University of Southern Queensland
Faculty of Health, Engineering and Sciences

QUANTIFYING THE TIME AND COST ASSOCIATED WITH THE REQUEST FOR INFORMATION (RFI) OR TECHNICAL QUERY (TQ) PROCESS - A DESIGNERS PERSPECTIVE

A dissertation submitted by

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Abstract

Within the modern construction industry, shrinking budgets have forced consultants to significantly reduce costs to remain competitive. Inside the overall design and documentation structure, the Request of Information (RFI) process is identified as a critical but non-value adding activity. To reduce the impact of this process on the efficiency of the designer, this research project aims to accurately quantify the time and cost accrued by the designer.

To meet the defined research objective a detailed methodology was created to collect data from real world projects. This case study data includes the collection of the project factors, the designers costs and additional factors. This collected data was then manipulated and analysed to revel potential relationships between the project data and the cost to designers.

From this analysis it was identified that the construction value of a project had the strongest correlation with the number of RFI's produced. This finding also confirms previous studies into this aspect of the process. More importantly to the research objectives, it was identified that the project factors with the strongest correlation to the average cost per RFI to designers, is the Construction Value, the Construction Duration and the Number of Construction Plans.

Following these conclusions, the factors identified were used to develop a method of estimating the number of RFIs on a project and the average cost per RFI to designers. By combining these methods, a means of estimating the total costs for responding to RFIs on a project, for within the limitations set for this research project, was developed.

These developed methods however do not reduce the number and cost of RFIs. To do this the root causes of RFI's on the case study projects were investigated. This investigation revealed that the major cause of RFI's within the data set includes the 'Insufficient Information' and 'Other' categories. To remedy these major causes several recommendations were made. These recommendations included; the better education of employees, the implementation of a definitive internal auditing process and the better definition of communication systems within the contract documents.

Following the above outline, this research project has achieved the defined objectives. By accurately quantify the time and cost to designers, developing an estimation method and by making recommendations the number, costs and impacts of RFI's on future projects can be successfully quantified and potentially mitigated**.**

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Limitations of Use

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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Peter John Sparksman

0050106248

Signature:________________________

Date: **29/10/2015**

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CHAPTER 1 - Introduction

In the modern construction industry, the formal process in which the contractor or builder requests further information from the projects designers is known as the 'Request for Information', or RFI process.

The RFI process begins during a construction project where the contractor encounters a problem or has a question regarding how a certain aspect of the project is to be completed. To start the process the contractor will create and submit a formal 'Request for Information' (RFI) form. This form should accurately detail the problem or question that needs to be answered. Once the RFI is created by the contractor it is passed to the owner, their representative, the project manager or the superintendent.

When the RFI is received by the project manager it is either answered directly or forwarded to the relevant technical consultant so that a solution or formal response can be drafted. This solution may be in the simple form of a written instruction or complex, such as a complete revision of construction drawings. If the solution is acceptable in terms of time and cost, the response is then forwarded back to the contractor. If the contractor then agrees with the response the RFI is closed and work proceeds.

The entire RFI process from initiation to resolution as detailed above can at times be a lengthy and costly exercise. How the RFI process is handled on a development and how severe the problems encountered are, can have a massive impact on the cost and efficiency of an entire project. Because of this risk, more research into the topic is needed to help better define the process and its associated costs. Although some of the cost of the process is normally absorbed by all parties, this research project aims to quantify the time and cost associated with this process from a designer's perspective.

1.1 Background History

During the post war modernising of the construction industry in the nineteen fifties and sixties, the industry shifted away from the traditional design and build approach. Where once ‘master builders’ would be in charge of the entire process a modern segregated system emerged. In this modern process the ‘master builder’ has been replaced by three main people, the architects, the engineer and the contractor. (Salisbury 1997)

This separation into specialty areas occurred because of a number of reasons including the increasing number, scale and complexity of projects. However this separation of services unfortunately lead to the breakdown of communication between parties and ultimately the increase of problems encountered on construction sites. To facilitate communication between parties, the ‘request for information’ (RFI) or ‘technical query’ (TQ) process was created. This process was eventually formalised in the 1970’s due to the increased requirement for project documentation, driven by public liability legislation (Simpson, Atkins & Atkins 2008).

This defined process was then refined over the years into the current system that we see today. In the following chapters this process will be further investigated to detail the roles of each stakeholder, critical steps, major causes and the overall effect of the process.

1.2 Research Objectives

To better define the overall process and total cost of RFI’s on construction projects, more research must be undertaken. Further to this, a small section of the process has been chosen to be the topic for this research paper. To better understand the whole system, this research project aims to quantify the time and cost associated with this process from a designer's perspective.

In order for the designer to successfully and economically complete a project they must adequately provision for the potential of ongoing RFI’s throughout the construction program. However, the amount to provision is currently only be estimated based on previous experience or other in house methods. Because of the severe lack of information on this subject, this research project aims to quantify the time and cost accrued by designers in the RFI process.

To achieve this goal, this research project will first conduct a detailed literature review into the current RFI process and a brief overview of construction projects. This review will then define the roles and responsibilities of all parties involved within the RFI process and review all components, such as the RFI Form and Register. The review also aims to define key factors in the process that will affect the designer's efficiency so that these may be further investigated.

After thorough analysis of the current process and procedures, the project will then develop a methodology for selecting a group of case study projects. This involves developing parameters that will determine what case study projects are to be collected. It will then detail the specific project and designer's data that is to be collected. A model of these factors and the cost incurred by the designer on these projects will then be created and combined into a usable database. This data will then be analysed to identify factors that influence both the number of RFI's, associated costs incurred by the designers and the actual cause of the RFI.

From these identified factors conclusions can be made on how they could be used to identify future high risk projects. Recommendations can then be made on how the number of RFI's and their cost to designers can be reduced on future projects.

1.3 Overview of Dissertation

This dissertation contains seven main chapters and brief summary of these chapters is provided below.

1. **Introduction -** A brief introduction to the historical evolution of the RFI process, how the current system operates and the objectives of this research project.

2. **Literature Review -** Provides a detailed review of the current literature in regards to the RFI process. The review also identifies key factors that may influence the amount of RFI's on a project and potentially the cost to designers.

3. **Methodology -** This chapter details the methodology required to meet the research objectives. This includes the parameters for collection of data, how the collected data will be analysed and the associated requirements involved.

4. **Results -** Using the above methodology, the data will be collected and collated to obtain an accurate model of case study projects, their factors and the actual designer's time and cost in responding to RFI's.

5. **Data Analysis -** From this model, the actual cost accrued by designers in the RFI process will be compared to the collected project factors, to identify any correlations or relationships.

6. **CHAPTER 5 -Discussion -** Using the above comparison, key factors identified in the results will be discussed and further analysis will be undertaken to create a method of estimating costs to designers on future projects.

7. **Recommendations and Conclusions -** Recommendations will then be made on how future 'high risk' projects can be identified and how the expected number of RFI's can be reduced on future projects.

CHAPTER 2 - Literature Review

2.1 Introduction

Since the introduction of the ‘Request for Information’ or ‘RFI’ process, the formal structure has been modified and modernised into the process that exists today. This process is generally employed within the construction phase of a project but can often occur within separate stages in the overall development time frame, with completely different stakeholders. An example of this would be the well-defined RFI process in the planning and design phase. In this type of process, the entire request is between consultants and authorities, such as a local council or service providers. In this type of RFI, the authorities are requesting further information on the planning and design of a project, from the consultants such as planner’s architects or engineers. As this type of RFI generally occurs prior to the construction phase they will not be considered within this research project.

In the modern construction process, a contractor will generally employ the use of a RFI when he requires further information, encounters a problem or needs clarification on a technical issue. This is done by issuing a formal RFI form to the owner or their representative. This form should include the details of the problem or query, a time frame for response and any cost implications or estimates. The owner or their representative is then required to respond to the RFI by issuing a formal response or technical instruction. Once this is received by the contractor and they agree with the instruction the process is complete. (Ikigai Consulting 2014) This process is now very formal and well documented so that all parties have sufficient records of the enquiries and responses throughout the life of the project.

This chapter provides an introduction to construction projects and undertakes a comprehensive review of the RFI process from initiation to conclusion. This detailed review of the current literature will also provide a technical foundation for the proposed research. This chapter will also review the current information available on the roles and efficiency of designers in the RFI process. From this review, the key stages of the process from a designer’s perspective will be identified and factors that affect efficiency will be investigated.

2.2 Construction Projects

During the past century the construction industry has developed into an important part of the Australia economy. According to the Australian Bureau of Statistics as of 2009 the construction industry accounted for 6.8% of Gross Domestic Product and for 9.1% of the national work force. (Australian Bureau of Statistics 2010) These statistics place the construction industry as the fourth largest industry in the modern Australian economy. In terms of total construction project value the industry is split almost evenly between building projects and engineering projects, with a total value of $156 billion dollars in 2009, as shown below in **Figure 1**.

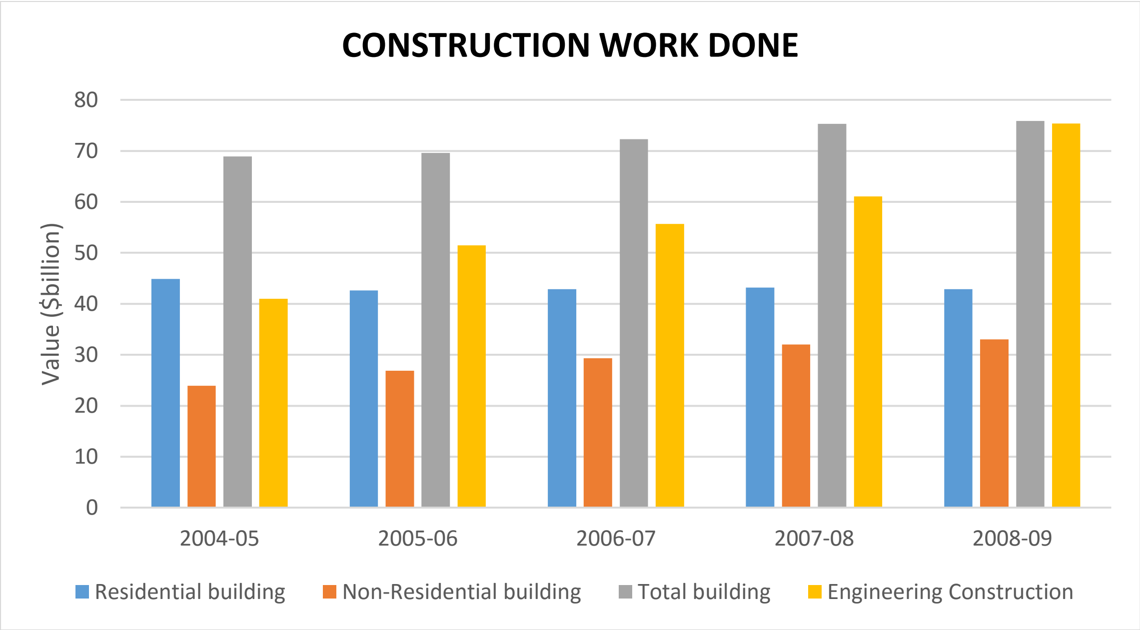


Figure 1: Total Construction Work (2004-2009) (Australian Bureau of Statistics 2010)

Although these figures have dropped over the past years due to the down turn in the national economy, the construction industry remains one of the true pillars of the economy. This down turn in funding within the industry has been shown to place even more pressure on stakeholders to perform the same roles but more efficiently. This pressure has also been shown to additionally reduce the level of service delivered and the consequences of this can be far reaching. These concepts will be further investigated within this chapter.

2.2.1 Types of Construction Projects

As shown above by the figures from the Australian Bureau of Statistics projects are split evenly into large groups. (Australian Bureau of Statistics 2015)

- Building projects such as residential, commercial, industrial and intuitional buildings.
- Engineering projects such as roads, highways, sub divisions, bridges and infrastructure.

These groups are further detailed in the subs sections below.

2.2.1.1 Residential Buildings

Residential buildings includes all new places of residence such as houses, townhouses, units or flats. These building projects can range from smaller two story buildings to large sky scrapers. However as the majority of these projects are generally small in value and complexity and therefore RFI's are not very common on these projects. The exception to this is multistorey apartment buildings where the sheer size and complexity of the project is known to increase the number of RFI's.

2.2.1.2 Commercial Buildings

Commercial Buildings include all retail, trade, entertainment, accommodation and office buildings. These construction projects can have a very wide range on size and complexity from small office buildings to large multistorey hotels and shopping complexes.

Figure 2: Westridge Shopping Centre (Kehoe Myers 2015a)

2.2.1.3 Industrial Buildings

Industrial Buildings include projects related to heavy industry such as factories, warehouses, mining operations and agricultural projects. The nature and size of these projects is generally large with most industrial areas needing a lot of room and facilities.

Figure 3: Homestyle Bakery (Kehoe Myers 2015a)

2.2.1.4 Institution Buildings

Institutional buildings include all schools, hospitals, healthcare, religious and aged care projects. These projects are generally very complex in nature as all of these buildings require vast amounts of services to be provided in high detail.

Figure 4: St Vincents Hospital (Kehoe Myers 2015a)

2.2.1.5 Infrastructure Projects

Infrastructure projects account for almost half of all projects completed in Australia by total value. This category relates to all infrastructure projects both public and private such as: roads, highways, bridges, railways, airports, water, sewerage, electrical and telecommunications.

Figure 5: New England Highway Stormwater Culvert (Kehoe Myers 2015a)

2.2.1.6 Subdivisions

Subdivisional works make up a large portion of the above infrastructure group as each subdivision includes several differed types of infrastructure to be installed at the same time. This category is also commonly a pre-requisite to all building projects as most buildings are created on new or reconfigured land.

Figure 6: Kara View Estate (Kehoe Myers 2015a)

2.2.2 Types of Procurement

These construction projects as shown above, either public or private are first initiated when a need for new infrastructure is identified. At the start of a construction project the proponent must first decide on the type of the procurement route to complete the development. This decision general depends on the timeframe, complexity and type of the project. The most common type of procurement route is traditional 'design bid build' method. (Designing Buildings 2015)

In the traditional type of procurement, the proponent engages a team of professionals to investigate and complete the project. In most instances the proponent first engages a Principal Consultant who in turn engages sub-consultants and ultimately the contractor who will carry out the construction.

This is in contrast to the modern design and construct process (D&C) where the construction contractor is involved from the inception of the project. In this model the contractor effectively takes control of the entire project as the superintendent, directing the consultant teams and the construction teams to deliver the project. This means that the RFI’s being submitted to the superintendent will not be of technical details because the design of the project is done within the project team (Rowe 1998). However in these Design and Construct jobs the superintendent will receive a number of RFI’s on how the design is to be completed such as site layout questions or aesthetics ect. The number of requests from the type of contract may be higher or lower than a normal construction project depending on the project complexity.

Another common type of contract is the modern construction alliance type. This procurement method attempts to strike the balance between the traditional and design and construct models. By focussing on the greater collaborate between design consultants and the contractor in good faith, the overall aim is to provide the best possible outcome for the project.

As the majority of construction projects follow the traditional method of procurement, this research project will only consider this type of construction projects and their associated RFI’s

2.2.3 Roles within the Construction Process

Within the traditional construction contract framework, the individual tasks and responsibilities of each stakeholder is well defined and are critical to the project's success. The individual roles of each party within this process is summarised in the following **Figure 7** and detailed in the sections below.

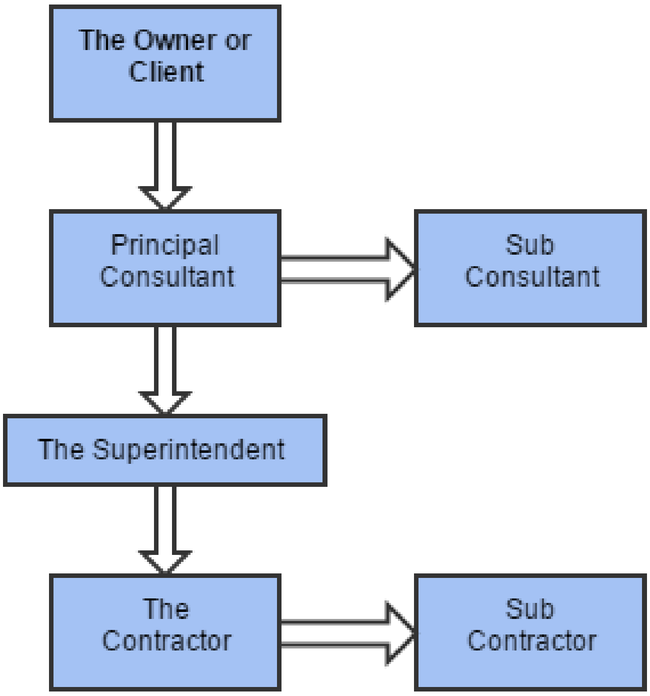


Figure 7: Construction Project Structure

2.2.3.1 The Principal

The Principal, owner or client in the construction process is in some regards the most important, as they initiate the development and provide the funds for the work to be completed. This process normally begins with a project that the client needs completed whether it is a straight forward private development or major public infrastructure.

As the principal is normally neither a designer nor a builder they will engage a team of consultants to plan, design and administer the work on their behalf. In a typical construction project a principal consultant is first engaged to identify, engage and manage all of the sub consultants required to deliver the project.

2.2.3.2 The Principal Consultant

The Principal Consultant within the construction project is the consultant engaged by the principal to manage the project and all sub consultants. The particular consultant chosen to be the principle consultant may come from many different disciplines depending on the nature of the project. For example building projects will usually have an architect as the principal consultant whereas a road or drainage project would usually employ a civil engineer. The chosen principal consultant is generally also appointed as the superintendent responsible for administering the construction contract, depending on the ability of the consultant to fill this role. Their role in the project includes organisation of the all project components such as the design and documentation, organisation of sub consultants, tendering, contract administration and construction management. (University of Illinois 2010)

The first role of the principal consultant or superintendent includes the design and documentation of the project. In this stage the owner engages the principal consultant to fully design and document the project in preparation for approvals, tendering and construction. This may include the use of sub consultants such as surveyors, planners, architects, certifiers or engineers. The range of sub consultants needed is entirely dependent on the type, complexity and requirements of the project.

Once the project has progressed through the design and documentation stage it is then put out to tender. In this process the project documentation is sent out to multiple contractors so that they may submit their proposed estimate of time and cost to complete the project. After the tender period has expired the principal consultant then provides to the owner a recommendation of which tenderer should be selected to complete the project. This can be based on several factors including price, timing, competency, qualifications and special project specific requirements.

Once the principal has agreed to engage the successful contractor, the superintendent then prepares contract documents to bind the contractor and principal to the agreement. These contract documents include the Formal Instrument of Agreement, Notice of Appointment of Principal Contractor, The successful Tender Form, Conditions of Contract, Project Specifications and construction drawings.

These documents are based on the appropriate Australian Standard for contracts such as AS2124 or AS4000 and will reference specific causes from these documents. This contract agreement once signed by all parties becomes a legally binding document and entitles the contractor to start work at the agreed time. (American Council of Engineering Companies of Kansas 2014)

After the projects contract has been prepared and signed the superintendent then shifts into a contract administration and project management role. At this point a sub consultant that specialises in project management may be engaged, depending on the type and complexity of the project. In the contract administration role the superintendent's job is to ensure that the conditions of contract are met by both parties such as progress claims, payments and contractual specifications. (Standards Australia 1992)

Management of the project is normally also assigned to the superintendent. This can be desirable so that any issues raised during construction can be quickly answered, maximising continuity and efficiency. Depending on the type of project this role may incorporate a range of responsibilities from undertaking inspections to project management and construction certification. (Government of Tasmania 2014)

2.2.3.3 The Designer

On smaller construction projects it is very common for the principal consultant or superintendent to be also the projects designer. As this research project is in fulfilment of the requirements of a Bachelor of Civil Engineering all further reference to 'the designer' will relate to a Civil Engineer known as the 'Design Engineer'.

2.2.3.4 The Contractor

Within the traditional construction project timeline the contractor is first brought into the project at the tendering stage. In traditional construction process the contractor is required to review the project documentation, specifications and subsequently assess the scope of works so that they can submit a conforming tender. If successful, the contractor is then required to sign the contract documents, as prepared by the superintendent, allowing works to begin. (Standards Australia 1997)

The internal management structure of the contractor varies depending on the size and nature of the company. The general framework usually consists of the ground staff, a site foreman and a project manager. An example of the general construction management frame work is shown in **Figure 8** below. (Hutchinson Builders 2013) Depending on the complexity of the project it may be necessary to engage in sub-contractors to complete some of the work if the main contractors do not have the sufficient skills or resources available.

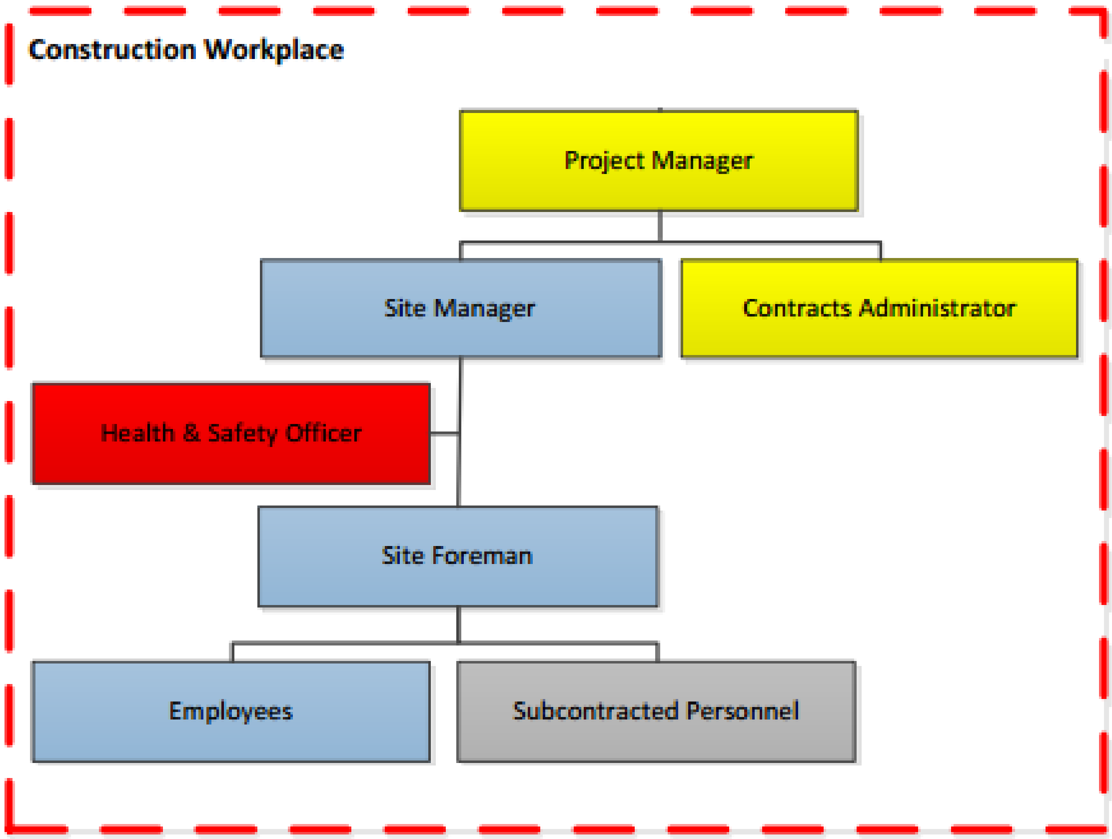


Figure 8: Flowchart of general construction management (Hutchinson Builders 2013)

2.3 The Request for Information (RFI) Process

At the start of a construction project a set of contract documents is agreed upon by both the principal and contractor. These documents which are normally prepared by the engineer or architect include the contract agreement, project drawings and specifications. On a perfect project these documents would be all that is required to complete the works, however this is rarely the case. In circumstances where additional information is needed to complete the project the contractor will employ the use of the Request for Information (RFI) process. (American Council of Engineering Companies of Kansas 2014).

The RFI process generally begins with a question raised by the contractors' management, an employee or a sub-contractor. This question will then be vetted up through the contractor's management framework and either rejected, answered or made into an official RFI. The official RFI first begins with the creation of the RFI form. This form should accurately detail the problem or question that needs to be answered. Additionally the RFI needs to reference the relevant project drawings, specifications, impact on time, quantify additional cost and if possible, propose a solution.

In some project management systems this traditional manual creation of forms has been replaced with virtual cloud based systems of creation, submission and resolution. These systems have the great advantage of automatic pre filling of information, tracking and redundancy systems. But at the same time the use of these systems in not wide spread and can also be expensive and hard to implement. Because of the limited use of these systems only the traditional method of creating RFI's will be considered in this research project.

Once the RFI is created by the contractor it is passed to the principal, their representative, the project manager or the superintendent. Once the RFI is received by the principal's representative a solution or formal response is then formulated. The impact on time and budget is then quantified by the project manager to verify the viability of the solution. If the solution is acceptable in terms of time and cost, the response is then forward back to the contractor. If the contractor then agrees with the response the RFI is closed and work proceeds. This entire process is summarised in the flow chart in **Figure 9** below.

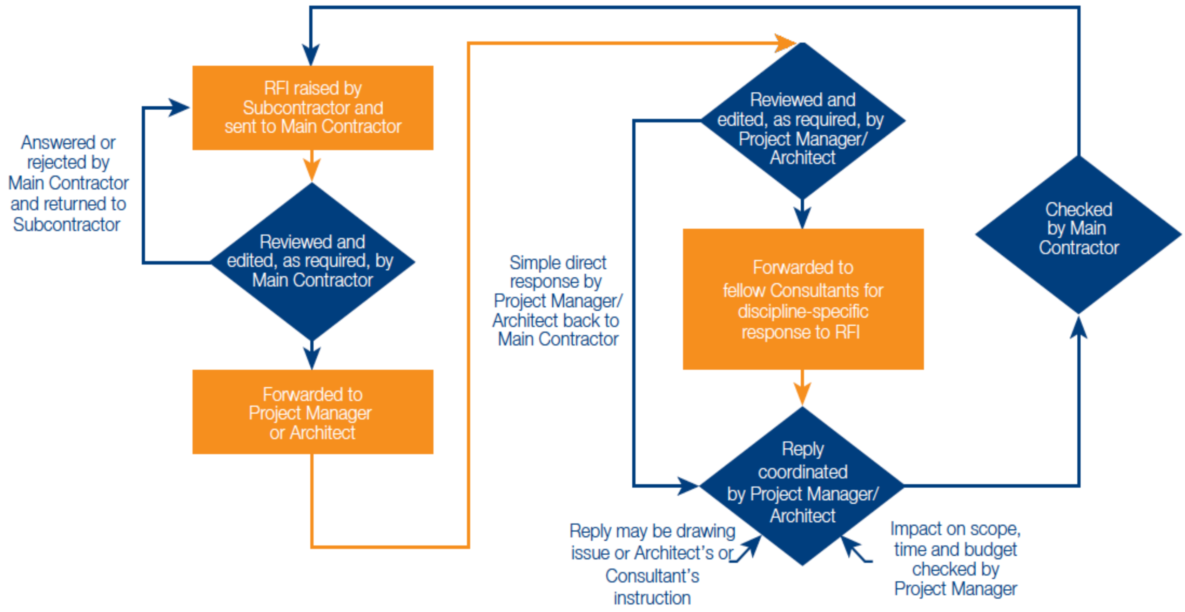


Figure 9: Overview of the RFI process (Aconex 2014)

2.3.1 Types of RFI

Although the request for additional information is the most general type of RFI used, there are several different roles that they can play including: (Kajewski, Weipper & Tilley 2002)

- Information Clarification. A request for clarification on a certain detail from the design engineer.
- Information Conformation. A request for conformation of a detail from the design engineer.
- Request for Approval. A request for approval of methods or materials.
- Request for Substitution. A request for approval of alternative materials.
- Alternative Design Solutions. A request for approval of an alternative design solution/s.

These categories make up the majority of cases but there are always other RFIs that do not fit into these categories due to their unique nature. Within this research project all types of RFI's will be considered as it is possible for contractors to exploit the system using these alternate categories, as further discussed in **Section 2.6**.

Within the overall RFI process, most stakeholders within the construction project will be involved. The following subsections give a summary of the roles of each participants in the RFI process.

2.3.2 The Principal

The principal or client's role in the construction process is somewhat removed from the RFI process. Because the principal has generally engaged a consultant to act as their representative within the contract, they will rarely be involved directly in the RFI process. However in the instance where an RFI may result in a major change or additional cost to the project, the owner may need to be involved to approve such a variation.

In occasions where the principal dose not engage a superintended they will therefore be the receiving party for all requests. In this case it will be the responsibility of the principal to either answer the RFI, if they have the required technical expertise or alternatively forward to an appropriate party who can answer it.

2.3.3 The Superintendent

As the superintendent is acting as the principal's representative within the contract, it is their role within the RFI process to review and answer the query. If the request cannot be directly answered by the superintendent it is his responsibility to pass it onto a nominated consultant or sub-consultant. In most circumstances this means that the RFI would be passed to a discipline specific representative that would be qualified to answer the query. (Aconex 2014)

Once the RFI is received by the relevant consultant a solution or formal response is created. This may be in the simple form of a written instruction or a complex as a complete revision of construction drawings. The formal response is then verified by the superintendent and then passed back to the contractor.

2.3.4 The Design Engineer

In the RFI process, the design engineer's main role is to answer technical questions from the contractor. These enquires can range from clarification on some construction details to a consideration of a complete alternative design solution.

Depending on the contractual arrangement, enquires maybe directed to the design engineer from the superintendent. Alternatively if the design engineer is the superintendent or principal consultant they are able to answer questions directly. Being able to answer these questions directly can save a significant amount of time and money on projects, as responses can be given directly to the contractor rather than having to be passed back through the superintendent.

2.3.5 The Contractor

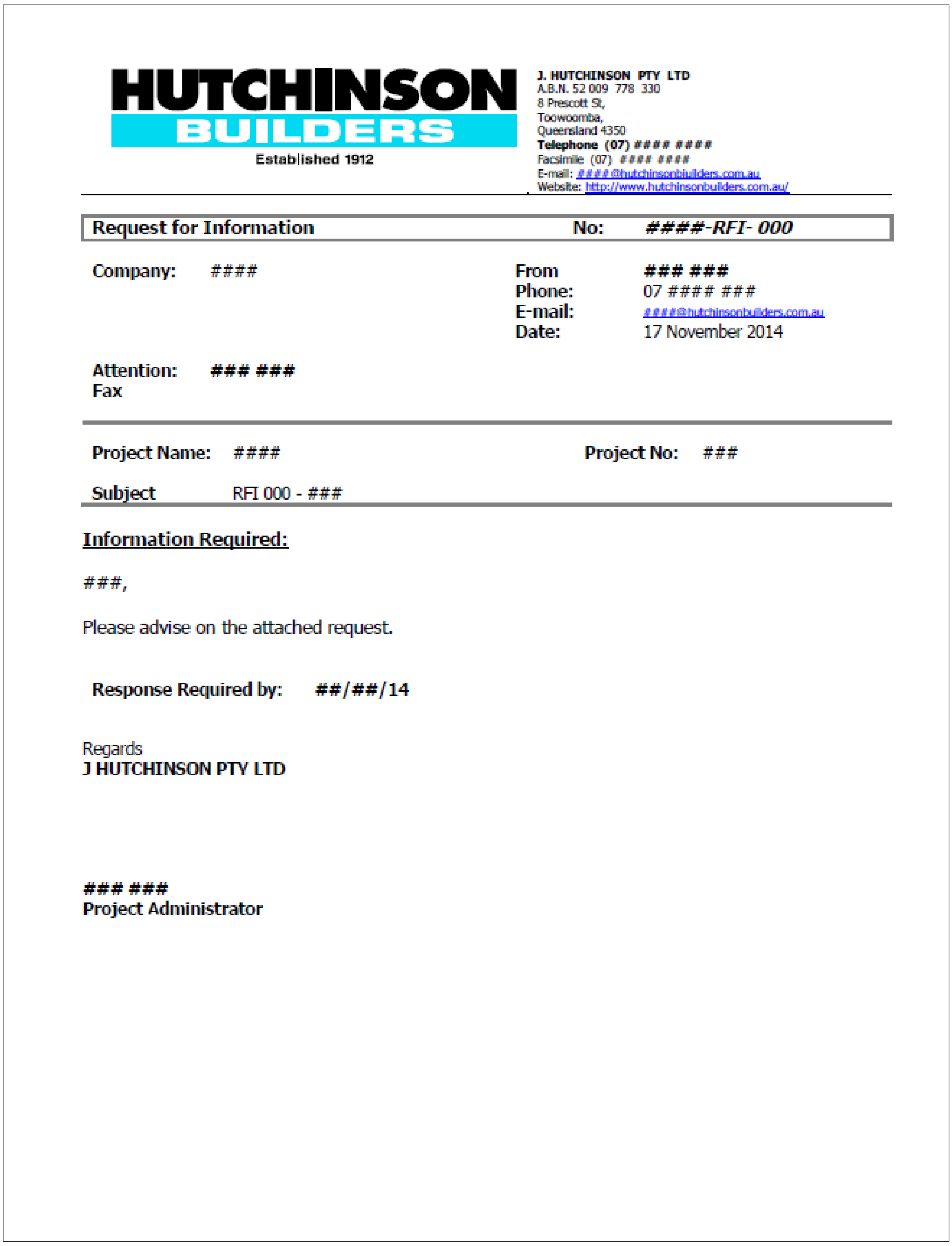
Within the RFI process the contractor is both responsible for creating, tracking and concluding RFI's. During a project if the design and documentation is lacking detail, approval is needed, a problem is encountered or alternative solutions are proposed the contractor may then employee the use of the RFI process. Within the construction management framework, questions or site issues may first be raised by employees or sub-contractors. In these cases it is important that the request is first passed up through the framework to the foreman, site manager and then project manager. This ensures that the request is not solvable by the contractor and will require an external solution from the superintendent.

Following this procedure it should be the responsibility of the project manager in all projects to create the official RFI Form and start the official process. This is generally completed using their specific system to create a RFI form relevant to the specific project. This form includes all significant details to the query such as the project, the problem and the time and cost associated. This form is then sent to the superintendent and logged on the RFI register.

Once the superintendent has reviewed the RFI they will prepare a formal response. This response then must be review and accepted by the contractors and thus ends the RFI process.

2.4 The RFI Form

The RFI form is in most cases the official start of the RFI process. While the contents of the form are generally the same, each contracting company will have a different format. This will depend on several factors such as the type of query, specific program or even the type of project. An example of the general layout of the RFI form is in shown in **Figure 10** below.



HUTCHINSON BUILDERS
Established 1912

J. HUTCHINSON PTY LTD
A.B.N. 52 009 778 330
8 Prescott St,
Toowoomba,
Queensland 4350
Telephone (07) #### ####
Facsimile (07) #### ####
E-mail: ####@hutchinsonbiuilders.com.au
Website: http://www.hutchinsonbuilders.com.au/

Request for Information **No:** ***####-RFI- 000***

Company: ####

From **### ###**
Phone: 07 #### ###
E-mail: ####@hutchinsonbuilders.com.au
Date: 17 November 2014

Attention: **### ###**
Fax

Project Name: #### **Project No:** ###

Subject RFI 000 - ###

<u>Information Required:</u>

###,

Please advise on the attached request.

Response Required by: **##/##/14**

Regards
J HUTCHINSON PTY LTD

###
Project Administrator

Figure 10: Request for Information (RFI) Form (Hutchinson Builders 2013)

The general structure of an RFI form will be similar to the example form shown above. This will first include an official title or header that includes:

- The project name and number. This project name and number is to help track the project through the contractor's internal documentation system. The superintendents or consultants project number may also be listed to assist with document control.
- The RFI number. The official RFI number is used to give reference to the RFI so that it may be tracked through the process.
- The name of the company and person responsible. The request like a formal letter will be addressed to the company responsible for the response and made attention of the person in charge. In most cases this will be the superintendent and the appropriate contact.
- Contact details. The RFI is always addressed from person responsible for raising the RFI which in most cases will be the project manager. Their contact details are always included on the RFI so that a response can be sent back to them promptly.

The main purpose of the RFI is then detailed within the subject section of the RFI form. This section should include all of the relevant details regarding the request depending on the type of request such as: (American Council of Engineering Companies of Kansas 2014)

- Clarification Needed. Details what aspect or detail of the project requires clarification. This type of request would normally include the drawings or specifications with areas of clarification highlighted.
- Information Conformation. The specifics of an item or detail that needs to be confirmed by the designers.
- Request for Approval. Methods or materials are requested to be approved by the designers or superintendent. This would include any relevant details on the method or material such as product specifications and/or standards.
- Request for Substitution. A request for approval of alternative materials. This request would be used if the contractor wished to uses an alternative product

to that specified in the contract documentation. This request would have to include all relevant information on the proposed product.

- Alternative Design Solutions. A request for approval of an alternative design solution/s. This request would be accompanied by the specifics of the alternative design solution including proposed methods, materials and specifications.

All of the above request types would usually be accompanied by the following: (American Council of Engineering Companies of Kansas 2014)

- References to any relevant drawings, details or specifications
- A statement of the impact of the request, including time and costs.

The final section of the RFI includes the official endorsement of the RFI by the project managers and a date for response. This due date for response is normally set as a certain period from lodgement, as defined within the contract. It should be noted that timeframe is one on the most critical aspects of an RFI. This is because this date not only sets a timeframe for a response but can also be used by the contractor to claim additional time and costs if it is exceeded.

