ARTICLE

Contract Documentation and the Incidence of Rework in Projects

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Abstract

Within the Australian construction industry, rework has been identified as a significant factor that contributes to cost increases and project completion delays. It has been suggested that a major cause of rework relates to the quality of contract documentation that is produced by design consultants and that higher fees paid to consultants would result in improved contract documentation quality. Using a questionnaire survey, this paper determines the key contract documentation variables that influenced rework costs in 161 construction projects. Evidence from the findings presented form the basis of practical suggestions made for improving the management of the design process and the production of contract documentation in projects. However, no significant relationship between contract documentation and rework could be established from the findings presented.

■ *Keywords*: Construction project management; contract documentation; quality; rework

INTRODUCTION

Rework represents a relatively new terminology in the modern construction management lexicon and can be defined as 'the unnecessary effort of redoing a process or activity that was incorrectly implemented the first time' (Love, 2002a). Within the Australian construction industry, rework has been identified as a significant factor that contributes to cost increases and project completion delays (Love, 2002a). Such a negative impact inevitably reduces the overall competitiveness of practitioners working within the construction industry and directly leads to client dissatisfaction, reduced profitability and, in extreme circumstances, litigation (Love, 2002b). Design-related problems, stemming from inadequate, incorrect or incomplete contract documentation, are considered to be the major source of rework in projects (Love *et al*, 1999). Tilley and McFallen (2000a,b,c) reported that the quality of contract documentation produced by design consultants appears to have significantly diminished since the abolition of established fee scales and the introduction of competitive tendering for consultancy services. Tilley and McFallen (2000a,b,c) have also indicated that increased fees are positively correlated with the quality of contract documentation produced by consultants. In turn, improvements gained will significantly ameliorate project performance.

Developing a panacea for all design-related rework problems is a difficult research dilemma, but attempting to discover the factors that influence rework is achievable. In this paper, a questionnaire survey sought to examine the work practices associated with the production of contract documentation and the influence of these upon rework costs. The research presents a propaedeutic study and, based upon the findings presented, practical suggestions for improving the management of the design process and the production of contract documentation are made.

MANAGEMENT PRACTICES AND REWORK

The *modus operandi* of construction organizations (designers and contractors alike) is typically detection-focused and, therefore, emphasis is placed on the product, procedures and/or service deliverables and the downstream producing and delivery processes. Dale

(1999: 6) states that in such an environment 'considerable effort is expended on after-the-event inspecting, trouble shooting, checking, and testing of the product and/or service and providing reactive "quick fixes" in a bid to ensure that only conforming products and services are delivered to the customer'. This narrow quality control approach has a proclivity to stifle creative and systematic work activities, while planning and improvements are neglected and defects (e.g. errors, which may subsequently lead to rework) remain undiscovered until late into the procurement process. Hidden defects (such as design errors) are costly and the longer they remain unnoticed then the greater the associated cost and time penalty will be, especially if work activities have been completed.

Although a detection system may prevent non-conforming products or services being delivered to a customer (either internal or external), it cannot prevent them from being made (Love and Josephson, 2003). Indeed, it is questionable whether such a system does, in fact, find and remove all non-conforming items. Australian design and construction organizations typically operate in a *reactive* environment that places emphasis on making good a non-conformance rather than *proactively* preventing it from arising in the first place. This is because organizations tend to focus on the short term 'bottom line' and often lack the vision, imagination and ideas that are capable of developing longer-term effective market *differentiation* (Gibson, 1997).

Gardiner (1994), Stasiowski and Burstein (1994), Richardson (1996) and Powell (1997) have all suggested that the insularity and aversion of architectural organizations to 'management' has resulted in poor service quality and their continual marginalization within the industry. This is because architects have been unable to respond to the changing construction environment and provide a service that meets the dynamic demands of customers. Put simply, a significant gap exists between consumers' a priori expectations of the service and their perceptions of the actual service delivery by an organization. Powell (1997: 84) states 'architects still cling to the notion that their future lies in building original works of art to last forever'. Symes *et al* (1995: 55) concluded from their study that 'without more training in how to manage a firm and adapt to the needs of their customers, most architects may well be doomed to work in small practices and thereby be further marginalized in the building process'. This problem is not unique to construction designers as engineering design consultants have been confronting a similar dilemma for some time (Culp, 1993; Tilley and McFallen, 2000a,b,c).

Barrett (1993) and Powell (1997) state that the strategic positioning of consultant organizations, for example architects, is founded on the organization's ability to differentiate its service or product from those offered by competitors. In response to growing marginalization, many architectural organizations have streamlined company activities to meet the challenge of an increasingly volatile and competitive market environment (Richardson, 1996). Rather than simply compete on quality of service offered, design organizations have adopted a market-driven strategy based on their fees (Rounce, 1998). Anecdotal evidence suggests that contract documentation quality is a major concern for those who rely upon information contained within such documentation (Syam, 1995).

According to DeFraites (1989), project quality is inextricably linked to the overall level of professional services provided. In addition, the process by which services are selected and fees negotiated may also determine service quality. Abolnour (1994) found a negative correlation relationship between the actual fee charged and documentation quality, that is, project costs increase when design fees are reduced. Conversely, Cravens *et al* (1985), Nelson and Nelson (1995) and Hoxley (2000) acknowledged the importance of fees, but did not consider them to be a significant factor that influences service and documentation quality.

