systems and procedures | 0.3813 |
| 46 | 10.1 | PROJ | socio-political environmental complexity | 0.4035 |
| 37 | 2.7.8 | CR | the overall client's representative contribution to project team harmony | 0.4045 |
| 2 | 1.3 | PROJ | number of basement levels | 0.4111 |
| 82 | 15.2 | KEY S-C | key sub-contractor's mechanistic-oriented management style | 0.4180 |
| 79 | 15.3 | CM | task-orientation of the CM's management style | 0.4289 |
| 33 | 2.7.4 | CR | the client's representative's confidence in the construction team | 0.4385 |
| 34 | 2.7.5 | CR | the client's representative's ability to mould shared project goals and aspirations | 0.4555 |
| 95 | 16.4.2 | DES | design team's decision making, communicating and actioning | 0.4661 |
| 40 | 5.1 | DES | design coordination complexity | 0.4782 |
| 86 | 15.4 | KEY S-C | direct use of power in key sub-contractor's management style | 0.4793 |
| 27 | 2.6.4 | CR | stability of client's representative decisions | 0.4863 |
| 4 | 1.6 | PROJ | the building's end use | 0.4882 |
| 47 | 11.1 | PROJ | impact of the IR environment | 0.4955 |
| 65 | 14.4 | KEY S-C | key sub-contractor's organizational structure to manage risk | 0.4991 |
| 69 | 15.3 | CR | task-orientation of the client's representative's management style | 0.5198 |
| 77 | 15.2 | CM | CM's mechanistic-orientated management style | 0.5577 |
| 80 | 15.3 | CM | CM's people-orientated management style | 0.5806 |
| 44 | 8.1 | PROJ | physical environmental complexity | 0.5887 |
| 3 | 1.4 | PROJ | number of floors being greater than two | 0.5939 |
| 92 | 16.3.2 | DES | decision making communication within the design team | 0.5962 |
| 11 | 2.2.1 | CR | client representative form | 0.6344 |
| 72 | 15.2 | DES | design team's mechanistic-orientated management style | 0.6463 |
| 8 | 1.9–10 | PROJ | construction time period | 0.6520 |
| 91 | 16.3.1 | CR | decision making communication within the client's representative team | 0.6567 |
| 83 | 15.2 | KEY S-C | flexibility of key sub-contractor's management style | 0.6666 |
| 76 | 15.4 | DES | direct use of power in the design team's management style | 0.6800 |
| 15 | 2.3.3 | CR | client organization's confidence in the client's representative | 0.6838 |
| 74 | 15.3 | DES | task-orientation of the design team's management style | 0.7062 |
| 64 | 14.3 | CR | client's representative's organizational structure to manage risk | 0.7319 |
| 35 | 2.7.6 | CR | the client's representative's willingness to accept effective and positive ideas | 0.7327 |
| 73 | 15.2 | DES | flexibility of design team's management style | 0.7479 |
| 31 | 2.7.2 | CR | client's representative's confidence in the project design team | 0.7550 |
| 43 | 7.3 | PROJ | general project complexity | 0.7588 |

**Table 2** Factors NOT significantly affecting construction time performance (in rank order)—continued

| | | | | |
|---|---|---|---|---|
| 63 | 14.2 | DES | design team's organizational structure to manage risk | 0.7829 |
| 24 | 2.6.1 | CR | client's representative's understanding the project's constraints | 0.7887 |
| 22 | 2.5.1 | CR | the level of influence exercised on construction time performance by the client's representative | 0.8001 |
| 98 | 16.6 | DES | design team's effective use of information technologies | 0.8341 |
| 67 | 15.2 | CR | level of client's representative mechanistic-orientated management style | 0.8344 |
| 94 | 16.4.1 | CR | client's representative decision making, communicating and actioning | 0.8388 |
| 21 | 2.4.6 | CR | credibility of achieving goals established by the client's representative/ client | 0.8440 |
| 25 | 2.6.2 | CR | client's representative's ability to quickly make authoritative decisions | 0.8553 |
| 48 | 11.3 | PROJ | impact of general environmental factors | 0.8681 |
| 102 | 15.5.9 | CM | opportunity for career advancement | 0.8696 |
| 81 | 15.4 | CM | direct use of power in the CM's management style | 0.8759 |
| 68 | 15.2 | CR | flexibility of the client's representative's management style | 0.8825 |
| 20 | 2.4.5 | CR | clarity of communication of client/client's representative objectives | 0.9145 |
| 85 | 15.3 | KEY S-C | key sub-contractor's people-orientated management style | 0.9342 |
| 14 | 2.3.2 | CR | client's representative's experience with the building procurement process | 0.9356 |
| 97 | 16.6 | CR | client's representative's effective use of information technologies | 0.9622 |
| 13 | 2.3.1 | CR | client organization's experience with the building procurement process | 0.9858 |

CR = client's representative, CM = construction management, DES = design team, PROJ = project factors, KEY S-C = key subcontractors, HY = Sub-Hypothesis, Sig. = significance.

