INDICATORS OF DESIGN AND DOCUMENTATION DEFICIENCY

Paul A. Tilley
CSIRO Building, Construction and Engineering, Brisbane, Australia
Adam Wyatt
CSIRO Building, Construction and Engineering, Brisbane, Australia
Sherif Mohamed
Griffith University, Gold Coast, Australia

Abstract
In an ideal world, the design and documentation provided for construction projects would be complete, precise and unambiguous. Unfortunately, this is rarely the case and quite often contractors are supplied with project documentation that is incomplete, conflicting or erroneous, thereby requiring revisions and clarifications to be provided by the designers. When this is the case, it is essential that the information be supplied to the contractor efficiently and without delay.

The 'Request For Information' (RFI) process, where contractors and sub-contractors formally obtain information clarifications regarding the contract documents supplied, is very common throughout the Australian construction industry. This process is however, highly inefficient due to the non-value adding delays which occur in obtaining the necessary information.

This paper proposes that an analysis of both the RFI process and the drawing registers can provide indicators of design and documentation deficiency and overall project performance. The paper assesses the changes in the number of drawings issued, defines and quantifies the main sources of RFIs and measures RFI response times. The results from a recent study of two construction projects are included and issues for further investigation are identified.

Keywords: request for information, design and documentation deficiency, performance indicators

Paul A. Tilley is a Construction Systems Researcher with the CSIRO, investigating issues relating to construction process re-engineering. He has extensive industry experience in construction planning, contract administration and project management.
Adam Wyatt is a Construction Scientist with the CSIRO, Division of Building, Construction and Engineering. His research interests include information management, planning and scheduling.
Sherif Mohamed is a lecturer in construction engineering and management at Griffith University. His research interests include information management and simulation modeling.

INTRODUCTION

Designers provide the graphic and written representations which allow contractors and subcontractors to transform concepts and ideas into physical reality. How effectively and efficiently this transformation occurs, depends largely on the quality of the design and documentation provided (Tilley and Barton 1997). Unfortunately, contractors are quite often supplied with project documentation that is incomplete, conflicting or erroneous, thereby requiring clarifications to be provided by the designers.

When this is the case, the Request for Information (RFI) process is generally used to formally obtain the information clarifications needed to allow construction to continue. To ensure progress is not disrupted, it is essential that the information required is supplied to the contractor efficiently and without delay. However the RFI process is highly inefficient, due to the high proportion of non-value adding delays which occur in obtaining the necessary information.

An ongoing investigation of the communication and information flow processes within construction projects has highlighted the RFI process as a particular problem area. One of the major aims of this investigation has been to define and categorise the reasons why RFIs are issued and to quantify not only their extent but also the various details relating to their processing.

Preliminary results of this investigation suggest that an analysis of both the drawing registers and the RFI process can provide indicators of design and documentation deficiency and overall project performance. This paper presents the results of this study which assesses the changes in the number of drawings issued, defines and quantifies the main sources of RFIs and measures RFI response times. The analysis of two case study construction projects are included and issues for further investigation are identified.

BACKGROUND

Anecdotal evidence in Australia suggests that over the past 10–15 years, there has been a decrease in the level of quality of design and documentation being provided to contractors. It is also claimed that this has led to a corresponding reduction in construction process efficiency, indicated by increased levels of contractor RFIs, design changes, design coordination problems, variations and rework, with corresponding increases in project administration workload for the various project personnel. Currently, the quality of design and documentation being produced in Australia is of major concern to many parties within the construction industry (Syam 1995).

As the quality of the design and documentation provided has a major influence on the overall performance and efficiency of construction projects (Burati et al 1992, Lutz et al 1990, Kirby et al 1988), a method of assessing design and documentation deficiency was deemed necessary. As the RFI process is primarily used to clarify uncertainties in the documented information supplied, an analysis of this process provides a foundation for developing a method of assessing design and documentation quality and overall project performance.

But what is design and documentation quality? The assessment of design and documentation quality can be highly subjective and open to interpretation.

When considering design quality, McGeorge (1988), stated that:

"a good design will be effective (i.e. serve the purpose for which it was intended) and constructible with the best possible economy and safety."