2.4.1 The RFI Register

The RFI register is the main tool that contractors and consultants use to keep track of the RFI's issued on a project. The sheet normally includes the details of the project, RFI numbers, the current status, brief description, date requested/required and any additional notes. (Royal Melbourne Institute of Technology 2002) This basic summary of the requests is a good tool for tacking RFI's and summarising all of the essential information on one page. In most modern RFI systems the register is automatically populated and updated as requests are produced and resolved. An example of a register is shown in below in **Figure 11.**

J HUTCHINSON PTY LTD 1

HUTCHINSON BUILDERS

PROJECT:		
JOB NO.:		Open
Document No:		Closed
DATE:		Urgent

REQUEST FOR INFORMATION REGISTER

HB RFI No.	Date RFI Sent	Sent By	Sub Ref	Details of RFI	Date Response Required	Discipline	Date Resolved	Comments
0001								
0002								
0003								
0004								
0005								
0006								
0007								
0008								
0009								
0010								
0011								
0012								
0013								
0014								
0015								
0016								
0017								

Figure 11: Request for Information (RFI) Register (Hutchinson Builders 2013)

2.4.2 Construction Discipline

Due to the complex nature of RFI's the forms are generally categorised of construction discipline. This allows for a high number of RFIs to be easily sorted and distributed to the correct departments so that answers can be obtained efficiently. In a large building project the list of these disciplines can be quite large and range from Architectural to electrical and mechanical.

As most Civil Engineering projects share common disciplines, the following categories have been adopted for this research project.

- Site Works. This category includes all enquiries related to the general site works such as clearing, bulk earthworks, building works, traffic control or geotechnical investigation.
- Road Works. All enquires in relation to roadworks fall into this category such as quires regarding road or kerb alignments and levels.
- Stormwater. All enquiries regarding all site stormwater is placed into this category. Such as pipe types, class, grades and levels.
- Sewerage. The category includes all enquiries regarding the sewerage reticulation. This could range from pipe sizes to manhole depths and drops.
- Water Reticulation. All enquiries regarding the water reticulation in a project. This may include questions regarding the alignment, clashes with other services or testing procedures.
- Electrical and Communications. This category includes all questions regarding electrical and communications on the project. Although these questions will normally be answered by the electrical designer it is the responsibility of the principal consultant to forward these queries on.

While these categories will cover the basic works on most civil projects it is noted that other types of projects, such as building projects, will produce RFIs that do not fit into any of these categories. Because of this it is proposed that a seventh category is adopted to cover these types. This seventh category is defined as:

- Other Types. As the nature of RFI’s is very dynamic the remainder of uncategorised RFI’s fall into this category.

2.5 Major Causes of RFIs

As the construction industry has modernised, the complexity of projects is also seen to be increasing. In recent years, this increase in complexity has also been restricted by shrinking budgets, forcing the owners, consultants, designers and contractors to improve efficiency wherever possible.

Separately increased competition within the engineering and architectural fields has increased in recent years, leading to consultants having to reduce the level of service offered in order to remain competitive. This coupled with the increase in project complexity has greatly increased the chance of errors and omissions being made in project documentation. (Zack 1998) Minor errors in the design drawings and documentation however are not normally noticed until the project is under construction. By this time the contractor is required to employ the RFI system to resolve the issue.

In a perfect world the documentation of a project would be so comprehensive that there would be no reason for the RFI process. In reality to achieve efficiency and commercial sustainability this level of documentation is not viable and hence the RFI system will be used to resolve any issues. (Mohamed, Tilley & Tucker 1999) The number of RFIs raised during a project can be directly related to the number of factors such as, project size, duration, organisation, contractual arrangement and the quality of the design drawings and documentation.

2.5.1 Design and Documentation Quality

The design and documentation, or the lack of, is arguably the largest cause of RFI's in all projects. This is due to the fact that if the design and documentation is lacking in quality or detail then the contractor will experience a large number of problems on site and subsequently produce a large amount of RFIs. This major cause can be broken down into the following sub categories (Tilley, Wyatt & Mohamed 1997).

- Conflicting Information. Where designers are asked to detail a large or complex project, there may be continuality issues that present conflicting information, details and specifications. In these cases the contractor is forced to request more information from the designer so that the correct information can be obtained.

- Incorrect Information. In some cases the designer will have detailed or specified something that is incorrect or that the contractor knows is wrong. These kind of enquiries must be answered by the designer so that the correct information can be passed on to the contractor.
- Insufficient Information. On some projects the lack of sufficient detail in the design documentation will force the contractor to request further information so that the project can be completed.
- Questionable Information. On some projects the information supplied in the contract documents is considered to be inappropriate for its application. This leads to an RFI been created to request the use of an appropriate solution.

In addition to these sub categories other notable cause of RFI's include:

- Misleading Information. In some projects the contractor or designer could be given incorrect information that leads misleading information. The most common cause of this is incorrect survey or as constructed information where the contractor is asked to match into existing but the connection is not in the specified location or not possible. In these cases the contractor is required to submit a request for additional information or may even request entire redesigns.
- Unforeseen Circumstances. In some cases there may be latent ground conditions (for example the presence of un-expected soil or ground water) that was not expected with the available information at the time of design and documentation. In these cases the contractor will submit an RFI to get appropriate direction from the designer.

From the above categories it can been seen that the majority of issues stem from omissions made by the designer when creating the documentation. Studies into the process have revealed that there was a steady decline in the quality of the design and documentation on construction projects from 1985 to 1999 and this trend may continue today. (Tilley, McFallan & Tucker 1999). This study pointed to a number of factors influencing this decline, including the drastic reduction in fees for design services and introduction of risk avoidance strategies due to increased litigation.

In this competitive industry often the level of service must be lowered to reduce the total costs so that jobs can be won. This lowering of service offered means that there will be more omissions within on the drawings and hence more RFIs will be created on the project.

2.5.2 Project Cost, Size and Duration

Although the cost, size and duration of a project is not the direct cause of RFI's there has been a well-documented increase in RFI under these circumstances. In a recent study of RFIs and their impact on construction projects by the Navigant Construction Forum found that on larger projects (with a contract value between $5 million and $5 billion) the total amount of RFI dramatically increases with the cost and duration.(Hughes et al. 2013) The findings of the article are shown below in **Figure 12** and **Figure 13.**

TABLE 2 - NUMBER OF RFIs PER $1 MILLION OF CONSTRUCTION COST
(PROJECTS WITH $5 MILLION - $5 BILLION CONSTRUCTION COST)

CONSTRUCTION VALUE	# OF PROJECTS	# OF RFIs	AVERAGE # OF RFIs/$1 MILLION
$5million - $50 million	333	349	17.2
$50 million - $100 million	173	587	8.3
$100 million - $250 million	143	715	5.0
$250 million - $500 million	90	757	2.3
$500 million - $1 billion	37	1016	1.6
$1 billion - $5 billion	50	1676	1.1
Grand Total	**826**	**617**	**9.9**

Figure 12: Number of RFI's Issued by Construction Value (Hughes et al. 2013)

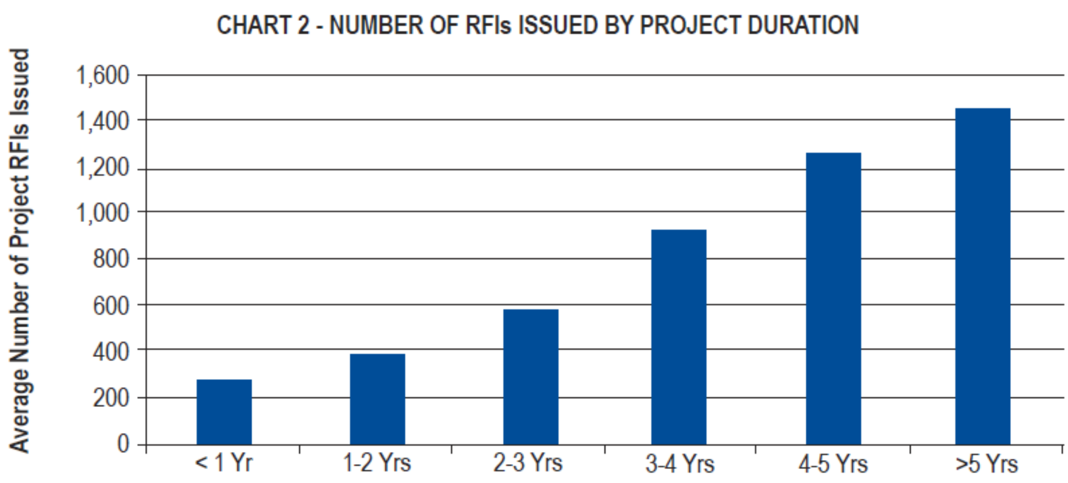


Figure 13: Number of RFI's Issued by Project Duration (Hughes et al. 2013)

As can be seen in these figures, both project cost and duration display a strong relationship with the total number of RFIs' on a project. It should however be noted that these values were collected on major infrastructure projects from all over the world with very large construction values and durations. Because of these constraints, care must be taken when making comparisons to this data.

Other studies of contractors and construction projects have shown similar relationships between factors. A 2013 study of the effects of the RFI process on contractors, collected data for total construction value of projects and plotted them against the total number of RFIs. These graphs are presented in **Figure 14** below. (Dinsmore 2013)

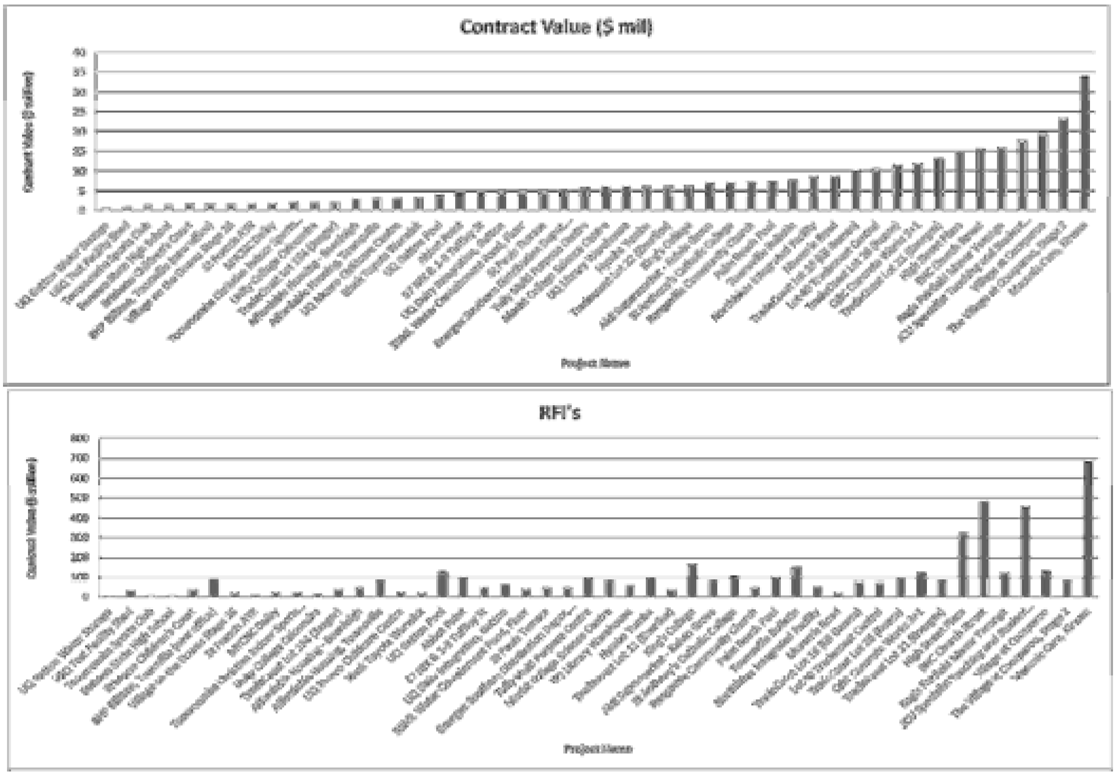


Figure 14: Visual trend for Contract Value verses number of RFIs (Dinsmore 2013)

From visual inspection of the above figure it can be seen that a significant relationship exists between the contract value and the number of RFIs on a given project.

This data set seems to complement the other data set given above by the Navigant Construction Forum, as it fills in the gap in contract values from zero to $20 million dollars.

Other conclusions from this study were that overall the number of RFIs increased with the following factors: (Dinsmore 2013).

- The projects are of high value from $15 to $34 million
- Have durations exceeding 11 months
- Complex projects such as residential dwellings or retirement villages.

Of the above factors it is likely that both the project value and duration are both related to the complexity of the project. Additionally as complexity increases so do the amount of materials, costs and time required to construct the project. It can then be assumed that project complexity is a factor of the projects size, cost and duration.

The level of complexity of a project, is seen to drive the overall number of RFI's as it also ties into the quality of documentation on any given project. With the increase of complexity of a project the complexity and extent of the documentation of the project also increases. This could lead to a higher chance of errors and omissions in the design and documentation, thus an increasing the number of RFI's

2.5.3 Project Organisation

The organisation of a project and its contractual arrangements can also have a large effect on the number of RFI issued during a project. This is due to not only the management of the site but also the effectiveness of communication and the amount of resources available to all parties.

On large construction project the potential for poor management of site and communications has the greatest potential to affect the amount of RFI's issued on a project. This is simply because of the large amount of personnel on site the higher chance that this framework may break down. A specific example of this is if the project manager is not reviewing RFI's sufficiently, two separate subcontractors could encounter the same problem and then two requests for the same information may be created.

As this cause of RFI's is more qualitative than quantitative, this subject will not be investigated further within this research project.

2.6 RFI Efficiency

Overall there are many different factors that influence the efficiency of the RFI process. The common factors include the effectiveness of communication between all parties, the administration time needed for requests and responses, and simple mistakes made while producing or responding to an RFI.

In the majority of cases the overall efficiency of the RFI process is directly linked to how well the parties involved are able to communicate. If all parties are able to effectively communicate, then problems and solutions are able to be communicated and understood, eliminating the need for continual clarification of the subject. Whereas poor communication can lead to incorrect information given in either the request or response and could lead to either party being misled as to what the actual problem or solution really is.

Administrative processes between parties can also have a large effect on the time taken to produce or respond to an RFI. These delays can either be caused by the administrative system employed or the staff involved with both the request and response. In larger projects the handling of RFI's is the duty of a specific employee. But on smaller projects this employee may have many other responsibilities and thus will not be able to handle the request quickly.

The other major factor that can impact to the efficiency of the RFI system is the potential abuse of the system by both contractors and consultants.

2.6.1 Abuse of the RFI system

While the general use of the RFI system is both useful and needed, there is now a growing trend with the construction industry towards the abuse of the RFI system. It is important to note that abuse of the system occurs on a small minority of projects but all parties need to be informed of the causes and consequences in case they arise.

The most common form of abuse of the systems is when a contractor submits a large number of 'false' RFI's for a number of different reasons, this can then create the illusion of negligence by the designer. As a consequence the contractor can then use this to further claim variations and extensions of time due to the impact these delays have had on the contractor's efficiency. (Zack 1998)

The abuse of the RFI system usually occurs by the contractor using the system for normal communications (Simpson, Atkins & Atkins 2008) such as:

- Inappropriate Questions. RFIs containing questions that are not appropriate to be answered by the superintendent or designers such as information on propriety products. This also covers cases where the contractor asks for details that are already stated within the drawings or specifications.
- Submissions of information. In this case the contractor is submitting information to the designers or superintendent such as test results.
- Responses to non-conformances. If the contractor is given a non-conformance notice they sometimes submit an RFI in response to the notice.
- Disagreeing with the Response. In some cases the contractor will receive an answer to an RFI, wait a length of time and then respond by either disagreeing with the response or asking for further clarification. By doing this the contractor effectively delays the closing date of the RFI, creating the illusion of delay.

2.6.2 Addressing Inefficiency and Abuse

While the majority of contractors will use the RFI system efficiently and without abuse, steps should be taken to ensure that efficiency is maintained and abuse is unlikely occur. In the journal article 'RFIs - use, abuse, control' the authors recommend that the solution to both efficiency and abuse is the implementation of clear definition of the communication procedures. (Zack 1998) The recommended definitions and processes that are to be considered for inclusions into the contract documents are the following:

- Drawing or Detail Clarification. Define a proper drawing or detail clarification system. Establish what the system should be used for and what the response time should be limited to.
- Non-Conformance Notice. Establish and define a system for notifying the contractor of a non-conformance. In this defined system the contractor is given a specific response notice that could be implemented instead of an RFI.

In this system the time frames of both the notice and the response is agreed upon by all parties.

- Project Communications. Define a clear communication pathway that information such as requests and responses will follow. Within this defined system an understanding must be reinforced that communications may be rejected if they do not conform to the proper procedures.
- Requests for Information. Establish that the RFI system should only be used when the contractor is in need of additional information that is not included within the drawings or specifications. Within this system make allowances that the RFI's may be rejected if they are simply routine communications or should be covered by a different system.
- Request for Conformation, Approval or Substitution. Establish and define a clear system for the contractor to submit requests for approval, conformations and substitutions.
- Improperly Made Requests. Define within the contract the contractor may not be entitled to claim extensions of time or variations where they have elected not to follow the previously defined procedures for submitting requests.

If these definitions and processes (or something similar) are included in the contract documents and adhered to by all parties, the efficiency of the RFI process could potentially be improved and the potential abuse of the RFI system should be mitigated.

2.6.3 Improving Design and Documentation Quality

As identified above in **Section 2.5.1,** one of the major cause of RFIs on a project is the quality of the Design and Documentation. Unlike any other of the major causes of RFIs, this category is unique as the Design Engineering exercises a large amount of control on it and can hence directly influence the potential number of RFIs on a project.

For this reason, improving the quality of design and documentation has been the subject of a number of research projects. One of these recent projects, based on a survey of industry members, concluded that:

“The survey results indicate that there are still major problems with the design and documentation process in the Australian construction industry, which are leading to construction inefficiencies and increased project costs and durations. To achieve improvements in overall construction process efficiency it is necessary to improve design and documentation quality well above their currently declining levels. “ (Tilley, McFallan & Sinclair 2001)

To achieve these improvements the authors proposed that an overall change in the industry is required to shift away from the risk avoidance culture and cost based procurement process that is seen to drive the current industry. In addition to these overall proposals, the authors also proposed number of strategies to improve the quality of design and documentation. These strategies include:

- **Education and Training.**
  Provide greater education and training to all employees through tertiary training and CPD
- **Design & Documentation Coordination.**
  Set predetermined standards for the coordination of design elements between parties.
- **Design & Documentation Time Allowances.**
  Create a greater awareness of the actual time require to properly design and document a project.
- **Design & Documentation Fee Allowances.**
  Educate on the advantages of non-price based selection of design consultants.
- **Procurement Methodologies.**
  Investigate the appropriate method of procurement for a project before commencement.
- **Independent Reviews.**
  Appoint an independent 3rd party consultant to review the documentation against minimum standards, prior to the documents being issued.
- **Value Management.**
  Conduct a value management studies on projects above the $10M mark.

- **Industry Perceptions.**

  Designers need to properly define their engagement with the client and need accurately consider the contractors capabilities when preparing documentation.
- **Accountability of design consultants.**

  Hold design consultants financially accountable for the consequences caused by lack of quality in design and documentation.
- **Client Briefs.**

  Client briefs need to clearly state what their requirements are for the project.
- **Knowledge Management.**

  All stakeholders within the industry must develop a method to capture and retain knowledge for the overall benefit of the industry.

Even with these improvement strategies defined, the real challenge to improving design and documentation quality is having these adopted by the industry. As most of these strategies are seen as been additional overhead expenses most will simple be ignored by most industry stakeholders.

2.7 Effects of the RFI Process

Although the use of the RFI system is necessary to handle site issues found during construction, due to the competitive nature of the industry, the time and cost associated with the RFI process is rarely documented. Significant time and cost can be incurred quickly due to a large number of RFI's being submitted, this has the potential to send the entire project off budget, for all parties involved. This research project aims to help define and quantify this process so that it can be better understood for all parties. The following subsections proved a brief overview of the impacts of the process on each stakeholder.

2.7.1 Impacts on the Principal

Although the costs involved within the RFI process are rarely documented, it can be assumed due to the competitive nature of the industry that some of the cost are passed on and shared by all stakeholders. However this does not account for additional costs that the principal would sustain that are unique to the principal.

The first major impact on the principal in the RFI process is obviously the potential increase in the cost of the project. At the start of the project the principal signs a contract with the contractor to complete the works for a certain price. Normally the client will then prepare a final budget with a certain amount of contingency in place for construction problems. If a severe RFI is encountered during the project and large change in design is required, the cost implications of this may exceed the contingency amount allowed for in the principal's budget

The second major cost to the project from the RFI system is the additional time needed to produce, resolve and implement the RFI. This delay time has the potential to significantly delay the project practical completion date and thus set back the hand over to the owner. Depending on the type of project this could potentially result in the inclusion of significant holding costs (such as interest repayments), additional penalties, fees and charges for financial arrangements, cash flow issues with delayed sales etc.

As the scope of this project is to focus on the time and cost accrued by the design engineer, further aspects of the costs to the owner will not be investigated.

2.7.2 Impacts on the Superintendent

As the role of the superintendent can vary so drastically the impacts of the RFI process on the superintendent can also vary. In some projects the superintendent may not be the design engineer so the only cost will be the management costs associated with handing requests on to the appropriate consultants and delivering solutions back to the contractor.

In this research project it has been assumed that the Design Engineer is the superintendent to the project. This assumption has been made to allow the collection of data from consultants easier and hence impacts on the superintendent are considered as impact on the Design Engineer.

2.7.3 Impacts on the Design Engineer

Depending on the contractual arrangements, the design engineer can have a wide range of responsibilities such as creating the project construction documentation, drawings, specifications and may also be required to answer any queries regarding them. This process has the potential to exhaust the design engineer's entire budget for the project depending on the amount and severity of the RFI's.

This process becomes critical to the design engineers budget if a large amount of RFI's are made and there is a high level of complexity and rework required for the responses. If the RFI's are minor in nature it may be possible to answer them quickly and the cost to the design engineer will be minimal. However in some cases, the RFI will bring into question major design elements or highlight major issues with the constructability of the project. In these cases, a major redesign of the project may be required. This has the potential to undermine the design engineers ability to cover their costs for undertaking the work and any chance of a making a profit.

It is this time and cost associated with design engineers actions within the RFI process that this research project aims to study and analyse.

2.7.4 Impacts on the Contractor

As it is normally the contractor who initiates the RFI process they are largely in control of the process and ultimately the number of RFI's created on a particular project. During the tender stage of the project the contractor formulates his estimate of the time and cost of the required to complete the works based off a set of project documents. If the tender documents are missing information or some aspects, then the design engineer is generally asked to answer any questions directly without the contractor having to raise an official RFI. If the questions become prolific, multiple contractors are asking the same question or the design documentation is required to be changed, the design engineer may opt to issue an addendum to all of the tenderers. The contractor who is successful in the tender process is then awarded the contract and they are then required to complete the works for the quoted price detailed within the contract.

As the project progresses and circumstances cause the contractor to request further information, the time and administrative costs associated with this process are added to their expenses. This delay in time can have large flow on effects like having to reschedule major works that could lead to financial costs such as cancellation or rescheduling fees. The delay in completion of the project may also entitle the projects principal to liquidated damages depending on the contractual arrangements.

As the scope of this research project is to focus on the time and cost accrued by the design engineer, further aspects of the costs to the contractor on construction projects will not be investigated.

CHAPTER 3 - Methodology

3.1 Overview

This chapter will detail the methodology adopted to meet the project objectives as outlined above in **Section 1.2**. The adopted project methodology will feature the following topics:

- Attributes of Case Study Projects.

  Before collection of data can occur, constraints on what projects are to be collected must first be identified. This will include all major aspects of the projects and will ensure that the data collected will be relevant and useable in the further analysis.

- Attributes of Design Engineers Time and Cost.

  To successfully determine the time and cost incurred by design engineer on these projects, a separate set of data must be collected. This set of data will include documented time and costs associated with responding to RFI's, preparing associated drawing changes, site instructions issued or variations received.

- Data Collection

  Using the defined constraints, case study data for multiple projects will be collected from industry sources. The type of data collected may vary depending on the source, so common factors and any missing information must be identified.

- Data Processing and Analysis

  The data collected from industry sources must then be presented in a form that can be easily manipulated and analysed. By analysing the collected data, factors can be identified that may indicate that project will have high cost of responding to RFI's

3.2 Case Study Projects

To obtain an accurate model of the time and cost incurred by the design engineer in the RFI process, constraints must first be set on the data sources. If data outside of these parameters is introduced into the database, the results may be skewed and thus return un-reliable results. So that all data collected is comparable it is important that these attributes are well defined and adhered to as detailed below.

It should also be noted that due to the constraints detailed below the results found as a part of this study will only be relevant to comparable projects.

3.2.1 Design Firms

For the extents of this study the primary source of data is to be from Kehoe Myers Consulting Engineers. To obtain this data from my employer I have gained permission from my director Grant Pendlebury.

Kehoe Myers Consulting Engineers is a small engineering consultancy practice situated in Toowoomba, Queensland first established in 1990 by Terry Kehoe and Chris Myers. Specialising in Civil, Structural and Hydraulic Engineering “Kehoe Myers can provide planning, design & construction management services for projects ranging from residential subdivisions & Infrastructure to industrial, commercial and residential buildings”. (Kehoe Myers 2015b)

To enable the comparison of data from more than one source the selection of data must be comparable to the main source of data. This means that all other sources of data will have to be from similar type sources where civil engineers are the project designers and are involved in the construction process preferably as the principal consultant and superintendent.

3.2.2 Project Location

As Kehoe Myers operates of out the Darling Downs and Lockyer Valley Regions it is proposed that case study projects are limited to this area. It is proposed to define this constraint to allow for better comparison of projects and their costs. This was derived from the fact that more remote work may have a higher cost to design engineer as travel time must be taken into account. Work in other areas of the country is also excluded as overheads and associated costs may be significantly different.

To better define these extents the boundaries of Local Governments have been adopted. The Local Government areas to be included are: Maranoa Region, Shire of Balonne, Western Downs Region, Goondiwindi Region, Southern Downs Region, Toowoomba Region, South Burnett Region and the Lockyer Valley Region. A map of the defined extents of South-East Queensland is shown below in **Figure 15**.

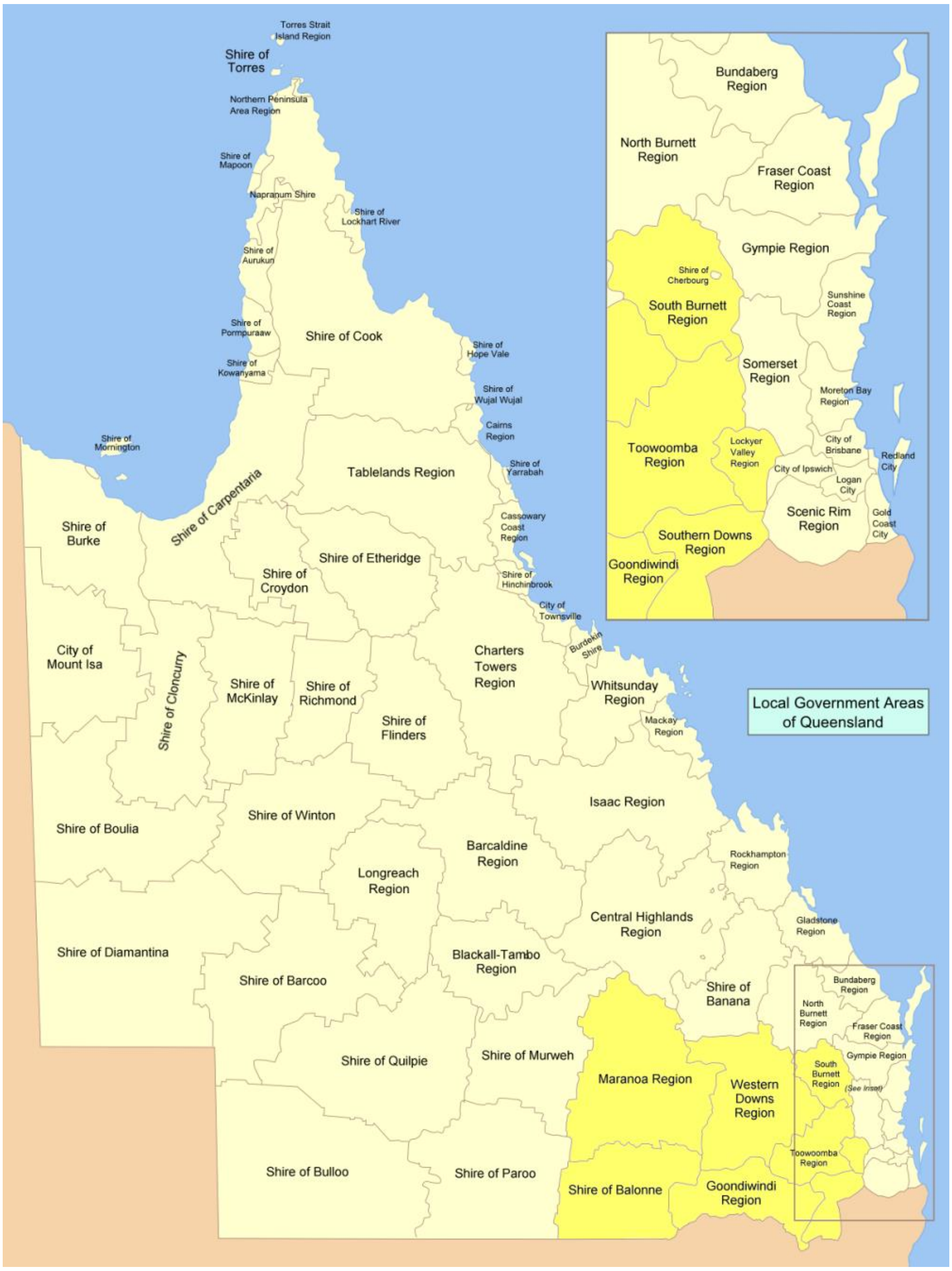


Figure 15: Map of Project Extents. (Wikimedia Commons 2009)

3.2.3 Construction Type

As Kehoe Myers is primarily engaged to design and document civil engineering projects the scope of this research paper will be limited the following type of projects:

- Residential Subdivisions
- Industrial Subdivisions
- Infrastructure Projects (Bridges and Roads)
- Institutional Facilities (Schools and Hospitals)
- Commercial and Industrial Facilities

So that project data collected may be compared, collected project data will be categorised in to one of the above categories. Any projects outside of these types shall be excluded from the project.

3.2.4 Construction Value

To enable the project data to be of viable size it is proposed that the construction value for each project be between $250,000.00 and $10,000,000.00. This will exclude minor works such as simple road reseals and large projects, such as an airport, from the data collected so that their data may not skew the results.

3.2.5 Construction Year

To enable direct comparison between costs and other factors the selected project must be recent. For the purposes of this study the collected projects will be from 2011 until 2015. This range of four years not only allows us to directly compare projects but also assures that records will not have been archived allowing for easier collection.

3.2.6 Construction Duration

So that projects are of appropriate size for comparison it is proposed that only projects with a construction duration between 4 and 52 weeks be considered. This will ensure that project size is adequate to enable RFI's to be generated and resolved.

3.2.7 Number of Plans

To ensure that selected projects are of a significant size and complexity the project must have at least 5 associated construction plans. While it is recognised that some smaller complex projects may have less than 5 construction drawings it is unlikely that these projects would contain a reasonable number of RFI's and hence are excluded from this research paper.

3.2.8 Number of Projects

Due to the time restraints and amount of bulk data to be collected and processed it is proposed that the number of projects collected be limited to no more than 30. This will ensure enough data to allow an accurate model of projects to be prepared, whilst allowing enough time to collate and analyse the data effectively.

3.3 Design Engineers Data

Once projects that meet the criteria above have been identified, actual project data from design engineer's perspective is to be collected. This data is then analysed to determine how the projects and their associated RFI's effect the design engineer's efficiency

3.3.1 RFI's

As the topic of the project is to quantify the time and cost of the RFI process from the design engineers perspective, the first and most critical data to be collected is the number of RFI's accumulated on the project.

The quickest and easiest way of obtaining this data is to take it directly from the projects RFI registers. This document should detail the current and resolved RFI's for the entire duration of each of the projects and is a valuable source of data for this research project.

In cases where there is no RFI register for the project it may be necessary to collate the individual RFI's for the project and enter the data manually. This will achieve the same outcome albeit slower as the data will have to be entered manually.

3.3.2 RFI Topics

The RFI register or corresponding RFI's will also contain critical information about the type of RFI's involved in the project. Most RFI registers include a 'Construction Discipline' section so that the specific areas can be identified. It is important that this information is also collected so that it may be identified as a part of the in-depth analysis. In the case where the RFS's or Registers do not record the appropriate 'Construction Discipline' it may be necessary to manually determine the category by the RFI Topic.

To enable a fair comparison between multiple projects the RFI topics will be grouped as per the categories defined above in **Section 2.4.2.** They are as follows:

- Site Work's.
- Road Work's.
- Stormwater.
- Sewerage

- Water Reticulation
- Electrical
- Other

As the collection of project data is to be mainly from civil infrastructure projects it has been decided that all building project RFI categories such as hydraulic, demolition or mechanical will be placed into the ‘other’. This will avoid having to use an extended list of RFI categories to collect a few or even no RFI’s.

3.3.3 Response Time

From the RFI register the dates of Issue and Response for RFI can be collected by summing the days between dates the ‘Response Time’ of the RFI can be collected. This resulting time can be used to gauge the severity of the RFI, the time spent and therefore the resulting cost to the design engineer. If no response time is recorded it may be useful to conduct a small survey of the design engineer to determine the approximate length of time spent on responding to the RFI’s.

3.3.4 RFI Causes

The next factor to be collected from the design engineer’s data is the cause of the RFI. This will be collected by examining the topic of the RFI and categorising it into one of the sections defined above in **Section 2.5.1**. These sections are:

- Conflicting Information.
- Incorrect Information.
- Insufficient Information.
- Questionable Information.
- Misleading Information.
- Unforeseen Circumstances.

In addition to these RFI categories any other requests received as an RFI will be categorised as ‘Other’. This will include all other requests including improperly made requests such as:

- Queries about propriety products
- Requests for details that are already stated within the drawings or specifications

- Submissions of information
- Responses to non-conformances
- Requests for alternative design solutions
- Request for Approval.
- Request for Substitution.

This alternative categories is included to catch all inappropriate RFI's submitted by contractors so that this figure may further be investigated and analysed.

Once categorised, these root causes of RFI can be then compared to the average cost to reveal the cost per cause.

3.3.5 Project Factors

A number of other factors could also be examined to enable a better understanding of how RFIs effect the design engineer's efficiency including:

- Re Issuing of Plans. The number of plans re issued in response to an RFI is a fair indication of how severe the RFI was and therefore how much time and cost was associated. To collect this data, a Document Transmittal for the project could also be collected and issued drawing dates could be compared to the RFI dates to indicate what plans were issued in response to the RFIs.
- Site Instructions Generated. The number of site instructions generated for a project could give an indication of the total effect of RFIs on a project. By collecting the Site Instruction Register for a project the number of site instructions a responses to RFIs could be determined.
- Extensions of Time. The number of Extensions of Time (EoT) on a given project may also be related the number of RFI's issued and should be collected via the Extension of Time Register or updated works programme.
- Variations Generated. The number of variations raised in response to RFI's could also give an indication of the severity the RFI and therefore the associated cost. To collect this data the projects Variation Register must be collected and analysed to identify variations raised as part of an RFI.

3.4 Costs Incurred by the Design Engineer

With the above factors and collected data it is important to be able to relate these back to the time and ultimate cost accrued by design engineers in the RFI process. This can be done in several ways but the most accurate way is by directly obtaining the design engineers project budget. This would log all of the actual costs accrued in responding to the RFI's and thus be able to determine the total cost accurately.

However as this is quite sensitive commercial information it may not be possible to obtain this data. Alternatively it is proposed that only hours of work be collected and an 'industry rate' be applied. The determined rate has been broken into different rates for a Principal Engineer, Civil Engineer and Drafter to allow for a better definition of the true costs. The adopted rates are as follows:

- Principal Engineer $300 per hour
- Civil Engineer $200 per hour
- Drafter $125 per hour

These rates will be universally applied to all consultants so that a fair comparison of costs can be made. This also resolves the ethical issues of obtaining competitors rates and budgets.

3.5 Data Collection

As detailed above the majority of the project data is to be collected from Kehoe Myers Consulting Engineers. As I am an Employee of Kehoe Myers and have gained approval from my directors, I will be extracting data directly from our records. This data will firstly comply with the 'Case Study Parameters' defined above in **Section 3.2.** Further details will then be added by extracted RFI data from registers and forms as defined above in **Section 3.3.** The actual time associated with responding to RFI's can then be directly gather from the project records as per **Section 3.4** above**.**

For the projects obtained from other consultants it is proposed that contact is first made in person. Preferably this meeting would be with someone in a senior position so that permission for use of the project data could be obtained directly. At this point care must be taken to avoid ethical issues as detailed below in **Section 0.**

Once permission has been obtained a clear list of project and detail requirements should be provided to the consultant. With this list the consultant should be able to compile the required data quickly and hence not waste any more time than which is required. The project data and design engineer's data could then be transferred by email or drop box depending on size. Once obtained from the consultant the data will need to be verified that the projects fit within the above defined parameters in **Section 3.2** and then entered into the data base

3.6 Data Processing and Analysis

Once the data has been collected it must then be organised into a database that can be easily read and manipulated. For ease of use Microsoft Excel has been selected to compile the data collected in this project. Because of the program's ability to organise, manipulate and then display data it is ideal for the task.

