FORENSIC PROJECT MANAGEMENT: THE UNDERLYING CAUSES OF REWORK IN CONSTRUCTION PROJECTS

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Construction professionals recognize that rework is a significant factor contributing to poor project performance, yet little is known about its antecedents and consequently it remains an innate problem. Because factors that contribute to its occurrence are not fully understood, the derivation of appropriate strategies for its reduction is problematic. Therefore, a comprehensive appreciation of the mechanisms that cause rework will enable project performance improvements to be made. Two longitudinal case studies were undertaken to determine the antecedents of rework. Based on the findings presented, strategies for reducing the incidence of rework are identified and discussed. This paper contributes to study of quality in construction by identifying the underlying factors that influence rework in projects.

Keywords: Australia; Contract documentation; Design firms; Quality; Rework

INTRODUCTION

Rework is defined as ‘the unnecessary effort of re-doing a process or activity that was incorrectly implemented at the first time’. Within the construction industry, rework has been identified as a significant factor that contributes to cost increases and schedule delays on projects (Love, 2002a). Previous research has generally focused on quantifying rework costs and identifying ‘apparent’ rather than ‘root’ causes (e.g. Burati et al., 1992; Willis and Willis, 1996; Josephson and Hammarlund, 1999; Josephson et al., 2002).

Little is known about the antecedents of rework in construction projects. Consequently, potential improvements in project performance are curtailed. According to the Australian Procurement and Construction Committee, various industry development initiatives have focused on addressing the symptoms rather than the causes of poor project performance (APCC, 1997). The implementation of emergent management fads (e.g. such partnering and supply chain management) in the hope of eliminating problems deeply rooted in the psyche of construction practice will, not by default, lead to the improvements sought (Love et al., 2002). These problems must be understood in a holistic manner and to that...
end it is therefore necessary to examine what actually happens in construction (Koskela, 2000).

By gaining an understanding of the problematic mechanisms causing rework, advancement toward its reduction can be made. In this paper, the antecedents of rework events that occurred in two construction projects are examined. Based on the findings presented, strategies for reducing the incidence of rework are identified and discussed.

REWORK IN CONSTRUCTION

There have only been a limited number of studies that have sought to determine rework costs in construction projects. For example, Table I provides estimates of rework costs that have been reported in the construction and the engineering management literature. A prominent feature of the data is the disparities among rework cost estimates. These variations derive as a result of differences in definitions, in particular scope, data collection methods used, and whether rework is calculated as a proportion of project or contract value (Tab. I). For example, Hammarlund and Josephson (1991) found defects to be 6% of production cost, whereas Burati et al. (1992) report quality deviations to be 12.4% of project value. Defects also arise during a building’s maintenance period and can range from 3% to 5% of the contract’s value (STATT, 1989).

While the calculation of rework can be arduous and time-consuming task, there is as imperative need for rework definition and measurement before an accurate assessment of direct costs can be made. Barber et al. (2000) found that when indirect costs are considered, the total cost of rework can be as high as 23% of contract value. Love (2002b) found that indirect rework costs could have a multiplier effect of up to five times the actual (direct) cost of rectification. Design-related changes, errors, and omissions in contract documentation have contributed significantly to rework (Love et al., 1999a; Love and Li, 2000). In particular, client design changes are frequent, and generate costly ripple effects that create delay and disruption throughout the project supply chain (Ibbs and Allen, 1995). Specifically, projects appear to progress smoothly until nearing completion, when errors made earlier are discovered, necessitating costly rework (Cooper, 1993; Eden et al., 2000). Such rework transpires as overtime, additional hiring of resources (including labour and plant), schedule slippage, and reductions in project scope or quality (Li et al., 2000). The adverse consequences of these difficulties include reduced profit, loss of market share and reputation, increased turnover of management and workforce, lower productivity, higher costs, and, all too frequently, costly litigation between participants over responsibility for overruns and delays (Ackermann et al., 1997; Eden et al., 2000).