All organizations involved in construction procurement, especially those providing professional consultancy services, should recognize that improvements to service quality can be achieved only when a suitable quality culture is embedded within the organization (Stasiowski and Burstein, 1994; Rounce, 1998; Bubshait *et al*, 1999). Yet, the apparent dearth of quality focus in many design organizations has meant that the concept of service quality has not been given adequate recognition (Stasiowski and Burstein,

1994; Richardson, 1996; Tilley and McFallen, 2000a). Consequently, contractors and subcontractors invariably act as 'quality buffers' and therefore identify, and reduce the impact of, quality deviations in contract documentation.

Burroughs (1993) reported that a major project undertaken by a prominent Australian contractor had incurred rework costs of 5% of the contract value (on average); these aforementioned costs were attributable to poor documentation produced by design consultants. More worryingly, subcontractors working on this project reported extreme perturbations in the rework cost trend. For example, it was found that the concreting subcontract experienced a cost increase of 31% due to rework. These variations apart, Gardiner (1994) estimates that design-related rework could be as high as 20% of the fee for a given project. Documentation quality may suffer when a firm submits a low design fee for a project, especially when design tasks are subjected to 'time boxing', which is when a fixed time period may be allocated to complete each task, irrespective of whether the documentation or each individual task is complete or not.

Poor workload planning within design organizations can also contribute to 'time boxing' and lead to inadequate time being allocated to prepare complete design documents (Coles, 1990; Stasiowski and Burstein, 1994; Rounce, 1998; Love *et al*, 2000). Moreover, Coles (1990) noted that the use of technically inexperienced and/or unqualified 'assistant' staff leads to errors and omissions in contract documentation being made if such employees are not adequately supervised. Svelinger (1996) found the most frequent causes of severe deviations, during the technical design of buildings, were attributable to deficient planning and/or resource allocation, deficient or missing input and changes. Rounce (1998) suggests a number of poor design management practices contribute to rework and waste in architectural firms. These include:

- jobs not having projected drawing lists to quantify the design workload
- jobs not having design programmes based on project drawing lists and, therefore, specific design deliverables are unable to be identified
- difficulty in estimating the physical progress of design
- uncertainty in advising other designers/quantity surveyors (QSs)/clients/contractors when information is likely to be available
- difficulty in justifying resources required to in-house managers based on actual workload; and
- lack of specific procedures (non-administrative) generally to control the design process in programme terms.

Tilley and McFallen (2000a) examined the rework conundrum from a client 'design-demand' angle and concluded that the greater the demand imposed by clients for earlier completion of projects, then the greater the likelihood that designers would produce incomplete and/or erroneous contract documentation. To eradicate this problem, they (*ibid*) suggest that projects should be procured using traditional means as these are far less susceptible to documentation errors in comparison with those procured using non-traditional means.

Mismanagement and poor quality service provided by design consultants has resulted in rework becoming an accepted norm and profits being eroded within architectural firms (Gardiner, 1994). Specific rework activities that contribute to reducing profit levels in architectural firms include (Rounce, 1998):

- redesign due to an inadequate brief
- changes arising from unchecked drawing issue
- redesign due to inappropriate drawing scale; and
- attending to design changes requested by the client.

Cooper (1993), for example, reported that the design of large construction projects may require up to two-and-a-half cycles of rework to 'get it right'. This finding provides demonstrable evidence that undertaking rework creates additional time, workload and cost for design consultants (and other parties involved during and after the construction phase).

CONTRACT DOCUMENTATION AND THE REWORK CYCLE

Undoubtedly, the production of poor contract documentation represents a major factor contributing

to construction project rework (Dalty and Crawshaw, 1973; Crawshaw, 1976; Gardiner, 1994; Oakland and Aldridge, 1995; Rounce, 1998; Yogeswaran, 1998; Tilley and McFallen, 2000a). Figure 1 provides an illustrative example of the rework cycle for the production of contract documentation. The boxes in Figure 1 represent activities that are undertaken during the contract documentation process.

At the start of the documentation phase, all activities are captured in a pool of work to be undertaken. As designers commence the documentation production process, changing levels of staff (people) working at varying productivity (output) levels may determine the progress of the work being undertaken (Bashir and Thomson, 2001). Poor rates of progress occur mainly when staff involved in the documentation process either leave the design organization (staff turnover) or become unavailable (due to illness or recreational leave) and replacement staff are needed to complete the documentation process. Discontinuity of design staff can have a significant impact on design process performance (Chapman, 1999). This is because all project knowledge and information accrued by each staff member cannot be readily passed directly from one individual to the next, even if a hand-over 'transient' period (and/or de-briefing) occurs (Chapman, 1999). Even staff recruited from the same office cannot acquire sufficiently detailed project knowledge immediately after they commence work on the project.

In practice, documentation activities are executed at varying levels (depending on the skill and experience of the individual designer) and, as a result, this is also likely to impact on documentation quality. However, it is noteworthy that the completeness and level of documentation quality achieved depends on many factors and conditions within the organization and the project environment (Busby, 2001). For example, these may include the design firm's workload, the design fee, time allowed for the design process, staffing levels, the amount of time allocated to prepare documentation and the procurement method.