Firstly each project will be entered into the master database with the all of the project and design engineers information entered. This will include but not be limited to all of the parameters and factors defined above in **Section 3.2** and **Section 3.3.**

The project data can then be summarised into the categories similar to the case study parameters as defined above in **Section 3.2.** These categories are as follows.

- Project Name
- Source
- Location
- Construction Year
- Construction Type
- Construction Value
- Project Duration
- Number of Plans

Following the above categories the following design engineer's data needs to be summarised in the database.

- Number of RFI's, Total and by RFI Type.
- Time Spent, Total and by RFI Type.
- Cost, Total and by RFI Type.

Lastly the project factors need to be recorded if available.

- Response Time
- Plans Re-issued.
- Site Instructions issued
- Extensions of Time
- Variations

A typical data sheet of specific project information is shown below in **Figure 16.**

Case Number	1
Source	KehoeMyers
PROJECT NAME	Hattonvale Ridge Stage 1
PROJECT NUMBER	C1415006
Location	Lockyer Valley Region
Construction Type	Residential Subdivision

Contract Value	$1,100,000
Project Start	Mar-15
Contract Duration	16 Weeks
Number of Plans	20

Number of RFIs

Total	Siteworks	Roadworks	Stormwater	Sewerage	Water	Electrical	Other	
0	0	0	0	0	0	0	0	0

Time Spent

Total	Siteworks	Roadworks	Stormwater	Sewerage	Water	Electrical	Other	
0	0	0	0	0	0	0	0	0

Cost of RFI's

Total	Siteworks	Roadworks	Stormwater	Sewerage	Water	Electrical	Other	
$0	$0	$0	$0	$0	$0	$0	$0	$0

RFI Data

RFI Number.	Date Received.	Request By.	Construction Discipline	Subject of RFI	Date Response Required.	Date Response Issued.
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Designers Cost

$/hr	$300		$200		$100
Time Spent By Principal	$0	Time Spent By Engineer	$0	Time Spent By Drafter	$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0
	$0		$0		$0

Project Factors

Response Time (Days)	Re-Issued Plans	Site Instructions	Extensions of Time	Variaitons
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				
0				

Figure 16: Typical Data Sheet for entry of project data.

Following the collection of the project and design engineers data for each individual case study data, the entire data set will be collated into a master database. This master database will contain all of the critical project data collected and a summary of the design engineer's data. This master database can then be manipulated to arrange the data in a presentable format, create plots of the data for visual investigation and then investigate the potential statistical relationships.

3.6.1 Statistical Analysis

From the collected data it is proposed that a statistical analysis of the variables is undertaken to reveal the characteristics of the data set.

An example of the simple statistical analysis of the project data and design engineers data is given in **Table 3-1** below.

Table 3-1: Typical Statistical Analysis

Construction Duration (Weeks)	
Average Value	18.8
Minimum Value	4.0
Maximum Value	36.0
Range	32.0
Median Value	20.0
Standard Deviation	7.4
Skew	0.48
First Quartile	15.0
Third Quartile	22.0
Interquartile range	7.0

The simple analysis of the data will help further analysis by determining the normality and distribution of the data. Additionally the data will be plotted as a histogram to enable visual analysis of the distribution of the collected values.

Following the collection and presentation of the collected case study data, the project data and design engineers data will be compared against each other to reveal any potential relationships. Any relationship between data sets will be further investigated by visual and statistical methods.

For the visual investigation it is proposed that both data sets are plotted together so that any trends in the data are easily identified. An example of plotting of two data sets is given in **Figure 17** below.

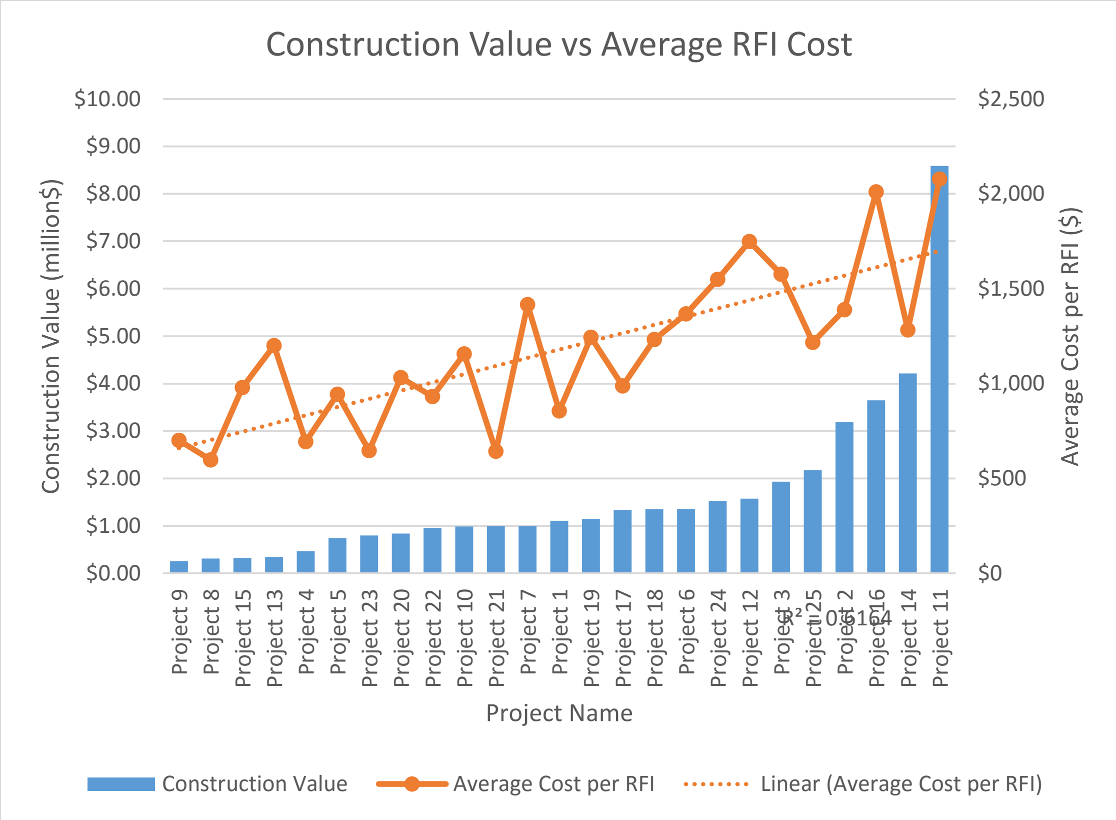


Figure 17: Typical Comparision of Data Sets.

Following the plotting of data sets, if a trend or relationship is identified it can be further investigated by statically methods. These methods could include the use of both a Pearson Product-Moment Correlation and a Spearman's Rank-Order Correlation to determine a coefficient of determinacy.

The Pearson Product-Moment Correlation is the measurement of the strength of a linear association between two data sets. (Laerd Statistics 2015a) The coefficient is obtained by dividing the covariance of the two data sets by the product of their standard deviations. The returned value will be between +1 and -1 with the degree indicating the relationship. Where +1 indicates a perfectly increasing linear relationship, -1 a perfectly decreasing linear relationship, 0 indicating no relationship and factors in-between indicating the strength of relationship.

A breakdown of the strength of relationship is given by the Loughborough University (Loughborough University 2015a) below:

- .00-.19 “very weak”

- .20-.39 “weak”
- .40-.59 “moderate”
- .60-.79 “strong”
- .80-1.0 “very strong”

The Spearman's Rank-Order Correlation is a measurement of the strength of association between two data sets without considering the actual values of the data. To do this the rank of the data is compared instead. This method is particularly useful where there are large outliers in data sets and association may not be particularly linear (Laerd Statistics 2015b). As above the returned coefficient will be between +1 and -1 with the degree indicating the relationship. Where +1 indicates a perfectly increasing linear relationship, -1 a perfectly decreasing linear relationship, 0 indicating no relationship and factors in-between indicating the strength of relationship.

Similar to the Pearson Correlation above the Spearman's Correlation strength can be described using the following guide.(Loughborough University 2015b)

- .00-.19 “very weak”
- .20-.39 “weak”
- .40-.59 “moderate”
- .60-.79 “strong”
- .80-1.0 “very strong”

3.6.2 Further Analysis

From the analysis, factors that return the strongest correlation will be further investigated to developed potential methods for estimating the number and cost of RFIs on a future project. This investigation will then be extended to further to analyse the root cause of RFIs on the case study projects to that recommendations can be made to potentially reduce the number and cost of RFI’s on future projects.

3.7 Project Planning

To execute the above methodology and achieve the above project goals, the resources required and associated risks must be first considered. As the above methodology follows a traditional 'desktop study' there are no special requirements or out of the ordinary risks involved. However as these components are still vital for all research projects a detailed list of project resources and risk management strategy has been included in **APPENDIX D .**

3.7.1 Ethical Issues

Ethically this project and its content is not very controversial, however the ethical aspects of the project must always be considered. As this is a so called 'desktop study' there are no ethical risks associated with testing. However there could be a potential conflict of interests when collecting and displaying the project data. Because I am currently employed by Kehoe Myers Consulting Engineers and will be requesting project data from other firms, there is potential that I will be given insight into a competitors business. This information could range from clients details, to project information and business costs.

With this information there is obviously a potential for misuse. To eliminate this potential it is proposed that I provide full disclosure to any firm that I request data from. This includes stating to them who I currently work for, what data I want from them, what I will be doing with that data and how I will present it. It should also be presented clearly in the data where I got the specific data from and all contributing firms should be credited within acknowledgements section. In the case of project specific costs given to me, it is proposed that only the hours of work are taken from this. The hours of work will then be used along with the 'industry rates' defined above in **Section 3.4.** For the information obtained from my employer I have gained specific permission from my Directors to obtain, use and present this data.

The additional ethical issue present in almost all research projects is proper referencing of others work. During the literature review in **Chapter 2** I reviewed a large number of topics that have previously been researched by others. It is important that these authors are credited and are correctly cited within the work, as referenced in **CHAPTER 8 -References**.

CHAPTER 4 - Results

Following the methodology and parameters defined above in **Section 3.2** a number of case study projects were collected from both Kehoe Myers Consulting Engineers and other local design firms.

From the design firms approached, data from 25 separate projects was successfully gathered. The majority of these projects came from Kehoe Myers Consulting Engineers, as prior permission had already been sought to collect this data. Of the other six local design firms approached, meeting the pre-qualifications described in **Section 3.2.1,** three were able to provide information, providing that commercial confidentiality was maintained. The remaining three firms were unable to provide data, either because of their inability to track time spent on responding to RFI's or due to commercial confidentiality restrictions.

As defined in the above methodology, the number of projects and sources collected should be sufficient to create an accurate model of the time and cost accrued by the design engineers in the RFI process.

The data resulting from this investigation was then processed using the methodology described above in **Section 3.6** and is presented in the following chapter in the same order as required by the above methodology.

4.1 Project Data

In order to ensure an accurate model is created, all of the collected case study projects must have reportable values for the following project factors. Additionally each of the project factors must fall within the allowed range of values as defined above **Section 3.2**.

This project data given below was collected through a number of methods, from simple inspection of the job file, to looking up the original contract. For each of the factors collected, a brief description of their context and source is given with the summary and analysis of the data below.

4.1.1 Project Location

From the collected data set, the case study projects were constructed in the following regions.

Table 4-1: Case Study Project Locations

Project Region	Number of Projects
Lockyer Valley Region	3
Maranoa Region	1
South Burnett Region	1
Southern Downs Region	1
Toowoomba Region	18
Western Downs Region	1

As can be seen in **Table 4-1** above, of the 8 regions specified in **Section 3.2.2,** six of them are represented within the data. The majority of these recorded case study projects were from the Toowoomba Region. This coincides with the fact that the all of data was from design firms based in Toowoomba.

As these values are qualitative, no statistical analysis is necessary.

4.1.2 Construction Type

Of the collected data set, the case study projects were from the following construction types.

Table 4-2: Case Study Project Construction Types

Construction Type	Number of Projects
Residential Subdivision	15
Industrial Subdivision	1
Infrastructure	3
Institutional Facilities	2
Commercial & Industrial Facilities	4

From the above **Table 4-2** it can be seen that a project from each type of construction has been collected while the most popular type of construction is by far Residential Subdivision. This coincides with the fact that the majority of data was from Kehoe Myers which specialises in the design and construction of Residential Subdivisions.

As these values are qualitative, no statistical analysis is necessary.

4.1.3 Construction Value

From the collected data set, the case study projects vary significantly in construction value. It should be noted that the construction value was taken as the original contract value, as variations to the contract and liquidated damages are to be considered as a separate factors. The values have also been taken as excluding GST and projects from the previous financial years have not been adjusted for inflation.

To display these values, the projects have been presented in following graph **(Figure 18)** in ascending order.

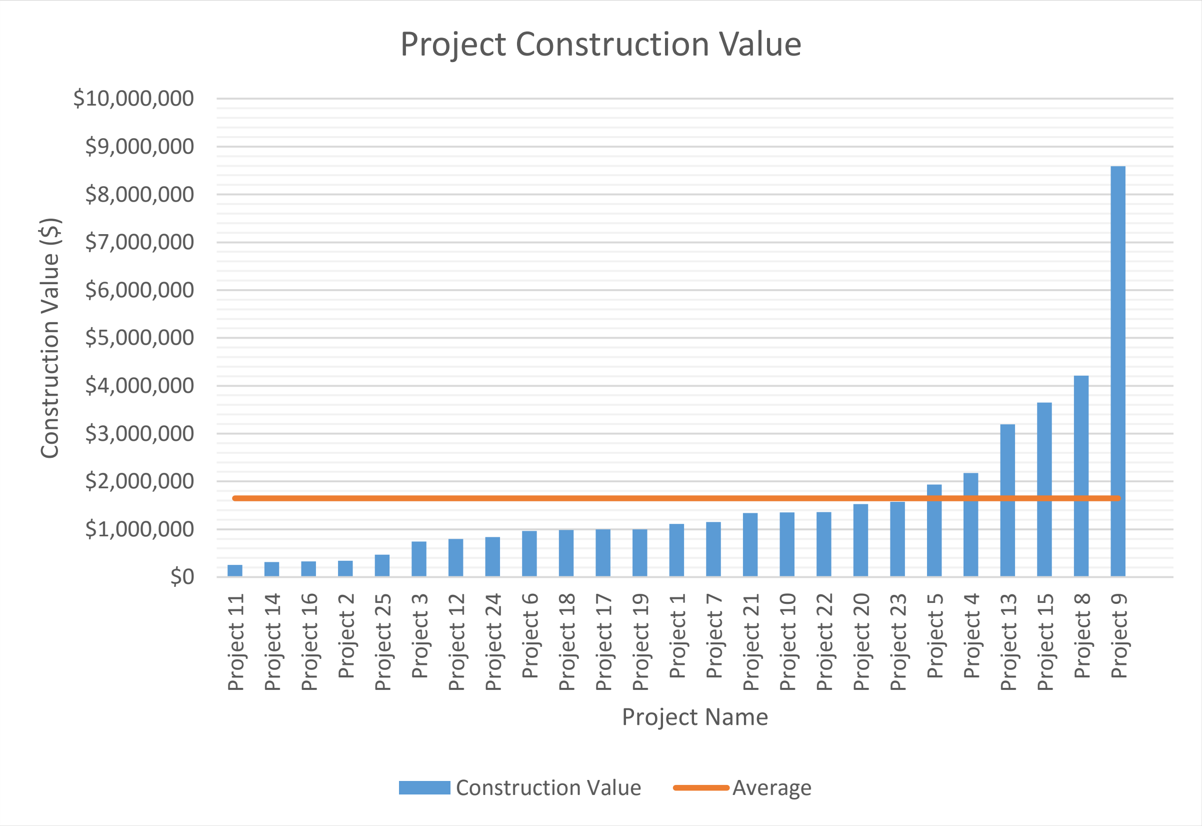


Figure 18: Project Construction Value

From visual inspection of the above figure it can be seen that the majority of projects are below the mean project construction value and there is a single larger value at the end of the data set. To further investigate this the data is plotted as a histogram in **Figure 19** and a statistical analysis of the data has been under taken in **Table 4-3** below.

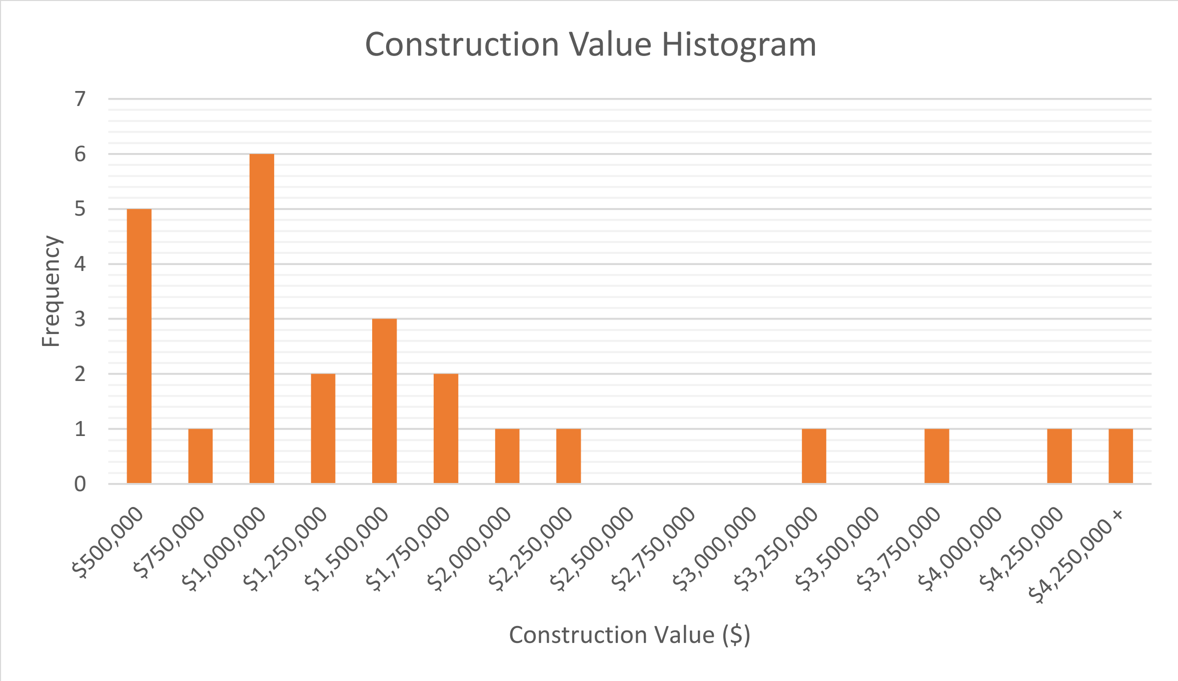


Figure 19: Project Construction Value Histogram

Table 4-3: Case Study Project Construction Value Statistics

Construction Value	
Mean Value	$1,648,123
Minimum Value	$256,545
Maximum Value	$8,590,261
Range	$8,333,716
Median Value	$1,110,001
Standard Deviation	$1,730,409
Skew	2.87
First Quartile	$772,517
Third Quartile	$1,752,497
Interquartile range	$979,980

As can be seen in the above break down, all of the projects collected fall within the acceptable minimum and maximum ranges as defined in **Section 3.2.4.** The data present however is quite skewed with some significant outliers in the larger value range.

4.1.4 Construction Year

Following the methodology defined in **Section 3.2.5,** all of the collected case study projects were undertaken within the last five years. A breakdown of the years of construction and the number of projects is given below in **Table 4-4**.

Table 4-4: Case Study Project Construction Year

Project Construction Year	Number of Projects
2015	2
2014	7
2013	10
2012	3
2011	3
2010	0

As can be seen in the table above the majority of the projects collected are from the last three years. This minimises the requirement to make significant adjustments to account for inflation and cost escalation.

As these values are qualitative, no statistical analysis is required to be undertaken on the collected values.

4.1.5 Construction Duration

Construction duration for each project was collected from the original contract period and was considered as whole weeks. The inclusion of Extensions of Time was not considered, as if they occur on a project they were to be collected as a separate factor. The spread of collected case study project duration is presented below in descending order.

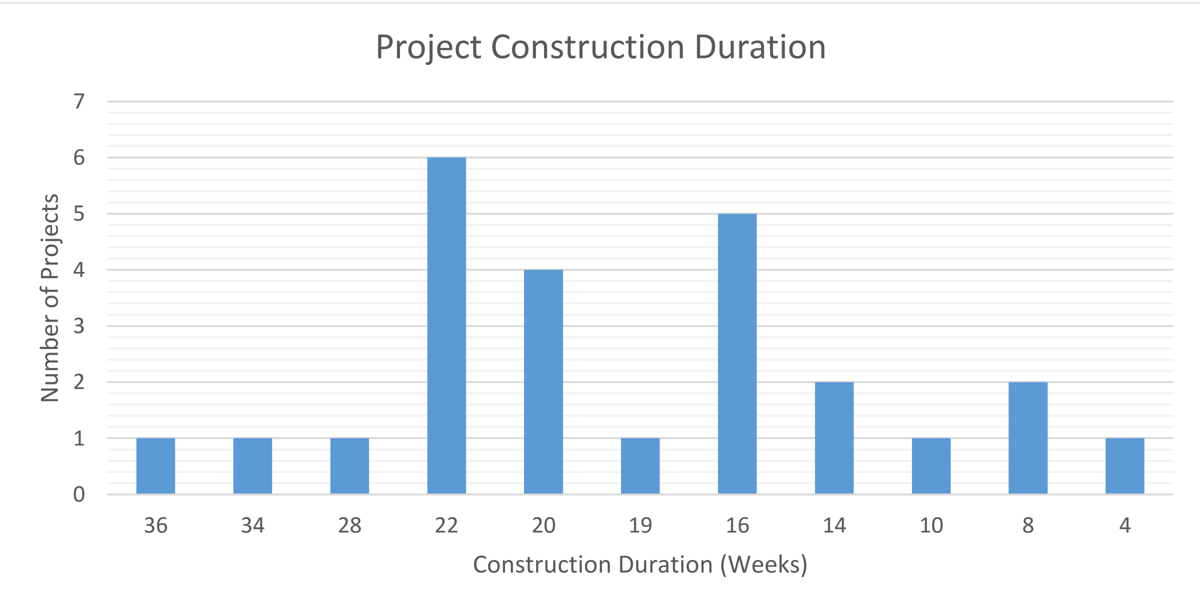


Figure 20: Project Construction Duration

To further break down this gathered data, a histogram is plotted in **Figure 21** and a statistical analysis of the data has been under taken in **Table 4-5** below.

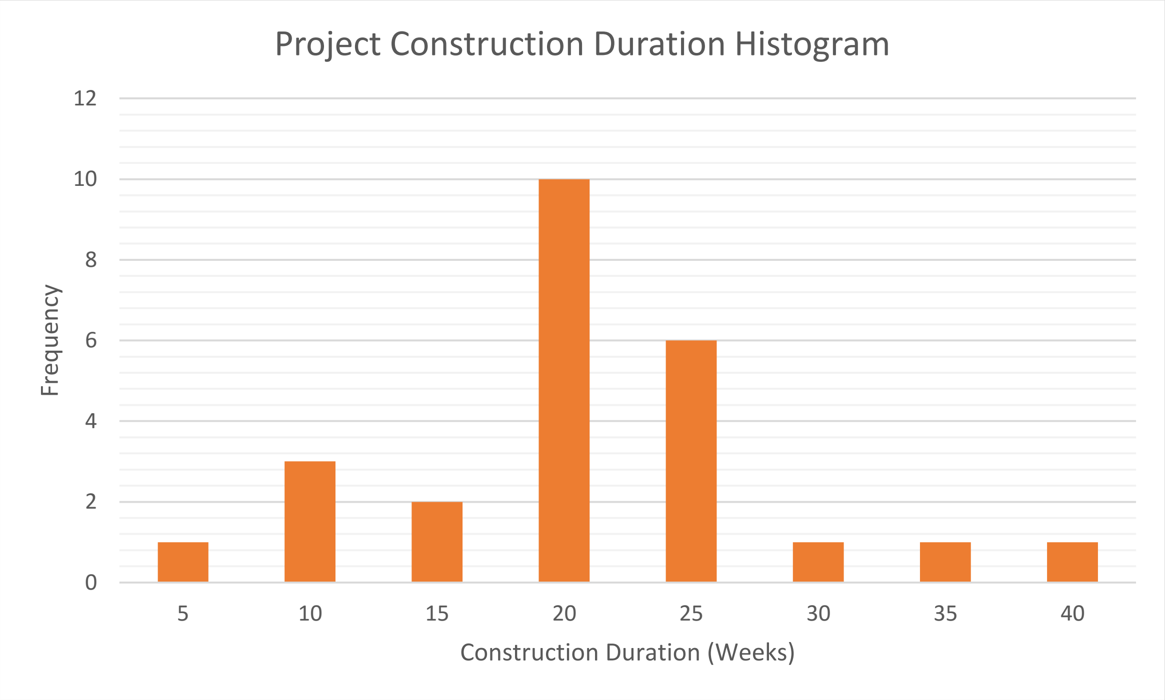


Figure 21: Project Construction Duration Histogram

Table 4-5: Case Study Project Construction Duration Statistics

Construction Duration (Weeks)	
Mean Value	18.7
Minimum Value	4.0
Maximum Value	36.0
Range	32.0
Median Value	20.0
Standard Deviation	7.2
Skew	0.37
First Quartile	15.0
Third Quartile	22.0
Interquartile range	7.0

As can be seen by the above breakdown of the construction duration data all of the values fall within the acceptable ranges defined within **Section 3.2.6** and appears to reflect a bimodal distribution, with no significant outliers in the data set.

4.1.6 Number of Plans

As indicated in the above methodology, the number of plans on a project can give a good indication of the relevant complexity of the project. For the case study projects investigated the number of plans was taken as the number of official 'signed' plans on the project created by the design engineer. Only these plans were considered because generally the design engineer would only be answering quires in relation to the information (or the perceived lack thereof) displayed on their own drawings.

From the collected data set, case study projects and their number of construction plans is displayed below in **Figure 22,** in ascending order.

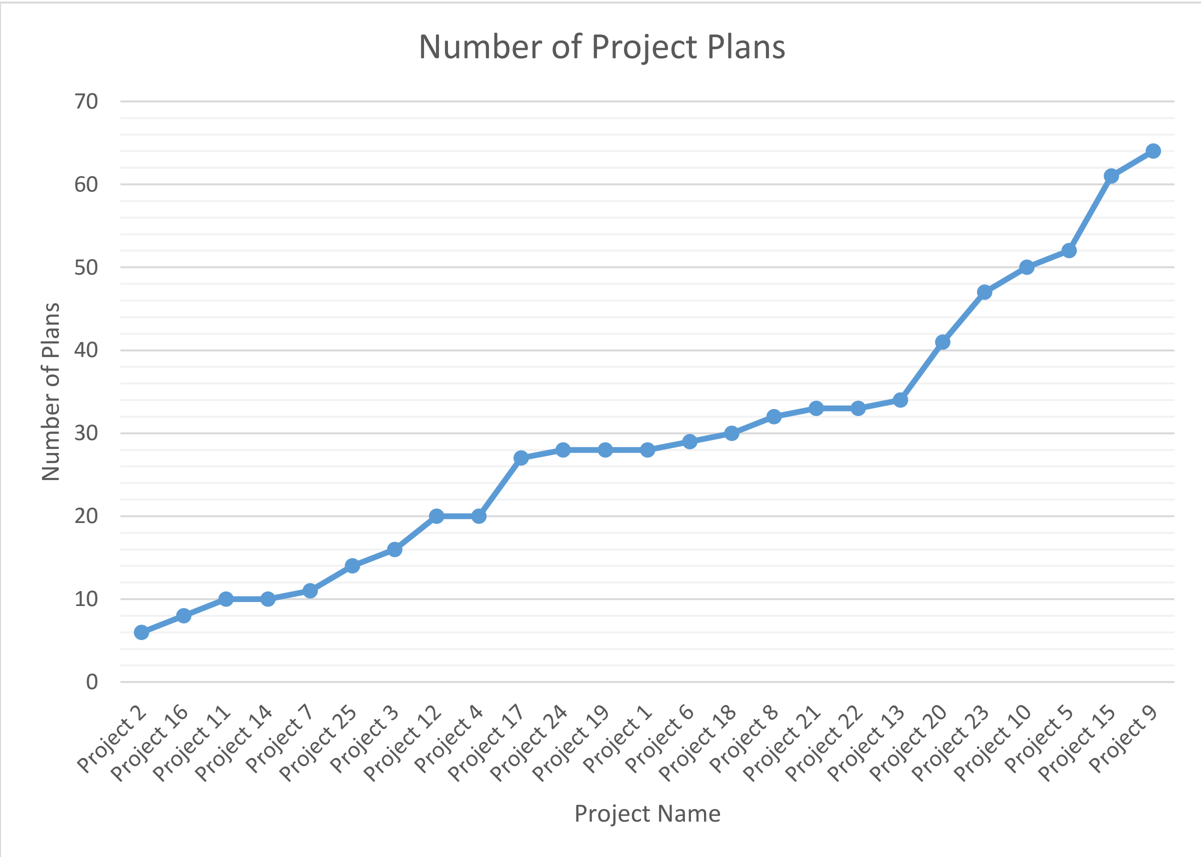


Figure 22: Number of Project Plans

From the project data displayed above, further analysis was undertaken by plotting the data as a histogram and conducting a simple statistical analysis. This further analysis is presented below in **Figure 23** and **Table 4-6.**

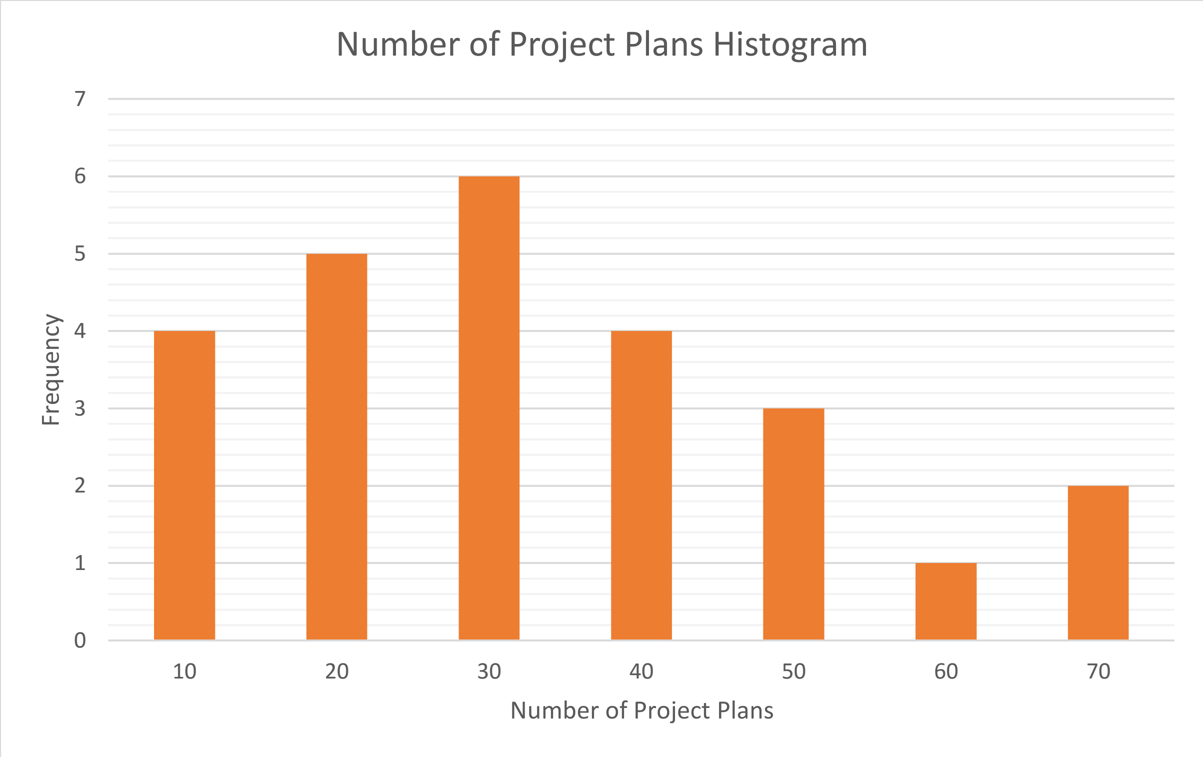


Figure 23: Number of Project Plans Histogram

Table 4-6: Case Study Project Number of Plans Statistics

Number of Project Plans	
Mean Value	29.3
Minimum Value	6.0
Maximum Value	64.0
Range	58.0
Median Value	28.0
Standard Deviation	15.9
Skew	0.55
First Quartile	15.0
Third Quartile	37.5
Interquartile range	22.5

From the above analysis of the collected data it can be seen that each project achieves the minimum amount required by the methodology defined in **Section 3.2.7.**

4.2 Design Engineers Data

Following the collection of the project data above, the design engineer’s data was gathered. This data is needed to determine how the previously collected project factors affect the design engineer’s efficiency and ultimately the associated cost within the RFI process.

The design engineer’s data was collected using the methodology defined above in **Section 3.3.** Firstly the RFI registers were collected for the each of the case study projects or was manually recorded from RFI forms if no register was provided. The RFI’s were then entered into the database along with their assigned topic category and critical dates. The results of the collection of this data is presented below.

4.2.1 Number of RFI’s

From the collected case study projects, the total number of RFI’s was recorded and is presented below in **Figure 24**.

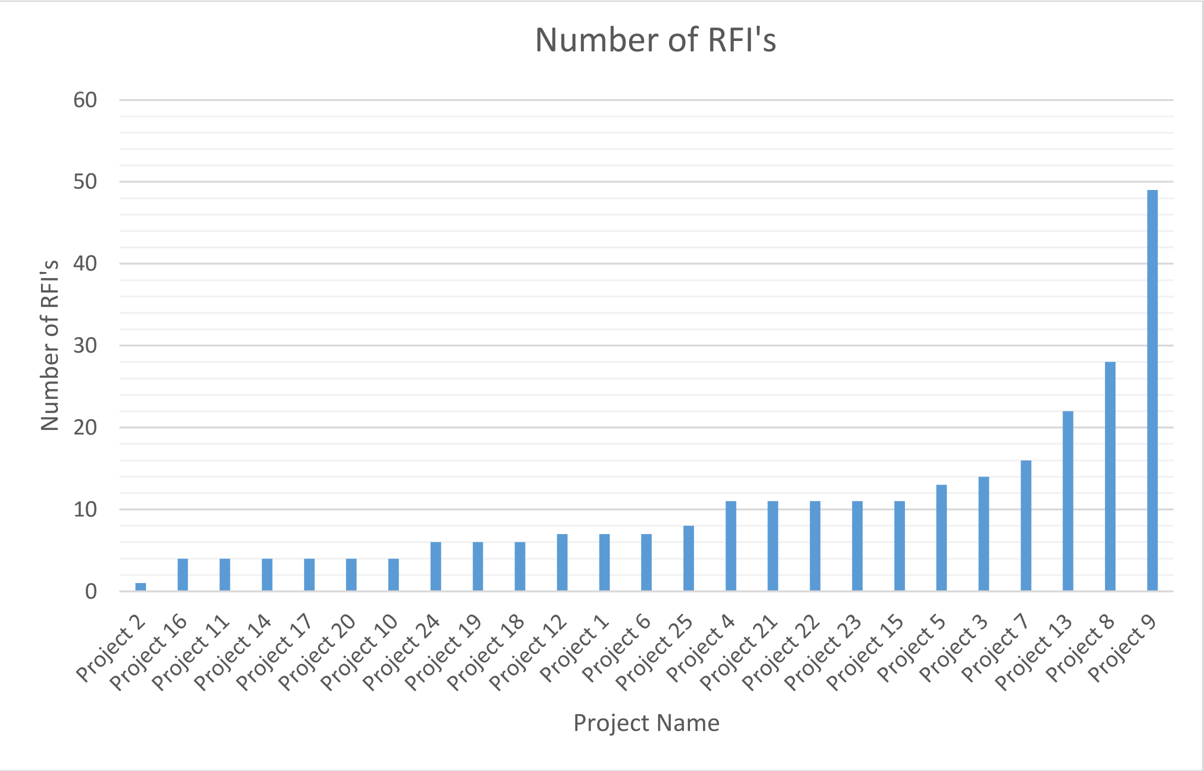


Figure 24: Case Study Projects – Number of RFI’s

To further break down this gathered data, a histogram is plotted and a statistical analysis of the data was under taken in **Figure 25** and **Table 4-7** below.