## Discussion

Walker's (1994) research findings suggest that many factors relating to project and environmental complexity do not affect construction time performance *per se*. This makes sense as many very complex projects built very quickly can be cited. The Broadgate project in London, The Empire State Building in New York, and The First Canadian Bank Tower in Toronto are but three examples of sites with acute site access problems. Only one factor affecting inherent site conditions was found to be significant; water table and geotechnical problems. The economy was a factor, due to its impact upon supply of resources during boom-bust cycles (not necessarily plentiful in bust and constrained in boom conditions). The industrial relations (IR) environment in Australia has been sufficiently stable recently to be an insignificant factor though it was found to have moderate association with the economic environment.

Factors pertaining to construction management actions support the findings of Ireland (1983) and Sidwell (1982, 1983). Planning appears to be an issue and so does communications management and managing conflict resolution. Effective management of information technologies (IT) was found to be a strong factor, also becoming an important issue in general management.

Influence of client and client's representative as a significant factor was expected but what was not expected was the nature of this influence. Team confidence in the client's representative rather than vice versa reflects the difficult rôle a client's representative plays as link-pin between a multi-dimensional client group with conflicting goals and the project team. Greater understanding of this uncomfortable rôle needs to be forthcoming from a project team for success to follow. The client's representative also is required to have a positive attitude and good team interaction skills. These findings contrast sharply with the image of a successful client's representative being punitive, diamond-hard, and narrowly focused doggedly advancing the client's agenda.

## Further Work

There are many strands of inquiry that can flow from this work. It would be interesting to continue the work by gaining data on parts of the survey from the client's representative and design team's perspective and compare perceptions of team leaders as to what they think affects construction time performance and how their team may influence project time outcome.

The survey could also be extended to other similar cities elsewhere in the world to help find out if project and environmental characteristics and management issues have similar weightings of importance to construction time performance. The research instrument can be used to gather data indicating cultural differences, for example, in management style, degree of impact that the client's representative exerts as well as management practices. It is anticipated that environmental factors would have greater impact in cities where political instability is featured so that management action would have to cope with this.

**Table 3** Moderate and high correlations with the variable tested

Sub-Hypothesis Number 60. Data Item: CM's organizational structure to maintain workflow

Spearman Rank correlation results for factors affecting construction time performance:

- ☐ Ability of the client's representative to contribute ideas to the design process ($C_s$ = 0.5378; sig. = 0.0028);
- ☐ The project design team's confidence in the client's representative contribution ($C_s$ = 0.4966; sig. = 0.0065);
- ☐ The construction team's confidence in the client's representative contribution ($C_s$ = 0.5770; sig. = 0.0011);
- ☐ Economic environmental complexity ($C_s$ = 0.5107; sig. = 0.0039);
- ☐ Impact of client's representative/CM working relationship ($C_s$ = 0.5781; sig. = 0.0011);
- ☐ CM's forecasting planning data ($C_s$ = 0.6849; sig. = 0.0001);
- ☐ CM's analysing construction methods ($C_s$ = 0.5851; sig. = 0.0009);
- ☐ Effectiveness of the construction team's planning ($C_s$ = 0.7410; sig. = 0.0000);
- ☐ CM's monitoring and updating plans to reflect work status ($C_s$ = 0.6551; sig. = 0.0002);
- ☐ CM's planning – responding to problems or opportunities ($C_s$ = 0.6396; sig. = 0.0003);
- ☐ CM's effectively coordinating resources ($C_s$ = 0.7481; sig. = 0.0000)
- ☐ Effectiveness of the construction team's monitoring and control ($C_s$ = 0.8248; sig. = 0.0000);
- ☐ CM's organizational structure to manage risk ($C_s$ = 0.7802; sig. = 0.0000);
- ☐ Key sub-contractor's task-oriented management style ($C_s$ = 0.4983; sig. = 0.0048);
- ☐ CM's communication management to facilitate decision making ($C_n$ = 0.5944; sig. = 0.0008);
- ☐ Decision making communication within the CM team ($C_s$ = 0.5359; sig. = 0.0024);
- ☐ CM decision making, communicating and actioning ($C_s$ = 0.7103; sig. = 0.0001);
- ☐ Effectiveness of the CM team in managing the construction process ($C_s$ = 0.7544; sig. = 0.0000).