But whilst the design itself needs to be “effective”, it also needs to be communicated effectively through the documentation (i.e. drawings, specifications, etc.). When documentation quality is considered, a number of criteria determine the level of quality:

- timeliness - being supplied when required, so as to avoid delays;
- accuracy - free of errors, conflicts and inconsistencies;
- completeness - providing all the information required;
- coordination - thorough coordination between design disciplines; and
- conformance - meeting the requirements of performance standards and statutory regulations.

Therefore, the quality of the design and documentation process can simply be defined as:

The ability to provide the contractor with all the information needed to enable construction to be carried out as required, efficiently and without hindrance.

As the design and documentation process has such a major bearing on the overall performance of the completed project, a method to assess the quality of the design and documentation process is also likely to provide an indicator of likely overall project performance. Therefore, a design and documentation quality performance indicator is one which:

Measures the efficiency of the design and documentation process.

PERFORMANCE INDICATORS

As indicated above, it is proposed that the analysis of project drawing and RFI registers can provide good indicators of the quality of the design and documentation process provided on construction projects, by highlighting areas of deficiency.

Drawing registers

As the overall quality of the documentation issued throughout a project affects project efficiency, a simple analysis of the drawing registers provides a good initial indication of areas of likely documentation deficiency. An analysis which highlights both the changes in the number of individual contract drawings issued and the number of revisions made, allows comparisons between projects and the design disciplines involved. Although the project procurement system used on each project will have a significant influence on the results achieved, this can be taken into account when assessing the data collected.

RFI process

An analysis of the RFI process provides a better indicator of the overall quality of the design and documentation process by quantifying the extent of the deficiencies in the documents and their relative severity. Analysing the volume of RFIs in relation to contract value and project duration provides an indication of the extent of design and documentation deficiencies, whilst an assessment of the response times to these RFIs provides an indication of their severity. Although the RFI process is used by contractors and sub-contractors for a variety of purposes (see Table 1), its *primary* function is:

To formally request additional information, or clarifications to existing information, in relation to how the project is to be constructed to meet the project requirements.

Due to the wide variety of tasks for which RFIs are used, only the analysis of these *primary* RFIs – classified as *information clarifications* – should be used to determine the indicators of the overall quality of the design and documentation process provided on each project.

RFI classifications

The RFI *type* classifications were determined from an assessment of data collected on a number of case study projects as shown in Table 1.

Table 1 List of RFI *type* classifications.

RFI type	Type description
Alternative design solutions	Alternative design solutions submitted to the design team/client for approval.
Approvals	Drawings, documents, material samples or technical information submitted to the design team/client for approval.
Information clarifications	Requests for additional information or clarifications to existing information, from the design team/client.
Information confirmations	Requests for confirmation of both verbal and written information, provided in a manner that is not contractually binding on the contractor.
Other	RFIs issued for any other reason.

A breakdown of these *information clarifications* can also be carried out to identify the causes of deficiency which are most prevalent and allow comparisons between projects. Again, based on an assessment of data collected on a number of case study projects, the RFI *cause* sub-classifications were determined as shown in Table 2. *Information clarifications* are considered to be the *primary* RFIs and they are also expected to be the most numerous.

Table 2 List of RFI *cause* sub-classifications.

RFI cause	Cause description
Conflicting information	RFIs issued when two or more contract documents provide conflicting information about the same item or element.
Incorrect information	RFIs issued when the contract documents provide information which is erroneous.
Insufficient information	RFIs issued when the information supplied in the contract documents is considered incomplete.
Questionable information	RFIs issued when the information supplied in the contract documents - although capable of being constructed as designed - is considered inappropriate in relation to its application in the project.

DATA AQUISITION

As part of an overall study into information and communication flows within construction projects, drawing issues and the RFI process were identified as areas to be investigated closely. The study required research staff to visit a number of sites on a regular basis, and collect specific data relating to the information being communicated and the efficiency of the communication processes involved. This data was then categorised and input into computer systems for comparative analysis. The data for this paper has come from two similarly sized projects, procured using minor variations to the traditional procurement process.

- **Project A** is a 9 storey, prestige development which incorporates function rooms, restaurants, apartments, retail shops, offices, a gymnasium and an international standard size swimming pool. With an estimated final contract value of $A15.05 million, the project was completed in 22 months - 6 months beyond the original time for completion. The contractual arrangement for the development was based on a competitive traditional lump sum contract, with the Architect as design team leader and superintendent.
- **Project B** is a 9 storey, resort style apartment complex consisting of 117 apartments. The development includes facilities such as underground parking, kiosk, gymnasium, tennis court and swimming pool. The development was completed within the 12 month contract period, for an estimated final contract value of $A14.87 million. The project's contractual arrangement was a negotiated guaranteed maximum price contract with ongoing design development during the construction period. A Project Manager was employed by the client to act as their representative and help coordinate the design team.