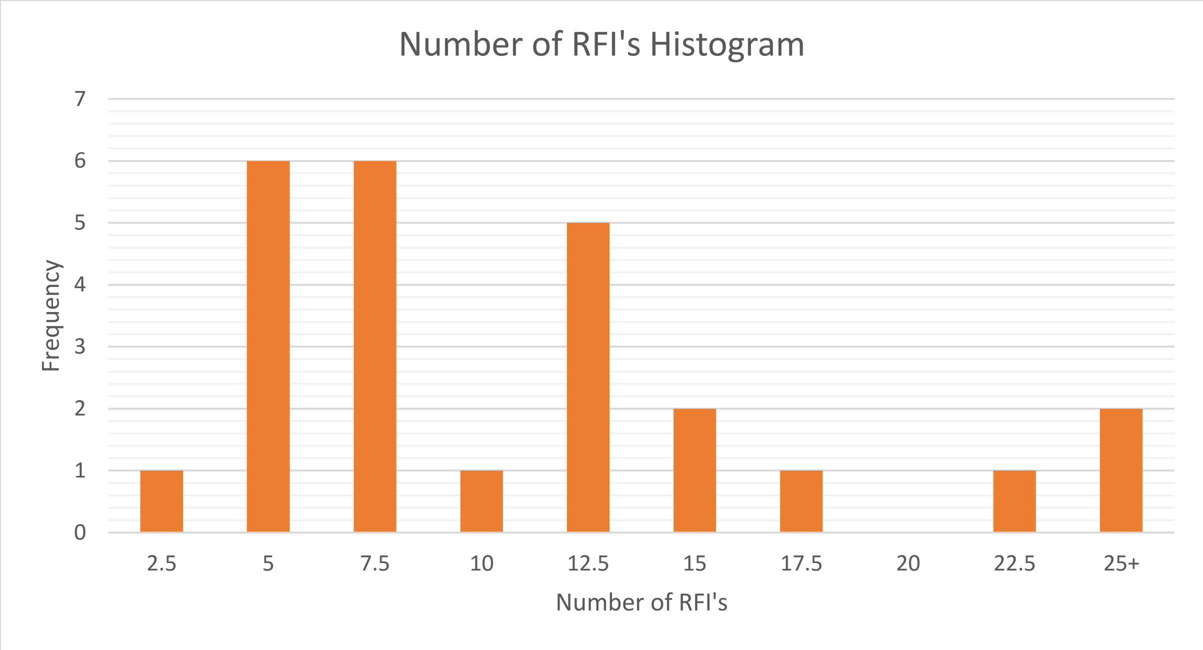


Figure 25: Case Study Projects – Number of RFI's Histogram

Table 4-7: Case Study Projects – Number of RFI's Statistics

Number of RFI's	
Mean Value	10.76
Minimum Value	1.00
Maximum Value	49.00
Range	48.00
Median Value	7.00
Standard Deviation	9.83
Skew	2.66
First Quartile	4.0
Third Quartile	12.0
Interquartile range	8.0

From the data presented above it can be seen that the data is quite skewed with a number of projects having significantly more RFI's than the average amount. These outliers have been maintained within the data set for further analysis.

To enable further discussion the number of RFI's on the collected case study projects will be further investigated in the following chapter.

4.2.2 RFI Topics

From the case study project RFI's collected, each was entered into the data base and assigned to a specific category as defined above in **Section 3.3.2.** The breakdown of number of RFI's per category for each project is given in below in **Figure 26.**

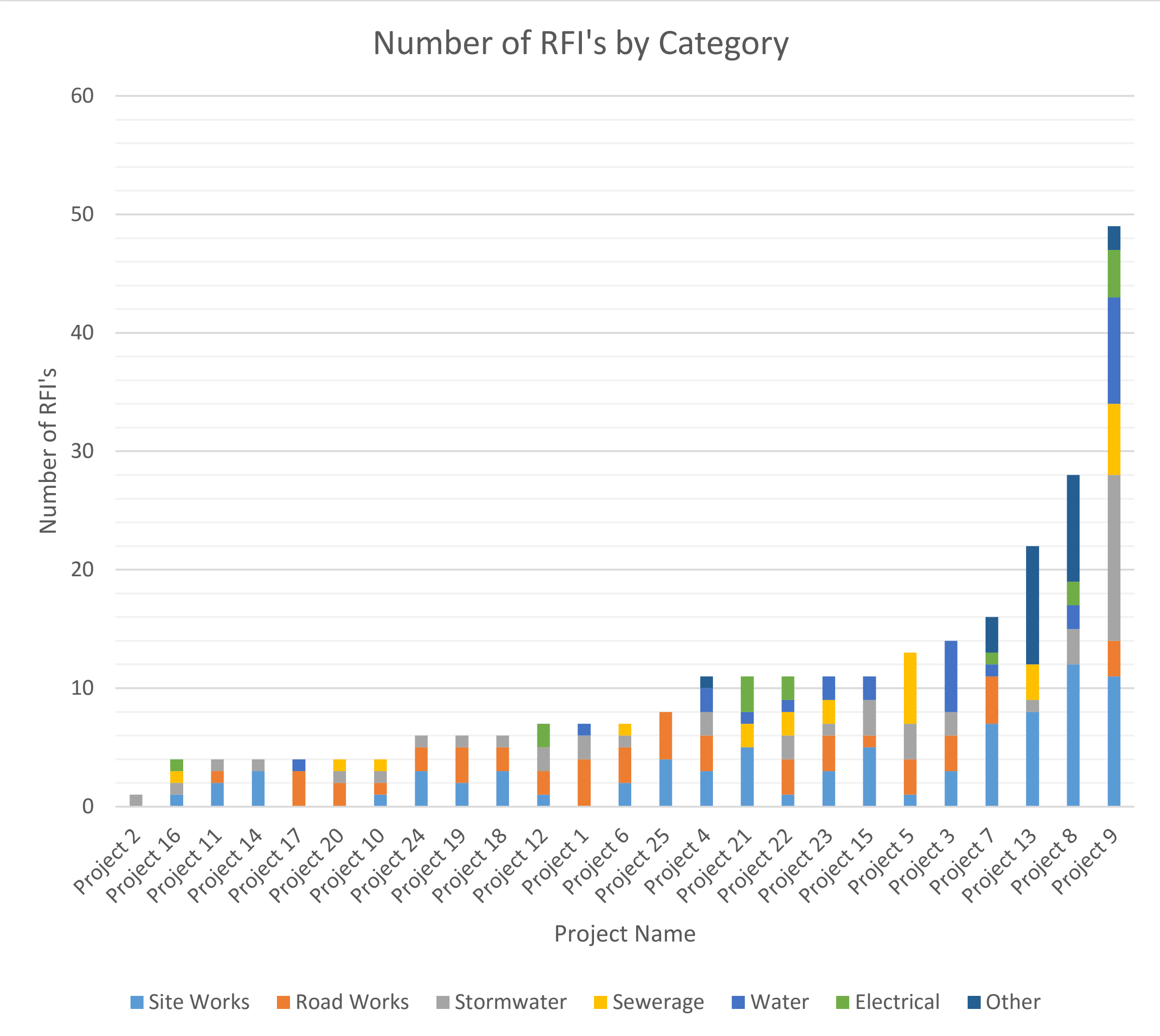


Figure 26: Case Study Projects – Number of RFI's by Category

To better display the overall break down of RFI's by Category the data was plotted as a histogram below in **Figure 27.**

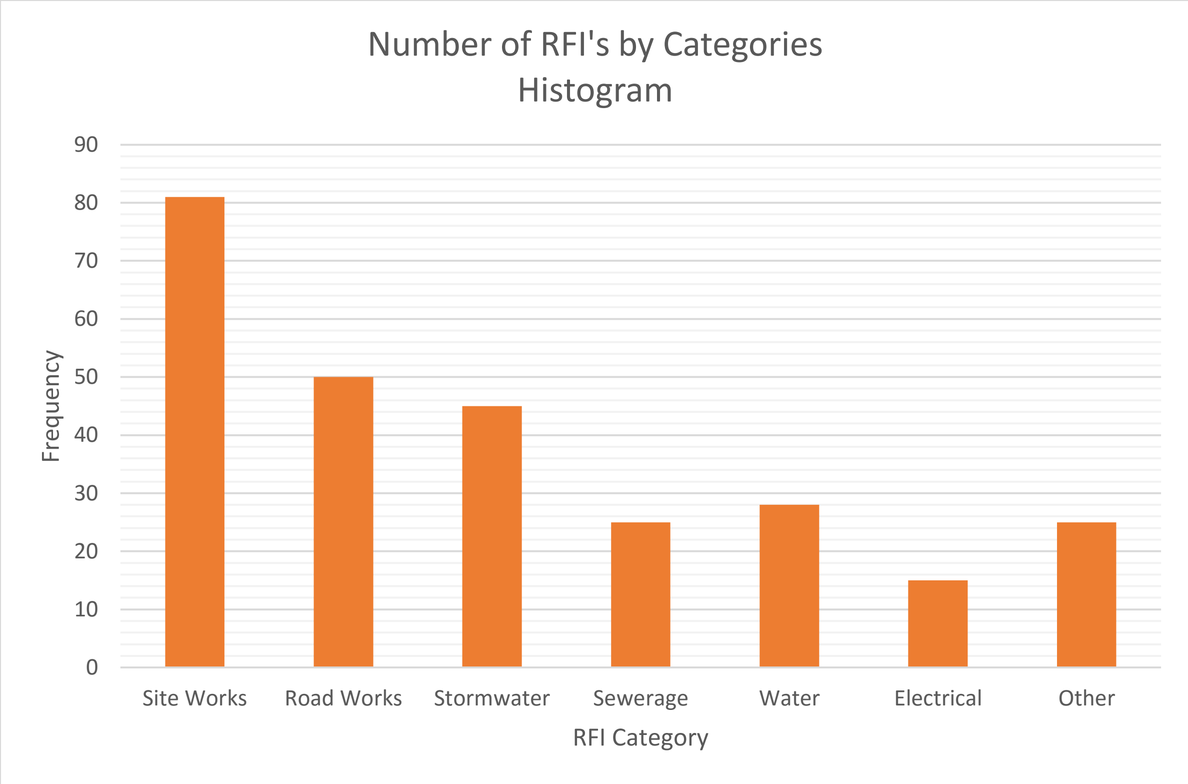


Figure 27: Case Study Projects – Number of RFI's by Category Histogram

As shown by the presented data above the majority of RFI's fell into the first three categories Siteworks, Roadworks and Stormwater. It should also be noted that there is an exceptional amount of RFI's been placed into the 'other' category. This can be explained by the fact that all building RFI's such as hydraulic or mechanical were placed into this category as defined in **Section 3.3.2** above. However as the number of building projects collected is minimal as seen in **Section 4.1.2** the data is not considered to have a great effect on the overall analysis of the time and cost.

The distribution of RFIs by topic will be further investigated in **Section 5.2.7** below.

4.2.3 Response Time

As discussed above in **Section 3.3.3,** the response time for an RFI can be a potential indicator of the severity of the RFI. To collect this data, the critical dates of an RFI were entered onto the data base with the RFI.

The response time was taken as the number of whole days between when the RFI was received and the date of response. This means that if a request was solved on the same day the response time is returned as zero. The data was then filtered to remove any weekends from the data set, it should however be noted that no holidays were factored out and hence some values may have low accuracy.

The total response time for a project RFI's and the average response time is displayed in ascending order below in **Figure 28** and **Figure 29**.

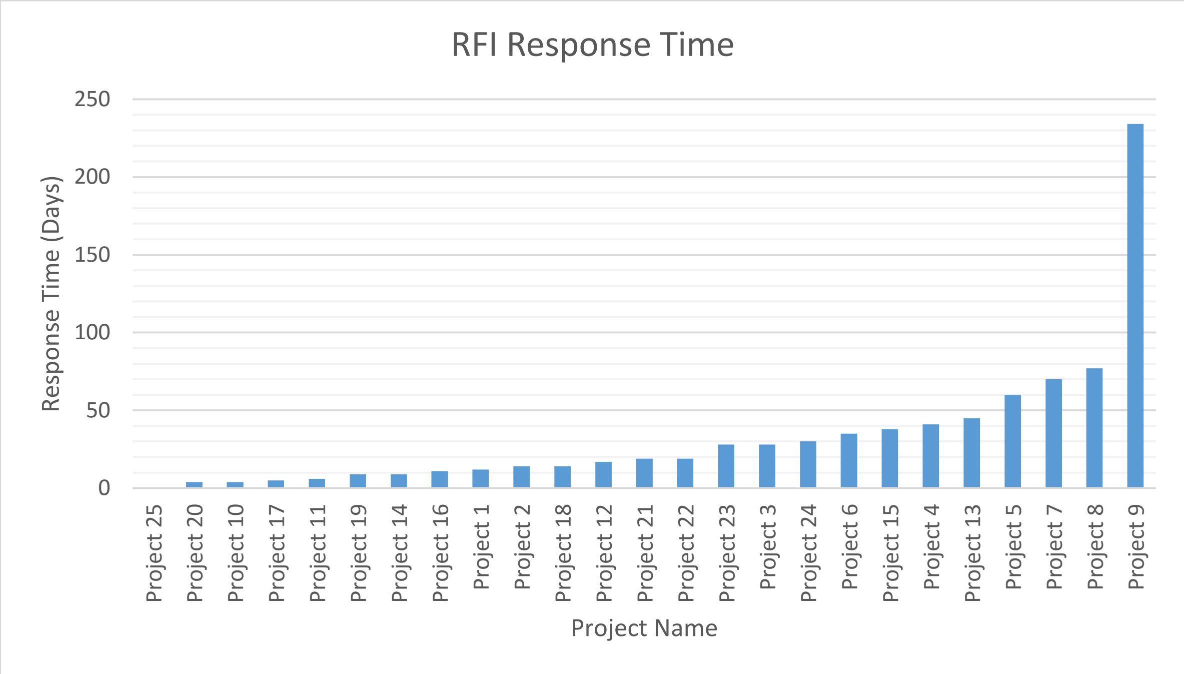


Figure 28: Case Study Projects – RFI Response Time

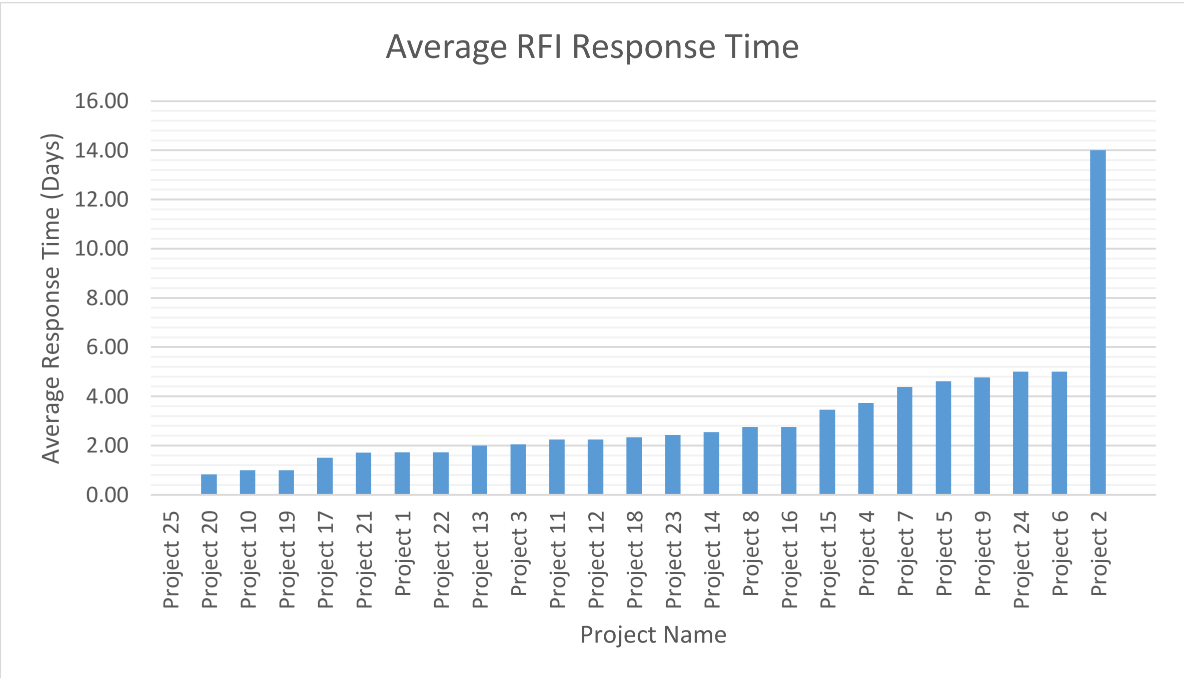


Figure 29: Case Study Projects – Average RFI Response Time

As can be seen in the above figures, the ascending order of projects significantly changes between the total response time and the average response time. This can be simply attributed to the fact that projects with a larger total response time are more likely to have a large number of RFI's. For this reason the average response time would make a more reliable factor to display and will be used in further analysis in **Section 5.2.8.** To further analyse the average response time collected, the data has been plotted as a histogram and a simple statistical analysis has been undertaken. This is presented below in **Figure 30** and **Table 4-8.**

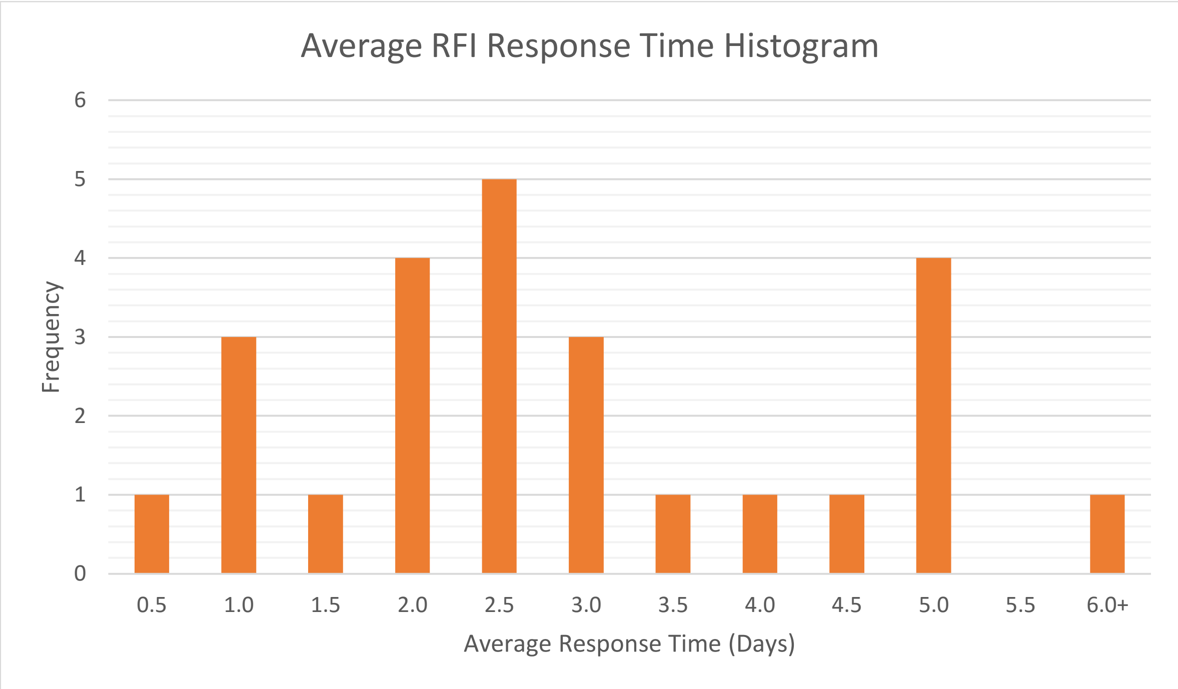


Figure 30: Case Study Projects – Average RFI Response Time Histogram

Table 4-8: Case Study Projects – Average RFI Response Time Statistics

Average Response Time (Days)	
Mean Value	3.03
Minimum Value	0.00
Maximum Value	14.00
Range	14.00
Median Value	2.33
Standard Deviation	2.61
Skew	3.06
First Quartile	1.7
Third Quartile	4.1
Interquartile range	2.3

As can be seen by the presented data above the collected RFI response time data is quite skewed reflecting a multimodal distribution, with one outlying project with a very large response time. However upon inspection of this data set, it can be seen that this large outlying response time is from a project with a single RFI. When further analysing this data this point may be culled from the set so that data is not inappropriately skewed. This will be further investigated in **Section 5.2.8.**

4.2.4 RFI Causes

The next factor collected from the design engineers data, was the root cause of the RFI. This was completed using the methodology defined above in **Section 3.3.5** and the overall frequency of the causes are presented below in **Figure 31.**

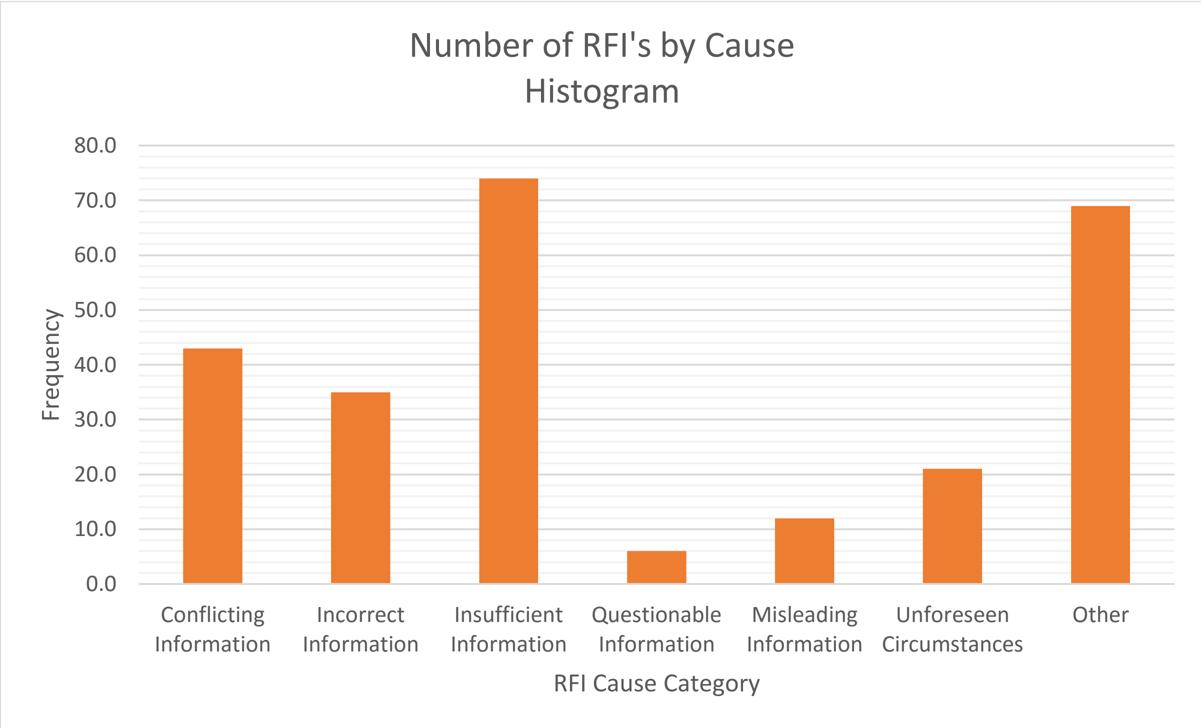


Figure 31: Case Study Projects – Number of RFI's by Cause Histogram

As can be seen by the presented data, the majority of RFI's can be categorised into the first three types, which is quite consistent with past research. The other notable category is the 'other' type, this contains all RFI's that do not fall into the other defined categories.

Upon closer inspection of this category it can be seen that the majority of these requests, were for the use of an alternative design solution or submission of information for approval, such as steel shop drawings. These categories will be further investigated and analysed in the following chapter.

4.2.5 Project Factors

Of the additional project factors described in **Section 3.3.5,** most were unable to be directly related to the RFI's on given projects and thus were not collected. As the given factors above in **Sections 4.1** and **4.2** are considered to be the most effective measure of a project and its cost to the design engineer, no additional project factors were considered as a part of the data set.

4.3 The Design Engineers Costs

Following the collection of the project and design engineer's data for the selected case study projects, the actual cost to the designers is to be collected. As the best indicator of incurred costs, the actual hours spent responding to individual RFI's were gathered as per the methodology defined in **Section 3.4.** This data was collected from both the internal project budget on Kehoe Myers projects or directly supplied by external consultants with their data transfer. This collected data is presented and analysed in the sections below.

4.3.1 Hours Spent on Response

The total hours spent on responding to RFIs on each individual project is the sum of the raw value entered into the database. This data is presented by project, in ascending order, in **Figure 32** below.

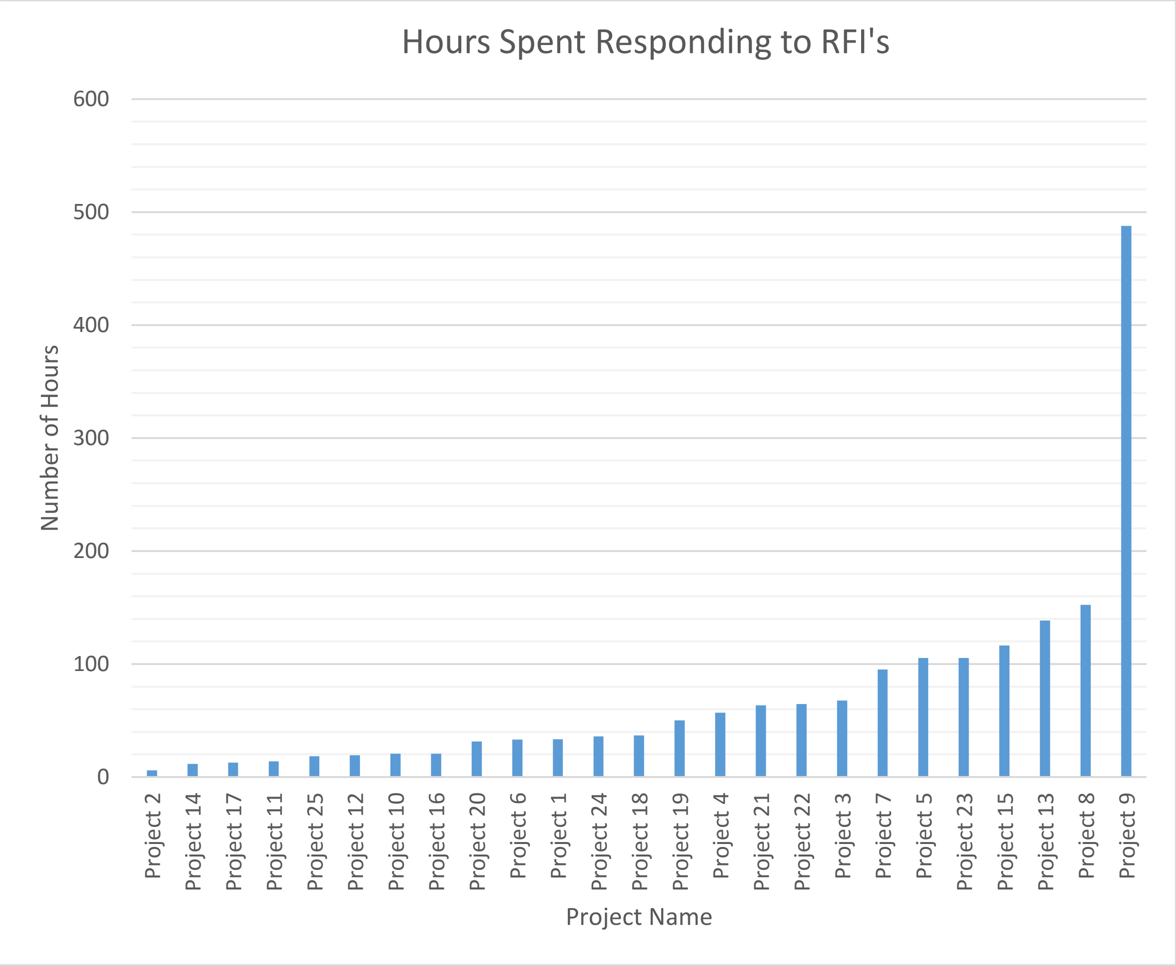


Figure 32: Case Study Projects – Hours Spent

From the data presented above, it is clearly evident that there is an outlier within the data set. To further break down the data, a histogram is plotted and a statistical analysis of the data has been undertaken below in **Figure 33** and **Table 4-9.**

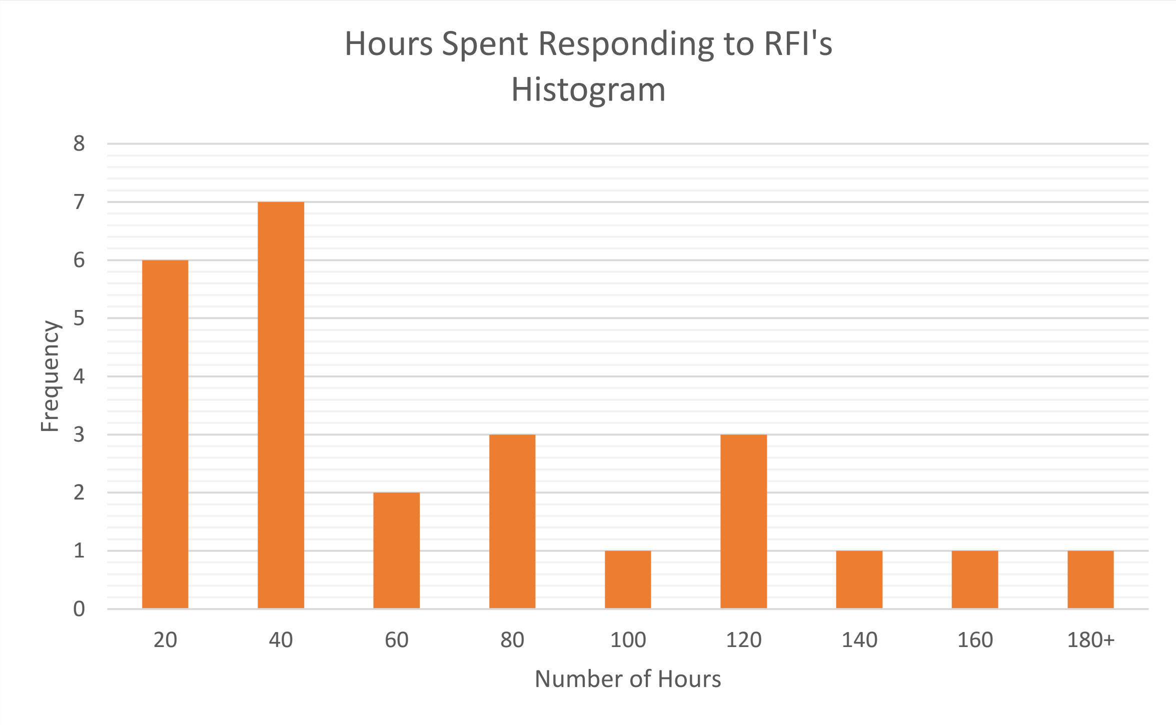


Figure 33: Case Study Projects – Hours Spent Histogram

Table 4-9: Case Study Projects – Hours Spent Statistics

Hours Spent Responding to RFI's	
Mean Value	71.91
Minimum Value	6.00
Maximum Value	487.65
Range	481.65
Median Value	36.75
Standard Deviation	94.28
Skew	3.61
First Quartile	19.9
Third Quartile	100.3
Interquartile range	80.4

As can be seen in the above breakdown of the data, the large outlying figure is skewing the data quite significantly. Whilst removing this outlying figure might be considered to obtain a better distribution of the data, as we are observing such a small data set its removal would be unwise. It also may still be relevant to the comparison of data investigated further on.

4.3.2 Average Time Spent on Response

To further analyse the hours spent on responding to RFI's, the total number of hours spent responding to RFI's was divided by the number of RFI's on each of the individual case study projects. This data is displayed in ascending order from least hours to the most, in **Figure 34** below.

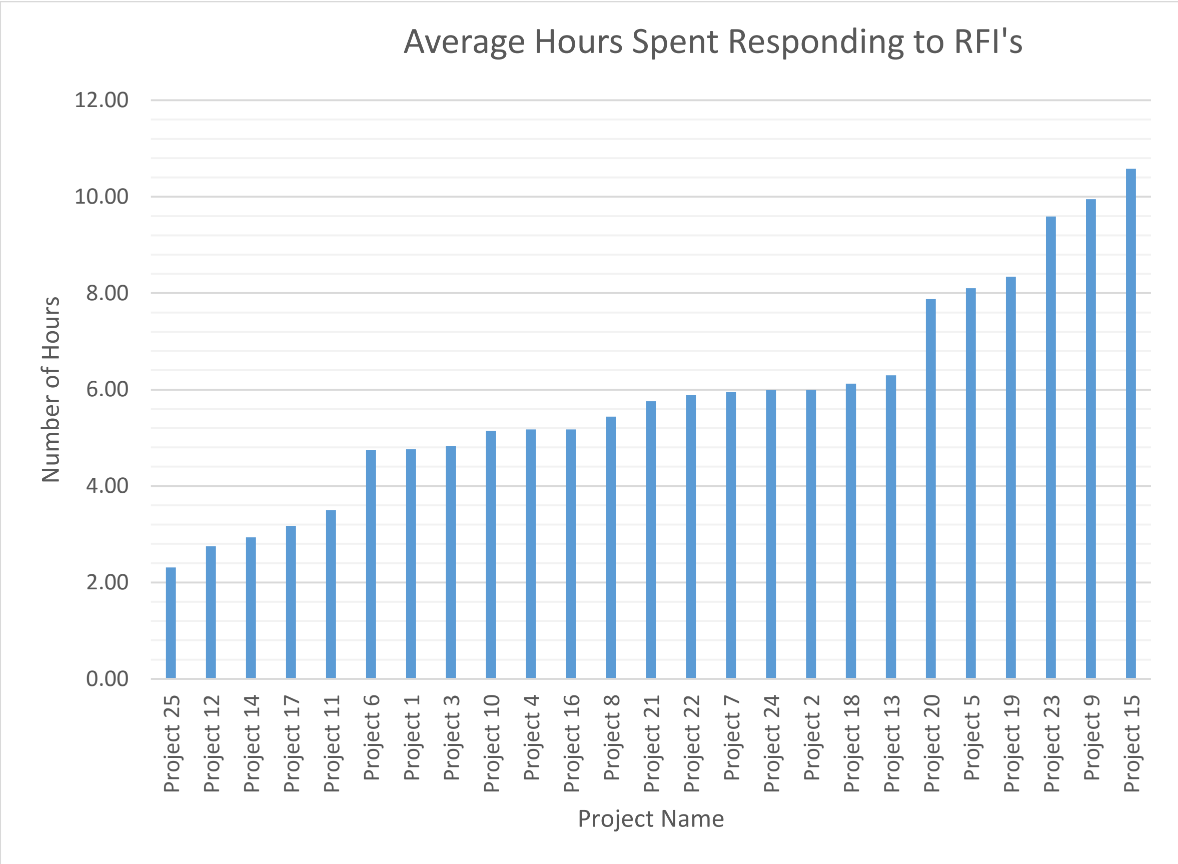


Figure 34: Case Study Projects – Average Hours Spent

As can be seen by visual inspection of the obtained data, there is a greater normalisation of the data compared to the total hours. This can be attributed to the fact that the large amount of hours spent is related to a large number of RFI's thus bringing down the average and making it more comparable to the rest of the data set.

To further investigate this process, the data has been plotted as a histogram and a simple statistical analysis has been undertaken. This is presented below in **Figure 35** and **Table 4-10.**

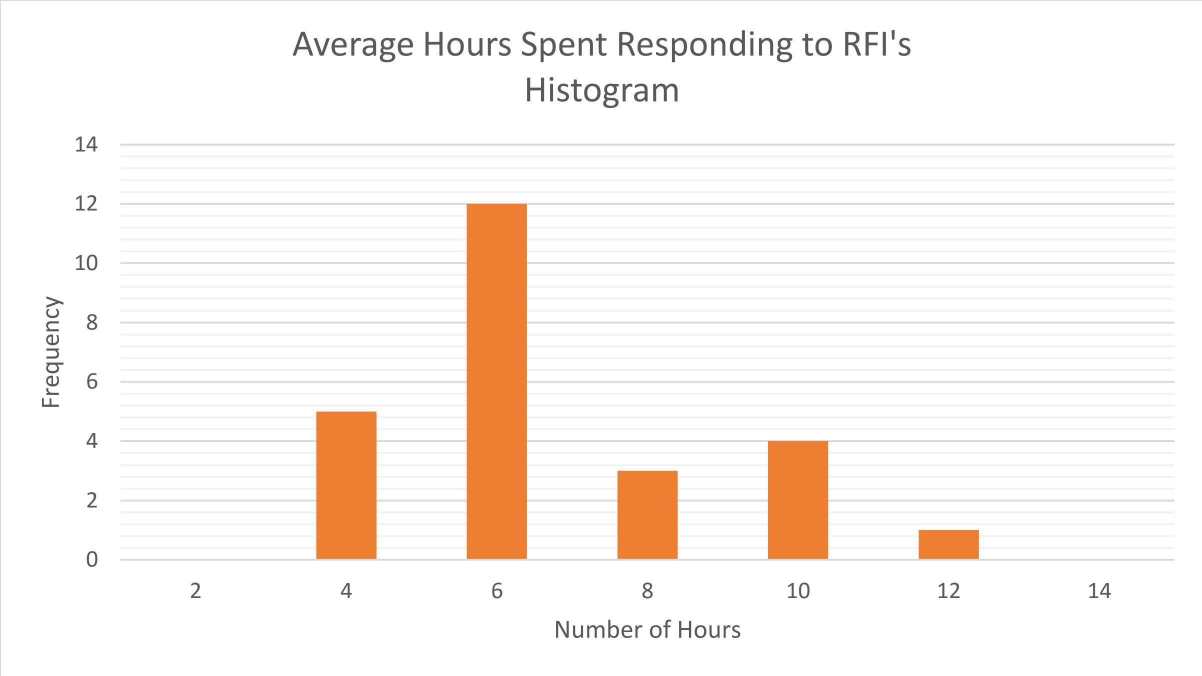


Figure 35: Case Study Projects – Average Hours Spent Histogram

Table 4-10: Case Study Projects – Average Hours Spent Statistics

Average Hours Spent Responding to RFI's	
Mean Value	5.86
Minimum Value	2.31
Maximum Value	10.58
Range	8.27
Median Value	5.76
Standard Deviation	2.17
Skew	0.52
First Quartile	4.8
Third Quartile	7.1
Interquartile range	2.3

As can be seen by the breakdown of the data above, the average time spent on the response to RFI's far more normalised than the total time dataset and presents a far smaller skew. Because of this normality, further investigation and analysis should focus on the average time spent per RFI rather than the total amount time spent on all RFI's for each project.