Management in the Design Firm

Gardiner (1994) and Powell (1997) have suggested that the insularity and averion of architectural organizations to ‘management’ has resulted in poor service quality and their marginalization within the industry. Powell (1997, p. 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, p. 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’. Likewise, engineering design consultants have been confronted by a similar dilemma (Tilley and McFallen, 2000).
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<tr>
<th>Author</th>
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<th>Descriptor</th>
<th>Costs</th>
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<tbody>
<tr>
<td>Cusack (1992)</td>
<td>Australia</td>
<td>Rework</td>
<td>10%*</td>
<td>Identified errors in design documentation to be the primary cause of rework</td>
</tr>
<tr>
<td>Burroughs (1993)</td>
<td>Australia</td>
<td>Rework</td>
<td>5%*</td>
<td>Reported the causes of rework in major project were due to poor documentationproduced by design consultants. Burroughs (1993) also revealed that a concreting subcontract experienced a cosy increase of 31% due to rework</td>
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<tr>
<td>Lomas (1996)</td>
<td>Australia</td>
<td>Rework</td>
<td>&gt;1%*</td>
<td>Rework less than 1% when a QA system is implemented. Lomas reported that rework costs were approximately 5% prior to the introduction of QA</td>
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<tr>
<td>CIDA (1995)</td>
<td>Australia</td>
<td>Rework</td>
<td>6.5%*</td>
<td>CIDA (1995) found that projects with a formal quality management system in place recorded lower levels of rework. The average cost of rework as a percentage of contract value for projects with a quality system was found to be 0.72%. Whereas those projects without a quality system in place have been found to have an average cost of rework 6.5%. Project procured using lump sum contracts were found to have rework costs as high as 15% of contract value</td>
</tr>
<tr>
<td>Love et al. (1999a,b,c)</td>
<td>Australia</td>
<td>Rework</td>
<td>3.15%*</td>
<td>Residential project procured using a traditional lump sum contract. Changes initiated by the client and end-user, as well as errors, and omissions in contract documentation were found to be the primary causes of rework</td>
</tr>
<tr>
<td>Love (2002a)</td>
<td>Australia</td>
<td>Rework</td>
<td>6.4%*</td>
<td>Sampled 161 projects and found the mean direct and indirect rework costs were found to be 6.4% and 5.6% of the original contract value, respectively. Rework costs were found not to significantly vary with project type and procurement method used</td>
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<tr>
<td>Cnudde (1991)</td>
<td>Belgium</td>
<td>Non-conformance</td>
<td>10%–20%†</td>
<td>Reported that 46% of total deviation costs were created during design, compared to 22% for construction deviations, which were due to poor execution of work</td>
</tr>
<tr>
<td>CIBD (1989)</td>
<td>Singapore</td>
<td>Rework</td>
<td>5%–10%†</td>
<td>CIBD stated that a proper quality management system would cost in the range of 0.1 to 0.5% of total project cost and return a saving of 3%</td>
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<tr>
<td>Nylén (1996)</td>
<td>Sweden</td>
<td>Quality failure</td>
<td>10%†</td>
<td>This research examined quality failure costs in four major railway-engineering projects. In the four cases studies, 232 failures during the production phase of the project were identified, which account for 10% of each project’s production costs. It was found that 10% of failures contributed to 90% of failure costs. 51% of failure originated from design due to communication problems between client and consultants</td>
</tr>
<tr>
<td>Hammarlund and Josephson (1991)</td>
<td>Sweden</td>
<td>Quality failure</td>
<td>6%*</td>
<td>79% of failure costs were attributed 20% of the failures that were recorded. Approximately 34% of failures were attributed to ineffective site management, 20% to design, and 13% to poor communication. It was found that 10% of production time was spent remedying failures</td>
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<td>Josephson and Hammarlund (1999)</td>
<td></td>
<td>Defects</td>
<td>2.3%–9.3%</td>
<td>This study examined the defect costs of seven building projects. The number of defects that occurred ranged from 283 to 480. 32% of defect costs were found to originate from design (design team), 45% originated from on-site (site management/subcontractors) and 20% from materials, plant and equipment. Lack of motivation due to 'carelessness or forgetfulness' was attributed as a cause of 50% of defect costs</td>
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<td>Farrington (1987)</td>
<td>USA</td>
<td>Quality deviation</td>
<td>12.4%†</td>
<td>Design changes, errors and omissions averaged 78% of total deviations and 79% of total deviation costs. Construction deviations averaged 16% of total deviations. These findings also reported in Burati et al. (1992)</td>
</tr>
<tr>
<td><strong>Q1 Willis and Willis (1996)</strong></td>
<td>USA</td>
<td>Quality deviation</td>
<td>3.3%†</td>
<td>Willis and Willis reported that the total cost of quality, which is the costs of prevention and appraisal plus cost of failure and correction was 12% of project cost: 8.7% prevention and appraisal costs and 3.3% deviation correction</td>
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<td>Abdul-Rahman (1993)</td>
<td>UK</td>
<td>Non-conformance</td>
<td>2.5%*</td>
<td>In a water treatment plant 62 non-conformances were identified. Not all non-conformances could be identified due to resource constraints and availability of site personnel. Estimated cost of non-conformance to be 6% of project cost</td>
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<td></td>
<td></td>
<td>Non-conformance</td>
<td>5%*</td>
<td>In a highway project 72 non-conformances were identified. The reported figure of 5% did not include material wastage and head office overheads. Non-conformances were attributable to the subcontractor, construction and design-related issues</td>
</tr>
<tr>
<td><strong>Q1 Barber et al. (2000)</strong></td>
<td>UK</td>
<td>Quality failure</td>
<td>3.6%*</td>
<td>Examined the quality failure costs of two highway projects that were procured using a Design–Build–Finance–Operate contractual arrangement</td>
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<td></td>
<td></td>
<td></td>
<td>6.6%*</td>
<td>Revealed that quality failure costs were 16% and 23% of contract value. These estimates include the costs of delay. When these are removed then it was estimated that quality failure costs were 3.6% and 6.6%. Design-related failures accounted for 90% failures</td>
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*% of contract value.  †% of project value.
The strategic positioning of a construction organization is founded on its ability to differentiate its unique service or the product from that produced by competitors (Barrett, 1993). In responding to marginalization, many design organizations have become leaner in order to adapt to the increasingly volatile and competitive market environment (Richardson, 1996). Rather than compete on service quality offered, design organizations have adopted a market-driven strategy based on their fees (Rounce, 1998). According to DeFraities (1989), a major determinant of project quality is the overall level of professional services provided. DeFraities (1989) states that the process of professional services selection and subsequent fees negotiated will influence service quality provided. Abolnour (1994) found a negative correlation between the actual fees charged and documentation quality, that is, project costs increase when design fees are reduced. Conversely, Hoxley (2000) acknowledges the importance of fees, but does not consider them to be a significant factor that influences service quality.

All organizations involved in the procurement of construction, especially those providing professional services, should embrace a quality culture (Oakland and Aldridge, 1995; Bubshait et al., 1999). The absence of a quality focus in design organizations has meant that the concept of service quality has not received serious recognition (Love et al., 2000). Consequently, contractors and subcontractors (who are customers in the supply chain), tend to act as ‘quality buffers’ and therefore burdened with the identification of quality deviations in contract documentation.