Documentation that is considered to be of adequate quality will enter the pool of documentation that is completed, which may not need redoing unless the client or contractor finds errors and requests design changes. Design changes may cause additional schedule pressures and place designers under considerable stress; this may have the knock-on effect of reducing morale and creating unnecessary conflict and fatigue due to overtime. The remaining completed documentation will probably need some rework, but for a period of time the documentation remains in the sub-pool known as 'undiscovered rework'. This sub-pool contains

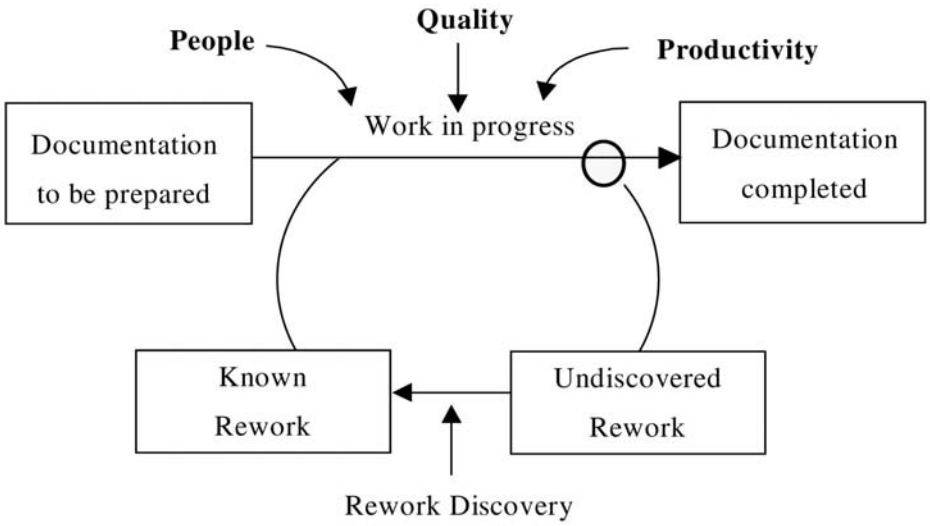

FIGURE 1 The structure of the rework cycle (adapted from Cooper [1993: 17])

undetected errors and is therefore perceived to be error-free. However, errors and omissions may be discovered in several ways e.g. through design checks and reviews, during the preparation of Bills of Quantities (BoQs) by the QS, in materials ordering or on-site by the contractor/subcontractor. The rework discovery period may occur over weeks, months or even years later (depending on project size and complexity) during which time dependent work may have already incorporated these errors. Once discovered, the known rework will have to be addressed, which may require additional resources or overtime or both to be undertaken. Busby (2001) notes that the detection of design errors in construction projects is a problematic task because of the inconsistencies that typically exist between design interfaces, which can hinder the early detection of errors.

In addressing the identified rework, work to be undertaken will enter the flow of work in progress and will be subject to similar productivity and quality variations. In addition, reworked items may flow through the same cycle. Indeed, poor quality contract documentation may cause more cycles of rework and require additional resources to rectify.

Design organizations that are not able to produce good quality documentation will not be able to maximize the return from fees. The rework cycle can also be applied to activities being undertaken on-site. Errors and omissions can affect both contractors and their subcontractors in the same way in which they affect design organizations, especially if preliminary items such as supervision, scaffolding and cranage are required for extended periods.

Wilson *et al* (1993) and Dale (1999) suggest that finding and solving a problem after a non-conformance has been identified is not an effective route towards eliminating its root cause. A lasting and continuous improvement in quality can be achieved only by directing organizational efforts toward planning and preventing problems occurring at source. Consequently, prevention, which is an inherent characteristic of quality assurance (QA), becomes an innate process for improving product and service quality and increases productivity by placing emphasis on product, service and process design.

Clearly, reductions in rework require design firms to re-examine the way they conduct their business and become prevention focused. In doing so, they should strive for better design management to:

- eliminate the need for unnecessary drawing revisions
- work to a structured programme that identifies specific design deliverables
- minimize management problems in the control of the design process that contribute resource wastage; and
- minimize variables that contribute to poor performance (Rounce, 1998).

Rounce (1998) recommends that to improve profitability, architectural firms, in particular, should ameliorate their internal management practices through quality management, particularly QA. When QA is effectively implemented, architectural firms would see non-conformance costs, as a percentage of their project fees, reduced by as much as 45% (Rounce, 1998).

QUESTIONNAIRE SURVEY

A questionnaire was developed as the main data capture mechanism and contained 116 measurement scales that examined three core influences on rework costs in projects, namely:

- project characteristics (project size, project type, facility type, contract value, project duration, procurement method, the tender type, gross floor area and number of floors [i.e. project height])
- organizational management practices (learning and quality management practices)
- project management practices (client/design team/contractor/subcontractor related causes, project scope, communication, contract documentation, design management and procurement strategies).

The research presented in this paper examines the production of contract documentation and its influence on rework observed during projects completed in Australia. Using a 5-point Likert scale, respondents were asked to respond to a series of statements regarding the production of contract documentation. At the end of the questionnaire, respondents were also

given an opportunity to suggest supplementary information about *why* rework occurred in the project that they had recently completed.

Stratified random sampling was used to select the study sample from the *Yellow Pages* telephone directory. This sampling technique ensured that duplication of selected projects was minimized by the geographical dispersion of the questionnaires throughout different states in Australia. Prior to determining the main study's sample size, a pilot survey was undertaken with 30 randomly selected firms, which included architects, project managers and contractors from the Geelong and Melbourne region, in the State of Victoria. The objective of the pilot was to test the potential response rate and the suitability and comprehensibility of the questionnaire. Each firm was contacted by telephone and informed of the research aim and objectives. On obtaining a firm commitment from respondents to collaborate with the work, the pilot questionnaire was mailed to them, with a stamped addressed return envelope enclosed. Respondents were also asked to critically review the survey's design and structure. A total of 25 responses were received (representing an 83% response rate) and all were positive and confirmed that the questionnaire should remain unaltered for the main survey. The composition of respondents who returned the questionnaire was as follows: architects (30%), contractors (50%) and project managers (20%).