Although the contractual arrangements of both projects were hybrids of traditional lump sum contracts, the communication practices were markedly different. The contractual arrangement on Project A dictated the flow of information and as a result all RFIs and ensuing responses flowed through the Architect. Conversely, the information flow on Project B was much less structured and RFIs could be sent directly to the project participant responsible, with a copy for circulation to the Architect and Project Manager. Responses were made in a similar fashion, although any action required had to be endorsed with an instruction from the Architect. Table 3 provides additional comparative information regarding the two projects.

Table 3 Comparative information relating to the case study projects.

Item	Project A	Project B
Original contract value	$13,639,098	$14,000,000
Final contract value	$15,050,000 (Est)	$14,870,000 (Est)
Original contract duration	16 Months	12 Months
Final contract duration	22 Months	12 Months
Total RFIs	1019	329
Total architectural drawing issues	398	91
Total architectural drawing revisions	412	233
Total engineering drawing issues	142	97
Total engineering drawing revisions	281	243

To collect the data, the various project correspondence files were searched and special forms devised for the purpose were filled out. Table 4 provides a list of the types of information collected regarding the RFI process. Access to project computer files of the documentation and drawing registers ensured accuracy and helped reduce the time taken to collect the data required.

Table 4 List of the main RFI data information collected.

Data description	Data item
Date	Date issued, date required, date response received
RFI number	Unique RFI number (for cross referencing to response mechanism)
References	Other documents referred
Issues	Number of issues raised/RFI
Initiator	Contractor, Sub-contractor
Recipient	Project manager, Client, Architect, Structural engineer, Mechanical engineer, Electrical engineer, Hydraulic engineer, Other consultants, Sub-contractor
CC Copy of RFI	Project manager, Client, Architect, Structural engineer, Mechanical engineer, Electrical engineer, Hydraulic engineer, Other consultants, Sub-contractor
Form of response	Site instruction /architects instruction (SI/AI), other correspondence, no response, other
Method of transfer	Fax, hand, courier, post
Trade	Trade package involved

DOCUMENTATION ANALYSIS

Project A

In Project A, there appeared to be a large disparity between the volume of architectural drawings and those produced by the engineering disciplines. The architectural drawing registers show that from an initial 150 drawings issued at the beginning of the project, the number of individual drawings issued steadily increased to 398 by project completion.