**Contract Documentation**

Contract documentation quality may be compromised when a firm submits a low design fee for a project, especially when design tasks are subject to ‘time boxing’ (Love et al., 2000). That is, a fixed period of time 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 result in inadequate time to prepare complete design documents (Coles, 1990; Rounce, 1998). Moreover, Coles (1990) noted that use of inexperienced staff that lack technical knowledge could lead to errors and omissions in contract documentation being made. Findings resulting from a study on the technical design of buildings found the most frequent causes of severe deviations during design were attributable to deficient planning and/or resource allocation, deficient or missing input and changes (Sverlinger, 1996). Rounce (1998) suggests a number of poor management practices contribute to the generation of 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 (QS)/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 (2000) found that unrealistic client demands for earlier completion of projects was a major contributing factor to the production of incomplete and erroneous contract documentation. Lack of attention to management and providing a poor quality service
by design consultants has resulted in rework becoming a 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):

- re-design due to an inadequate client brief;
- changes arising from unchecked drawing;
- re-design due to inappropriate drawing scale; and
- attending to client driven design changes.

To reduce rework in architectural firms, a re-examination of the way business should be conducted and suitable focus given to prevention. This inward appraisal should strive to eliminate unnecessary drawing revisions, work to a structured programme that identifies specific design deliverables and minimize management problems in the design process that contribute to resource wastage (Rounce, 1998).

Quality Management

Rounce (1998) recommended that an architectural firm’s profitability can be improved by ameliorating internal management practices through quality management, particularly quality assurance (QA). To be effective, architectural firms would see non-conformance costs, as a percentage of their project fee, reduced by as much as 45% (Rounce, 1998). Contrastingly, Tilley and McFallen (2000) and Love and Sohal (2002) found that many Australian design organizations have no formal QA system in place and did not consider certification to ISO 9000 to be an important management function. The Building Research Establishment in the UK identified the need for a formal and systematic approach to quality control in construction (BRE, 1981). In particular, a number of factors were found to hamper construction quality of buildings, these included the fact that:

- achievement of good quality relies mainly on the motivation and commitment of site management;
- site management inevitably has insufficient time for quality management;
- management structures have considerable impact on quality achieved, yet the contractual arrangement has little influence on the level of quality achieved;
- insufficient information provided by design organizations restricted the contractor’s ability to achieve quality;
- the quality performance measure was considered to be a low priority; and
- a lack of client involvement in the project hindered quality achievements.

Both design and contracting organizations have an active role to play in improving quality during the project’s design and production phases, though the extent of involvement is dependent upon the method of procurement used. Therefore, quality control programmes implementation is a prerequisite requirement within organizations that seek to improve overall project quality.

Findings published by the BRE (1982) provided the impetus for examining how quality management can be implemented by design organizations, during the early stages of a project. The BRE provided demonstrable evidence that the introduction of quality management practices could stimulate significant cost benefits. Figure 1 reveals that at least 15% savings on total construction costs can be achieved through eliminating rework (BRE, 1982).

Jaafari (1996) suggests that the QA practice, developed by contractors, has been based on post-production quality control and resultantly this has meant increased costs without commensurate savings. In stark contrast, Lomas (1996) of Barclay Construction Ltd (Australia) reported that prior to the implementation of QA system, their rework costs were 5% of
contract value; this being reduced to 1% following QA implementation. Lomas (1996) found that QA contributed to an aggregate company saving to in excess of Australian dollar 4.2 million in 1996, which equates to approximately 1% of their turnover.

CIDA (1995) noted that projects with a formal quality management system in place record lower levels of rework. The average cost of rework, as a percentage of contract value, for projects with a quality system can be as low as 0.72%. Conversely, projects without a quality system in place have an average rework cost of 6.5% of contract value. Burati et al. (1989) argue that when total quality management (TQM) is applied holistically in conjunction with reward schemes, rework can be significantly reduced or eliminated. Factors identified during construction that contribute to rework include (e.g., Josephson and Hammarlund, 1999):

- poor management and employee training;
- low skill level of subcontractors;
- lack of supervision and on-site inspection;
- damage due to carelessness;
- poor planning and coordination of on-site resources; and
- poor workmanship and use of materials.

Although design related issues form a significant proportion of rework costs, a greater number of rework-related incidents tend to occur during construction and therefore likely to increase indirect costs due to consequential disruption and delays (Love, 2001). To gain an in-depth understanding about how and why rework occurs, two longitudinal case study projects were undertaken.

**RESEARCH METHODOLOGY**

A case study is exploratory in nature, based on interviews and relies heavily on verbal reports and unobtrusive observation as primary data sources. This methodology should be used to investigate the technical aspects of a contemporary phenomenon within a real life context.
Q1 (Yin, 1984). It is particularly useful when the boundaries between phenomenon and context are difficult to ascertain and when multiple sources of evidence are used (Yin, 1984). A case study can provide analytical rather than pure statistical generalizations and can capture the complexity and dynamism of organizational settings in projects. Theory in this instance can be defined as a set concepts and generalizations about the antecedents of rework. Because there is limited knowledge about the antecedents of rework in construction projects, the case study approach seems best suited to this research work.

Case Study Selection

Construction contractors operate at the interface between the design and construction process, and were thus the focal point for this research. The contractor participating in this research was the first building and construction company to be certified to the dual standards of ISO 9001/AS 3901 and AS 2990 Category A in Australia. Since certification in 1991, the company has developed and implemented an effective continuous improvement program that has reduced project rework and thus improved its market position.