In the main survey, 420 questionnaires were distributed to practitioners (architects, contractors, electrical engineers, mechanical engineers, project managers, QSs and structural engineers) throughout Australia. 136 valid responses were received from the main survey representing a much lower response rate than that recorded for the pilot study and thus reinforcing the inherent value of preliminary telephone calls. Pilot questionnaires were added to the sample as no changes were made to it thereby giving a total of 161 valid responses (or 38% response rate). This response rate is considered within the range of acceptability for a survey focusing on gaining responses from industry practitioners (Alreck and Settle, 1985).

Figure 2 provides a breakdown of the valid responses by respondent type and reveals that contractors, architects and consultant project managers accounted for approximately 81% of the respondents. While superficially it would appear that QSs, structural, mechanical and electrical engineers are

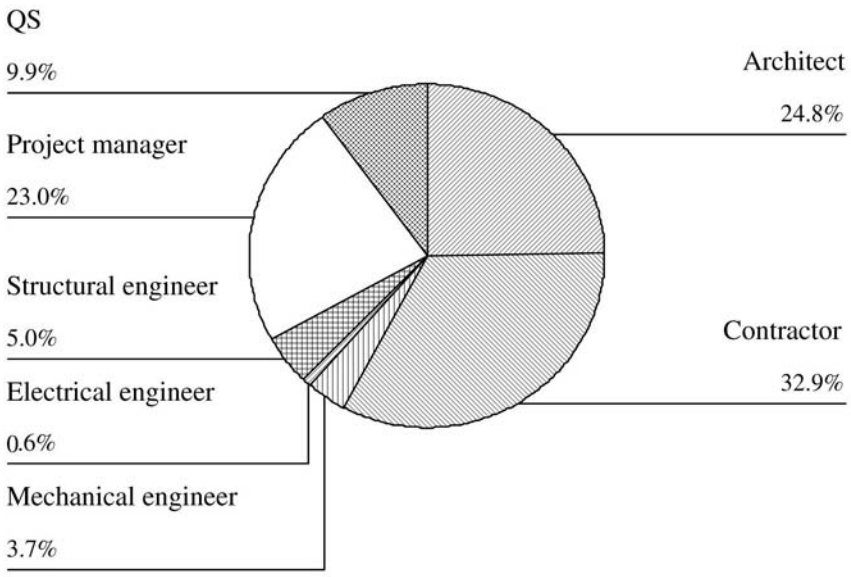

FIGURE 2 Respondents by profession

under-represented, it should be noted that many consultancy firms offer project management services and, as a result, may have undertaken a role of project manager for a project that they selected.

DATA RELIABILITY

Data reliability is related to data source and is therefore inextricably linked to the position held by the person who completed the questionnaire (Oppenheim, 1992). Thus, it was imperative that respondents had detailed knowledge about the procurement processes associated with a project. With this prerequisite in mind, the questionnaire was mailed to senior personnel within the organizations identified. From the 161 completed questionnaires, most respondents held senior positions within their organizations. It was therefore confirmed that the direct mailing to individuals in organizations seemed to have achieved its primary objective of reaching those who were closely involved with delivering construction projects. Figure 3 provides a breakdown of the respondents who answered the questionnaire by state.

As there were low response rates from the QSs and the engineering profession, the respondents were recategorized under the following headings for analysis purposes:

- design consultants, comprising architects, QSs, structural, mechanical and electrical engineers (44%)
- contractors (33%); and
- consultant project managers (23%).

ANALYSIS

Information obtained from respondents was used to develop a contract documentation work practice index (CD_{wi}). In calculating the CD_{wi} the mean and standard deviation of each individual variable were considered not to be appropriate statistics to evaluate the overall rankings, as they do not reflect any relationship between them (Holt, 1997). Thus, all the numerical scores for each identified rework cause were transformed to indices to assess the relative rankings of the variables (Holt, 1997). The CD_{wi} was calculated using the following formula:

$$\frac{\sum w}{AN}, \quad (0 \le CD_{wi} \le 1)$$

where,

w = weighting given to each factor by the respondent, which in this case ranged from 1 to 5, where 1 is not important and 5 is extremely important

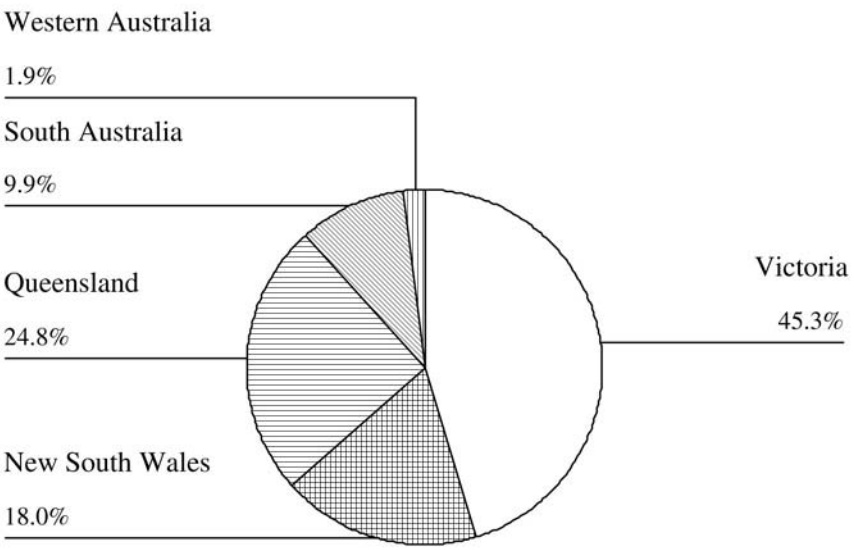

FIGURE 3 Respondents by state

A = the highest weighting (i.e. 5 in this case); and
N = the total number of respondents

Bi-variate correlation analysis was used to examine the relationship between selected variables and rework costs. The Kruskal-Wallis test was undertaken to test whether there were differences between respondents' rankings of the independent variables. This test was undertaken because variables had a continuous distribution and was measured using an ordinal scale of measurement.