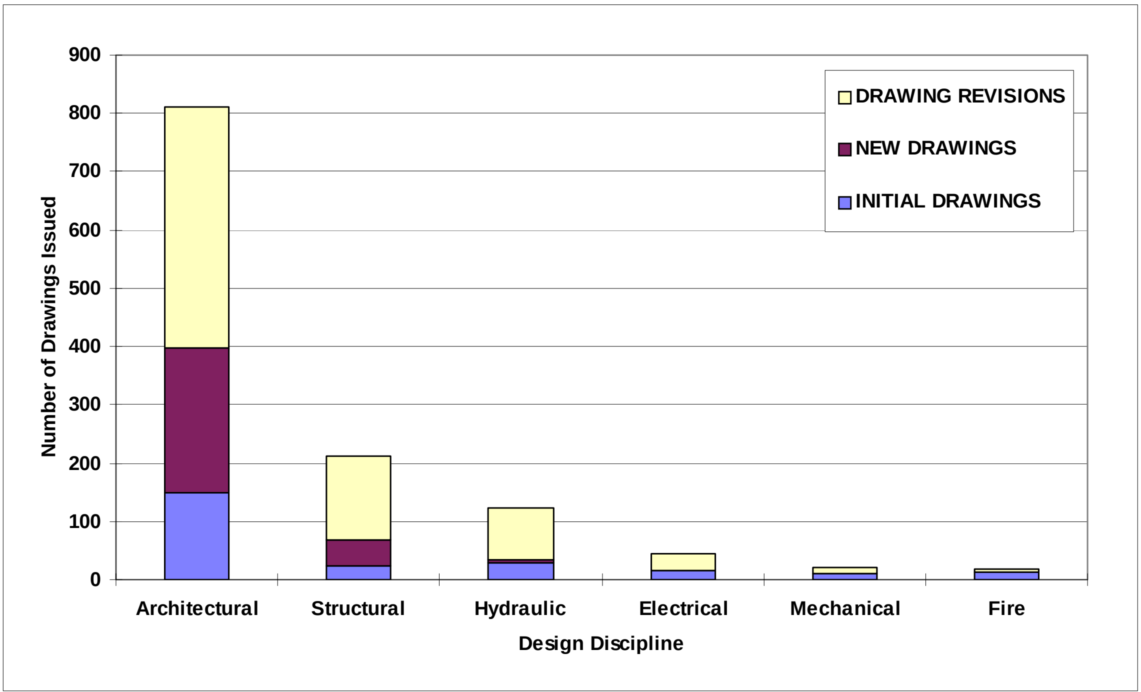

Figure 1 Breakdown of total drawings produced by discipline (Project A).

In addition to this increase in the number of contract drawing issues, the registers show that 412 drawing revisions had also been issued. This would seem to indicate that the initial issue of architectural drawings was insufficient to carry out the scope of works.

The registers for the drawings from the engineering disciplines show a completely different situation. A total of 92 engineering drawings were initially issued, increasing to 142 by the end of the project. However, of the 50 new engineering drawings issued during the project, 42 of these - the bulk of the new structural drawings - were issued within the first month and should probably be considered as initial drawings. Although 142 individual engineering drawings were issued, the registers also show that 281 drawing revisions were also issued.

These figures contrast dramatically with those of the architectural drawings. Although the number of architectural drawings issued had more than doubled, the number of engineering drawings remained fairly constant through the life of the project. The proportion of drawing revisions to contract drawings issued is much less for the architectural drawings than for the structural drawings. The majority of the engineering revisions were probably issued to accommodate the numerous changes to the architectural drawings. These results provide a clear indication of major deficiencies with the architectural design process.

Project B

In contrast to Project A, the analysis of Project B provided a level of similarity between the architectural and engineering disciplines.

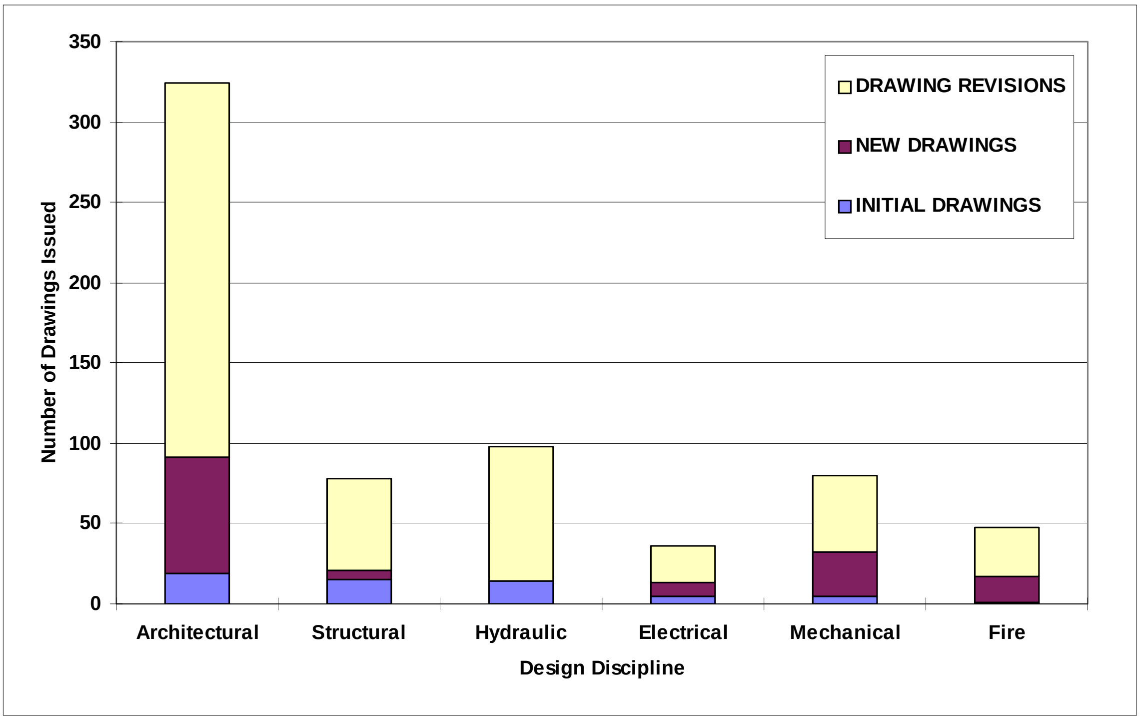

Figure 2 Breakdown of total drawings produced by discipline (Project B).