4.3.3 Cost of Response

Following the methodology detailed within **Section 3.4** above, the given 'industry rates' were applied to the total time spent responding to RFI's. This then produced the total costs given to responding to RFI's on each case study project. This data is presented in the following graph (**Figure 36**) below.

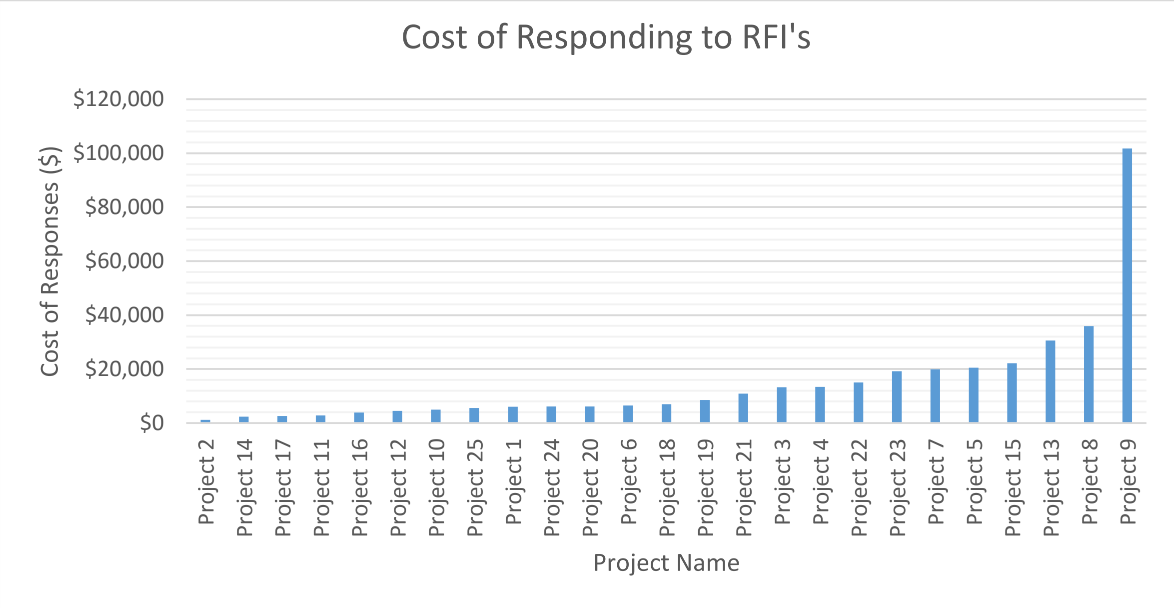


Figure 36: Case Study Projects – Total Cost of Response

From the visual inspection of the presented data it can be seen that the large outlier is still present in the data, as also seen above. To further break down the data, a histogram is plotted and a statistical analysis of the data has been undertaken below in **Figure 37** and **Table 4-11.**

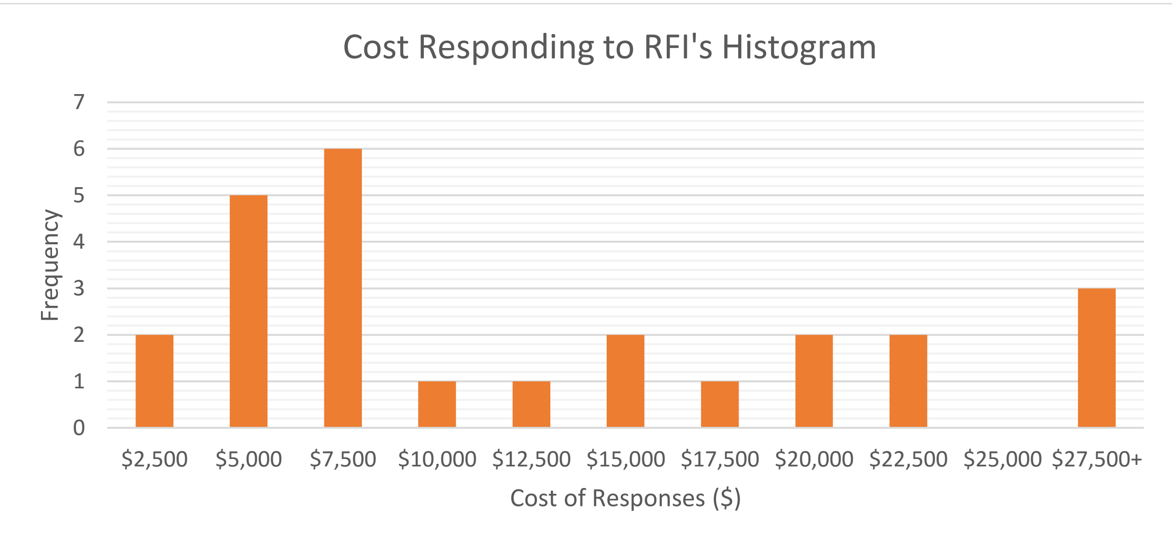


Figure 37: Case Study Projects – Total Cost of Response

Table 4-11: Case Study Projects – Total Cost of Response Statistics

Cost Responding to RFI's	
Mean Value	$14,833
Minimum Value	$1,200
Maximum Value	$101,798
Range	$100,598
Median Value	$6,944
Standard Deviation	$19,850
Skew	3.57
First Quartile	$4,729
Third Quartile	$19,575
Interquartile range	$14,846

As before, it can be seen from the above presented data that the large value in the outlying project contributes to a large skew in the data. To remedy this the data will be transformed into the average cost, per RFI.

4.3.4 Average Cost of Response

To further investigate the cost of responding to RFI's, the total cost of responding to RFI's was then divided by the total number of RFI's. This resulted in the creation of the average cost per RFI for each case study project. This information is presented below in **Figure 38.**

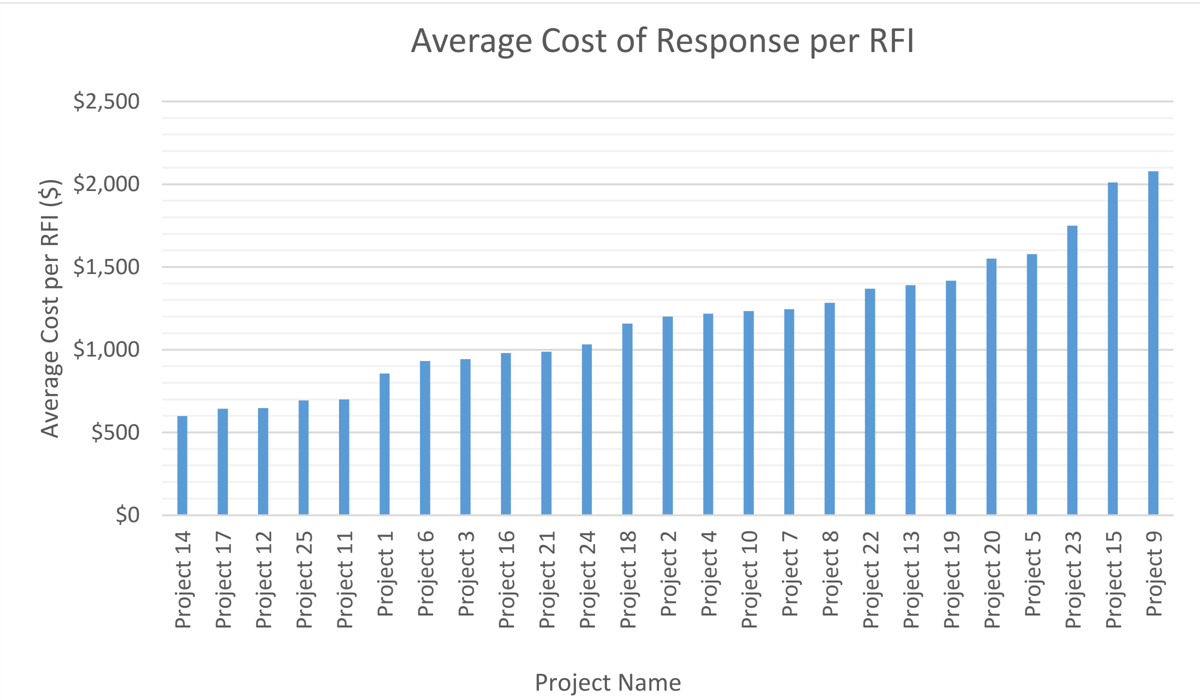


Figure 38: Case Study Projects – Average Cost of Response

As seen above, by considering the average cost for each RFI, the outliers have been converted into a more normalised data set. To further analyse the data, a histogram is plotted and a statistical analysis of the data has been undertaken below in **Figure 39** and **Table 4-12.**

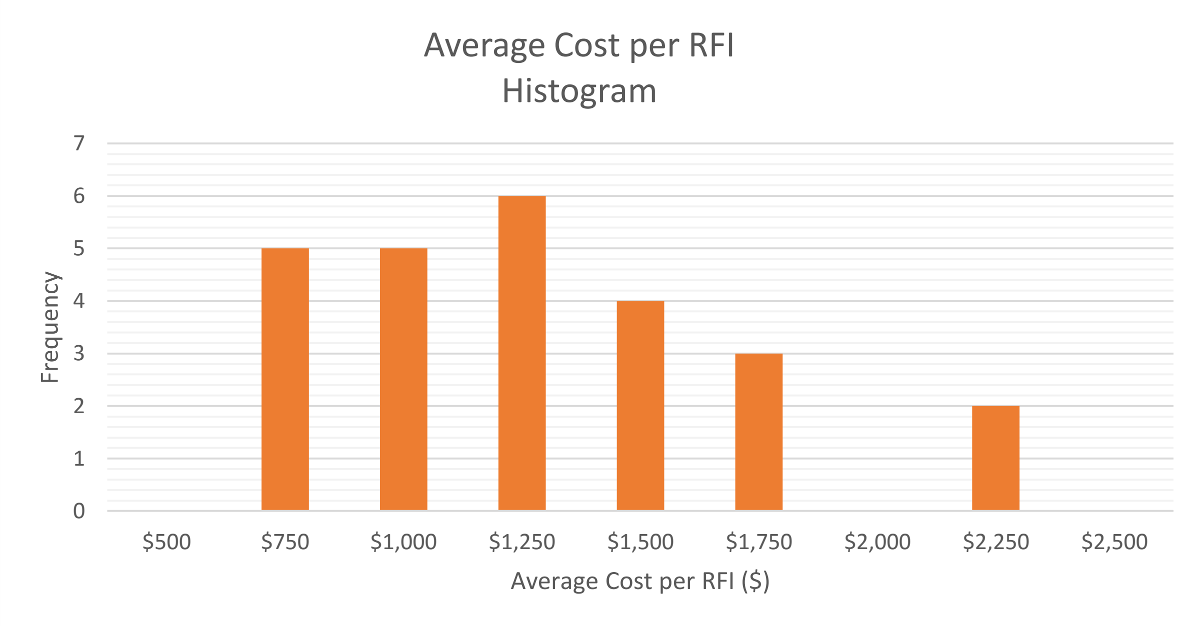


Figure 39: Case Study Projects – Average Cost of Response Histogram

Table 4-12: Case Study Projects – Average Cost of Response Statistics

Average Cost per RFI's	
Mean Value	$1,179
Minimum Value	$598
Maximum Value	$2,078
Range	$1,479
Median Value	$1,200
Standard Deviation	$398
Skew	0.55
First Quartile	$894
Third Quartile	$1,403
Interquartile range	$510

As seen before, the average cost of response to each RFI's presents a more normalised data set than the overall total cost per project. Because of this, further investigation and analysis should focus on the average cost per RFI, rather than the total cost or total hours.

4.3.5 Comparison of Time and Cost

Before further analysis of the data is undertaken is important to first compare the data collected for time and the data calculated for cost. Because the associated cost is calculated by using somewhat arbitrary 'industry rate' it could be possible that the applied rates, skew the resulting calculated costs. To make this comparison the total time will be graphed against the total cost of responding to RFI's and the average time will be graphed against the average cost of responding to RFI's. The first of the required graphs is shown below in **Figure 40.**

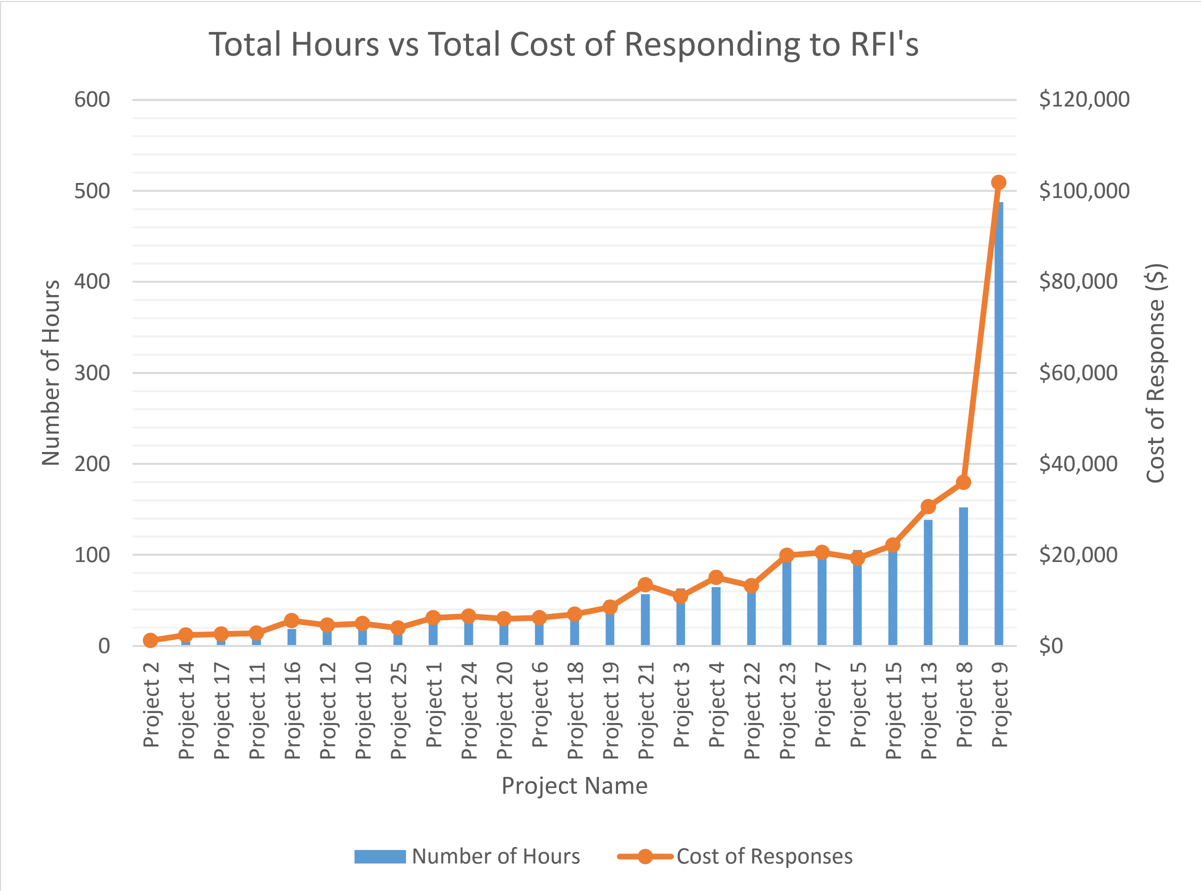


Figure 40: Case Study Projects – Total Hours vs Total Cost of Response

As before there is a large outlier present within the dataset. To further investigate the data set has been statistical analysed in **Table 4-13** below. Additionally as two data sets have been compared, a simple statistical analysis of the relationship has been undertaken in **Table 4-14** below.

Table 4-13: Case Study Projects – Total Time & Total Cost of Response Statistics

Total Hours & Total Cost of Responding to RFI's		
Mean Value	71.91	$14,833
Minimum Value	6.00	$1,200
Maximum Value	487.65	$101,798
Range	481.65	$100,598
Median Value	36.75	$6,944
Standard Deviation	94.28	$19,850
Skew	3.61	3.57
First Quartile	19.93	$4,729
Third Quartile	100.30	$19,575
Interquartile range	80.38	$14,846

Table 4-14: Case Study Projects – Total Time vs Total Cost of Response Statistics

Total Hours vs Total Cost of Responding to RFI's	
Covariance	1,866,099
Product of Standard Deviations	1,871,384
Pearson's Coefficient	0.997
Spearsman Coefficient	1.000

As can be seen by the statistical analysis of the selected data, although the data is quite skewed by a few outliers, there is almost perfect linear relationship between the data sets. Although this was expected due to the defined relationship between time and cost, it is good to confirm this with above statistical analysis.

To further investigate this relationship, the average time and average cost spent responding to RFI will be investigated and both data sets are plotted below in **Figure 41.**

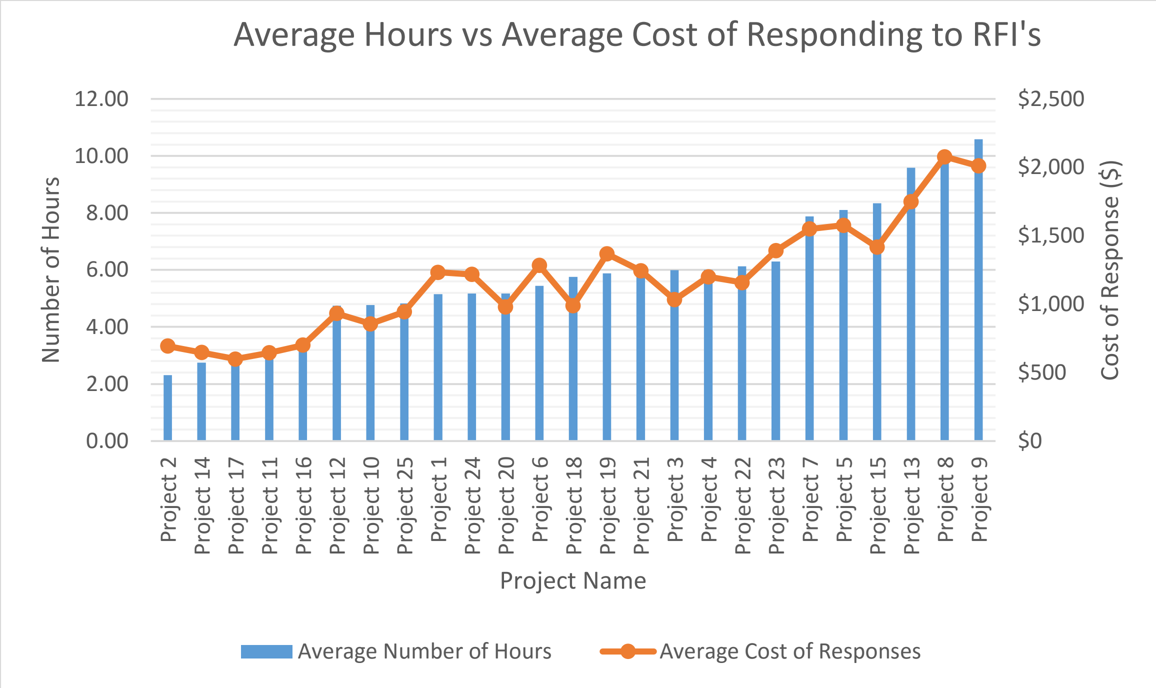


Figure 41: Case Study Projects – Average Hours vs Average Cost of Response

As can be seen by visual inspection of the above graph, although the data is now more uniformly distributed, the correlation between data sets is weaker than before. To further investigate this, the data sets and its relationship to each other is further broken down by statistical analysis in **Table 4-15** and **Table 4-16** below.

Table 4-15: Case Study Projects – Average Time & Average Cost of Response Statistics

Average Hours & Average Cost of Responding to RFI's		
Mean Value	5.86	$1,179
Minimum Value	2.31	$598
Maximum Value	10.58	$2,078
Range	8.27	$1,479
Median Value	5.76	$1,200
Standard Deviation	2.17	$398
Skew	0.52	0.55
First Quartile	4.76	$894
Third Quartile	7.09	$1,403
Interquartile range	2.33	$510

Table 4-16: Case Study Projects – Average Time vs Average Cost of Response Statistics

Average Hours vs Average Cost of Responding to RFI's	
Covariance	824
Product of Standard Deviations	863
Pearson's Coefficient	0.955
Spearsman Coefficient	0.918

As can be seen in the above breakdown, the presented average values have created a more uniformly distributed data set and while the strength of the relationship has decreased it can still be considered as a ‘very strong’ correlation. The decrease in the strength of this relationship can be attributed to the decrease in accuracy of calculations due to rounding and are hence negligible.

Because of the uniformity of the distribution of data and because ultimately the cost to designers is the main point of interest. The Average Cost of Response will be taken as the factor to be further analysed against the project factors in the following chapter.

CHAPTER 5 - Data Analysis

Following the collection and presentation of the collected case study data, the project and design engineers factors will now be compared against the average associated cost to reveal any potential relationships. Any relationship between data sets will be further investigated by visual and statistical methods as detailed above in **Section 3.6.1**

Whist the collected design engineers data is compared and analysed to the average cost, it should be noted that the main focus of the analysis will be on the collected project data. This is because the factors collected as a part of the project data set are known prior to the commencement of construction and even sometimes the design itself. This means that any correlation discovered between the average cost of RFI's and the project data can then possibly be related to values known prior to the design phase. This could hence predict the cost of RFI's on a future project. This concept will be further investigated in the following chapters.

5.1 Average Number of RFIs

Following on from the data collected and then presented in **Section 4.2.1**, the total number of RFI's on projects is now further investigated. From the detailed literature review in **Section 2.5.2**, it is known that there is a significant relationship between a projects contract value and the number of RFIs on a given project. Because of this known relationship only this project factor will be further investigated in regards to the number of RFI's on a project.

5.1.1 Average Number of RFIs by Contract Value

From the collected contract values presented above in **Section 4.1.3**, the total number of RFI's on a project was then graphed against the contract value of each project as seen in **Figure 42** below.

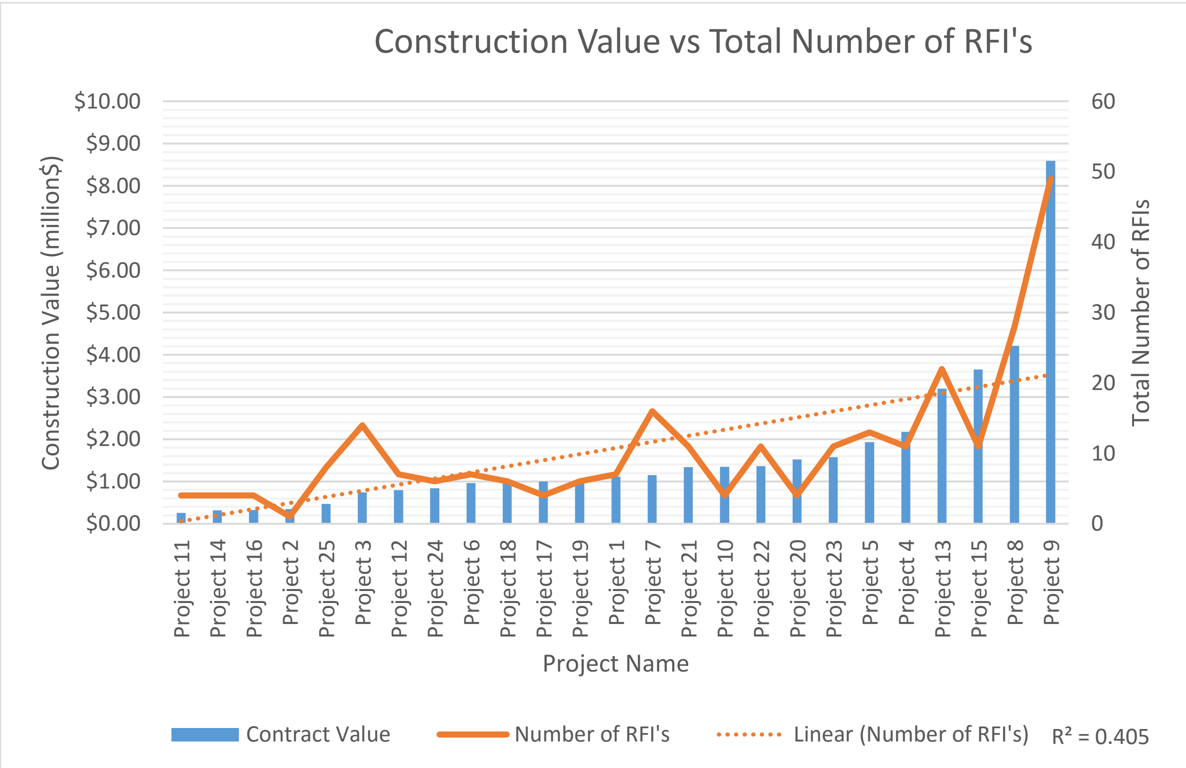


Figure 42: Projects by Construction Value vs Total Number of RFI's

When plotted together, a visual trend in the data is easily identifiable. To better visualise this trend a linear line of best fit has been applied to the total number of RFIs data set. To further investigate the relationship between the data sets, a simple statistical analysis has been undertaken in **Table 5-1** and **Table 5-2** below.

Table 5-1: Construction Value (million$) & Total Number of RFI's

Construction Value (million$) & Number of RFI's		
Mean Value	$1.648	10.76
Minimum Value	$0.257	1.00
Maximum Value	$8.590	49.00
Range	$8.334	48.00
Median Value	$1.110	7.00
Standard Deviation	$1.730	9.83
Skew	2.87	2.66
First Quartile	$0.773	4.00
Third Quartile	$1.752	12.00
Interquartile range	$0.980	8.00

Table 5-2: Construction Value (million$) vs Total Number of RFI's

Construction Value vs Average Cost	
Covariance	16
Product of Standard Deviations	17
Pearson's Coefficient	0.920
Spearsman Coefficient	0.731

By analysis of the data sets both visually and statistically, the total construction value can be seen to have a 'very strong' correlation to the average cost of responding to an RFI.

These results confirm the prior research by the Navigant Construction Forum and Robert Dinsmore, summarised in **Section 2.5.2.** Both of these prior papers concluded that the number of RFI's would increase with the contract value.

To further analyse this data the number of RFIs per million dollars is calculated by dividing the number of RFI's by the Contract Value (in millions dollars). This data is presented below as a histogram in **Figure 43** and a simple statistical analysis has been undertaken in **Table 5-3**.

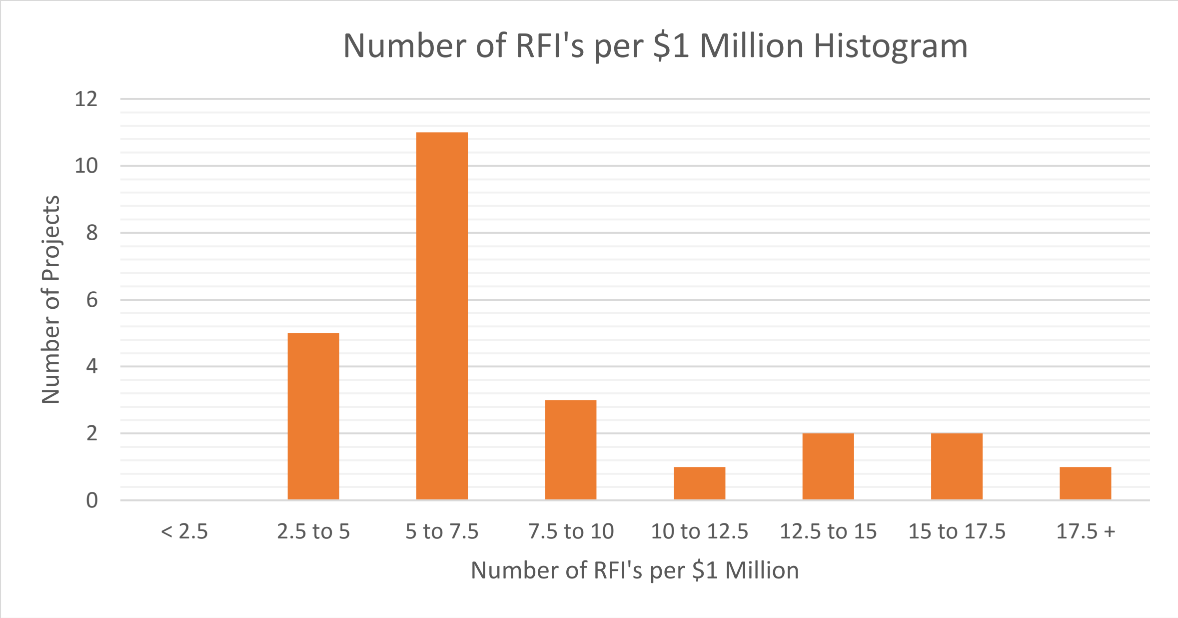


Figure 43: Number of RFI's per $1 Million Histogram

Table 5-3: Number of RFI's per $1 Million Histogram Statistics

Number of RFI's per $1 Million	
Mean Value	8.07
Minimum Value	2.62
Maximum Value	18.77
Range	16.14
Median Value	6.88
Standard Deviation	4.40
Skew	1.03
First Quartile	5.38
Third Quartile	10.50
Interquartile range	5.12

When this data is value is compared the average values given by the Navigant Construction Forum (for the $5 million to $50 million category), it can be seen that the calculated average (8.07) is under half the Navigant value (17.2).

This can be explained by the far different constraints given to the different data sets. The calculated values are from projects in the greater Toowoomba Region, with construction values between $250,000 and $8.4 million. Where the given Navigant values are from all over the world and is for a range of projects from $5 million to $50 million. Because of this mismatch of constrains the values cannot be accurately compared to each other.

Instead it is proposed that the values actually complement each other, as logically, the number of RFI's per million dollars would need to decrease to zero as the construction value reaches zero. This means from the Navigant values given the number of RFI's per $1 million must decrease at lower construction values and the calculated values above could be adopted to complete this model.

Because of this known and now defined relationship, the potential number of RFI's on a given project will be further investigated and discussed in the following chapter, using the contract value as a basis.

5.2 Average Cost per RFI

Following the presentation and analysis of the number of RFI's on a project the average cost per RFI will be compared to the collected project and design engineers factors.

5.2.1 Average Cost per RFI by Project Location

From the case study projects collected, the breakdown of number of projects per location, the average cost per RFI by location and the overall average cost is displayed in **Figure 44** below.

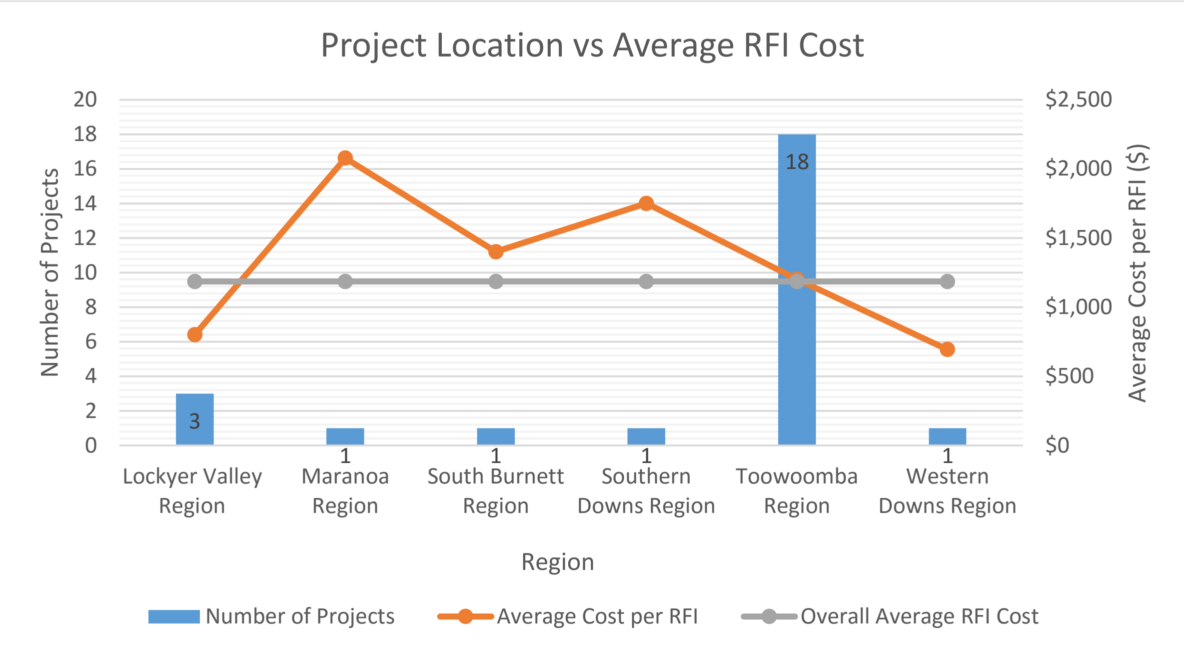


Figure 44: Projects by Location vs Average RFI Cost

As can be seen by visual inspection of the above data, the average cost for the Toowoomba region is nearly equal to the overall average amount. With the other regions, the largest average cost per RFI seems to correlate with been the largest distance from Toowoomba. This somewhat confirms the prior assumption that the relative distance between the project and the office may affect the cost of responding to RFI's. However since the size of the data sets for projects outside of the Toowoomba region is quite limited, the correlation in these data sets cannot be sufficiently confirmed.

Because of the lack of data for this comparison, no further statistical investigation or discussion of this factor will be required.

5.2.2 Average Cost per RFI by Project Type

From the case study projects collected, the breakdown of number of projects by type, the average cost per RFI by type of construction and the overall average cost is displayed in **Figure 45** below.

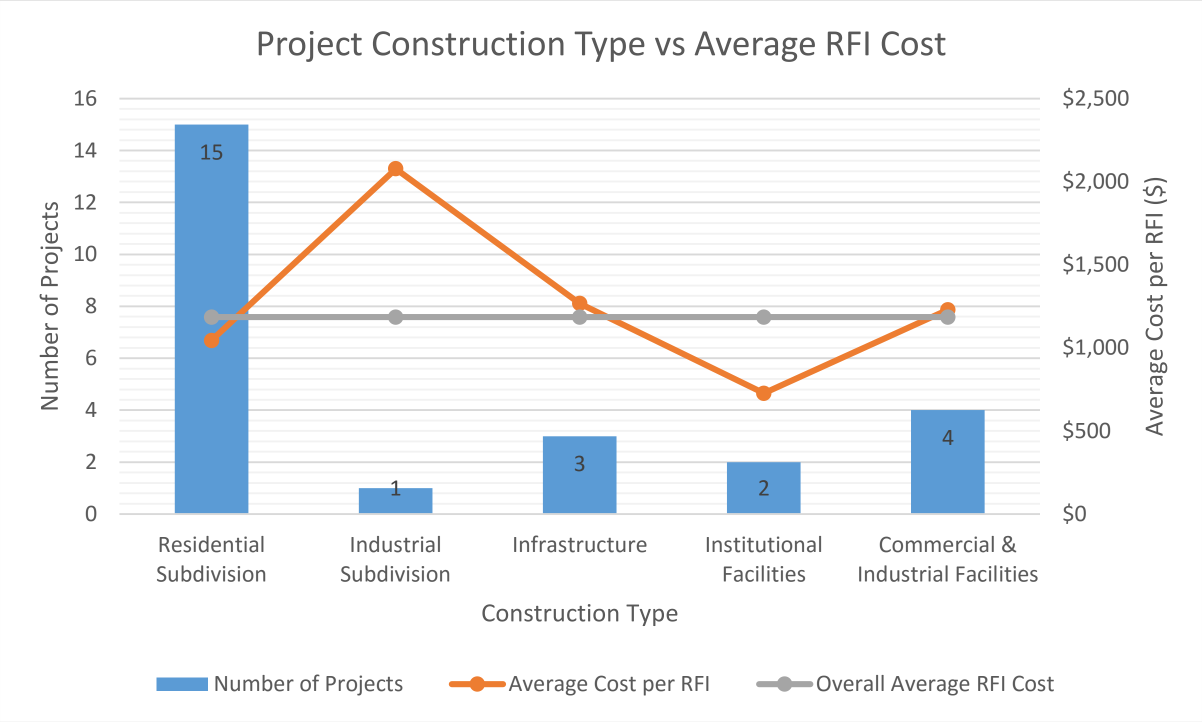


Figure 45: Projects by Construction Type vs Average RFI Cost

As can be seen by visual inspection of the data, the average cost per RFI on Residential Subdivisions, Infrastructure projects and Commercial and Industrial Facilities all fall near to the overall average. Where Industrial Subdivisions are far higher and Institutional facilities are somewhat below the overall average. However, again, as the sample size for these outliers is so small (only one project for industrial Subdivisions and two for Institutional facilities), no conclusions or relationships can be drawn from this data.

Because of this lack of data for comparison, no further statistical investigation will be required.

5.2.3 Average Cost per RFI by Construction Value

From the collected contract values presented above in **Section 4.1.3,** the average cost per RFI for each project was calculated and then graphed against value of each project as seen in **Figure 46** below.