The authors established personal contact with senior management within the contracting organization to explain the nature, purpose and scope of the research, which was to determine the causes and costs of rework in construction projects. During initial discussions, two projects were about to commence on-site. Consequently, these two projects became the subject of the research. These were:

- **Residential Apartments (Project A):** This project consisted of two residential blocks of six-storeys, which comprised of 43 units on the edge of Brisbane’s Central Business District, in Queensland. Underground car parking, a landscaped podium and swimming pool are among the facilities and features incorporated into this development. The project had a contract value of Australian dollar 10.96 million, a contract period of 43 weeks and was delivered using a traditional lump sum procurement method. Five weeks of extensions of time (EOT) was granted but was delivered, 8 weeks ahead of the re-scheduled completion date. While the project was delivered ahead of time, cost overruns were experienced due to contract change orders and defects. The project experienced a direct cost overrun equating to an additional 10.05% (Australian dollar 1,105,900) of the original contract value. Change orders as result of additions initiated by the client and occupiers accounted for 7.35% (Australian dollar 806,356) and 3.15% (Australian dollar 345,504) were a direct result of rework. In fact, rework can take the form of a change order if it directly influences a project’s progress and causes disruption. In this case, change orders that resulted in direct rework accounted for 2.7% (Australian dollar 299,544) of the original contract value. The remaining 0.45% (Australian dollar 45,960) of rework costs were due to errors and minor defects that were the responsibility of the contractor and subcontractors.

- **Warehouse, Solvent and Book Repository (Project B):** This project consisted of a two-storey warehouse at a major university campus in Brisbane, Queensland. The project provides facilities for car parking, the storage of solvents and books. The project had a contract value of Australian dollar 4.45 million, a contract period of 30 weeks and was delivered using a design and construct procurement method. The contractor was awarded the contract on March 20, 1996. Construction began on-site on April 15, 1996. Eight weeks of EOT was granted, and the project was delivered two weeks ahead of the re-scheduled completion date. The project was delivered ahead of time but cost overruns were experienced due to change orders and defects. Change orders initiated by the client and occupiers contributed to a project cost increase of
7.17% (Australian dollar, 319,333). Direct rework costs were found to be 2.40% of contract value, with the client and occupiers being accountable for 0.5% (Australian dollar 22,280), the contractor 1.46% (Australian dollar 65,223) and subcontractors 0.43% (Australian dollar 19,390) of the costs incurred in the project.

Specific details about the rework costs that were incurred in these projects can be found Love and Sohal (2003).

Data Collection

Data was collected throughout the construction phase. Each site was visited between one and three times a week throughout the project duration for periods lasting anywhere between 2 and 5 h. The time allocated for collating data varied because during the project’s early stages rework incidents reported or identified by the project managers were sparse. Two block visits of 4 days were also conducted for each project and timed to coincide with periods of increased site activity.

As the projects progressed, rework began to emerge, and consequently a considerable amount of time was required to collate information from various sources. In some instances, the researcher relied on personal industry experience to identify rework events were uncovered while reading through contract documentation. Before events were categorized as rework, each rework item was validated by the project manager, site foreman, or contracts administrator. Every attempt was made not to disrupt the project workflow, for example, visits were usually undertaken at 7.00 a.m. to enable complete access to contract documentation. Between 7.00 and 7.30 a.m. unstructured interviews with the project manager/contract administrator were conducted to discuss the project’s performance, problems, and to identify any rework that had occurred. During times of intense construction activity on-site, visits were undertaken between 4.00–6.00 p.m. to collate information from documentary sources.

Interviews with subcontractors, site management, and design consultants occurred in their site offices and on certain occasions, at their head offices. Interviews sought to identify and obtain additional information about particular rework events, corroborate evidence and any other interpretations of events that occurred. When concluding interviews, notes were given to each interviewee to check for discrepancies and eliminate any interviewer bias.

RESEARCH FINDINGS

In this section, examples of rework events and the underlying factors that contributed to their occurrence are identified. These include:

- lack of understanding for end-user requirements;
- poor contract documentation and low consultant fees;
- poor standard of workmanship;
- lack of a quality focus; and
- poor supervision and inspection.

Each event is discussed in turn before commencing the general discussion.

Lack of Understanding for End-User Requirements

In project A, purchasers of apartments initiated the majority of design changes, though some changes also occurred due to oversights in design and constructability. Client initiated
changes, such as changes to wall finishes, light fittings, and internal wall layouts began to impact the programme, project cost and the motivation of site management and subcontractors. The contractor requested, on several occasions, for the client’s project manager to implement a design freeze, which was refused, as the requirements for purchasers had not been finalised. Thus, the contractor requested an EOT for 5 weeks, which was subsequently granted.

In project B, almost all of the client/occupier-initiated rework that arose was attributable to poor or inadequate occupier consultation. The Building and Grounds Division of the University along with representatives from several internal committees that had been established were supposed to examine the requirements and needs of the facility’s occupants. In addition, a process of pro-active consultation with respect to the building’s spatial layout and functionality was supposed to occur between a representative from each committee and occupiers. However despite the provision of a client feedback loop system, occupiers were rarely consulted about their requirements and needs. Consequently, occupiers demanded changes to be undertaken. For example, the external window that was installed for the male toilets was comprised of clear glass. The occupiers’ representative did not approve of this and consequently requested a tint be installed, even though the window was 7 m above ground level.

According to the client’s project manager, occupiers were divorced from the decision-making process because a bureaucratic structure had been established through the several levels of consultative committees that assumed vicarious authority. Consequently, many occupiers were dissatisfied with their lack of involvement in the decision-making process.

To reduce costs some elements were deleted from the project without prior occupier approval. For example, the occupants required glazing in a partition wall, which was subsequently documented because the contractor had not informed the architect of this decision. The glazing was deleted at the request of the contractor, as it was not included in their contract. In fact, the client’s project manager had informed the contractor that this item was to be deleted prior to the project’s commencement on-site. When representatives of the occupiers inspected the facility they then discovered that the glazing had been omitted. They immediately requested that the glazing be installed. The contractor agreed to this request as long as the client body agreed to pay for the cost of the glazing. Approval was granted, but at a cost of Australian dollar 6500.