FINDINGS AND DISCUSSION

DESIGN TEAM INFLUENCES

The first five variables that were identified as the main factors that contributed to rework for the design team (Table 1) were:

- ineffective use of information technology (IT) ($CD_{wi} = 0.652$)
- staff turnover/allocation to other projects ($CD_{wi} = 0.643$)
- incomplete design at the time of tender ($CD_{wi} = 0.614$)
- insufficient time to prepare contract documentation ($CD_{wi} = 0.611$)
- poor coordination between design team members ($CD_{wi} = 0.583$).

Overall, the 'ineffective use of IT' was ranked as being a primary cause, albeit respondent rankings within professions differed. For example, both designers and contractors ranked 'poor coordination of design team members' first, whereas project managers ranked it fourth. To determine whether significant differences in the rankings of respondents existed, a Kruskal-Wallis test was undertaken. Results reveal no significant differences between respondents with respect to the 'ineffective use of quality management practices', 'time boxing' and 'insufficient time to complete contract documentation' ($p < 0.05$). The 'ineffective use of quality management practices' was ranked lower than the aforementioned variables and thus was not considered to be a cause of rework. It would appear that the design causes of rework in projects are exogenous to design consultants. Consequently, their quality procedures and systems are unable to control these variables. Despite the changes imposed on a firm, they do have control over the quality management systems and the management practices used to produce contract documentation.

A Kruskal-Wallis test was also undertaken to identify any significant differences between design team practices of rework for different procurement methods and project types. Results reveal no significant differences between procurement methods and design team causes of rework ($p < 0.05$). Thus, the design processes associated with the procurement of projects

TABLE 1 Design team influences index and rank

	MEAN		CONTRACTOR		PROJECT MANAGER		DESIGN CONSULTANTS	
DESIGN TEAM	CD_{wi}	RANK	CD_{wi}	RANK	RANK	CD_{wi}	CD_{wi}	INDEX
Ineffective use of quality management practices	0.552	7	0.585	6	0.568	6	0.518	8
Inadequate client brief to prepare detailed contract documentation	0.467	10	0.589	5	0.616	3	0.569	5
Ineffective use of information technologies	0.652	1	0.491	10	0.443	10	0.479	10
Poor coordination between design team members	0.583	5	0.732	1	0.605	4	0.620	1
Time boxing	0.543	8	0.604	4	0.508	7	0.606	2
Poor planning of workload	0.571	6	0.577	7	0.503	8	0.538	7
Lack of manpower to complete required tasks	0.512	9	0.574	8	0.589	5	0.561	6
Staff turnover/allocation to other projects	0.643	2	0.528	9	0.497	9	0.513	9
Incomplete design at the time of tender	0.614	3	0.709	2	0.638	1	0.603	4
Insufficient time to prepare contract documentation	0.591	4	0.611	3	0.622	2	0.603	3

(whether they are sequential or overlapped through fast tracking) are not responsible for causing rework, but rather the ability of design consultants to adapt effectively to their external environment. Essentially, effective client management is the key to reducing change. A project manager stated that in order to reduce rework:

> *Good project management of the design team and the contractors [is] essential. Contract terms and conditions can minimize the effect of rework by placing the responsibility on the contractor, but it is the client-instigated change that is the most disruptive.*

Arguably, good project management is fundamental, but the problem here is defining what good project management means in this context. However, placing all the risk and responsibility onto the contractor for rework will not eliminate the problem at hand, as most rework originates from the design phase of projects.

'Incomplete design at the tender stage' was identified as being a prominent cause by contractors and project managers, but not by design consultants. This would, however, appear to be prevalent in most projects, as increasing pressure is exerted on firms to maximize their fee and thus, revert to 'time boxing'. This practice places enormous stress on staff, particularly if project workload is ill-planned and staff turnover is high.

All design team practices were significantly correlated with one another ($p < 0.01$). The 'ineffective use of quality management practices' was found to be significantly correlated with 'errors in contract documentation', $r_s = +0.27$, $n = 161$, $p < 0.01$, two tails, and 'omissions of items from contract documentation', $r_s = +0.24$, $n = 161$, $p < 0.01$, two tails. This implies that firms are not using their quality systems in an effective manner to limit contract documentation errors and omissions.

No significant correlations were identified between design team practices and rework. However, it was also revealed that there was a significant correlation between schedule growth and 'lack of manpower to complete required tasks', $r_s = +0.18$, $n = 161$, $p < 0.05$, two tails. This is an unexpected finding considering that previous case study research suggests that the identified practices contribute to rework (Love *et al*, 1999). Clearly, no single variable influences rework and it is suggested that a number interact together to contribute to its occurrence in projects. Simply trying to isolate variables and address each accordingly will not lead to a reduction in rework *per se* but this is something that researchers have been trying to do. A panacea to rework problems can be found once an organization critically examines its work practices holistically to determine areas that will improve internal operations and project interface. Having reconciled internal problems and identified ways of improving work practices, organizations may then be more able to embrace innovative practices for managing projects.