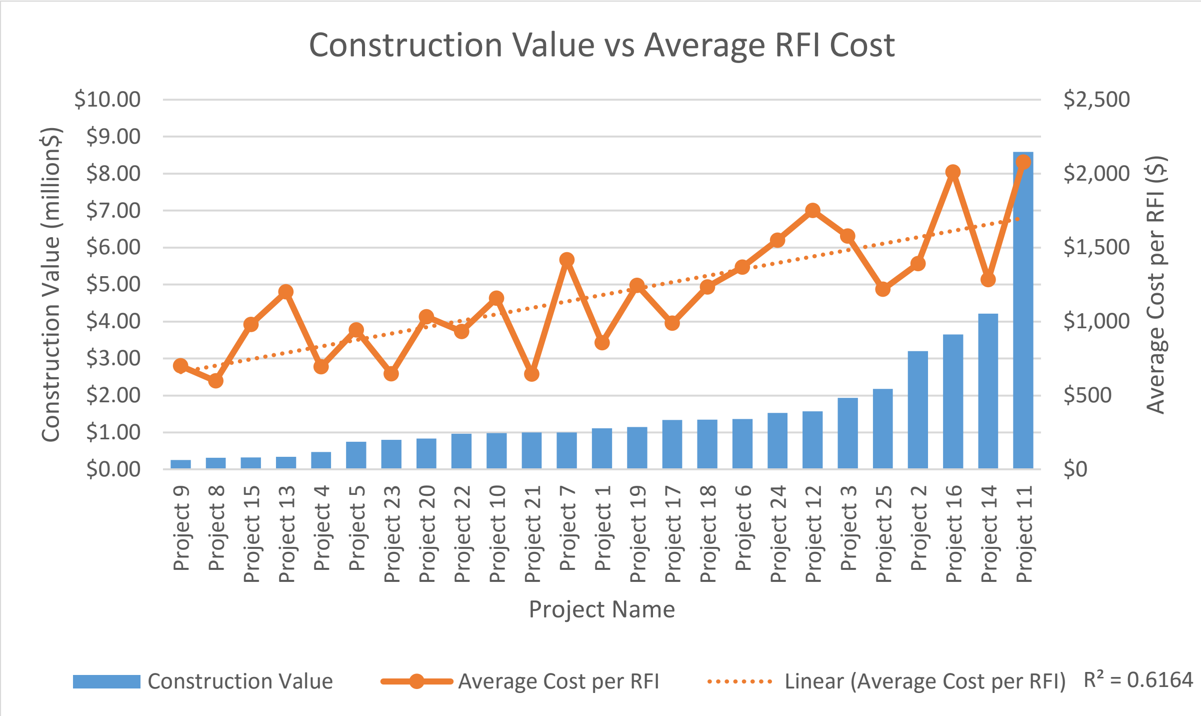


Figure 46: Projects by Construction Value vs Average RFI Cost

When plotted together, a visual trend in the data is easily identifiable. That is, as project construction value increases so does the average cost of responding to RFI's. To better visualise this trend, a linear line of best fit has been applied to the average cost per RFI data set. To further investigate the relationship between the data sets, a simple statistical analysis has been undertaken in **Table 5-4** and **Table 5-5** below.

Table 5-4: Construction Value (million$) & Average Cost Statistics

Construction Value (million$) & Average Cost		
Mean Value	$1.648	$1,179
Minimum Value	$0.257	$598
Maximum Value	$8.590	$2,078
Range	$8.334	$1,479
Median Value	$1.110	$1,200
Standard Deviation	$1.730	$398
Skew	2.87	0.55

First Quartile	$0.773	$894
Third Quartile	$1.752	$1,403
Interquartile range	$0.980	$510

Table 5-5: Construction Value (million$) vs Average Cost Statistics

Construction Value vs Average Cost	
Covariance	483
Product of Standard Deviations	689
Pearson's Coefficient	0.701
Spearsman Coefficient	0.795

By analysis of the data sets both visually and statistically, the total construction value can be seen to have a 'strong' correlation to the average cost of responding to an RFI. This relationship will be further discussed in the following chapter.

5.2.4 Average Cost per RFI by Construction Duration

From the collected database, each project was grouped together by construction durations and the average cost of response was calculated for each group. These values were then graphed against the construction duration in ascending order and the number of projects, in **Figure 47** below.

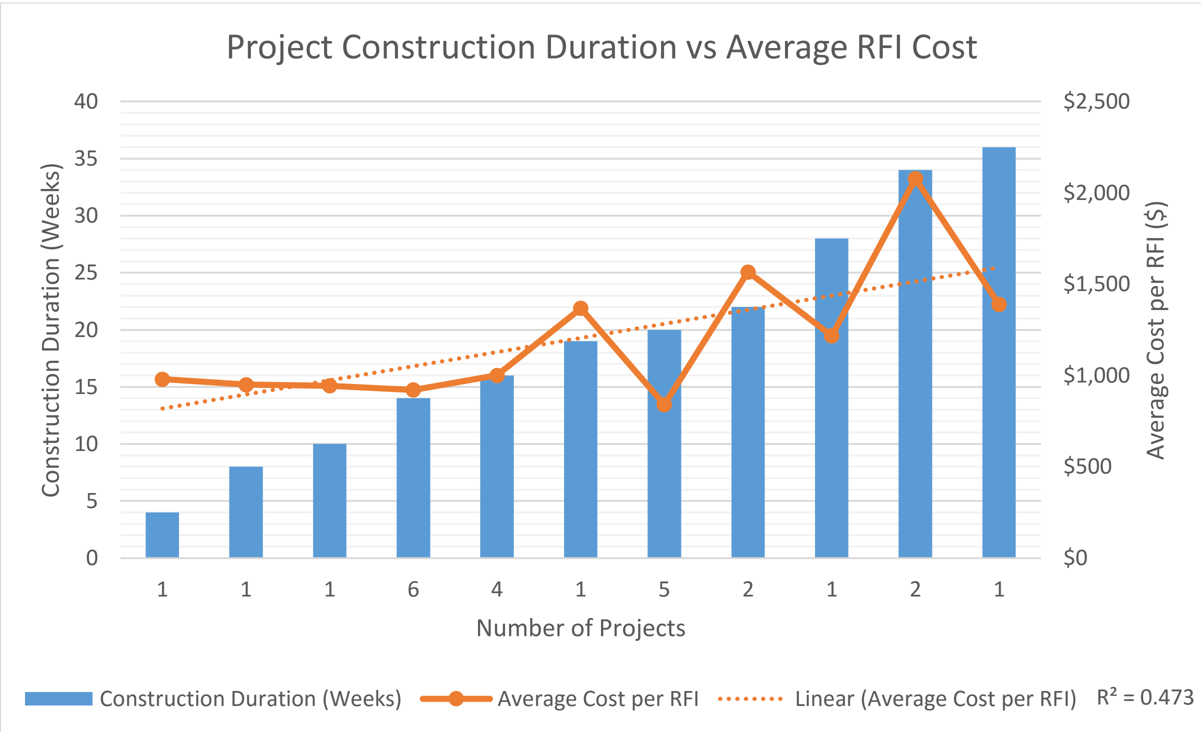


Figure 47: Projects by Construction Duration vs Average RFI Cost

From visual inspection of above graph it can be seen that there is a slight correlation between construction duration and the average cost of responding to RFI's. That is as the construction duration increases so does the average cost of responding to RFI's. This relationship between the data sets is further investigated in the simple statistical analysis undertaken in **Table 5-6** and **Table 5-7** below.

Table 5-6: Construction Duration (Weeks) & Average Cost Statistics

Construction Duration (Weeks) & Average RFI Cost		
Mean Value	19.2	$1,205
Minimum Value	4.0	$840
Maximum Value	36.0	$2,078
Range	32.0	$1,237
Median Value	19.0	$1,001
Standard Deviation	9.8	$356
Skew	0.3	1.40
First Quartile	10.0	$944
Third Quartile	28.0	$1,390
Interquartile range	18.0	$446

Table 5-7: Construction Duration (Weeks) vs Average Cost Statistics

Construction Duration (Weeks) vs Average RFI Cost	
Covariance	2,637
Product of Standard Deviations	3,502
Pearson's Coefficient	0.667
Spearsman Coefficient	0.664

As can be seen in the above statistical analysis, averaging the costs of responding to RFI's by projects of the same duration results in a much larger skew compared to the average per project calculated. However when comparing the data sets both coefficients still indicate a 'strong' correlation. Because of the strength of this correlation this relationship will be further discussed in the following chapter.

5.2.5 Average Cost per RFI by Number of Plans

From the collected database, the number of construction plans on a project and the corresponding average cost of RFI's is plotted in **Figure 48** below.

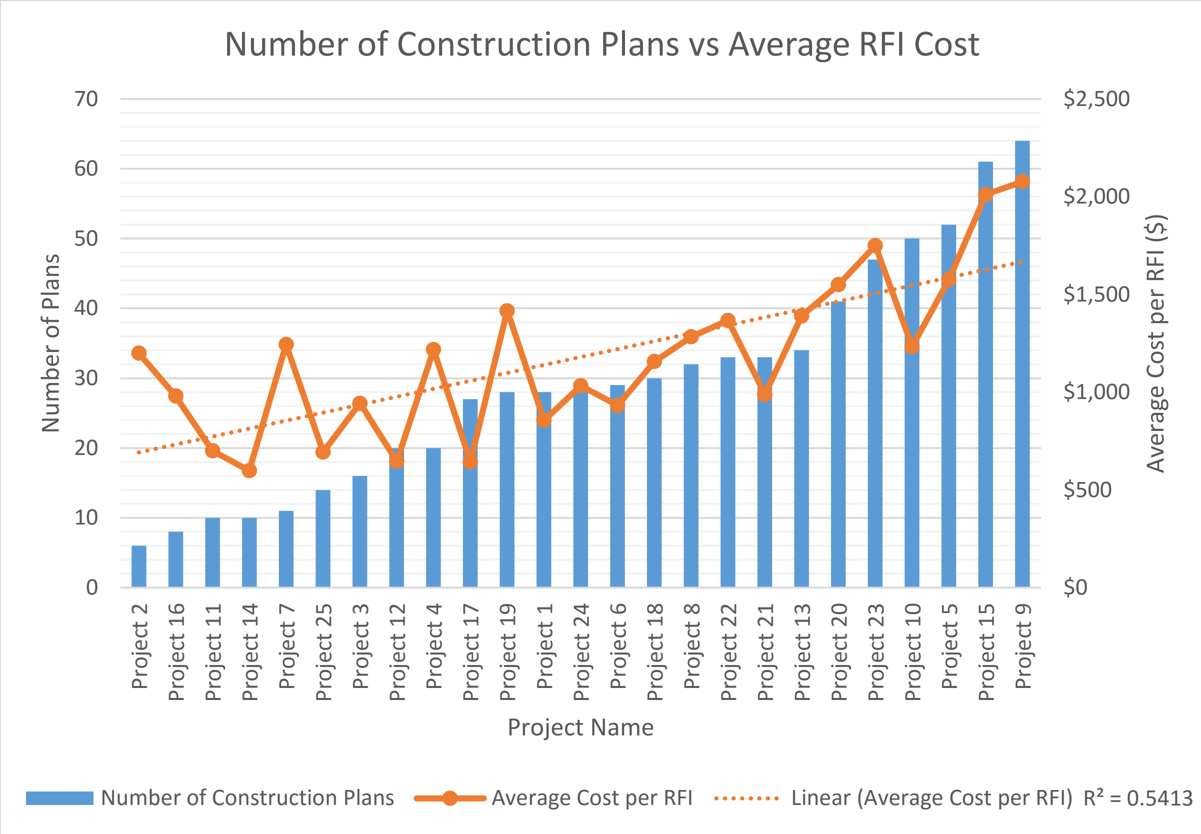


Figure 48: Number of Construction Plans vs Average RFI Cost

From visual inspection of the above graph a clear correlation can be identified between the number of construction plans and the average cost of RFI's on an individual project. This relationship between data sets will be further investigated in the statistical analysis presented below in **Table 5-8** and **Table 5-9**.

Table 5-8: Number of Plans & Average Cost Statistics

Number of Plans & Average Cost		
Mean Value	29	$1,179
Minimum Value	6	$598
Maximum Value	64	$2,078
Range	58	$1,479
Median Value	28	$1,200
Standard Deviation	15.91	$398
Skew	0.55	0.55
First Quartile	15.00	$894
Third Quartile	37.50	$1,403
Interquartile range	22.50	$510

Table 5-9: Number of Plans vs Average Cost Statistics

Number of Plans vs Average Cost	
Covariance	4,925
Product of Standard Deviations	6,340
Pearson's Coefficient	0.777
Spearsman Coefficient	0.719

From the above statistical analysis the data sets are shown to be both have a 'strong' relationship. The further investigation of this relationship will be presented in the following chapter.

5.2.6 Average Cost per RFI by Number of RFI's

From the collected case study data, the number of RFI's on a project and the average cost spent responding to each RFI is plotted in **Figure 49** below.

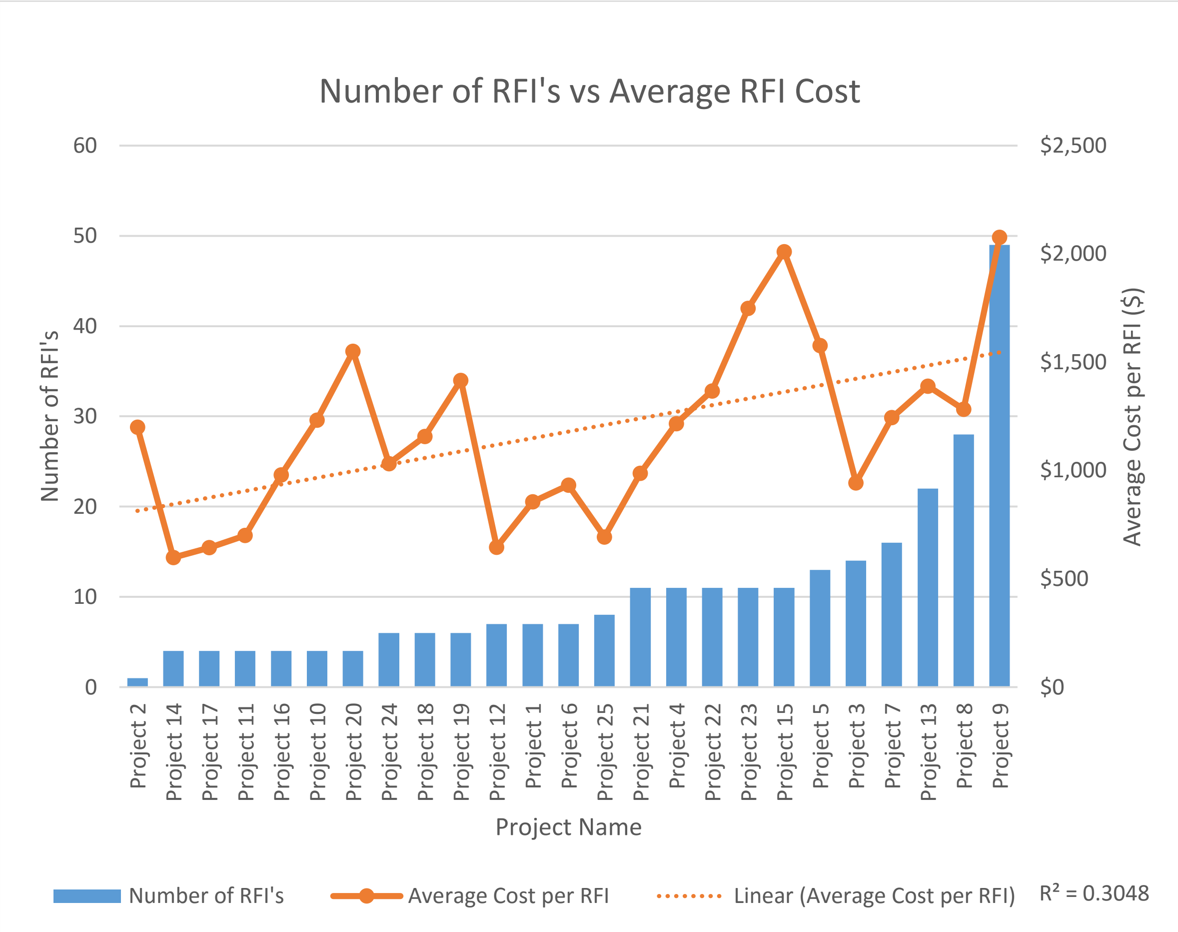


Figure 49: Number of RFI's vs Average RFI Cost

From visual inspection of the graph above it can be seen that there is a slight trend in the data but it is not very strong. To further investigate this, the data sets were statistically analysed and the results are shown below in **Table 5-10** and **Table 5-11**.

Table 5-10: Number of RFI's & Average Cost Statistics

Number of RFI's & Average Cost		
Mean Value	11	$1,179
Minimum Value	1	$598
Maximum Value	49	$2,078
Range	48	$1,479
Median Value	7	$1,200
Standard Deviation	9.86	$398
Skew	2.63	0.55
First Quartile	4.00	$894
Third Quartile	12.50	$1,403
Interquartile range	8.50	$510

Table 5-11: Number of RFI's vs Average Cost Statistics

Number of RFI's vs Average Cost	
Covariance	2,183
Product of Standard Deviations	3,930
Pearson's Coefficient	0.556
Spearsman Coefficient	0.459

As can be seen in the analysis and graph above, the data set for the number of RFI's contains a few outliers that are contributing to a skew of the data. Once the two data sets were statically analysed it can be seen that a 'moderate' correlation is present between values. This can be simply attributed to the fact that any given RFI may vary greatly in complexity and hence cost of response. The correlation in these datasets is more than likely to be influenced by another, primary factor. Such as the shown relationship between the number of plans increasing the number of RFI's and hence the cost. For this reason, the primary factor should be the focus of further analysis and discussion.

5.2.7 Average Cost per RFI by RFI Topic

From the database of collected information the RFI's were categorised by topic and the total cost of RFI's per topic was divided by the number of RFI's per topic to calculated the average cost per RFI per topic. The results of this and the overall average cost per RFI is graphed in **Figure 50** and a simple statistical analysis has been conducted in **Table 5-12** below.

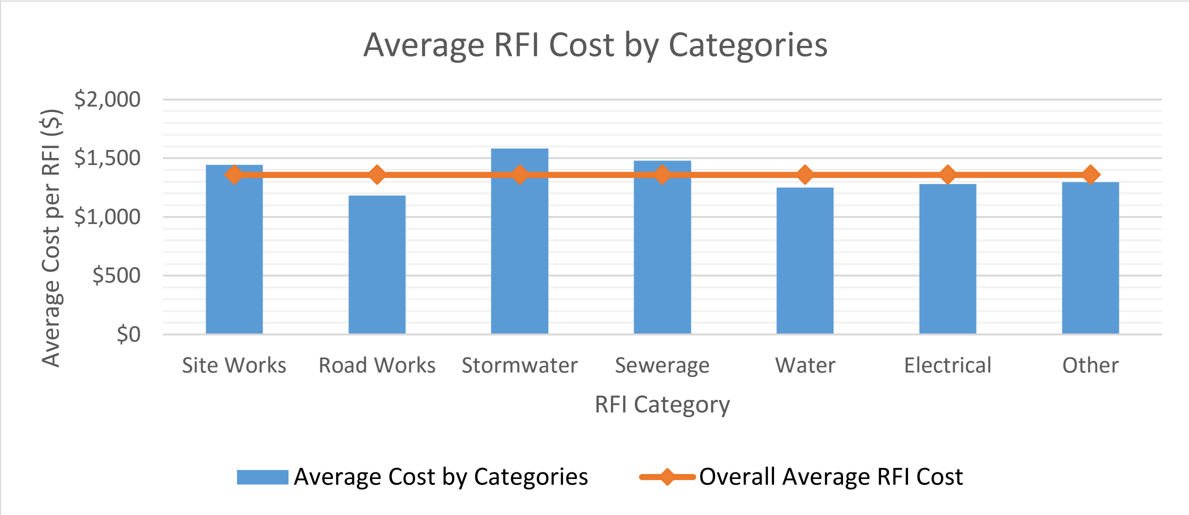


Figure 50: RFI Topic vs Average RFI Cost

Table 5-12: RFI Topic & Average Cost Statistics

Average Cost by Categories	
Mean Value	$1,359
Minimum Value	$1,182
Maximum Value	$1,581
Range	$399
Median Value	$1,296
Standard Deviation	133.1
Skew	0.45
First Quartile	$1,250
Third Quartile	$1,479
Interquartile range	$229

As can be seen from the plotted data and statistical analysis the calculated average costs per RFI by topic does not vary much from the average. This can be attributed to the fact that the sample size for total RFI's is quite large and when divided by the total cost will result in values quite close to the overall average. Because of this relationship, the topic of an RFI is shown to have minimal effect on the potential cost and hence further investigation is not required.

5.2.8 Average Cost per RFI by Response Time

From the database of collected data, the average RFI response time for each project was calculated by the method detailed within **Section 4.2.3** above. This average response time was then plotted against the average cost of response to create the graph shown below in **Figure 51**.

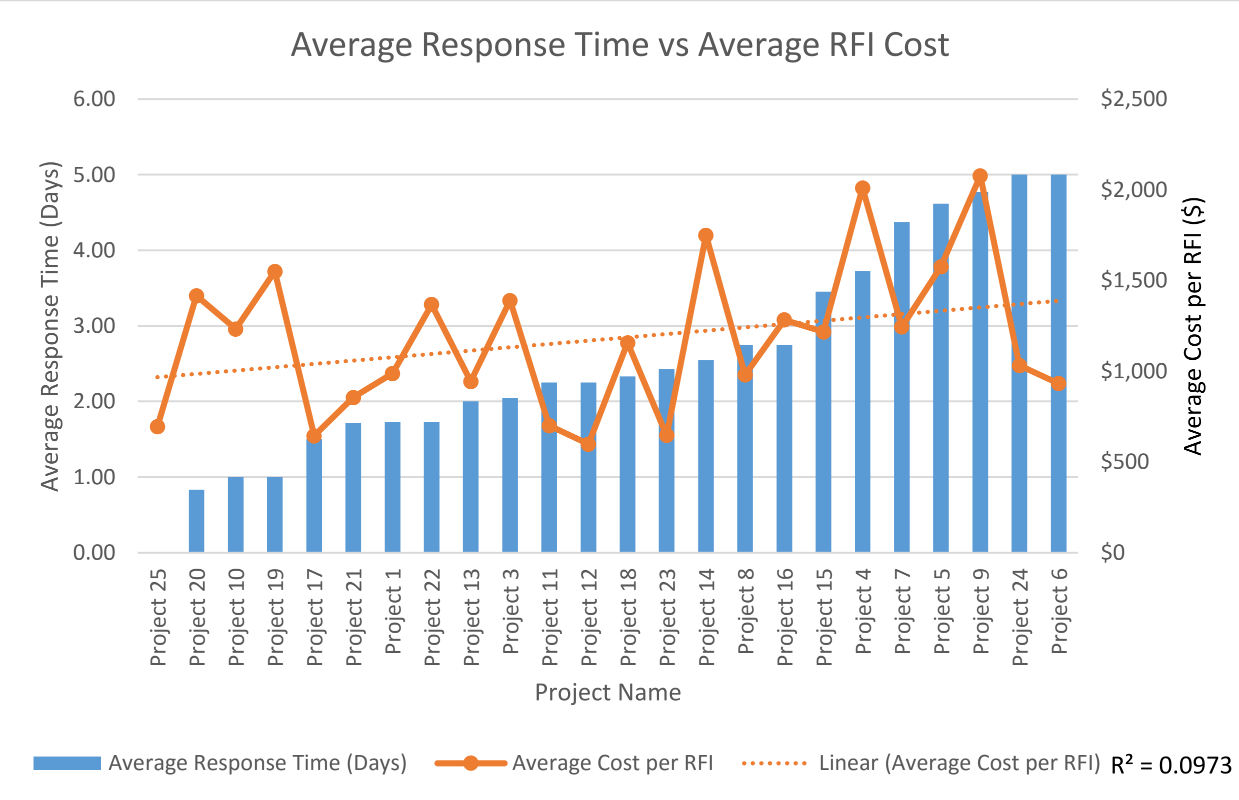


Figure 51: Response Time vs Average RFI Cost

From visual inspection of the above graph it can be seen that no distinct correlation between the data sets is present. This analysis of data also excludes the large outlier identified in **Section 4.2.3,** but even with this exclusion no real correlation exists. To further investigate this a simple statistical analysis is under taken in **Table 5-13** and **Table 5-14** below.

Table 5-13: Response Time & Average Cost Statistics

Average Response Time & Average RFI Cost		
Mean Value	4	$1,179
Minimum Value	0	$598
Maximum Value	18	$2,078
Range	18	$1,479

Median Value	3	$1,200
Standard Deviation	3.42	$398
Skew	2.73	0.55
First Quartile	2.19	$894
Third Quartile	5.94	$1,403
Interquartile range	3.75	$510

Table 5-14: Response Time & Average Cost Statistics

Average Response Time vs Average RFI Cost	
Covariance	267
Product of Standard Deviations	1,364
Pearson's Coefficient	0.195
Spearsman Coefficient	0.186

As can be seen in the above analysis of the data sets (both visually and statistically), the correlation between the two can be described as ‘very weak’. This is possibly because although the response time on RFI’s can give a good indication of how long it took to respond it does not take into account how much time in that duration was actually spent actually working towards a response. Because of this poor association, the response time will not be further investigated.

5.2.9 Average Cost per RFI by RFI Cause

From the data set, the RFIs were categorised by types of causes, as defined in **Section 3.3.5** and the average cost of responding was then calculated for each type. The results of these calculations and the overall average cost per RFI is graphed in **Figure 52** and a simple statistical analysis has been conducted in **Table 5-15** below.

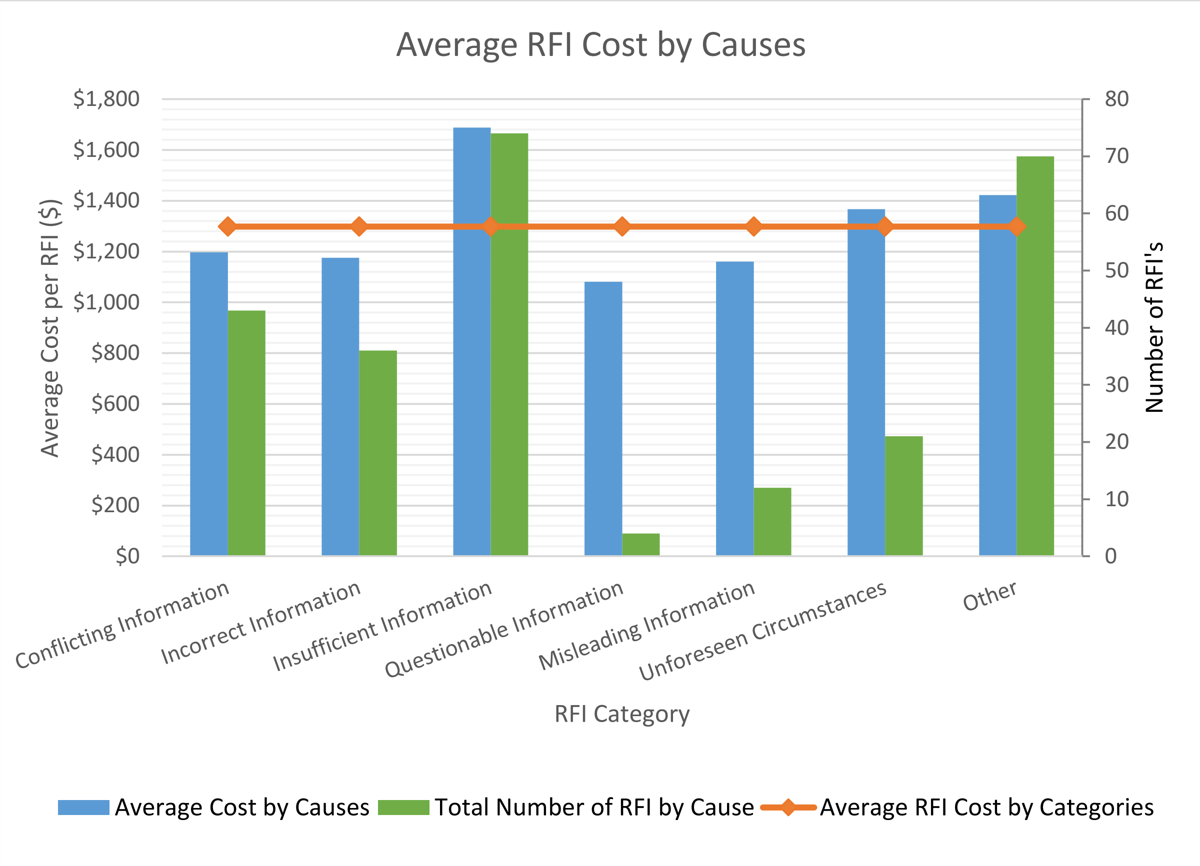


Figure 52: Average RFI Cost by RFI Cause

Table 5-15: Average RFI Cost by RFI Cause Statistics

Average RFI Cost by RFI Cause	
Mean Value	$1,440
Minimum Value	$1,046
Maximum Value	$2,226
Range	$1,180
Median Value	$1,367
Standard Deviation	373.9
Skew	1.43
First Quartile	$1,161
Third Quartile	$1,688
Interquartile range	$527

As can be seen from the plotted data and statistical analysis, the calculated average costs per RFI by cause varies a lot from the average cost on some of the categories. While the majority of projects fall under the overall average value, two categorises out rank it.

On further investigation of this, it can be seen that these two outliers, Insufficient Information and Other, also make up the two largest data sets. Because of this it can be assumed that the large data sets contribute to the modest increase of these category from the average. As the seen increase and decrease between categories is minor it can be considered that the cause of RFI's has little relationship with the overall average cost.

However as this factor is ultimately very important in the overall process this greater relationship between the cost of RFI's and the cause of RFI's will be further investigated in the next chapter.

CHAPTER 6 - Discussion

As can be seen from the data analysis above, significant relationships have been identified between the Contract Value and the Number of RFI's on a project. Additionally it was revealed there is also a significant relationship between the average cost per RFI and the Contract Value, the Project Duration and the Number of Construction Plans. This chapter will further investigate these relationships to evaluate the possible recommendations that can be made for designers engaging in future projects.

6.1 Number of RFI's

As seen in above in **Section 5.1.1** the average number of RFIs per project has been given as 8.07 per $1 million of contract value. This value has been compared to prior research and has been found to fill in a necessary gap within the literature for the defined limitations.

To further investigate the relationship between Construction Value and the Number of RFI's, the two data sets have been plotted against each other in **Figure 53** below. A linear line of best fit has been also applied to the graph to mathematically define the relationship.

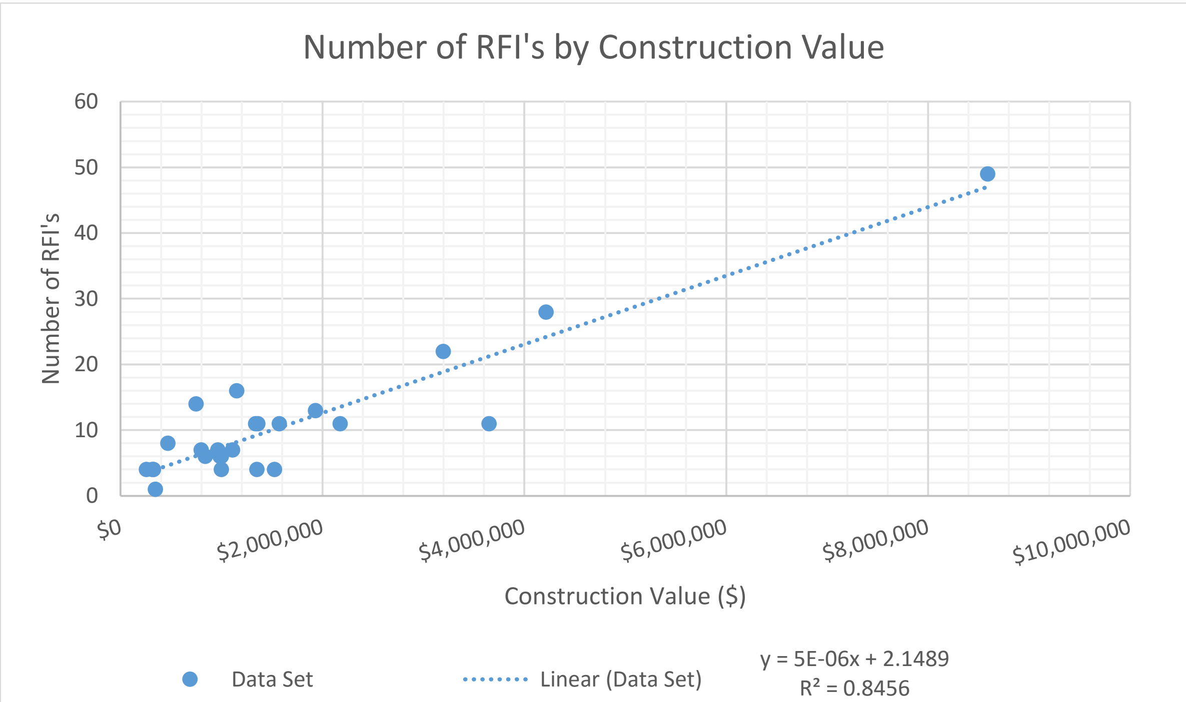


Figure 53: Number of RFI's by Construction Value

From this graph it can be seen that the linear line of best fit follows the relationship of the data sets with high accuracy ($R^2 = 0.8465$). Because this it is proposed that this linear relationship can be defined to estimate the number of RFI's on future design projects. This relationship is defined as:

Equation 1:

$$Number\ of\ RFIs = (0.000005 * Construction\ Value)\ +\ 2.1489$$

Where the construction value is the whole dollar amount of the original contract value, as defined above in **Section 3.2.** The figure then returned from this calculation can then be rounded up or down to produce the approximate number of RFI's on a given project.

For the validation of this equation the estimated number of RFIs on a project was calculated for the known contract values. The returned estimated number of RFIs was then compared to the known number of RFI's and statistically analysed. The results of this analysis is given below in **Table 6-1.**

Table 6-1: Known Number of RFIs vs Estimated Number

Known Number of RFIs vs Estimated Number	
Mean Value	20.2%
Minimum Value	-57.1%
Maximum Value	300.0%
Range	357.1%
Median Value	0.0%
Standard Deviation	75.4%
Skew	239.3%
First Quartile	-18.2%
Third Quartile	17.4%
Interquartile range	35.6%

From the above statistical analysis it can be seen that the average error present in the estimated values is 20.2%. This means the values calculated from this equation should be used as strictly estimates only. As the purpose of this chapter is to provide discussion on the given data, the degree of error in this estimate method should be acceptable.

6.2 Average Cost per RFI

As discovered in the above **Section 5.2,** the project factors of Contract Value, Project Duration and Number of Construction Plans have been found to have a strong correlation with the average cost per RFI.

As previously discussed in **Section 2.5.2,** it has been proposed that these values are closely linked, to the point of been products of each other. That is, as the number of plans increase so does the duration and hence the construction cost. To further investigate the link between these factors and the average cost per RFI, the data sets have been plotted against each other in **Figure 54, Figure 55** and **Figure 56** below. A linear line of best fit has been also applied to each graph to mathematically define the relationship.