The client’s project manager’s lack of consultation with occupiers caused a degree of disharmony within the client organization, as different by stakeholder agendas by stakeholder were being pursued. This disharmony was directed at the contractor, who was perceived to be the culprit for cutting costs and not building the facility to their requirements. However, the offender in this instance was the client’s project manager who was confronted with a difficult dichotomy, that is, by having to satisfy occupiers’ requirements while simultaneously reduce project costs.

**Poor Contract Documentation and Low Consultant Fees**

In both projects, the contractor and design consultants actively sought future from clients. Consequently, they had to be competitive as well as demonstrate an inherent ability to undertake the project successfully. Continuation in workload juxtaposed with a keen desire to solicit future work meant that short-term sacrifices were made. Fees and profits were therefore reduced and staff subjected to increased pressure to perform the tasks that were thrust upon them.

Interviews with the contractor, subcontractors, and purchasers in project A revealed that errors and omissions within the design documentation contributed to design-related rework. The contractor suggested that the project team had not been effectively coordinated
and integrated by the client’s project manager during the project’s design phases. The architect had designed and began documenting the project before the engineering consultants were appointed and therefore did not give due consideration to the mechanical, electrical, and hydraulic service requirements. Poor coordination of drawings during design process resulted in service clashes occurring. When the architect was probed about why these clashes rose, it was revealed that inadequate time combined with the use of inexperienced personnel contributed to errors in documentation. Moreover, the late inclusion of the engineering consultants in the project resulted in them to having to design and document services around the architectural design.

In one case, the architect specified that the floor to soffit in the basement slab to be 2.1 m. Although this clearance corresponded with the minimum requirement identified by the building code, no allowance was made for the inclusion of basement hydraulics (stormwater and sewer drainage). Thus, the basement hydraulics systems had to be re-designed, so as to conform to the building code. Dimensions for the basement architectural drawings significantly differed between sections, elevations, and plans. The foreman noticed these errors during excavation works and reported them immediately to all parties involved. This meant that the hydraulics engineer had to hastily develop an alternative solution to the problem otherwise the project’s critical path would have been adversely affected. The solution developed resulted in a change order being issued for Australian dollar 24,239.

When the contract documentation for subcontract packages for both projects had been produced, the foremen and contract administrators checked its content for any inconsistencies. As a safeguard, the contractor also relied on their subcontractors to identify anomalies contained within their tender documents. Upon identification of errors and omissions the design consultants were required to spend additional time clarifying and rectifying the erroneous documentation. In project B, the pressure to produce documentation in the tight time frame required by the contractor took its toll on all the design consultants who were unable to meet the unrealistic demands. Instead of the consultant firms providing additional resources to the project, staff were required to work longer hours. This proved to be a stressful and demoralising experience. The constant and immediate pressure to rework documentation, as well as progress with the documentation of other subcontract packages further exacerbated the situation and led to additional errors.

As the design consultants became more familiar with this research, they began to converse more freely about their internal management practices. An architect stated that recent graduates (in preference to more senior architects) were used to produce documentation in order to maximise profitability. Another important factor was that the design consultants involved in both projects were not certified to ISO 9000 and no design checks, verifications or reviews were undertaken prior to the documentation leaving their respective offices.

Poor Standard of Workmanship

A large number of errors occurring on-site, on both projects, required rework. Many were due to the subcontractor’s poor quality workmanship or carelessness. A predominant number of faults were minor and therefore did not significantly impact the project’s performance in terms of time or cost. For example, while the piling subcontractor was inserting pile foundations the plant operator reversed the pile rig into a pile that had already been inserted and subsequently damaged it. Instead of trying to rectify the damaged pile, it was decided to re-install another at an additional cost of Australian dollar 2000 was borne by the subcontractor.

An error made by one subcontractor can have an adverse impact on succeeding trades. For example, the blockwork subcontractor constructed 2 m high core-filled block wall in the
building’s basement. Upon inspection, the foreman noticed that the wall was offset and therefore required dismantling, and re-building. This error was identified on a Friday morning and threatened to cause a major project delay because the first floor concrete slab was scheduled to be poured the following day. The blockwork, formwork and reinforcement subcontractor worked together to complete the required ‘critical path’ task without any hesitation or complaint. The blockwork subcontractor stated that ‘these things happen. The apprentice got the “set-out” wrong; it’s easily done when you’re learning’. However, the subcontractor suggested that the contractor’s foreman should have also checked the wall’s alignment before blocks were laid.

The subcontractors had worked with each other previously and had developed a good work relationship. In a time of crisis, these subcontractors expressed their solidarity by assisting their colleagues to rectify any problem encountered. The estimated cost of demolishing the wall was Australian dollar 1000, and Australian dollar 2700 to re-erect it, of which Australian dollar 500 was attributable to the formwork subcontractor, Australian dollar 1600 to the blockwork subcontractor and Australian dollar 600 for reinforcement. These additional sums of money may appear to be negligible yet, the subcontractors involved were relatively small firms and such a loss was treated with the utmost concern.

Dynamic interpersonal relations played a significant part in the distribution of the financial responsibility borne by the subcontractors for the additional work. Although three separate firms were involved in the demolition and re-construction of the wall, the individuals involved were part of an effective and cohesive informal group that had formed over 10 years of working together on previous projects. The contractor’s project manager had known the subcontractors for nearly 20 years and previously worked for the formwork subcontractor as a carpenter, along with the blockwork and reinforcement subcontractors. Being in a position of power and control, the project manager adopted a paternalistic role to managing the subcontractors by being supportive and providing constructive advice when required; this contributed to the esprit de corps amongst those on-site. As soon as the misalignment of the wall was noticed, the project manager rallied the subcontractors together and informed them of the urgency to demolish and re-construct it. As the rework task was relatively straightforward, the project manager’s leadership style appeared to become more structured, as specific details and instructions were given on the wall’s re-construction.