CONTRACT DOCUMENTATION

Table 2 identifies the ranks and respective index weighting for contract documentation. The mean

TABLE 2 Contract documentation index and rank

	MEAN		CONTRACTOR		PROJECT MANAGER		DESIGN CONSULTANTS	
CONTRACT DOCUMENTATION	CD_{WI}	RANK	CD_{WI}	RANK	CD_{WI}	INDEX	CD_{WI}	INDEX
Contract documentation was of a high standard compared with other projects (CD-1)	0.549	3	0.442	6	0.584	3	0.611	3
Contract documentation was cross-checked to ensure changes, if any, had been coordinated (CD-2)	0.554	2	0.442	5	0.568	4	0.631	2
Contract documentation was prepared by inexperienced personnel (CD-3)	0.504	5	0.577	1	0.449	5	0.479	5
Design reviews and verifications were undertaken (CD-4)	0.622	1	0.574	2	0.622	1	0.659	1
An assessment of the status of the architect's/engineer's design and potential for change was provided to the contractor (CD-5)	0.516	4	0.506	3	0.589	2	0.485	4

TABLE 3 Correlation matrix for contract documentation

VARIABLE	CD-1	CD-2	CD-3	CD-4	CD-5	COST GROWTH	SCHEDULE GROWTH	REWORK
CD-1	1.00							
CD-2	0.71*	1.00						
CD-3	–0.32*	–0.39*	1.00					
CD-4	0.41*	0.48*	–0.35*	1.00				
CD-5	0.29*	0.34*	–0.25*	0.43*	1.00			
Cost growth	–0.23*	–0.17**	0.19**	–0.16**	–0.24*	1.00		
Schedule growth	–0.10	–0.16**	0.10	–0.11	–0.24*	0.32*	1.00	
Rework	–0.13	–0.07**	0.07	–0.07	–0.21*	0.60*	0.44*	1.00

**Correlation is significant at the 0.01 level (two-tailed) * Correlation is significant at the 0.05 level (two-tailed)

rankings reveal that 'design verifications and reviews' was ranked first as the most common practice implemented (CD_{wi} = 0.622). Similarly, 'contract documentation was cross-checked to ensure changes, if any, had been coordinated' was ranked the second most common practice implemented (CD_{wi} = 0.554). 'Contract documentation was of a high standard compared with other projects' was ranked third (CD_{wi} = 0.549), 'an assessment of the status of the architect's/engineer's design and the potential for change was provided to the contractor' was ranked fourth (CD_{wi} = 0.516) and 'contract documentation was prepared by inexperienced personnel' was ranked fifth (CD_{wi} = 0.504).

To determine if there were any significant differences between the mean ranks of respondents for contract documentation, a Kruskal-Wallis test was conducted. A number of differences were identified for the following variables ($p < 0.05$):

- 'contract documentation was of a high standard compared with other projects'
- 'contract documentation was cross-checked to ensure changes, if any, had been coordinated'; and
- 'contract documentation was prepared by inexperienced personnel'.

It would appear that inexperienced personnel are perceived to have produced contract documentation, which would explain why errors and omissions were prevalent in the projects sampled. The use of inexperienced personnel, such as recent graduates, to prepare contract documentation appears to be standard practice in Australia (Tilley and McFallen, 2000a). The perceived payment of low fees by clients curtails the time that more experienced (and technically competent) members of a design firm can spend on the project. So in order to maximize short-term fee income, less experienced staff (usually recent graduates or perhaps even undergraduates) prepare the contract documentation. Ultimately, errors and omissions in contract documentation ensue and are often identified by the contractor and/or the subcontractors late in the construction phase.

Good quality contract documentation will invariably identify the design *raison d'être* in a coherent manner, which a contractor and subcontractors can understand and, thus, price and construct accordingly. Tilley and McFallen (2000b) have implied that poor quality documentation often leads to misunderstandings and requests for further information (RFIs) and, as a result, stimulates the contractor into seeking construction method changes that will improve the project's constructability. Furthermore, the undertaking of design reviews and verifications may well act as a prevention mechanism for reducing errors due to inappropriate construction methods, especially if the contractor is involved. This would, however, tend to occur in projects where the contractor has direct control over the design and documentation process, for example, projects that are delivered using a design and construct procurement method.

Surprisingly, only one contract documentation variable was revealed to be significantly correlated with rework costs, namely 'an assessment of the status of the architect's/engineer's design and the potential for change was provided to the contractor', $r_s = -0.21$, $n = 161$, $p < 0.01$, two tails. Explicitly, informing the

contractor about a potential for change, error or omission from the design and contract documentation may reduce rework, although such a practice may not limit those changes that are idiosyncratically requested by clients. 'Contract documentation was of a high standard' and 'an assessment of the status of the design and the potential for change was provided to the contractor' (CD-5) were significantly negatively correlated with cost growth ($p < 0.01$). Moreover, variables 'contract documentation was cross-checked to ensure changes were coordinated' (CD-2) and 'design verifications and reviews' were also significantly negatively correlated, although at a lower significance level ($p < 0.05$). Two contract documentation variables were found to be significantly correlated with schedule growth, namely, CD-2, $r_s = -0.16$, $n = 161$, $p < 0.05$ and CD-5, $r_s = -0.24$, $n = 161$, $p < 0.01$.

REDUCING REWORK FROM CONTRACT DOCUMENTATION

AUDITING CONTRACT DOCUMENTATION

In reducing rework in projects, organizations must ultimately assume responsibility for their actions. As organizations learn and understand the total cost of rework, they are likely to take positive action to prevent its future occurrence. The effect, however, of poor service quality is not always visible. In construction, particularly with respect to design consultants, rework may not transpose as an 'obvious' physical waste, but rather as 'hidden' additional management time and labour man-hours.