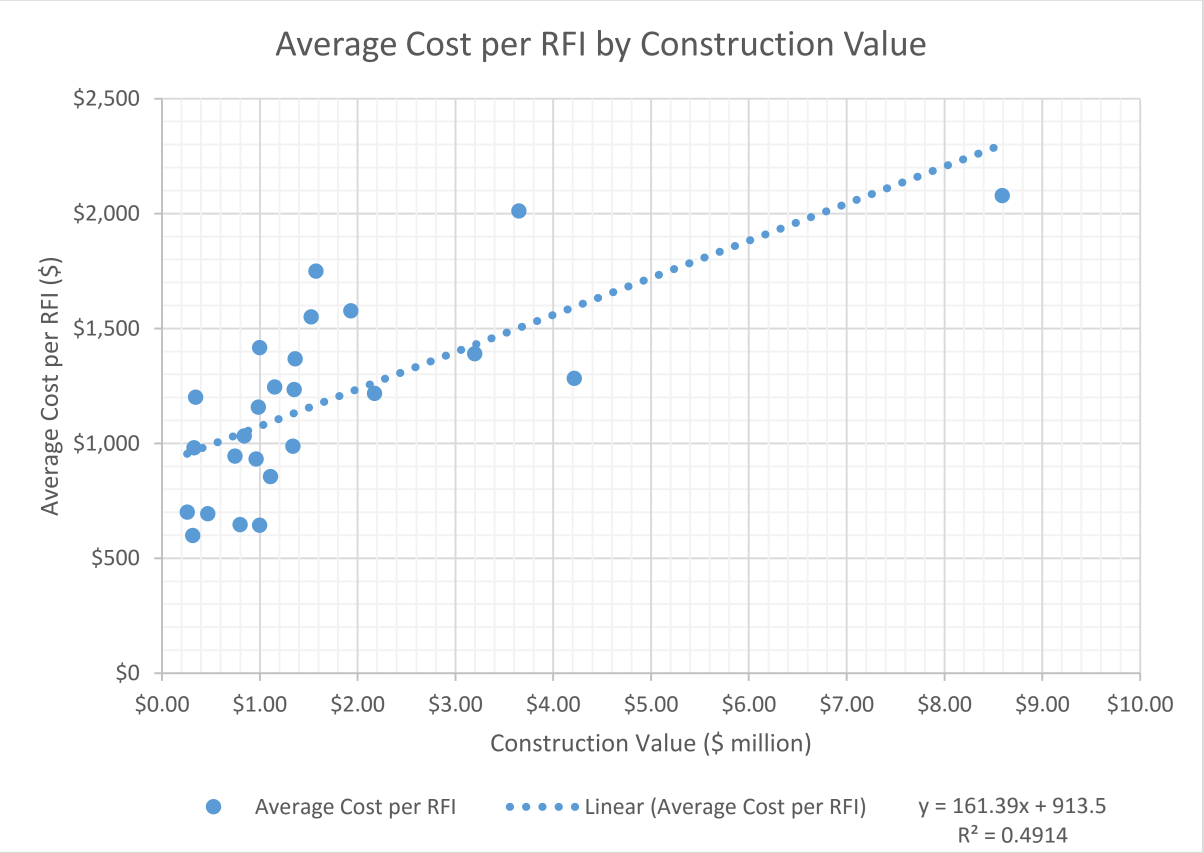


Figure 54: Average RFI Cost by Construction Value

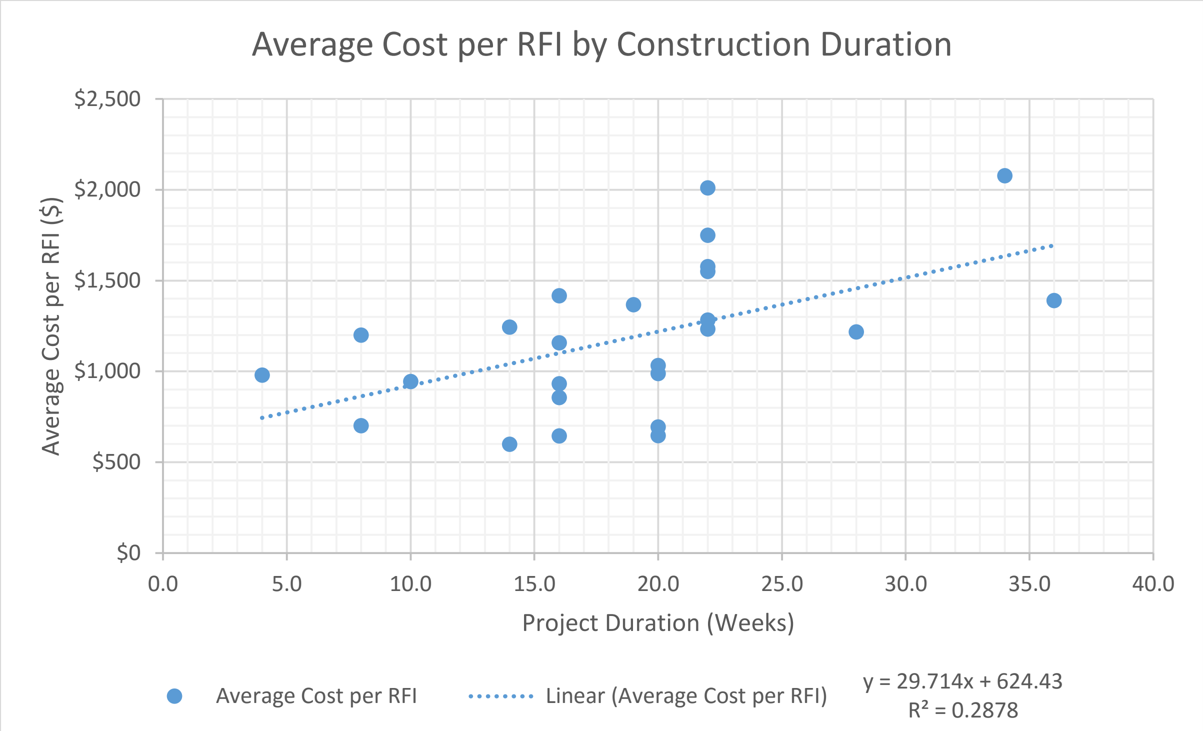


Figure 55: Average RFI Cost by Construction Duration

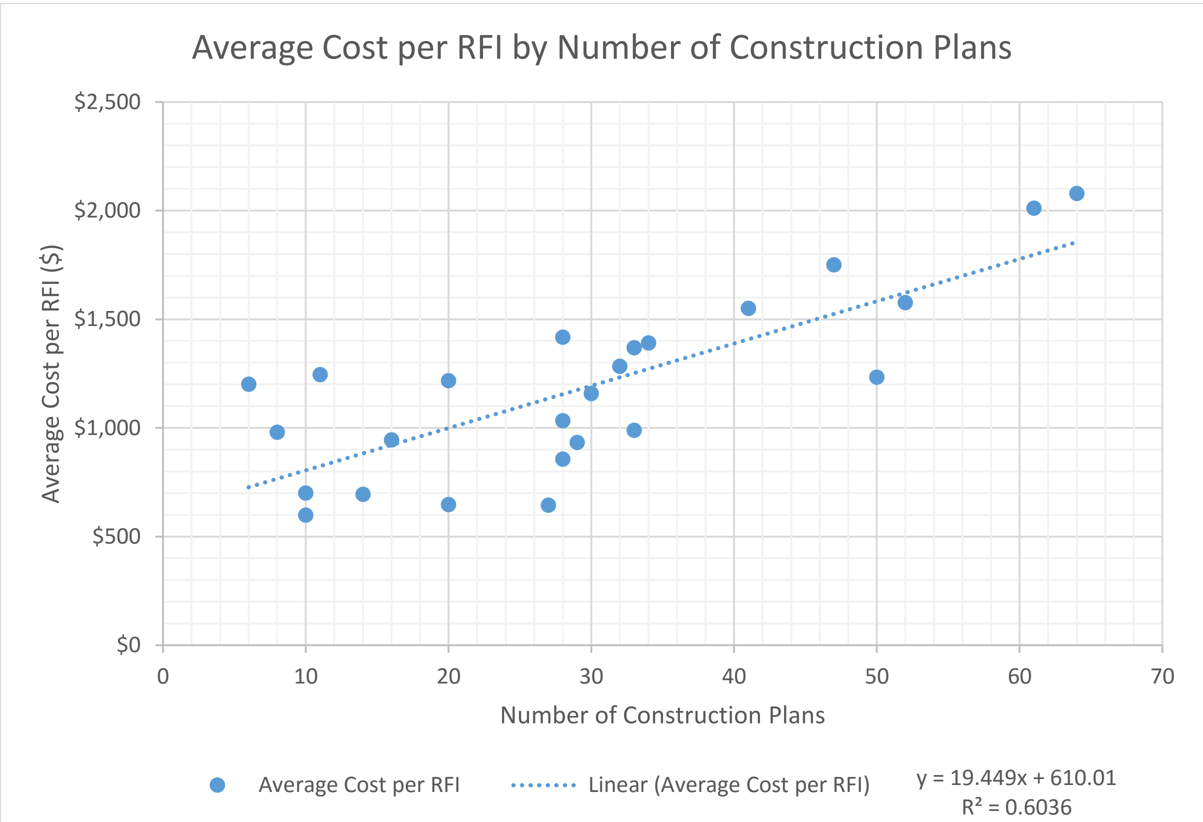


Figure 56: Average RFI Number of Construction Plans

From the above figures it can be seen that while there is a relationship shown between the average cost per RFI and the project factors, when the relationship is interpreted mathematically there is significant error in the equations(with R^2 values from 0.28 to 0.60).

This error can simply be explained by the resolution of the data (values for Duration are significantly grouped) and by the very complex nature of the RFI process. Because each of these factors vary immensely on each project the relationship between them can never be truly defined.

Because of this error it would be unwise to use these values to calculate an exact value for the average cost of RFIs on any given project. Instead it is proposed that a simple method of estimation is to be created that may be used by consultants in the future to better understand and predict the impacts of the RFI process.

To achieve this it is first proposed that the Number of Plans be combined with the Construction Duration to create a project 'Complexity Factor'. This created factor is just a simple method of combining factors so that an estimation method can be created. The complexity factor is then defined as:

Equation 2:

$$Complexity\ Factor = Cf = Number\ of\ Plans * Construction\ Duration$$

The average cost of RFIs per Complexity Factor can then be calculated by taking the average of both of the known values for each factor. These calculated values can then be plotted vs the Complexity Factor to investigate the resulting relationship, as shown below in **Figure 57.**

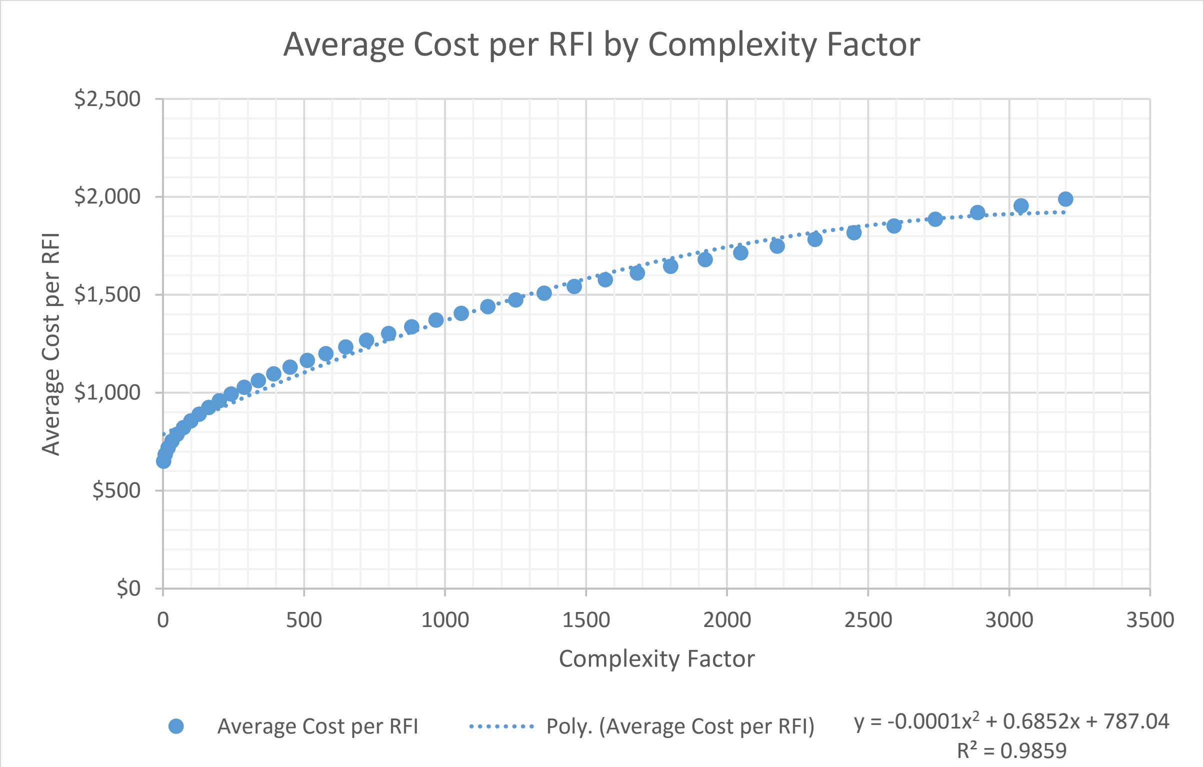


Figure 57: Average RFI Cost by Complexity Factor

As can be seen in the above graph, the trend in the data set follows a distinctive relationship. This trend has been defined by the application of a second order polynomial and the equation for this line is shown below in **Equation 3.**

Equation 3:

$$Average\ Cost\ per\ RFI = -0.0001Cf^2 + 0.6852Cf + 787.04$$

To validate this equation the estimated Average Cost per RFI on a project was calculated using the above **Equation 3** for the known Complexity Factors (calculated by the above **Equation 2**). The returned Estimated Average Cost per RFI was then compared to the known Average Cost per RFI and statistically analysed. The results of this analysis is given below in ***Table 6-2***

Table 6-2: Known Average Cost per RFI vs Estimated Cost

Known Average Cost per RFI vs Estimated Cost	
Mean Value	9.34%
Minimum Value	-14.07%
Maximum Value	38.66%
Range	52.73%
Median Value	7.88%
Standard Deviation	15.18%
Skew	22.70%
First Quartile	-4.55%
Third Quartile	21.36%
Interquartile range	25.92%

From the above statistical analysis it can be seen that the average error present in the estimated values is 9.34%.To gain better accuracy for the final estimation, it is proposed that this calculated value is then averaged against the value calculated from the Construction Value. To do this the equation for the linear line of best fit presented above in **Figure 54** is adopted:

Equation 4:

$$Average\ Cost\ per\ RFI\ =\ 161.39(Construction\ Value)\ +\ 913.5$$

The equations are then combined to create the final equation for the estimation of the Average Cost per RFI.

Equation 5:

$$Average\ Cost\ per\ RFI\ =$$

$$= \frac{(-0.0001Cf^2 +\ 0.6852Cf\ +\ 787.04\ ) + (161.39(Construction\ Value)\ +\ 913.5)}{2}$$

Because of the know error in these equations it is critical that these values are to be taken as an estimation only. To do this it is proposed that the equations are plotted into an estimation contour plot so that the factors can be combined and approximate figure can be returned. This contour plot is shown below in **Figure 58**.

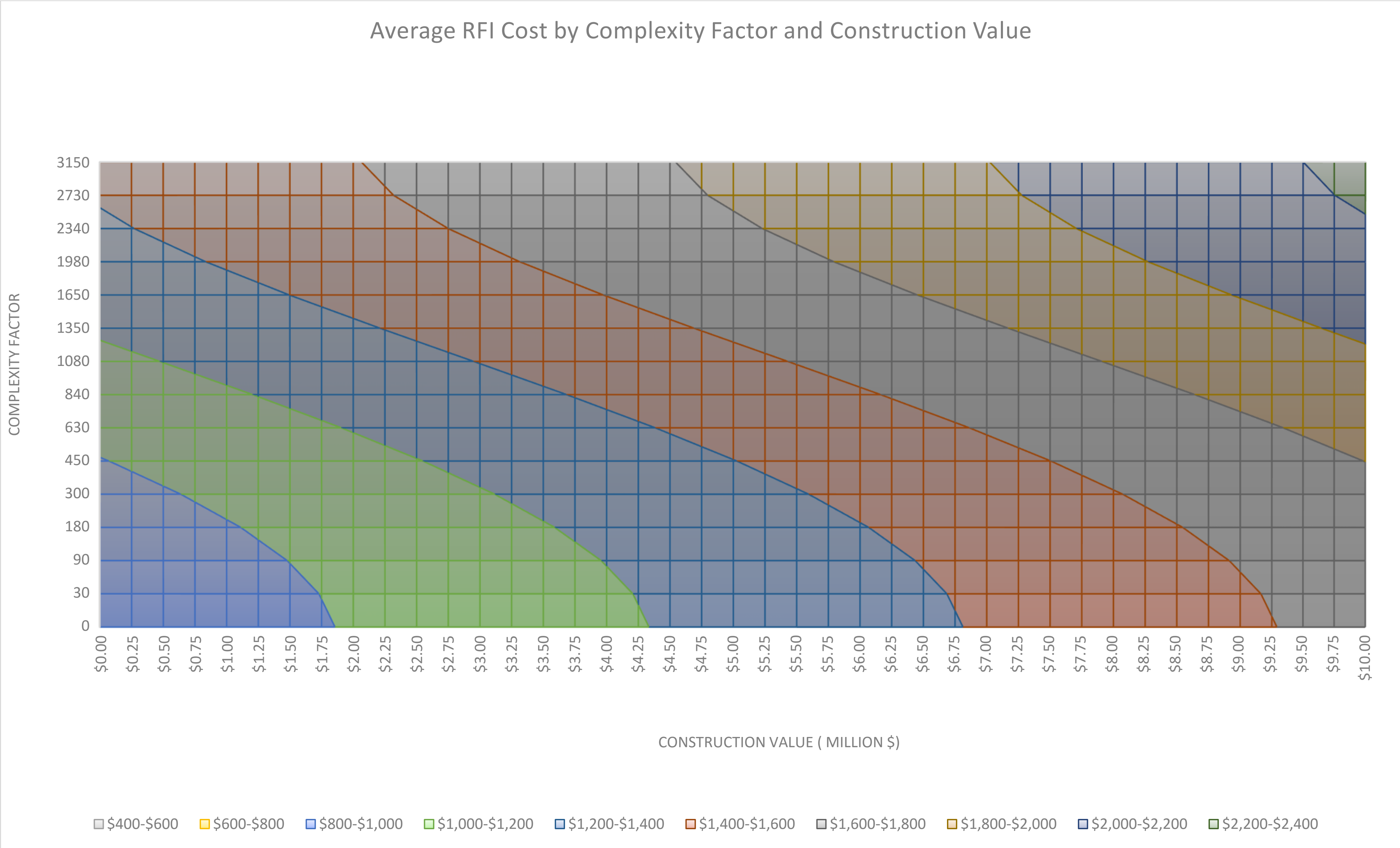


Figure 58: Average RFI Cost by Complexity Factor and Construction Value

To validate this equation and presented contour plot, the estimated Average Cost per RFI on a project was calculated using **Equation 5** for the known case study project factors. The returned final estimation of the Average Cost per RFI was then compared to the known Average Cost per RFI and statistically analysed. The results of this analysis is given below in **Table 6-3.**

Table 6-3: Known Average Cost per RFI vs Final Estimated Cost

Known Average Cost per RFI vs Final Estimated Cost	
Mean Value	5.85%
Minimum Value	-26.95%
Maximum Value	66.12%
Range	93.07%
Median Value	2.15%
Standard Deviation	26.94%
Skew	84.90%
First Quartile	-17.71%
Third Quartile	22.17%
Interquartile range	39.88%

From the above statistical analysis it can be seen that the average error present in the estimated values is 5.85%. This related back to the average cost yields an error of approximately $60. As the contour plot shown in **Figure 58** is to be adopted as the primary means of estimation this error is well within the resolution of the method. Additionally as this tool is to be only used to estimate the potential value of RFIs on a given project this degree of error should be acceptable.

6.3 Causes of RFIs

Following the data presented in **Section 5.2.9** it was shown that the cause of RFI's had minimal effect on the average cost per RFI. However due to the importance of the cause of RFI's on the entire project, the relationship between the cause and the cost of RFI's needs to be further investigated.

To conduct this further analysis the Total cost of Responding to RFIs was calculated for each RFI cause category as defined in **Section 3.3.5.** The results of these calculations were then plotted against the total number of RFI's per cause and the average cost per category, as shown below in **Figure 59.**

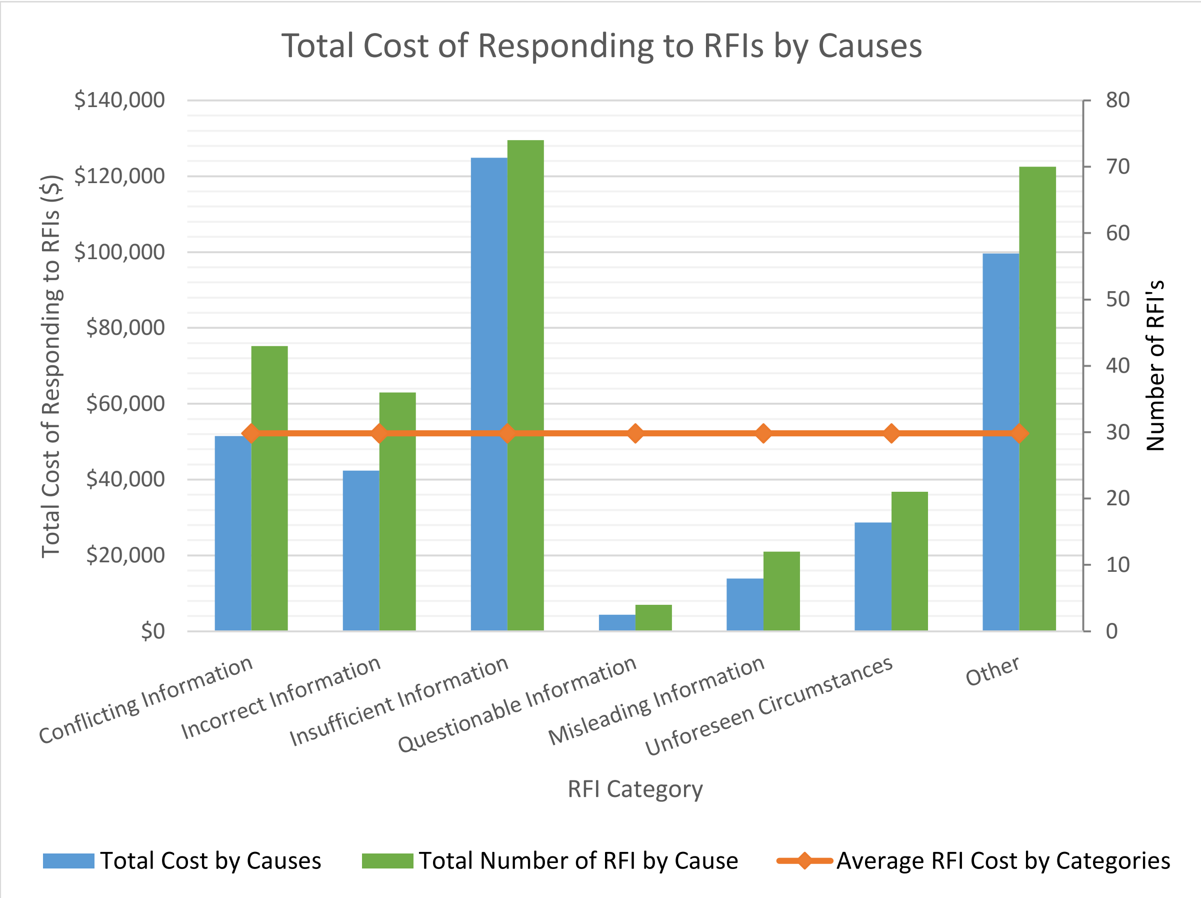


Figure 59: Total Cost of Responding to RFIs by Causes

From the above presented data it can be clearly seen that as expected, the total cost of responding to RFIs by cause is closely linked to the number of RFIs by cause. It can also be seen that while the majority of categories fall under the average cost the categories of Insufficient Information and Other are both over double the average.

This conclude that within the case study projects the major causes of RFI’s are ‘Insufficient Information’ and ‘Other’ types.

These ‘Other’ type of RFIs are defined above in **Section 3.3.5** and include:

- Requests for alternative design solutions
- Request for Approval.
- Request for Substitution.
- Queries about propriety products
- Requests for details that are already stated within the drawings or specifications
- Submissions of information
- Responses to non-conformances

Following the above analysis recommendations must now be made on how these factors identified can be used to highlight future at risk projects and how RFI’s may be reduced on future design projects.

CHAPTER 7 - Recommendations and Conclusions

From the preceding chapter and the above literature review it was identified that there is strong correlation between the number of RFI's on a project and the Construction Value. From this analysis a simple method of estimating the number of RFI's on a project was defined. Following this analysis, the average cost per RFI was investigated further. By comparing the average cost per RFI, to a number of project factors, a method of estimating the average cost per RFI was created. By combining both methods of estimation an accurate method of estimating the total cost for responding to RFI's can then be made.

Although this is a good start, this estimation of the cost to design engineers is just a method of quantifying the impact of the RFI process and does not help reduce the number of RFIs occurring on future projects. To be able to make recommendations on how to potentially reduce the number of RFI's, further analysis of the root causes of RFIs is to be undertaken.

7.1 Causes of RFI's

Following the analysis of the time and cost associated with the RFI process the root causes of RFIs were then investigated. This primary analysis as detailed above in **Section 5.2.9** revealed the cause of an RFI had little effect on the average cost per RFI. However further analysis in **Section 6.3** revealed that the two major causes of RFIs, in the terms of total number and total cost were the 'Incorrect Information' and 'Other' categories. As these categories have been identified as the most influential to the cost to designers it is proposed that recommendations are made to try and mitigate their effects.

To improve both these categories it is proposed that a two-step solution is formulated based on prior research detailed above in **Section 2.6.** These recommendations could then implemented on future projects so that the total number and average cost of RFIs could potentially be reduced.

7.1.1 Insufficient Information

The first major cause identified by the analysis of the case study projects is the 'Insufficient Information' category. From the detailed literature review above in **Section 2.5.1,** it can be seen that the overall cause of this category can be linked back to the competitive nature of the design and documentation industry. In this competitive industry often the level of service given by designers must be lowered to reduce the total costs, so that jobs can be won. This lowering of service may result in more errors and omissions within the drawings and hence more RFIs will be created on the project. To completely remedy this a complete change in the culture of the construction industry would be required. By changing from a cost based system to a performance based, qualifications based or other type system, this need to reduce service could be eliminated. However a whole system change cannot be achieved by a single consultant and therefore other recommendations must be made.

When investigating the cause of the 'Insufficient Information' category, it can be seen that there are two major break downs in the design and documentation process. The first of these is when the error or omission is made by the designer and/or drafter and the second is where this error or omission is then missed by the reviewer.

In the first instance when the mistake is made by the designer or drafter, the best way to prevent this occurring is by further training of the employees in all fields of the project. This training should be varied across both technical and practical as both aspects can give a designer critical insight into the how and why a construction process occurs. This training program can then be built into the internal company CPD program and then can be further pursued through accreditation pathways such as tertiary education or professional accreditation and registration. By further educating all employees the chance of someone picking up on an error or omission is increased and therefore the number of RFI's should be reduced.

Following the education and training of all personal, the checking and approval process needs to be improved to become more thorough and effective, while also been affordable and efficient. To achieve this, a comprehensive quality management scheme must be developed implemented and adhered to. This system should include a defined method of collating plans, checking them and distributing this data to stake holders.

By the implementation of the two above strategies it is possible that the design engineers can still be competitive within the market, while actively working to increase the level of service delivered to clients and thus reducing the number of RFI on a project.

7.1.2 Other Types

From the above analysis in **Section 6.3** it was revealed that the second largest source and cost of RFIs on a project was the 'Other' type category. This category includes all other types of RFI's that don't fit into the major causes types such as:

- Requests for alternative design solutions
- Request for Approval.
- Request for Substitution.
- Queries about propriety products
- Requests for details that are already stated within the drawings or specifications
- Submissions of information
- Responses to non-conformances

As can be seen, all of the above categories are not actually requests for information but are rather submissions of information or other communications. Because of this it is proposed that a system for submission of this information outside the RFI process is developed to improve efficiency.

This system would need to be defined within the contract documents and would include various alternative means of communications. The categories for these communications methods were well defined by James Zack in his journal article titled 'RFIs - use, abuse, control' (1998) and were discussed above in **Section 2.6.2.** These communication methods include:

- Drawing or Detail Clarification. Define a proper drawing or detail clarification system. Establish what the system should be used for and what the response time should be limited to.
- Non-Conformance Notice. Establish and define a system for notifying the contractor of a non-conformance. In this defined system the contractor is given a specific response notice that could be implemented instead of an RFI. In this system the time frames of both the notice and the response is agreed upon by all parties.

- Project Communications. Define a clear communication pathway that information such as requests and responses will follow. Within this defined system an understanding must be reinforced that communications may be rejected if they do not conform to the proper procedures.
- Request for Conformation, Approval or Substitution. Establish and define a clear system for the contractor to submit requests for approval, conformations and substitutions.
- Improperly Made Requests. Define within the contract the contractor may not be entitled to claim extensions of time or variations where they have elected not to follow the previously defined procedures for submitting requests.

By defining these alternative methods and including them within the contract documents all parties should be aware of the proper processes and are bond to adhered to them.

While including these new defined methods of communication will not necessarily reduce the number of RFI's been received on a particular project, by better defining them it will be easier for requests to be passed on to the appropriate employee and thus reduce handling time. This should improve the overall efficiency of the design engineer in the process and thus reduce the time and cost associated with the response.

7.2 Limitations

Throughout the above research project a number of assumptions and limitations have been established to enable the collection and analysis of data. These assumptions were then further built on to facilitate the production of estimation methods, to draw conclusions from the data set and to make recommendations for future projects. While the recommendations made can be adopted by the broader industry, to enable the use of the estimation methods by a member of the industry these limitations and assumptions must be considered.

The first and largest of these limitations is the scope of projects that was collected to produce the case study project database. These limitations include:

- Type of Consultancy Firm
- Location of the Project
- Construction Value
- Construction Year
- Construction Duration
- Number of Project Plans

These limitations are all defined above in **Section 3.2** and form the basis for the collection of data for this research project. These defined factors first restrict the type of consultancy firm and the scope of the projects that the estimation methods are applicable to.

The next set of limitations apply to the accuracy of the results given. As these methods of estimation are based on the mathematical simplification of the relationships identified within the data set, the degree of accuracy is very low. This combined with the very dynamic nature of construction projects means that the values produced should only ever be used as a rough estimation of costs.

Further to this, the costs identified in this study are based on hours recorded or provided for the response to RFI's. The accuracy of this data is then limited to the accuracy of the recorded time and thus the accuracy of the time sheets recorded by individual employees. While this accuracy may be acceptable for this study and for rough estimations of cost it has the potential to produce large skews in the data set and further analysis with a large scope would be required to validate these results.

Additionally arbitrary industry rates were then applied to the collected values of time spent responding to RFIs to produce the total cost. These rates, defined in **Section 3.4**, represent a simplified industry cost and therefore induce another factor of error into the estimation method.

Further to the analysis of the collected data and the definition of methods of estimating the cost of RFIs, a number of recommendations were made to reduce the number of RFIs. While these recommendations are very broad and could be potentially be adopted by most industry stakeholders it should be noted that these recommendations were made from the identification of major causes of RFI's within the data set. Going back to that determination of these causes, it should be noted that these were identified and categorised by the subjective analysis of the individual RFI. This subjective assessment of cause's places a large limitation on the conclusion made but does not in any way void the recommendations made.

7.3 Further Work

Following on from the above research there are many opportunities for further work to be conducted if the time and resources are available. These include:

- Investigation of the potential relationship between the number of RFIs produced and the number and magnitude of variations on a project. This could possibly lead to the study of quantifying how much RFIs increase the overall project cost.
- Investigation of the potential relationship between the number of RFIs produced and the number and /or length of Extensions of Time accrued on a project. This could possibly lead to the study of how the number of RFI's influence the duration of a construction project.
- Investigation of the RFI process within other contract types such as D&C and modern alliance contracts.
- Investigation of the time and cost associated the RFI process from other perspectives such as the architect or sub consultant such as an electrical engineer.
- Investigation of the viability of implementing the recommended strategies with in **Section 7.1**.

7.4 Conclusions

The purpose and objective of this research project was to investigate the RFI process and quantify the overall costs from a designer's perspective. This objective was achieved within the above chapters starting with the detailed review the current literature and research. From this review a comprehensive methodology for the quantifying the time and cost associated with the RFI process was defined.

This included the creation of a methodology to collect select case study projects and an associated method of analysis of this collected data. Following this methodology, a model of case study projects was then created using the data collected from local consultants. This model was then manipulated to analyse the various project factors that may influence the time and cost accrued by designers.

From this comprehensive analysis it was revealed that the project construction value has the strongest correlation to the number of RFI's on a project. This conclusion was also backed up by prior research identified as a part of the detailed literature review. Because of this strong correlation a method of estimating the number of RFIs was then created and is defined above in **Section 6.1.**

Using this method it would be possible for Design Engineers to estimate the potential number of RFI's that will occur on a future project. To be able to then create a budget for these RFI's, the cost of RFI's was then further analysed. This further analysis created a method that will yield a rough estimate for the average cost per RFI on a given project.

From the analysis of the created data set, it was found that the project factors that had the strongest correlation to the average cost per RFI was the Project Duration, the Construction Cost and the Number of Plans. These correlations are further detailed above in **Section 6.2**. This set of factors can be explained by the fact that all these factors increase with each other, as all factors are products of the projects complexity.

To further analyse the cost to designers, these factors were mathematically defined and then combined to create a more accurate method of estimation of the average cost per RFI on a project.

This final estimation of the average cost per RFI was then graphed as a contour plot for ease of use in estimation. This method is defined above in **Section 6.2** and **Figure 58.**

By then combining the methods of estimating the number of RFI's on a project with the method of estimating the average cost per RFI, the total cost of responding to RFI's on a project can then be accurately estimated.

Although the creation of this estimation method is a decent way to gauge the potential costs to designers, an effort should always be made to reduce the number of RFIs on future projects. To do this the root causes of RFI's on a the case study projects were further investigated. This analysis revealed that the major cause of RFI's within the data set includes the 'Insufficient Information' and 'Other' categories.

To remedy these major causes, recommendations were made based on the past work and literature reviewed above in **Chapter 2.** These recommendations included the better education of employees, the implementation of a definitive internal auditing process and the better definition of communication systems within the contract documents. These recommendations are detailed above in **Section 7.1.**

Concluding the above summary, a detailed analysis of case study projects has been undertaken to accurately quantify the time and cost to designers, an estimation method for future project has been created for the defined limitations and recommendations have been made to reduce the number and cost of RFI's on future projects.

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CHAPTER 9 - Appendices

APPENDIX A - Project Specification

University of Southern Queensland
Faculty of Health, Engineering and Sciences

Engineering Research Project 2015
PROJECT SPECIFICATION

FOR: Peter Sparksman

TOPIC: QUANTIFYING THE TIME AND COST ASSOCIATED WITH THE REQUEST FOR INFORMATION (RFI) OR TECHNICAL QUERY (TQ) PROCESS - A DESIGNERS PERSPECTIVE

SUPERVISOR: Paul Tilley

ENROLEMENT: ENG 4110 – S2, EXT, 2014
ENG 4111 – S1, EXT, 2015
ENG 4112 – S2, EXT, 2015

PROJECT AIM: To examine and document the time and costs associated with the designers role within the request for information (RFI) process, so that the overall impact on the designers efficiency can be quantified.

SPONSORSHIP: University of Southern Queensland

PROGRAMME: Issue A - March 2014

1. Examine the current RFI process, procedures and relevant literature. Define key stages in the RFI process, the role of designers and how this process effects the designers efficiency.

2. Develop the methodology for collecting and analysing case study data from industry sources. Case study projects are to be from firms where Civil Engineers were the designers and were involved in the construction process.

3. Collect case study data from multiple industry sources using the defined methodology. Data should include both the project data and the cost accrued by the designers responding to the RFI's. This direct cost could be obtained by either actual project budgets or brief survey of designers.

4. Analyse the collected data to obtain an accurate model of the projects RFI's and the designers time and costs associated with subject projects.

5. From the modelled data, identify factors that influence the number of RFIs and factors that influence the cost accrued by designers responding to the RFIs

6. Using the identified factors, detail how these could be used to highlight future at risk projects and make recommendations on how RFI's may be reduced on future design projects.

APPENDIX B - Example RFI Form

J. HUTCHINSON PTY LTD
A.B.N. 52 009 778 330
8 Prescott St,
Toowoomba,
Queensland 4350
Telephone (07) #### ####
Facsimile (07) #### ####
E-mail: ####@hutchinsonbuilders.com.au
Website: http://www.hutchinsonbuilders.com.au/

Established 1912

Request for Information **No:** ***####-RFI- 000***

Company: ####

From **### ###**
Phone: 07 #### ###
E-mail: ####@hutchinsonbuilders.com.au
Date: 17 November 2014

Attention: **### ###**
Fax

Project Name: #### **Project No:** ###

Subject RFI 000 - ###

Information Required:

###,

Please advise on the attached request.

Response Required by: **##/##/14**

Regards
J HUTCHINSON PTY LTD

###
Project Administrator

APPENDIX C - Example RFI Register

J HUTCHINSON PTY LTD 1

HUTCHINSON BUILDERS
Established 1912

PROJECT:		
JOB NO.:		Open
Document No:		Closed
DATE:		Urgent

REQUEST FOR INFORMATION REGISTER

HB RFI No.	Date RFI Sent	Sent By	Sub Ref	Details of RFI	Date Response Required	Discipline	Date Resolved	Comments
0001								
0002								
0003								
0004								
0005								
0006								
0007								
0008								
0009								
0010								
0011								
0012								
0013								
0014								
0015								
0016								
0017								

APPENDIX D - Additional Project Planning

APENDIX D.1 Resource Requirements

As this research project is a so called ‘desktop study’ there are no special resources required. The simple resources required for this project will be mainly provided by the student and are detailed in the table below.

Table 9-1: Project Resource Requirements

TASK	ITEM	AMOUNT	SOURCE	COST
	Case Study Data	TBA	Industry Sources	NIL
	Transport to Obtain Data	N/A	Student	NIL
	Communication to Obtain Data	N/A	Student	NIL
	Microsoft Word	N/A	Student	NIL
	Microsoft Excel	N/A	Student	NIL
	EndNote	N/A	Student	NIL

APENDIX D.2 Risk Assessment

The associated risks with this project are very minimal since the research is to be a desktop study. However there are still hazards that are present in an office environment and these should be documented accordingly. Additionally the risks associated with the timing and completion of this study should be detailed so that they can be mitigated if present.

The following risk management plan has been adapted from the USQ safe standard safety management plan.(University of Southern Queensland 2014) The first table details the potential consequences of a hazard and compares it to the probability of it occurring to gain a ‘risk level’. This table goes on to detail a recommended action plan and thus will give us a good procedure to analyse potential hazards

Table 9-2: Risk Assessment – Probability vs Consequence Matrix

	CONSEQUENCE				
PROBABILITY	INSIGNIFICANT No Injury	MINOR First Aid	MODERATE Med Treatment	MAJOR Serious Injury	CATASTROPHIC Death
ALMOST CERTAIN 1 in 2	M	H	E	E	E
LIKELY 1 in 100	M	H	H	E	E
POSSIBLE 1 in 1 000	L	M	H	H	H
UNLIKELY 1 in 10 000	L	L	M	M	M
RARE 1 in 1 000 000	L	L	L	L	L
RECOMMENDED ACTION GUIDE					
E = EXTREME RISK – TASK MUST NOT PROCEEED					
H = HIGH RISK – SPECIAL PROCEDURES REQUIRED					
M = MODERATE RISK – RISK MANAGEMENT PLAN / WORK METHOD STATEMENT REQUIRED					
L = LOW RISK – USE ROUTIEN PROCEDURES					

APPENDIX D.2.1 Personal Risk Assessment

The second table, on the following page details the associated risks involved with completing the project in an office environment as per the standard USQ Template (University of Southern Queensland 2014). By first identifying the risks and its potential hazards we can examine existing controls and thus determine a ‘risk level’ via the matrix above. From this assessment we can identify if the risk is acceptable or if further mitigation is required.