The salience of the task indicated that individuals were committed to rectifying the error with little concern about the financial implications imposed upon them. Implicitly, the highly effective inter-organizational and interpersonal relations that had been established over a period of time acted as an effective mechanism for preventing conflict, and a subsequent monetary claim. Moreover, the blockwork subcontractor indicated that over time, both the formwork and reinforcement subcontractors would need their help in future.

Lack of a Quality Focus

Poor workmanship by a concrete subcontractor in project B was identified as a principal reason for the poor quality concrete finish within the lift shaft. This resulted in a change order being issued to the painting subcontractor, for which the main contractor paid the cost. The external walls of the lift shaft were supposed to be left exposed, but the foreman decided that they should be painted to improve their aesthetic appearance. The contract administrator refused to pay the painting subcontractor for these additional costs because there was no formal instruction to do so, but the foreman disagreed.

The foreman and contract administrator proceeded to enter into confrontational discourse about who was responsible for the additional cost of painting. Essentially, the contract administrator focused upon saving money, whereas the foreman focused upon ‘getting the
job done’. It transpired that the contractor administrator had not been made aware that the concrete subcontractor had undertaken additional work, at no additional cost, at the request of the foreman some weeks prior to the completion of the lift shaft.

The foreman’s instruction had not been formally documented even though this was a prerequisite requirement of the project QA system. Resultantly, the contract administrator was not formally notified that the work had been undertaken. This may have left the contracts administrator in a quandary, especially if the foreman was allocated to another project or some unfortunate event happened to him. The foreman stated that rework was not documented due to the time required to issue instructions to subcontractors. In remedying these incidents, so called ‘deals’, which were similar in nature to the aforementioned, were made on site with subcontractors. The fluidity and arbitrary nature of the foreman’s actions generated unnecessary conflict, albeit unintentionally, as the pressures for early completion and to reduce project costs impaired his communication and decision-making. Matters that were considered trivial negatively impacted upon contractor and subcontractor relations, as the costs for painting should have been attributed to the concrete subcontractor.

Upon discovering the foreman’s ‘deals’ with subcontractors, the contractor’s project manager instructed the foreman to document all future instructions given so as to reduce the risks of disputes and potential cost increases. In doing so, additional rework occurring could be easily identified. Although the consequences of the rework did not adversely impact project cost and schedule, conflict did arise and relations with the subcontractor were, at times, severely jeopardized.

**Poor Supervision and Inspection**

For both projects the subcontractor’s work was not inspected by the foreman on a regular basis, which meant that poor workmanship went unnoticed until later in the project. By this time, many of the subcontractors had left the site and had to return to rectify their work. For example, a 10-m length of fascia channel had only been partly painted, and the scaffolding had been removed. This resulted in the painting subcontractor having to return to site, and hire additional scaffold to complete the work that should have cost only Australian dollar 20 to rectify. It was estimated that the indirect cost associated with rectifying this defect were:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Travelling time (2 h @ Australian dollar 35 h⁻¹)</td>
<td>Australian dollar 70</td>
</tr>
<tr>
<td>(ii) Hire of scaffold (1/2 a day @ Australian dollar 200)</td>
<td>Australian dollar 200</td>
</tr>
<tr>
<td>(iii) Loss of productivity (5 h @ Australian dollar 35 h⁻¹)</td>
<td>Australian dollar 180</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Australian dollar 450</strong></td>
</tr>
</tbody>
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Here, the indirect cost was a staggering 22 1/2 times the actual cost of rectification!

Numerous defects identified before the project’s hand-over were incomplete items of work; that is, they had been installed incorrectly. They were considered to be defects because they did not conform to the original requirements stipulated in the contract specification. An analysis of the defects listed prepared by the contractor for both projects indicated that only a minority of the defects identified were technical in origin. For example, in project B a shelving system showed signs of deflection without a load being imposed on it and needed replacing. Poor planning was a common and recurrent factor that contributed to incomplete work. According to an electrical subcontractor, the pressure to complete critical task activities on time meant that non-critical activities were rectified at the end of the project.
DISCUSSION

Design Management
Considering the findings identified from the case studies, rework prevention should begin by focusing on change mitigation. Clients cannot always be explicit about their requirements at the project’s outset because of the many different interests that have to be satisfied. Therefore, a degree of change can be expected in a project (O’Brien, 1998). With an effective project scoping strategy in place, which has been based upon a strategic needs analysis (Wyatt and Smith, 2000) and quality function deployment (QFD) (Karma, 1999), clients should freeze the scope of their project as early as possible to minimise the risk of cost and schedule increases.

Constructability and value management (VM) programmes should be undertaken after the baseline scope has been developed. Love (2001) has shown that design scope freezing, VM, constructability analysis, and teambuilding are key strategies for reducing rework, particularly design-related changes. Although design scope freezing may be a useful tool to reduce change, it can also increase change if the scoping process has been ineffectively undertaken (Love, 2001). Dell’Isola (1997) states that VM should be performed as early as possible in the project development process if management seek to curtail the investment, that is, required to implement a change. After the project scope has been developed, a VM study should be undertaken with the entire project team, including the contractors and relevant subcontractors so as to improve project constructability and reduce the potential for change.

Design is an iterative process and therefore design changes are inevitable, if a realistic solution to a problem is to be developed. Fundamentally, the creative leap is more a process of building a bridging concept between the problem and the solution (Lawson, 1994). To find an acceptable design solution requires a team-based approach to problem solving (Miller, 1993; Sonnenwald, 1996). Once the solution is identified a design team will invariably try to make it work, especially if members have some form of input into the design process – a process known as satisfying (Akin, 1986). This is, however, contrary to the conventional-based approach, where an architect identifies several possible solutions and each is evaluated and refined until a proposed solution is considered acceptable (March, 1976). This process can be time-consuming and frustrating for some clients, especially those who are inexperienced, as many are unable to define their specific requirements. Simply understanding the client’s problem and translating such into a design that can be effectively documented and constructed is one of the panaceas for reducing change initiated rework.