Spearman Rank correlation results for factors NOT affecting construction time performance:

- ☐ Ratio of EOT: actual construction time ($C_s$ = 0.4475; sig. = 0.0114);
- ☐ Stability of client/client's representative objectives ($C_s$ = 0.6456; sig. = 0.0003);
- ☐ Clarity of communication of client/client's representative objectives ($C_s$ = 0.5702; sig. = 0.0013);
- ☐ Complexity of client's representative's influence upon the project's management ($C_s$ = 0.5238; sig. = 0.0030);
- ☐ Stability of client's representative decisions ($C_s$ = 0.5868; sig. = 0.0009);
- ☐ The client's representative's confidence in the construction team ($C_s$ = 0.5291; sig. = 0.0032);
- ☐ CM's effectiveness in influencing the client's representative decision making process ($C_s$ = 0.4643; sig. = 0.0086);
- ☐ CM management systems and procedures ($C_s$ = 0.8032; sig. = 0.0000);
- ☐ CM's analysing resource movement ($C_s$ = 0.5917; sig. = 0.0010);
- ☐ CM's developing an organizational structure to maintain workflow ($C_s$ = 0.7197; sig. = 0.0000);
- ☐ Client's representative's organizational structure to manage risk ($C_s$ = 0.5267; sig. = 0.0029);
- ☐ Key sub-contractor's organizational structure to manage risk ($C_s$ = 0.5802; sig. = 0.0012);
- ☐ CM's effectiveness in team management to achieve synergy ($C_s$ = 0.6063; sig. = 0.0006);
- ☐ Task-orientation of the CM's management style ($C_s$ = 0.4503; sig. = 0.0109);
- ☐ CM's people-oriented management style ($C_s$ = 0.4621; sig. = 0.0089);
- ☐ Decision making communication within the client's representative team ($C_s$ = 0.6371; sig. = 0.0007);
- ☐ Client's representative decision making, communicating and actioning ($C_s$ = 0.5172; sig. = 0.0034).

The methodology provides a useful approach for adding to the body of research into procurement methods and their effect upon construction time performance as well as further exploring issues on an international scale such as 'does a government client tend to experience poorer construction time performance than a private client?' The research indicates that government clients have no significantly better or worse construction time performance than private clients.

The area of construction time performance and effectiveness of IT use or effective communication between teams needs to be addressed in more depth. There is no shortage of ideas to extend the research.

## Conclusion

The contribution made by this work lies in its identification of factors affecting construction time performance. A model was developed which describes factors affecting construction time performance. A major issue raised by the model is its demonstration that it is the construction management team who, ultimately, has to deal with ineptitude, incompetence or poor management by other members of the greater project team.

This model indicates that many project characteristic factors are identified as having no significant impact upon construction time performance (other than project scope which provides a significant input to the determination of predicted time) because they are subject to management planning and control. Many project challenges associated with design and access issues, for example, can be compensated for by employing good risk assessment and management practices. Problems arise when tenderers do not recognize that they may be dealing with a less than adequate design team or that proactive measures may have to be allowed for to anticipate buildability issues or potential site access problems. Many environmental factors can be planned for and those risks out of the control of the contractor e.g. weather, national IR disputes or political events, can be taken on board by the client or construction management team which should be adequately compensated for any risk accepted.

The model indicated that the client's representative was important to construction time performance. Many warning signs of poor client's representative management performance can be anticipated by the construction manager and alternative plans formulated to cope with such an eventuality. Research findings indicating that the client's representative needs the confidence of the design and construction teams leads to the conclusion that this is one fruitful area of research which can lead to concrete and economic recommendations regarding client's representative selection procedures.

Impact of the design team upon construction time performance has been largely ignored in this paper although this was not intended. Unfortunately, the data were not as reliable as would be desired in dealing with this aspect and so no comment upon design team impact has been offered.

There is a need to develop benchmark measures for client's representative performance. Secondly benchmark measures should be developed to determine favourable construction manager characteristics. Table 1 offers a promising start to the development of such benchmark metrics and the questionnaire used in the study (Walker, 1994) provides a useful means of gathering data and formulating benchmark measures. This work can then be used to assist in a process of implementing kaizen and the development of an environment where a learning organization can be maintained.

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