Design-related rework is the most costly to rectify (Love, 2001). Yet design consultants generally do not pay for the errors and omissions that result from production of documentation. In the event of determining design liability, however, an enormous amount of auditing is required to apportion blame (Uff, 1991). Gaafar and Perry (1999) suggest that the extent of liability is not necessarily dependent upon who does what, but rather who accepts liability? In other words, the type of contract used for appointing design consultants, contractors or specialist subcontractors is important in identifying who is fundamentally responsible for the rework. Design consultants should take reasonable care to ensure that the information approved for construction is correct. Furthermore, documents should be regularly checked and cross-referenced with other design consultants who are involved with the project. Love *et al* (2003), however, found that these practices are not regularly undertaken in Australian projects, as the fees of design consultants are considered to be so low that only a minimal service can be provided.

MANAGING DESIGN AND DOCUMENTATION RISK

When there is insufficient time to complete contract documentation, the design team should provide the contractor with an assessment of design status and the potential for change. This information would enable the contractor to provide a realistic tender price and project programme as well as establish the mechanisms and procedures for administrating changes.

Systematic and formalized meetings that aim to utilize the knowledge, judgement and experience of project teams should be undertaken to classify and identify any potential risks so that strategies and actions for their minimization can be implemented. In essence, effective risk management requires the project team to shift their emphasis from expecting project success to seriously considering its possible failure (Conroy and Soltan, 1998). According to Mak *et al* (1998), however, there is a lack of appreciation toward a systematic approach to identifying and quantifying any risks that may be contained within contract documentation. This is because contract documentation is supposed to have been prepared in a diligent and professional manner and, thus, assumed to be error-free.

In reality, this is not the case, as design consultants are reluctant to expose themselves to any potential liability. Because uncertainty requires a contingency, it is important to quantify the contingency levels necessary to cover any real construction project risks that exist (Mak and Picken, 2000). A common practice is to use hidden contingencies in project estimates to cover for any cost overruns. However, excessive project budgets can permit the inefficient and ineffective use of resources.

Conducting a risk audit of contract documentation prior to its release to the contractor would ensure that changes, errors and omission are kept to a minimum. As part of the auditing process, clients should sign-off work as the design progresses and they should be

aware of the consequences associated with initiating a change. Essential changes should be reviewed and authorized through a systematic and structured scope and change control programme that has been developed by the client's representative in conjunction with the project team.

CONCLUSION

No significant relationship between contract documentation and rework could be established from the findings presented. However, significant differences were found between the professions as to the variables that were deemed to contribute to rework. This indicates that an intricately 'complex' interwoven array of variables contribute to rework. To simply isolate one variable, such as fees, and state that their increase will improve the quality of contract documentation produced by consultants would be rather naïve, considering the complexity associated with the management of the design process. In fact, it was impossible to identify a specific cause and effect relationship because of the interdependency of work arrangements, dynamic social interactions between project participants, and the socio-economic and political structure that exists in projects. The recommendations that have been identified as having an immediate impact on reducing the incidence of rework are relatively simple to implement in practice but, sadly, most have generally been ignored by many practitioners.

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REFERENCES

Abolnour, M.M., 1994, *The Relationship of Fee Structure in Engineering Offices and Design Deficiency*, unpublished MSc dissertation, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Alreck, P.L. and Settle, R.B., 1985, *The Survey Research Handbook*, Homewood, IL, Richard D. Irwin Inc.

Barrett, P., 1993, *Profitable Practice Management for the Construction Professional*, London, E&F Spon.

Bashir, H.A. and Thomson, V., 2001, 'Models for estimating design effort and time', in *Design Studies*, 22(2), 141–155.

Bubshait, A.A., Farooq, G., Jannadi, M.O. and Assaf, S.A., 1999, 'Quality practices in design firms', in *Construction Management and Economics*, 17, 799–809.

Burroughs, G., 1993, 'Concrete quality assurance: the contractor's role', in *Proceedings of Quality Assurance in the Construction Industry, Concrete Institute of Australia, September, Melbourne*.

Busby, J.S., 2001, 'Error and distributed cognition in design', in *Design Studies*, 22(3), 223–254.

Chapman, R.J., 1999, 'The likelihood and impact of changes of key project personnel on the design process', *Construction Management and Economics*, 17(1), 99–106.

Coles, E.J., 1990, *Design Management: A Study of Practice in the Building Industry*, Occasional Paper No 42, Ascot, The Chartered Institute of Building, 32.

Cooper, K.G., 1993, 'The rework cycle: benchmarking for the project manager', in *Project Management Journal*, 24(1), 17–22.

Cravens, D.W., Dielman, T.E. and Kent, C., 1985, 'Using buyers' perceptions of service quality to guide strategy development', in R.F. Lusch *et al* (eds), *American Marketing Association Educators' Proceedings*, *Chicago*, Chicago, AMA Educators, 297–301.

Crawshaw, D.T., 1976, *Co–ordinating Working Drawings*, Current Paper CP 60/76, Watford, UK, Building Research Establishment.

Conroy, G. and Soltan, H., 1998, 'ConSERV, a project specific risk management concept', in *International Journal of Project Management*, 16(6), 353–366.

Culp, G., 1993, 'Implementation of TQM in a consulting engineering firm', in *ASCE Journal of Management in Engineering*, 9(4), 340–366.

Dale, B., 1999, *Managing Quality*, 3rd edn, Oxford, UK, Blackwell Business.

Dalty, C.D. and Crawshaw, D.T., 1973, *Working Drawings in Use*, Current Paper CP 18/73, Watford, UK, Building Research Establishment.