A lack of input into finding a mutually beneficial problem solution and being involved at a later stage of the project’s development may discourage a sense of project ownership amongst design team members. This can lead to ineffective design coordination at respective interfaces, which can inadvertently translate into errors and omissions being contained within contract documentation.

Auditing Contract Documentation
Because documentation errors were not detected until particular activities had commenced on-site, rework and delays to subcontracts occurred. It is was not possible to pin-point exactly who was primarily responsible for causing rework, but those organizations who paid rectification costs could be readily identified (refer to Love and Li, 2000). To be reduce rework, organizations must assume responsibility for their actions. As organizations learn the total cost of rework, they 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 ‘hidden’ additional management time and labour man-hours.

Design-related rework was the most costly (Love and Li, 2000). Yet design consultants did not pay for the errors and omissions that resulted 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 contract, that is, used for appointing design consultants, contractors, or specialist subcontractors) is important in identifying who is fundamentally responsible for the rework.

In the case studies presented, access to specific contract conditions was restricted. However, considering the nature of the contract that was used (a modified version of a standard form of contract (AS2124)), the design consultants’ liability was based on their ability to provide reasonable skill and care. Design consultants should take reasonable care to ensure that the information, that is, 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 (2001), 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.

Poor coordination and integration of design team members with respect to contract documentation contributed to rework significantly. In the case studies, problems of coordination appeared where design consultants were reluctant to sanction the approval of each other’s work.

Figure 2 illustrates the cause and effect by time and location of errors in a project. Such errors reside within the processes of individual firms, the design process and the interfaces between design team members. It can be seen that there is a time delay, as well as a change in organisational location, before the symptom – a dimensional error in the drawings – is identified by the foreman (or other site personnel) during construction on-site. Here, effort and time is expended in attempting to correct the specific symptom. The processes that generated the error(s) may also continue to create additional problems that appear later and therefore may have a significant affect on project schedule as well as the morale and motivation of the workforce.
This dynamic structure reinforces itself by consuming resources for problem solving and decreases the capability to invest in upstream work to remove problem causes. The ephemeral nature of construction projects often results in organizations only ever working together once, which constrains the formation of trust and the development of harmonious relations. Moreover, construction projects generally do not have mechanisms (e.g. audits) to learn from mistakes that they have made (Love and Sohal, 2002). Hence, the cause and effect of rework is inseparable, which may be a plausible explanation as to why there has been limited attention given to determining the causes and costs of rework by construction organizations.

Lost profit and increased pressure to rectify initial errors may result in the firms upstream in the procurement process being reactive to the problems that arise and insufficient resources to address the specific cause. In fact, the organization may be unable to identify and prevent specific causes because they do not have the tools and techniques to do so. In this instance, there is a severe limitation placed on the ability of firms to reduce errors, when improvement efforts are restricted to having the foreman and subcontractors being the problem-solvers.

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 (CII, 1990). This information enables 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 (Chapman, 1998). 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 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 alerted to the consequences associated with initiating a change. Essential changes should be reviewed and authorized through a systematic and structured scope and change control program that has been developed by the client’s representative in conjunction with the project team.

The Need for a Quality Focus

The case studies revealed that design consultants (and to so extent, contractors) lack of quality focus significantly affects project cost performance. The prevention of poor quality was not considered an issue and resultantly external failures occurred downstream during production. This is because many construction organizations do not implement QA
effectively or that they do understand how quality management activities can improve business performance (Love and Sohal, 2002).

Some organizations have become so disheartened with QA in that they resist investing further time and finance into other quality practices. This is understandable to a certain extent, when considering the way that QA has been adopted by the industry. However, organizations must realize that QA is only the starting point and the benefits of becoming quality focused will only arise through the continued investment of resources and time.

Measuring quality in the project’s design phase is arguably difficult because all too often the designer is not the final user assessing the product’s quality performance (Abdul-Rahman, 1993). Arge (1995) suggests that direct and constant communication between the architect and client/end-user is a critical factor that can affect the final product’s quality. Furthermore, Arge (1995) suggests that if architects are to deliver clients/end-users quality architecture, they must improve their internal management practices and consider limiting the commissions they undertake. Contractors are the custodians of the production process hence, they must receive ‘the right’ information, to enable them to manage their subcontractors. Incomplete, conflicting, inappropriate, or changed information causes rework, which can delay the project’s progress. Contractors quality systems are unable to prevent errors and omissions, which originate from consultants, nor can they thwart changes, but they can provide prevention mechanisms and give early warnings of poor quality. To ensure quality in contract documentation, design consultants, and particularly contractors when using design and construct methods, should give greater attention to the following quality management practices:

- the requirements of clients and end-users;
- producing correct and complete drawings and specification;
- coordinating and checking contract documentation (including inter-organisational coordination);
- conducting design verification through design analysis reviews;
- controlling changes (e.g. scope freezing); and
- committing to providing a quality service.

By giving adequate attention to these preventative items design QA can be improved, which in turn will reduce errors, and omissions. Moreover, to produce good quality contract documentation an organization has to harness the skills of the right people at the right time and integrate and coordinate their work with other organizations involved with a project (Hollis, 1993). TQM explicitly encourages inter-organisational integration through partnership formation and therefore acts as a mechanism for reducing any potential conflict during project’s design and construction.