The registers for the architectural drawings show that from an initial 19 drawings, the number of individual drawings issued steadily increased to 91 by the end of the project. In addition to the increase in the number of contract drawings, the registers show that 233 drawing revisions had also been issued. Again this would seem to indicate that the initial issue of architectural drawings was insufficient to carry out the scope of works. However as noted previously, ongoing design development during the construction phase was part of the contractual arrangement with the builder.

The registers for the drawings from the engineering disciplines show a similar situation. A total of 40 engineering drawings were initially issued, increasing to 97 by the end of the project. The registers also show that 243 drawing revisions were issued.

Although the increase in the number of architectural and engineering drawings was consistent with the ongoing design development arrangement, the high number of revisions would seem to indicate major deficiencies in the architectural design development process. As with Project A, it is considered that the majority of the engineering revisions were issued to accommodate the numerous changes to the architectural drawings.

RFI ANALYSIS

Classifications

As indicated above, the *primary* RFIs are those classified as *information clarifications*, and it is these RFIs that provide an indication of the overall quality of the design and documentation process on each project. As shown in Figure 3, the main type of RFIs recorded for both projects were *information clarifications*, with Project A indicating 57.4% of all RFIs issued and Project B, 64.6%.

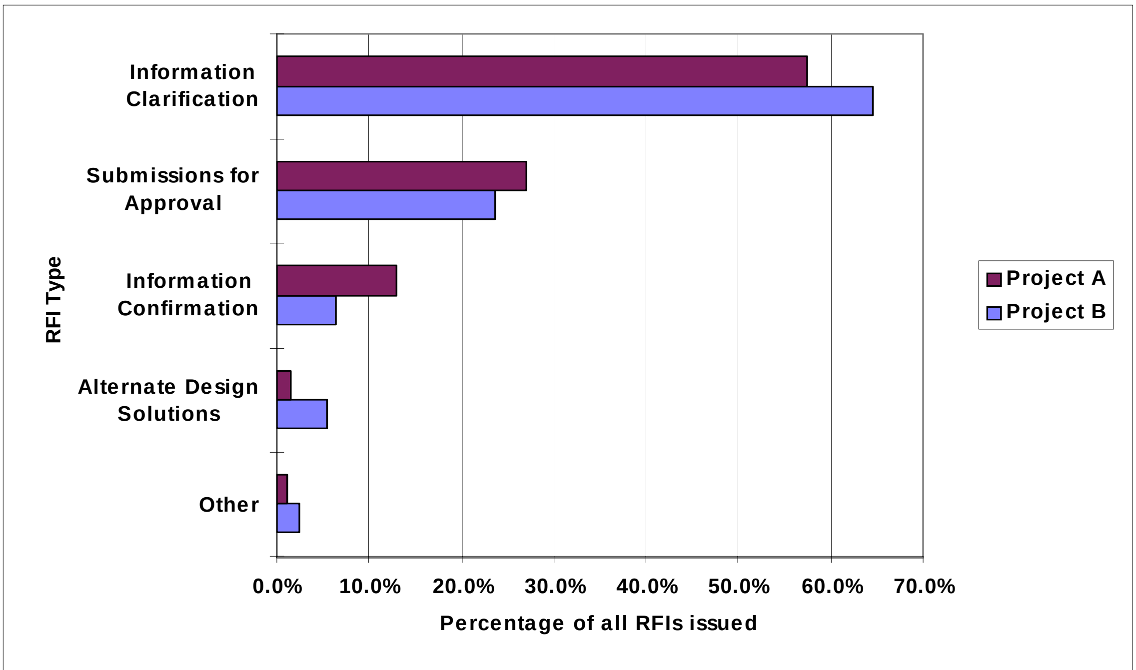

Figure 3 Comparison of RFI types.

As shown in Figure 4, the main cause for the issuance of *information clarifications*, was *insufficient information* in the documentation supplied.