DeFraites, A.A. Jnr., 1989, 'Fee versus quality', in *ASCE Journal of Professional Issues in Engineering*, 115(2), 125–128.

Gaafar, H.K. and Perry, J.G., 1999, 'Limitation of design liability for contractors', in *International Journal of Project Management*, 17(5), 301–308.

Gardiner, J., 1994, 'Management of design documentation, where do we go from here?' in R.R. Wakefield and D.G. Carmichael (eds), *Construction and Management, Recent Advances*, Rotterdam, Balkema, 113–118.

Gibson, P.R., 1997, 'Strategic reengineering of the construction industry organization', in *International Conference on Construction Process Re-engineering, Gold Coast, Australia*, *July 1997*, Gold Coast, Griffin University, 367–374.

Holt, G.D., 1997, 'Construction research questionnaires and attitude measurement: relative index or mean', in *Journal of Construction Procurement*, 3(2), 88–96.

Hoxley, M., 2000, 'Are competitive fee tendering and construction professional service quality mutually exclusive?', in *Construction Management and Economics*, 18(5), 599–605.

Love, P.E.D., Li, H. and Mandal, P., 1999, 'Rework: a symptom of a dysfunctional supply–chain', in *European Journal of Purchasing and Supply Management*, 5(1), 1–11.

Love, P.E.D., Smith, J., Treloar, G. and Li, H., 2000, 'Some empirical observations of service quality in construction', in *Engineering Construction and Architectural Management*, 7(2), 191–201.

Love, P.E.D., 2001, *Determinants of Rework in Australian Construction Projects*, unpublished PhD Thesis, Department of Management, Faculty of Business and Economics, Monash University, Melbourne, Australia.

Love, P.E.D., 2002a, 'Influence of project type and procurement method on rework costs in building construction projects', in *ASCE Journal of Construction Engineering and Management*, 128(1), 18–29.

Love, P.E.D., 2002b, 'Auditing the indirect consequences of rework in construction: a case based approach', in *Managerial Auditing Journal*, 17(3), 138–46.

Love, P.E.D. and Josephson, P-E., 2004, 'The role of the error-recovery process in projects', in *ASCE Journal of Management in Engineering*, 20(2), 70–79.

Love, P.E.D., Irani, Z. and Edwards, D., 2004, 'A rework reduction model for construction projects', *IEEE Transactions on Engineering Management*, 51(4), 426–440.

Mak, S., Wong, J. and Picken, D., 1998, 'The effect on contingency allowances of using risk analysis in capital cost estimating. A Hong Kong case study', in *Construction Management and Economics*, 16(6), 615–619.

Mak, S. and Picken, D., 2000, 'Using risk analysis to determine construction project cost contingencies', in *ASCE Journal of Construction Engineering and Management*, 126(2), 130–136.

Nelson, S.L. and Nelson, T.R., 1995, 'RESERV: An instrument for measuring real estate brokerage quality', in *The Journal of Real Estate Research,* 10(1), 99–114.

Oakland, J.S. and Aldridge, A.J., 1995, 'Quality management in civil and structural engineering consulting', in *International Journal of Quality and Reliability Management*, 12(3), 32–48.

Oppenheim, A.N., 1992, *Questionnaire Design, Interviewing, and Attitude Measurement*, London, Pinter Publishers.

Powell, C., 1997, 'Responding to marginalization', in *Architectural Research Quarterly*, 2, 84–89.

Richardson, B., 1996, *Marketing for Architects and Engineers: A New Approach*, London, E&F Spon.

Rounce, G., 1998, 'Quality, waste, and cost consideration in architectural building design management', in *International Journal of Project Management*, 16(2), 123–127.

Stasiowski, F.A. and Burstein, D., 1994, *Total Quality Management for the Design Firm*, New York, Wiley.

Svelinger, P.-O., 1996, *Organisatorisk samordning vid projektering* (Organizational Coordination in the Design Phase), Report 44, Göteborg, Sweden, Institution för byggnadsekonomi och byggnadsoganisation, Chalmers techiska högskola.

Syam, A., 1995, 'Editorial', *Journal of the Australian Institute of Steel Construction*, 29(1), 1.

Symes, M., Eley, J. and Seidal, A.D., 1995, *Architects and Their Practices: A Changing Profession*, London, Butterworths.

Tilley, P. A. and McFallen, S. L., 2000a, *Design and Documentation Quality Survey Designers' Perspectives,* BCE DOC 00/113, Melbourne, Australia, CSIRO – Building, Construction and Engineering.

Tilley, P. A. and McFallen, S. L., 2000b, *Design and Documentation Quality Survey Contractors' Perspectives,* BCE DOC 00/114, Melbourne, Australia, CSIRO – Building, Construction and Engineering.

Tilley, P. A. and McFallen, S. L., 2000c, *Design and Documentation Quality Survey Comparison of Designers' and Contractors' Perspectives, BCE DOC 00/115,* Melbourne, Australia, CSIRO – Building, Construction and Engineering.

Uff, J., 1991, 'The ICE conditions of contract. 6th Edition: new thoughts of old issues', in *The International Construction Law Review*, 8(2), Lloyds of London Press Ltd.

Wilson, P.F., Dell, L.D. and Anderson, G.F., 1993, *Root Cause Analysis: A Tool for Total Quality Management*, Milwaukee, Wisconsin, ASQC Quality Press.

Yogeswaran, K., 1998, *Sources, Causes, and Minimization of Contractual Claims in Civil Engineering Projects in Hong Kong*, unpublished PhD Thesis, Department of Civil Engineering, The University of Hong Kong.