Training and Skill Development

Lack of knowledge and carelessness contributed to errors occurring in the projects, both of which can be corrected (Hellard, 1991). Human resources should be given appropriate attention since they are capable of producing and preventing errors. Oakland and Sohal (1996) indicate that effective human resource management is an integral component of TQM and therefore provides the foundation for error prevention. Although Love and Sohal (2002) found no significant relationship between training and rework costs, evidence from the normative literature clearly demonstrates that investment in training can reduce rework costs (Mandal et al., 2000). Improved training and skill development can improve the competence base of site management and subcontractors. Efficient management of the
construction process can lead to minimum variability, minimum waste, and maximum use of resources. Achieving effective quality management demands an understanding of process variability and the necessary actions to prevent it.

According to Abdul-Rahman (1993, p. 231) the tradition of ‘if it meets specification then it’s ok’ is no longer applicable in construction projects. However, this philosophy clearly continues to thrive. To improve business performance and thus secure future contracts, organisations should aspire to exceed client expectations by reducing process variability. The corollary to this is that clients should provide incentives to organizations that reduce project process variability.

Supervision and Inspection On-site

Site management and subcontractors can play an active role in reducing errors by providing ameliorated supervision and leadership on-site. Site personnel (such as the foreman) invariably assume the role of production inspectors and therefore possess knowledge, on the causes and prevention of rework. During construction, the foreman is the project driver, as they direct the specific work that needs to be undertaken (Howell et al., 1993). Unfortunately, foremen (and other project personnel) are often reluctant to impart their knowledge because their advice is unlikely to be given the recognition it deserves (Ashford, 1992). Yet ultimately, site personnel can reduce rework that is attributable to human error or poor workmanship. Shimbun (1990) suggests that individuals should use the following major inspection techniques to prevent defects:

- judgement – separate defective products from good ones;
- informative – determine the cause of a defect and provide feedback into the process; and
- source – correct a mistake before it manifests itself as a defect.

Site foremen should see quality problems as an opportunity to improve performance and therefore should be encouraged to identify their causes as a precursor to developing mechanisms to prevent their recurrence. According to Ozeki (1990) a classification for identifying problems may include those related to:

- worker skill and attitude;
- the workplace quality system;
- lack of motivation to solve problems;
- problems in workplace culture; and
- problems that originate from design, the manufacturer or supplier.

In adopting the above classification, foremen should not be treated as quality inspectors but rather teachers who can convince those making errors that it is ‘safe’ to report them (Ballard, 1997). Failure to recognise the separation of cause and effect is an important barrier to learning, which needs to be overcome if rework is to be reduced.

Production Planning

Poor planning and coordination on the contractor’s behalf can directly influence the resource planning of subcontractors. Therefore, both the contractor and subcontractor need to work together to ensure that when planned activities deviate, remedies are available to minimise possible disruption and delays. In deriving effective remedies to reduce variability and stabilise the flow of work activities, the traditional approach to project planning must be re-examined (Ballard, 1994).
Ballard and Howell (1997) state that the traditional approach to project planning is effective for informing people about what should be done, as it is used to monitor and enforce conformance of ‘did’ to ‘should’. This can work well until something goes wrong and then a chain reaction of unforeseen events can take place. For example, an architect fails to provide approvals for shop drawings; this can delay the fabrication process, and the delivery of materials to site, which may have impact on the project’s critical path. As the available float disappears from the schedule, increasing pressure is placed on people involved within that specific chain to minimize the delay’s impact. This can further exacerbate matters and increase the likelihood of errors being made as people work harder to meet the program dates. Hence, Ballard and Howell (1997) argue that if the traditional approach to planning worked perfectly then did would always match should.

Research undertaken by Ballard and Howell (1997) has revealed that what actually is undertaken differs significantly from what should have been done by one-third in projects. In other words, approximately 33% of planned activities were not completed within the planned period due to inappropriate drawings and a lack of materials. When project rework occurs, the contractor and subcontractors must learn how to pro-actively manage the situation by utilizing the last planner approach. The last planner is responsible for the operational planning of the production process (Ballard, 1994). Therefore, stabilising the work environment begins by learning to make and keep commitments to doing what should be done, only to the extent it can be done. The foreman is typically the last planner and should select only those activities that can and will be done rather than those activities that should be done to compensate the project’s schedule for the rework that has occurred. Working closely with subcontractors will enable the foreman to determine the resources needed for what can be done (Ballard, 2000). If what should be done is addressed instead, then the site workforce may inherit the uncertainty and variation of workflow that have not been prevented. This may result in a high degree of non-productive time and a de-motivated workforce. The last planner approach shields the site workforce from up-stream variation and uncertainty and therefore improves the ability to control capability and variability of the workforce.

CONCLUSION

Superficially, the reasons for rework appeared to be relatively straightforward. However, a closer examination the rework events presented revealed that an intricately ‘complex’ interwoven array of factors contributed to its occurrence. In fact, it was impossible to identify a specific cause and effect relationship in the case studies undertaken because of the interdependency of work arrangements, dynamic social interactions between project participants, and the socio-economic and political structure that existed between the client and their occupiers. Notwithstanding this, an attempt was made to determine the antecedents of rework that occurred in the project. The change orders initiated by clients, errors, and omissions in contract documentation, and poor planning appear to be generic factors that can induce rework to occur. Rework not only contributes to cost and schedule growth but also can have an adverse affect on intra- and inter-organizational relations and the psychological well-being of individuals (e.g. stress). To reduce rework in projects it has been suggested that attention should be given to a number of design and production management strategies. These include:

- understanding and identifying client and end-user requirements and implementing techniques for mitigating change;
• auditing contract documentation and provide a risk assessment for the potential of change and errors;
• implementation of quality management practices;
• implementation of training programmes to enhance skills and knowledge; and
• the use of the last planner approach during the production planning process.

The introduction of these strategies into the design and production management process is deemed to be relatively a straightforward task; albeit, they do not require significant changes to current practice. The major challenge, however, lies with design consultants – they must realize that to ameliorate their documentation, emphasis needs to be placed on design quality management practices and not simply advocating for higher fees from their clients.

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