However, in Project B, a large proportion of these RFIs were also due to problems with *conflicting information*. Although both projects indicate that the documents supplied provided insufficient detail to allow the contractors to carry out the work, the results for Project B indicate that design coordination problems were significantly greater, than on Project A.

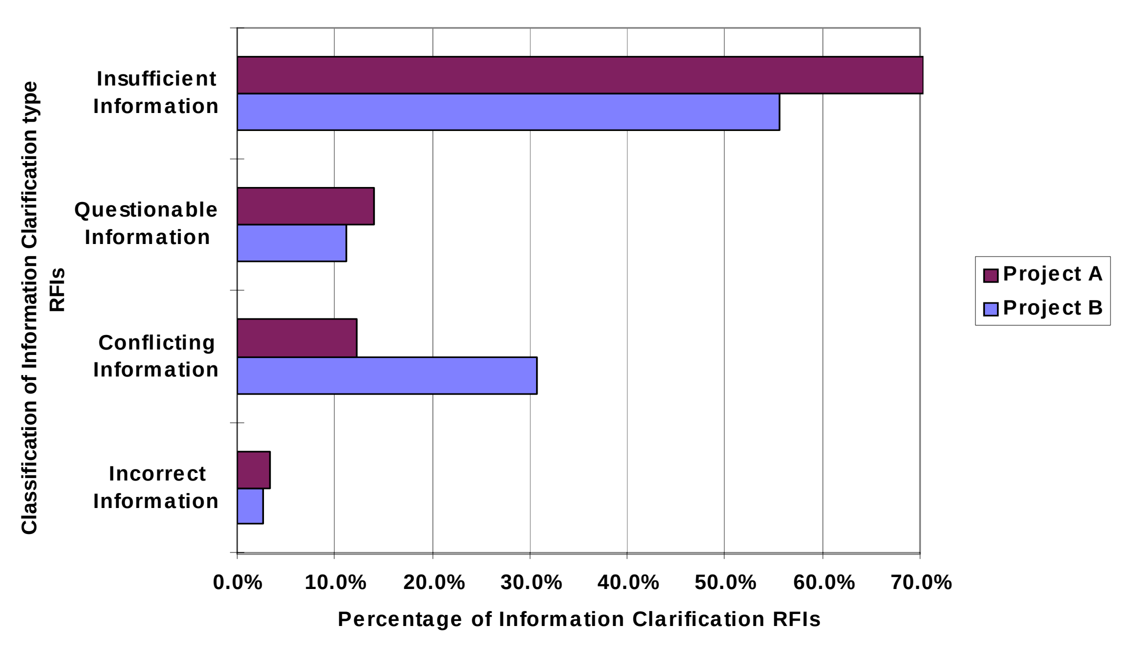

Figure 4 Comparison of classifications within information clarification RFIs.

These figures would seem to conflict with the results indicated in a recent industry workshop of contractors, who felt that "insufficient coordination between design disciplines" was the major problem with design and documentation (Tilley and Barton 1997). Although the extent of *insufficient information* is shown as being proportionally greater, the effect of *conflicting information* on construction process efficiency may be more significant than the percentages would suggest.

Extent of information clarification RFIs

When assessing the extent of *information clarification* type RFIs issued on a project, two variables which appear to have a significant impact are project size and complexity. The greater the size and complexity of a project, the greater the number of *information clarification* type RFIs likely to be expected. To allow comparisons between different sizes and types of projects, a method to account for these two variables was needed.

In considering project size and complexity, the product of final contract value and initial project duration was seen as being both simple and adequate for the task. Therefore, based on the above, the following performance indicator is proposed to provide a measure of the extent of design and documentation process deficiency:

$$PI_1 = \frac{N_c}{CV \times D}$$

where: N_c = number of *information clarification* type RFIs
CV = estimated final contract value ($100,000's)
D = initial project duration (months)

When comparing Projects A and B, the results shown in Table 5 were obtained.

Table 5 Comparison of projects showing the PI_1 performance indicator.

	N_C	CV	D	PI_1
Project A	586	150.5	16	0.243
Project B	153	148.7	12	0.086

The $\boldsymbol{PI_1}$ values achieved for both projects are plotted against the chart shown in Figure 5, which provides an indication of the performance of the design and documentation process in relation to the quality of the documents provided.

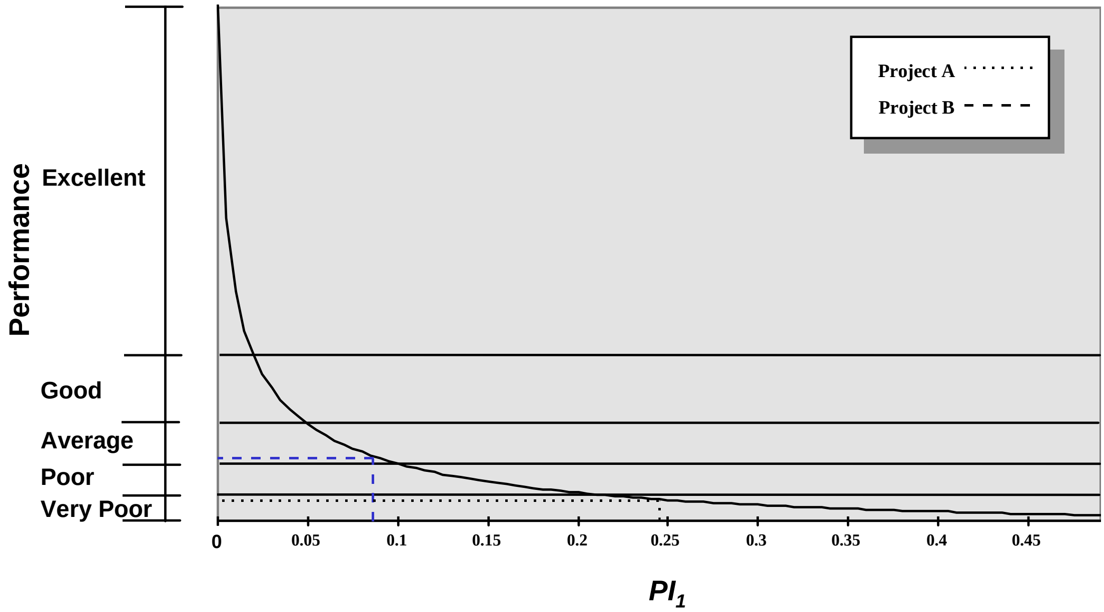

Figure 5 Comparison of the PI_1 indicators.

The results indicate that the initial ability of the documents to provide all the information required by the contractor was significantly greater for Project B than for Project A. Due to the issue of an excessive number of *information clarification* RFIs in relation to the project's size and complexity, the quality of the design and documentation process was rated as *very poor.* This rating would also seem to be supported by the large number of new architectural drawings and overall drawing revisions issued. Although the results for Project B indicate relatively better performance, the design and documentation process was still only considered to be *average* due to the high number of *information clarification* RFIs issued.

Time of response to *information clarification* RFIs

Integral with the issuance of *information clarification* type RFIs is a determination by the contractor as to the time the information is required to ensure that the project is not delayed. The ability of the design team to respond within these time frames ensures that the impact of deficient documentation is not aggravated. However where responses are provided late, the delays incurred in waiting for the required information ensure a reduction in the efficiency of the construction process. By measuring the extent of these delays, it is proposed that the following performance indicator, can provide a measure of the severity of the problem.

$$PI_2 = \frac{1}{N_c} \sum \frac{T_a - T_r}{T_a}$$

where: N_c = number of *information clarification* type RFIs with a response time specified
T_r = response time required (days)
T_a = actual time of response (days)

condition: If $T_r \geq T_a$ then $(T_a - T_r) = 0$

This mathematical constraint is provided to eliminate the counter-acting effect that *within-time* responses would have upon the value of the *beyond-time* performance indicator.

When comparing Projects A and B, the results shown in Table 6 were obtained.

Table 6 Comparison of projects showing the PI_2 performance indicator.

	PI_2
Project A	0.376
Project B	0.571

The PI_2 values achieved for both projects, are plotted against the chart shown in Figure 6, which provides an indication of how well the design and documentation process performs in relation to responding to deficiencies in the documents provided.

The results indicate that the ability of the design and documentation process to respond to the information requests of the contractor was greater for Project A than for Project B. However, due to the overall lateness of the majority of the *information clarification* RFIs, neither project rated well, indicating that the severity of the deficiencies with the design and documentation process was considered to be high on both projects.

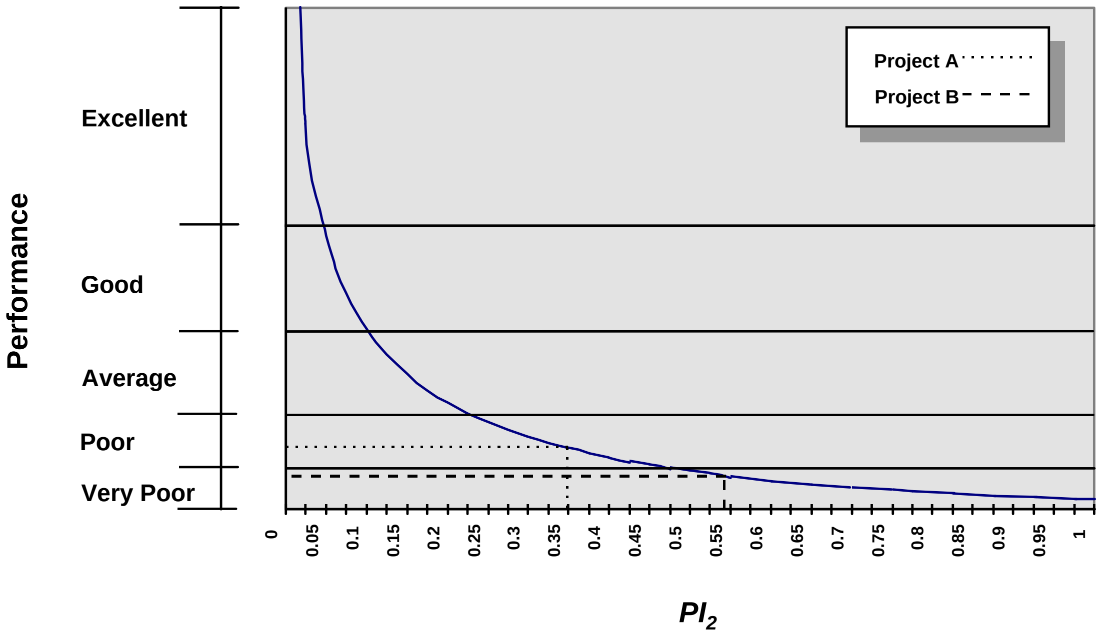

Figure 6 Comparison of the PI_2 indicators.

CONCLUSIONS

The quality of the design and documentation being provided, along with its effect on construction process efficiency, is of major concern to many parties within the

Australian construction industry. Due to this concern, a method of assessing design and documentation deficiency to allow project comparisons, was deemed necessary.

This paper has proposed three performance indicators to highlight areas of deficiency, by analysing project drawing and RFI registers. Factors such as the number of drawing issues and revisions, project duration, contract value, number of RFIs issued and requested and actual response times for individual RFIs, were used to develop these performance indicators. Where the analysis of the drawing registers gives an overall impression of design and documentation deficiency, the analysis of the RFI registers provides a method of measuring its extent and severity. To support the proposed indicators, the paper analyses data collected from two case study construction projects, thereby allowing comparisons between them to be made. The paper provides a simple and straightforward numerical assessment by which design and documentation deficiency can be assessed and compared to that of other projects.

It is noted that further research into the use of these performance indicators is needed to confirm the adequacy of the ratings proposed and address other issues relating to the impact that specific RFI sub-classifications might have on project performance.

REFERENCES

Burati, J.L., Farrington, J.J. and Ledbetter, W.B. (1992) Causes of quality deviations in design and construction. *Journal of Construction Engineering and Management,* 118(1), 34–49.

Kirby, J.G., Douglas, A. and Hiks, D.K. (1988) Improvements in design review management. *Journal of Construction Engineering and Management*, 114(1), 69-82.

Lutz, J.D., Hancher, D.E. and East, E.W. (1990) Framework for design-quality-review data-base system. *Journal of Management in Engineering*, 6(3), 296–312.

McGeorge, J.F. (1988) Design productivity: a quality problem. *Journal of Management in Engineering*, 4(4), 350–362.

Syam, A. (1995) Editorial. *Journal of the Australian Institute of Steel Construction*, 29(3), 1.

Tilley, P.A. and Barton, R. (1997) Design and documentation deficiency - causes and effects. *Proceedings of the First International Conference on Construction Process Reengineering*, Gold Coast, Australia, 703–712.