Table 9-3: Personal Risk Assessment

HAZARDS: Hazards identified as a part of a task or scenario	**THE RISK:** What can happen with exposure to the Hazard?	**EXISTING CONTROLS:** What are the existing controls that are in place	**RISK ASSESSMENT:** C	P	Risk Level	**ADDITIONAL CONTROLS REQUIRED?** Are additional controls required to reduce the risk level?
Working with computers 1.Ergonomic: •Poor posture •Excessive duration in a seated position •Incorrect setup of workstation •Repetitive movements	•Physical injury to the wrists, arms, neck, shoulder or back. •Eye strain	•All personnel are provided with the USQ Setting up your Workstation guide •Individual personnel are responsible for taking breaks and doing stretches •Personnel are advised to report any symptoms ASAP	MINOR	LIKELY	LOW	NO
Working with computers 2. Electrical Hazards	•Electrical shock, Fire, Burns, •Physical injury from tripping over cords	•Inspection, Testing and Monitoring Procedure •Individual RCD's on specific equipment •Regular workplace inspections	MAJOR	RARE	LOW	NO
Meetings/ face to face dealings with personnel and students •Physical /emotional intimidation •Aggression towards personnel members	•Physical or emotional injury to personnel' •Malicious damage	•Consultation with personnel •Procedures to minimise risk •Workplace bullying policy communicated to all personnel •Workplace violence Prevention and management policy	MINOR	RARE	LOW	NO
Telephone and email enquiries and communication •Aggression towards personnel members •Intimidation and harassment issues	•Emotional injury to personnel	•Consultation with personnel •Procedures to minimise risk •Workplace bullying policy communicated to all personnel •Workplace violence Prevention and management policy	MINOR	RARE	LOW	NO
Working inside a building •Slips, trips and falls •Fire in building •Working after hours/ working alone	•Physical injury •Burns and smoke inhalation •Personal assault	•Building fire safety •Compliance with Emergency drills •Making sure personnel are aware of emergency procedures •Workplace inspections to identify slip and trip hazards	MINOR	UN-LIKELY	LOW	NO
Thermal comfort in offices •Excessive heat •Lack of ventilation/air flow	•Heat exhaustion •Dehydration •Headaches •Dizziness	•Providing fans and opening doors, windows and vents where practical; •Providing water •Monitor personnel for signs of heat distress	MINOR	UN-LIKELY	LOW	NO

APPENDIX D.2.2 Project Risk Assessment

The following table details potential 'risks' to the project's completion. Unlike the table above this 'risk assessment' is just based on the probability of occurrence as each 'risk' has the same consequence i.e. the project not been completed on time.

Table 9-4: Project Risk Assessment

HAZARDS:	**THE RISK:**	**EXISTING CONTROLS:**	**RISK ASSESSMENT:**	**ADDITIONAL CONTROLS REQUIRED?** Are additional controls required to reduce the risk level?
Failure to collect enough case study examples. •Shortage of industry sources •Shortage of suitable projects •Shortage of RFI from projects	•Lack of data will mean that a proper analysis could not be completed.	Preliminary contact has been made with industry sources and preliminary projects sought from current employer.	Low (20%)	NO
Personal health issues. •Physical injury or sickness could affect the completion of the project.	•Physical Injury •Sickness •Effects of Stress	The student is currently covered by health insurance and regularly works out to maintain health and wellbeing. During the project the student is to take appropriate breaks from work to avoid stress and burnouts.	Low (<10%)	NO
Hardware failure. Data lost. •Computer Failure •Program Failure •Power Outage/Surge	•Data Lost •Documents Lost	Student's equipment is to be checked as a part of the start-up phase. The documents and data is to be regularly backed up in both hard copy and on the cloud. The student is also to save work on a regular interval to avoid losing work.	Low (<10%)	NO
Poor time management. •Poor time management could result in the project being incomplete by submission data.	•Failure to complete project	Student is to follow the objectives and schedule detailed in this research proposal.	Low (<10%)	NO

APPENDIX E Case Study Projects Database

	Project Data							
Case Study Number	**Project**	**Source**	**Project Location**	**Construction Year**	**Construction Type**	**Contract Value**	**Contract Period (Weeks)**	**Number of Plans**
1	Project 1	Kehoe Myers	Lockyer Valley Region	5/03/2015	Residential Subdivision	$1,110,001	16	28
2	Project 2	Kehoe Myers	South Burnett Region	16/01/2015	Infrastructure	$344,553	8	6
3	Project 3	Kehoe Myers	Lockyer Valley Region	16/12/2014	Commercial Facilities	$746,040	10	16
4	Project 4	Kehoe Myers	Toowoomba Region	22/09/2014	Institutional Facilities	$2,173,600	28	20
5	Project 5	Kehoe Myers	Toowoomba Region	22/05/2014	Residential Subdivision	$1,931,729	22	52
6	Project 6	Kehoe Myers	Toowoomba Region	21/02/2014	Residential Subdivision	$962,499	16	29
7	Project 7	Kehoe Myers	Toowoomba Region	6/02/2014	Commercial Facilities	$1,150,000	14	11
8	Project 8	Kehoe Myers	Toowoomba Region	24/01/2014	Institutional Facilities	$4,214,000	22	32
9	Project 9	Kehoe Myers	Maranoa Region	19/11/2013	Industrial Subdivision	$8,590,261	34	64
10	Project 10	Kehoe Myers	Toowoomba Region	18/11/2013	Residential Subdivision	$1,350,346	22	50
11	Project 11	Kehoe Myers	Toowoomba Region	7/10/2013	Residential Subdivision	$256,545	8	10
12	Project 12	Kehoe Myers	Toowoomba Region	2/10/2013	Residential Subdivision	$798,993	20	20
13	Project 13	Kehoe Myers	Toowoomba Region	18/09/2013	Commercial Facilities	$3,195,973	36	34
14	Project 14	Kehoe Myers	Lockyer Valley Region	22/07/2013	Industrial Facilities	$314,400	14	10
15	Project 15	Kehoe Myers	Toowoomba Region	16/07/2013	Residential Subdivision	$3,650,116	22	61
16	Project 16	Kehoe Myers	Toowoomba Region	24/06/2013	Infrastructure	$326,820	4	8
17	Project 17	Kehoe Myers	Toowoomba Region	22/05/2013	Residential Subdivision	$996,918	16	27
18	Project 18	Kehoe Myers	Toowoomba Region	7/05/2013	Residential Subdivision	$985,873	16	30
19	Project 19	Kehoe Myers	Toowoomba Region	16/12/2012	Residential Subdivision	$998,467	16	28
20	Project 20	Kehoe Myers	Toowoomba Region	14/11/2012	Residential Subdivision	$1,525,479	22	41
21	Project 21	Commercially Confidential	Toowoomba Region	25/05/2012	Residential Subdivision	$1,338,429	20	33
22	Project 22	Commercially Confidential	Toowoomba Region	30/11/2011	Residential Subdivision	$1,360,764	19	33
23	Project 23	Commercially Confidential	Southern Downs Region	13/09/2011	Residential Subdivision	$1,573,264	22	47
24	Project 24	Commercially Confidential	Toowoomba Region	1/08/2011	Residential Subdivision	$839,011	20	28
25	Project 25	Brandon's	Western Downs Region	29/07/2014	Infrastructure	$469,000	20	14

	Project Data	Number of RFIs								Time Spent							
Case Study Number	Project	Total	Site-W	Road-W	SWD	SEW	WAT	Elec	Other	Total2	Site-W3	Road-W4	SWD5	SEW6	WAT7	Elec8	Other9
1	Project 1	7	0	4	2	0	1	0	0	33.35	0	7	12.5	0	13.85	0	0
2	Project 2	1	0	0	1	0	0	0	0	6	0	0	6	0	0	0	0
3	Project 3	14	3	3	2	0	6	0	0	67.6	25.5	3	17.5	0	21.6	0	0
4	Project 4	11	3	3	2	0	2	0	1	56.9	13.75	7.6	10.75	0	17.35	0	7.45
5	Project 5	13	1	3	3	6	0	0	0	105.35	1	41.6	24.5	38.25	0	0	0
6	Project 6	7	2	3	1	1	0	0	0	33.25	13.5	6.25	11	2.5	0	0	0
7	Project 7	16	7	4	0	0	1	1	3	95.25	46.75	19.75	0	0	11.5	4	13.25
8	Project 8	28	12	0	3	0	2	2	9	152.25	57.4	0	12.8	0	38.75	5.5	37.8
9	Project 9	49	11	3	14	6	9	4	2	487.65	113.9	27.75	167.45	66.7	56.35	48.5	7
10	Project 10	4	1	1	1	1	0	0	0	20.6	5.25	8.35	2.5	4.5	0	0	0
11	Project 11	4	2	1	1	0	0	0	0	14	4.25	6.5	3.25	0	0	0	0
12	Project 12	7	1	2	2	0	0	2	0	19.25	3	8.5	6.25	0	0	1.5	0
13	Project 13	22	8	0	1	3	0	0	10	138.55	47.05	0	2	13.25	0	0	76.25
14	Project 14	4	3	0	1	0	0	0	0	11.75	8.75	0	3	0	0	0	0
15	Project 15	11	5	1	3	0	2	0	0	116.4	96.15	4.5	12.75	0	3	0	0
16	Project 16	4	1	0	1	1	0	1	0	20.7	5	0	4.6	5.6	0	5.5	0
17	Project 17	4	0	3	0	0	1	0	0	12.7	0	11.7	0	0	1	0	0
18	Project 18	6	3	2	1	0	0	0	0	36.75	25.75	8	3	0	0	0	0
19	Project 19	6	2	3	1	0	0	0	0	50.05	14.25	28.3	7.5	0	0	0	0
20	Project 20	4	0	2	1	1	0	0	0	31.5	0	23.5	0	8	0	0	0
21	Project 21	11	5	0	0	2	1	3	0	63.35	30.1	0	0	7	7.5	18.75	0
22	Project 22	11	1	3	2	2	1	2	0	64.7	5.5	18.95	11.5	9	6.25	13.5	0
23	Project 23	11	3	3	1	2	2	0	0	105.5	13	44.5	4	31.5	12.5	0	0
24	Project 24	6	3	2	1	0	0	0	0	35.95	15.1	10.85	10	0	0	0	0
25	Project 25	8	4	4	0	0	0	0	0	18.5	10.5	8	0	0	0	0	0

	Project Data	Cost of RFI's								Analysis.			
Case Study Number	Project	Total10	Site-W11	Road-W12	SWD13	SEW14	WAT15	Elec16	Other17	Time Per RFI	Cost Per RFI.	Response Time	Average Response Time
1	Project 1	$5,989	$0	$1,363	$2,700	$0	$1,926	$0	$0	4.76	$855.54	12.00	1.71
2	Project 2	$1,200	$0	$0	$1,200	$0	$0	$0	$0	6.00	$1,200.00	14.00	14.00
3	Project 3	$13,213	$5,325	$563	$3,363	$0	$3,963	$0	$0	4.83	$943.75	28.00	2.00
4	Project 4	$13,390	$3,855	$1,830	$2,175	$0	$3,620	$0	$1,910	5.17	$1,217.27	38.00	3.45
5	Project 5	$20,495	$200	$7,251	$5,550	$7,494	$0	$0	$0	8.10	$1,576.54	60.00	4.62
6	Project 6	$6,525	$2,800	$1,450	$1,775	$500	$0	$0	$0	4.75	$932.14	35.00	5.00
7	Project 7	$19,906	$10,175	$4,125	$0	$0	$2,106	$850	$2,650	5.95	$1,244.14	70.00	4.38
8	Project 8	$35,925	$14,004	$0	$3,215	$0	$6,556	$1,600	$10,550	5.44	$1,283.04	77.00	2.75
9	Project 9	$101,798	$23,961	$6,269	$36,638	$13,885	$10,458	$9,563	$1,025	9.95	$2,077.50	234.00	4.78
10	Project 10	$4,933	$1,575	$1,995	$463	$900	$0	$0	$0	5.15	$1,233.13	4.00	1.00
11	Project 11	$2,800	$1,175	$1,200	$425	$0	$0	$0	$0	3.50	$700.00	9.00	2.25
12	Project 12	$4,525	$600	$2,000	$1,625	$0	$0	$300	$0	2.75	$646.43	17.00	2.43
13	Project 13	$30,585	$10,935	$0	$600	$2,775	$0	$0	$16,275	6.30	$1,390.23	45.00	2.05
14	Project 14	$2,394	$1,875	$0	$519	$0	$0	$0		2.94	$598.44	9.00	2.25
15	Project 15	$22,116	$17,841	$950	$2,525	$0	$800	$0		10.58	$2,010.57	41.00	3.73
16	Project 16	$3,920	$863	$0	$1,020	$963	$0	$1,075		5.18	$980.00	11.00	2.75
17	Project 17	$2,575	$0	$2,375	$0	$0	$200	$0		3.18	$643.75	6.00	1.50
18	Project 18	$6,944	$4,419	$1,925	$600	$0	$0	$0		6.13	$1,157.29	14.00	2.33
19	Project 19	$8,500	$2,625	$4,450	$1,425	$0	$0	$0		8.34	$1,416.67	5.00	0.83
20	Project 20	$6,200	$0	$4,200	$0	$2,000	$0	$0		7.88	$1,550.00	4.00	1.00
21	Project 21	$10,864	$5,320	$0	$0	$1,150	$1,550	$2,844		5.76	$987.61	19.00	1.73
22	Project 22	$15,044	$1,200	$4,544	$2,738	$1,950	$1,625	$2,988		5.88	$1,367.61	19.00	1.73
23	Project 23	$19,244	$2,475	$8,406	$800	$5,363	$2,200	$0		9.59	$1,749.43	28.00	2.55
24	Project 24	$6,194	$2,569	$1,825	$1,800	$0	$0	$0		5.99	$1,032.29	30.00	5.00
25	Project 25	$5,550	$3,150	$2,400	$0	$0	$0	$0		2.31	$693.75	0.00	0.00

	Project Data	Number of RFI's by Cause							
Case Study Number	**Project**	**Total3**	**Conflicting Information**	**Incorrect Information**	**Insufficient Information**	**Questionable Information**	**Misleading Information**	**Unforeseen Circumstances**	**Other4**
1	Project 1	6.00	0	2	1	0	0	2	1
2	Project 2	1.00	0	0	1	0	0	0	0
3	Project 3	14.00	2	1	5	0	0	3	3
4	Project 4	11.00	1	1	6	0	0	0	3
5	Project 5	13.00	1	2	3	0	1	0	6
6	Project 6	7.00	0	2	1	0	1	2	1
7	Project 7	16.00	1	3	4	1	0	0	7
8	Project 8	28.00	6	3	12	0	0	0	7
9	Project 9	49.00	11	7	17	0	1	5	8
10	Project 10	4.00	1	1	1	0	0	0	1
11	Project 11	4.00	0	1	1	0	0	0	2
12	Project 12	7.00	2	0	3	0	0	0	2
13	Project 13	22.00	2	3	5	2	2	2	6
14	Project 14	4.00	1	0	2	0	0	0	1
15	Project 15	11.00	1	0	2	0	0	1	7
16	Project 16	4.00	2	0	0	0	0	1	1
17	Project 17	4.00	0	1	2	0	0	0	1
18	Project 18	6.00	2	1	1	0	0	0	2
19	Project 19	6.00	1	2	1	0	1	1	0
20	Project 20	4.00	1	1	1	0	1	0	0
21	Project 21	11.00	3	1	2	0	1	2	2
22	Project 22	11.00	3	2	1	0	2	1	2
23	Project 23	11.00	1	2	1	1	1	1	4
24	Project 24	6.00	1	0	1	0	1	0	3
25	Project 25	0.00	0	0	0	0	0	0	0

	Project Data	TimeSpent on RFI's by Cause							
Case Study Number	**Project**	**Total5**	**Conflicting Information6**	**Incorrect Information7**	**Insufficient Information8**	**Questionable Information9**	**Misleading Information10**	**Unforeseen Circumstances11**	**Other12**
1	Project 1	33.35	0	7	0.5	0	0	15.85	10
2	Project 2	6	0	0	6	0	0	0	0
3	Project 3	67.6	5.85	0.75	25	0	0	16.75	19.25
4	Project 4	56.9	2.8	1.95	36.7	0	0	0	15.45
5	Project 5	105.35	0	5.25	44.85	0	13.75	0	41.5
6	Project 6	33.25	0	4	3.25	0	2.5	12	11.5
7	Project 7	95.25	4	10.75	31	6.25	0	0	43.25
8	Project 8	152.25	24.1	13.8	73.15	0	0	0	41.2
9	Project 9	487.65	111.05	76.35	204.15	0	6	38.35	51.75
10	Project 10	20.6	2.5	4.5	8.35	0	0	0	5.25
11	Project 11	14	0	3.25	6.5	0	0	0	4.25
12	Project 12	19.25	4	0	11.25	0	0	0	4
13	Project 13	138.55	18.25	13.3	46	7.5	5.25	10.75	37.5
14	Project 14	11.75	2.25	0	6.5	0	0	0	3
15	Project 15	116.4	1	0	12.75	0	0	11	91.65
16	Project 16	20.7	9.6	0	0	0	0	5.5	5.6
17	Project 17	12.7	0	5.2	4.5	0	0	0	3
18	Project 18	36.75	5	2.5	5.5	0	0	0	23.75
19	Project 19	50.05	11	16.5	12.8	0	6.5	3.25	0
20	Project 20	31.5	7	0	16.5	0	8	0	0
21	Project 21	63.35	10.75	6.5	12.25	0	5.5	9	19.35
22	Project 22	64.7	15	13.95	9.75	0	13	6.25	6.75
23	Project 23	105.5	19	14	14.5	7.5	4	12	34.5
24	Project 24	35.95	7.6	0	4.25	0	6.6	0	17.5
25	Project 25	0	0	0	0	0	0	0	0

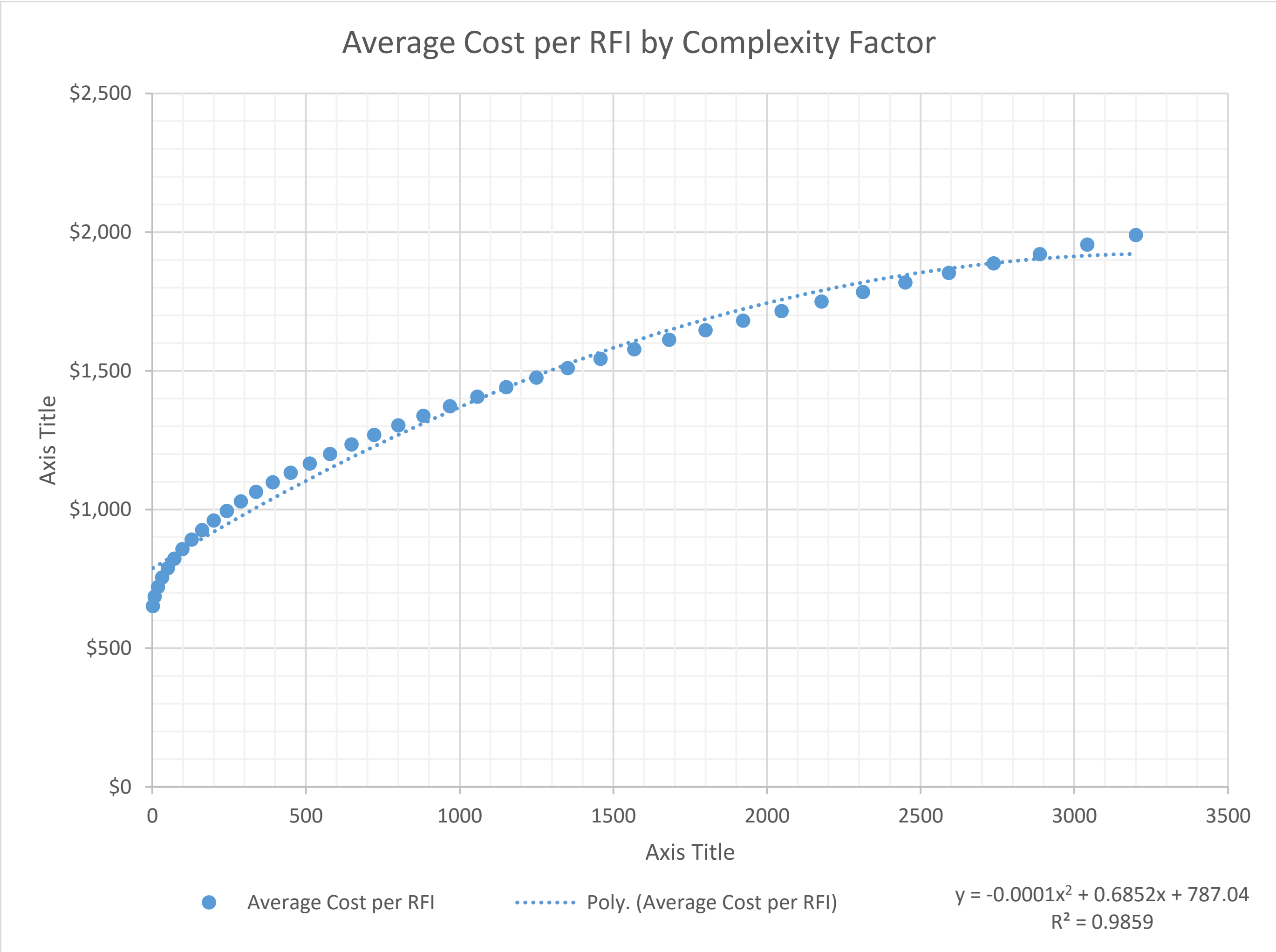
	Project Data	Cost of RFI's by Cause							
Case Study Number	**Project**	**Total13**	**Conflicting Information14**	**Incorrect Information15**	**Insufficient Information16**	**Questionable Information17**	**Misleading Information18**	**Unforeseen Circumstances19**	**Other20**
1	Project 1	$5,989	$0	$1,363	$100	$0	$0	$2,326	$2,200
2	Project 2	$1,200	$0	$0	$1,200	$0	$0	$0	$0
3	Project 3	$13,213	$788	$150	$5,025	$0	$0	$3,575	$3,675
4	Project 4	$13,390	$690	$465	$8,550	$0	$0	$0	$3,685
5	Project 5	$20,495	$0	$825	$8,001	$0	$2,419	$0	$9,250
6	Project 6	$6,525	$0	$800	$750	$0	$500	$2,075	$2,400
7	Project 7	$19,906	$875	$2,325	$6,700	$1,300	$0	$0	$8,706
8	Project 8	$35,925	$6,455	$3,459	$15,526	$0	$0	$0	$10,485
9	Project 9	$101,798	$20,985	$17,374	$43,119	$0	$1,650	$7,358	$11,313
10	Project 10	$4,933	$463	$900	$1,995	$0	$0	$0	$1,575
11	Project 11	$2,800	$0	$975	$1,200	$0	$0	$0	$625
12	Project 12	$4,525	$800	$0	$2,775	$0	$0	$0	$950
13	Project 13	$30,585	$3,850	$2,710	$9,950	$1,800	$1,125	$3,050	$8,100
14	Project 14	$2,394	$450	$0	$1,425	$0	$0	$0	$519
15	Project 15	$22,116	$300	$0	$2,525	$0	$0	$2,800	$16,491
16	Project 16	$3,920	$1,883	$0	$0	$0	$0	$1,075	$963
17	Project 17	$2,575	$0	$825	$1,050	$0	$0	$0	$700
18	Project 18	$6,944	$1,050	$700	$1,225	$0	$0	$0	$3,969
19	Project 19	$8,500	$2,106	$2,775	$2,113	$0	$988	$519	$0
20	Project 20	$6,200	$1,125	$0	$3,075	$0	$2,000	$0	$0
21	Project 21	$10,864	$1,825	$925	$1,919	$0	$800	$1,900	$3,495
22	Project 22	$15,044	$3,313	$2,931	$2,575	$0	$2,825	$1,625	$1,775
23	Project 23	$19,244	$3,119	$2,838	$3,100	$1,225	$800	$2,400	$5,763
24	Project 24	$6,194	$1,400	$0	$1,000	$0	$825	$0	$2,969
25	Project 25	$0	$0	$0	$0	$0	$0	$0	$0

APPENDIX F Data Analysis Calculations

APPENDIX F.1 Calculation of Average Cost by Complexity Factor

Plans	Duration	Average Cost by Number of Plans	Average Cost by Duration	Complexity Factor	Average Cost per RFI
2	1	648.908	$654.14	2	$652
4	2	687.806	$683.86	8	$686
6	3	726.704	$713.57	18	$720
8	4	765.602	$743.29	32	$754
10	5	804.5	$773.00	50	$789
12	6	843.398	$802.71	72	$823
14	7	882.296	$832.43	98	$857
16	8	921.194	$862.14	128	$892
18	9	960.092	$891.86	162	$926
20	10	998.99	$921.57	200	$960
22	11	1037.888	$951.28	242	$995
24	12	1076.786	$981.00	288	$1,029
26	13	1115.684	$1,010.71	338	$1,063
28	14	1154.582	$1,040.43	392	$1,098
30	15	1193.48	$1,070.14	450	$1,132
32	16	1232.378	$1,099.85	512	$1,166
34	17	1271.276	$1,129.57	578	$1,200
36	18	1310.174	$1,159.28	648	$1,235
38	19	1349.072	$1,189.00	722	$1,269
40	20	1387.97	$1,218.71	800	$1,303
42	21	1426.868	$1,248.42	882	$1,338
44	22	1465.766	$1,278.14	968	$1,372
46	23	1504.664	$1,307.85	1058	$1,406
48	24	1543.562	$1,337.57	1152	$1,441
50	25	1582.46	$1,367.28	1250	$1,475
52	26	1621.358	$1,396.99	1352	$1,509
54	27	1660.256	$1,426.71	1458	$1,543
56	28	1699.154	$1,456.42	1568	$1,578
58	29	1738.052	$1,486.14	1682	$1,612
60	30	1776.95	$1,515.85	1800	$1,646
62	31	1815.848	$1,545.56	1922	$1,681
64	32	1854.746	$1,575.28	2048	$1,715
66	33	1893.644	$1,604.99	2178	$1,749
68	34	1932.542	$1,634.71	2312	$1,784
70	35	1971.44	$1,664.42	2450	$1,818
72	36	2010.338	$1,694.13	2592	$1,852
74	37	2049.236	$1,723.85	2738	$1,887
76	38	2088.134	$1,753.56	2888	$1,921
78	39	2127.032	$1,783.28	3042	$1,955
80	40	2165.93	$1,812.99	3200	$1,989

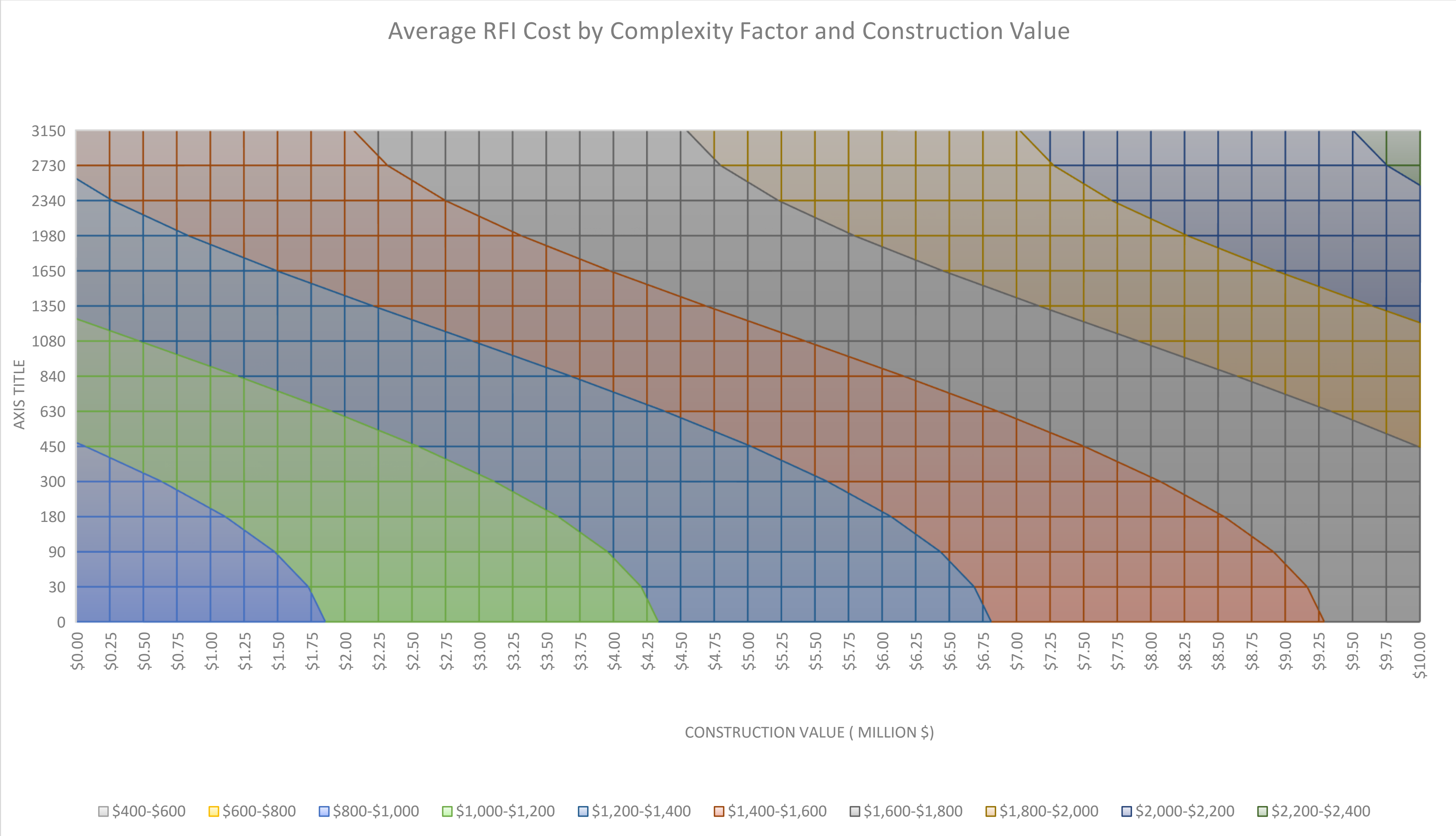
APPENDIX F.2 Plot of Average Cost by Complexity Factor



APENDIX A.1 Calculation of Average RFI Cost by Complexity Factor and Construction Value

		Complexity Factor														
		0	30	90	180	300	450	630	840	1080	1350	1650	1980	2340	2730	3150
Construction Value	0	$850	$861	$881	$910	$949	$994	$1,046	$1,103	$1,162	$1,222	$1,279	$1,333	$1,378	$1,413	$1,433
	0.25	$870	$881	$901	$930	$969	$1,014	$1,066	$1,123	$1,182	$1,242	$1,300	$1,353	$1,398	$1,433	$1,454
	0.5	$891	$901	$921	$951	$989	$1,035	$1,087	$1,143	$1,202	$1,262	$1,320	$1,373	$1,419	$1,453	$1,474
	0.75	$911	$921	$941	$971	$1,009	$1,055	$1,107	$1,163	$1,222	$1,282	$1,340	$1,393	$1,439	$1,473	$1,494
	1	$931	$941	$961	$991	$1,029	$1,075	$1,127	$1,183	$1,243	$1,302	$1,360	$1,413	$1,459	$1,494	$1,514
	1.25	$951	$961	$982	$1,011	$1,049	$1,095	$1,147	$1,204	$1,263	$1,323	$1,380	$1,433	$1,479	$1,514	$1,534
	1.5	$971	$982	$1,002	$1,031	$1,070	$1,115	$1,167	$1,224	$1,283	$1,343	$1,400	$1,454	$1,499	$1,534	$1,554
	1.75	$991	$1,002	$1,022	$1,052	$1,090	$1,136	$1,187	$1,244	$1,303	$1,363	$1,421	$1,474	$1,519	$1,554	$1,575
	2	$1,012	$1,022	$1,042	$1,072	$1,110	$1,156	$1,208	$1,264	$1,323	$1,383	$1,441	$1,494	$1,540	$1,574	$1,595
	2.25	$1,032	$1,042	$1,062	$1,092	$1,130	$1,176	$1,228	$1,284	$1,344	$1,403	$1,461	$1,514	$1,560	$1,594	$1,615
	2.5	$1,052	$1,062	$1,082	$1,112	$1,150	$1,196	$1,248	$1,305	$1,364	$1,423	$1,481	$1,534	$1,580	$1,615	$1,635
	2.75	$1,072	$1,082	$1,103	$1,132	$1,170	$1,216	$1,268	$1,325	$1,384	$1,444	$1,501	$1,555	$1,600	$1,635	$1,655
	3	$1,092	$1,103	$1,123	$1,152	$1,191	$1,236	$1,288	$1,345	$1,404	$1,464	$1,522	$1,575	$1,620	$1,655	$1,675
	3.25	$1,113	$1,123	$1,143	$1,173	$1,211	$1,257	$1,309	$1,365	$1,424	$1,484	$1,542	$1,595	$1,640	$1,675	$1,696
	3.5	$1,133	$1,143	$1,163	$1,193	$1,231	$1,277	$1,329	$1,385	$1,444	$1,504	$1,562	$1,615	$1,661	$1,695	$1,716
	3.75	$1,153	$1,163	$1,183	$1,213	$1,251	$1,297	$1,349	$1,405	$1,465	$1,524	$1,582	$1,635	$1,681	$1,716	$1,736
	4	$1,173	$1,183	$1,203	$1,233	$1,271	$1,317	$1,369	$1,426	$1,485	$1,544	$1,602	$1,655	$1,701	$1,736	$1,756
	4.25	$1,193	$1,203	$1,224	$1,253	$1,292	$1,337	$1,389	$1,446	$1,505	$1,565	$1,622	$1,676	$1,721	$1,756	$1,776
	4.5	$1,213	$1,224	$1,244	$1,273	$1,312	$1,357	$1,409	$1,466	$1,525	$1,585	$1,643	$1,696	$1,741	$1,776	$1,796
	4.75	$1,234	$1,244	$1,264	$1,294	$1,332	$1,378	$1,430	$1,486	$1,545	$1,605	$1,663	$1,716	$1,761	$1,796	$1,817
	5	$1,254	$1,264	$1,284	$1,314	$1,352	$1,398	$1,450	$1,506	$1,565	$1,625	$1,683	$1,736	$1,782	$1,816	$1,837
	5.25	$1,274	$1,284	$1,304	$1,334	$1,372	$1,418	$1,470	$1,526	$1,586	$1,645	$1,703	$1,756	$1,802	$1,837	$1,857
	5.5	$1,294	$1,304	$1,325	$1,354	$1,392	$1,438	$1,490	$1,547	$1,606	$1,665	$1,723	$1,776	$1,822	$1,857	$1,877
	5.75	$1,314	$1,324	$1,345	$1,374	$1,413	$1,458	$1,510	$1,567	$1,626	$1,686	$1,743	$1,797	$1,842	$1,877	$1,897
	6	$1,334	$1,345	$1,365	$1,394	$1,433	$1,478	$1,530	$1,587	$1,646	$1,706	$1,764	$1,817	$1,862	$1,897	$1,918
	6.25	$1,355	$1,365	$1,385	$1,415	$1,453	$1,499	$1,551	$1,607	$1,666	$1,726	$1,784	$1,837	$1,883	$1,917	$1,938
	6.5	$1,375	$1,385	$1,405	$1,435	$1,473	$1,519	$1,571	$1,627	$1,686	$1,746	$1,804	$1,857	$1,903	$1,937	$1,958
	6.75	$1,395	$1,405	$1,425	$1,455	$1,493	$1,539	$1,591	$1,647	$1,707	$1,766	$1,824	$1,877	$1,923	$1,958	$1,978
	7	$1,415	$1,425	$1,446	$1,475	$1,513	$1,559	$1,611	$1,668	$1,727	$1,787	$1,844	$1,897	$1,943	$1,978	$1,998
	7.25	$1,435	$1,446	$1,466	$1,495	$1,534	$1,579	$1,631	$1,688	$1,747	$1,807	$1,864	$1,918	$1,963	$1,998	$2,018
	7.5	$1,455	$1,466	$1,486	$1,516	$1,554	$1,600	$1,651	$1,708	$1,767	$1,827	$1,885	$1,938	$1,983	$2,018	$2,039
	7.75	$1,476	$1,486	$1,506	$1,536	$1,574	$1,620	$1,672	$1,728	$1,787	$1,847	$1,905	$1,958	$2,004	$2,038	$2,059
	8	$1,496	$1,506	$1,526	$1,556	$1,594	$1,640	$1,692	$1,748	$1,808	$1,867	$1,925	$1,978	$2,024	$2,058	$2,079
	8.25	$1,516	$1,526	$1,546	$1,576	$1,614	$1,660	$1,712	$1,769	$1,828	$1,887	$1,945	$1,998	$2,044	$2,079	$2,099
	8.5	$1,536	$1,546	$1,567	$1,596	$1,634	$1,680	$1,732	$1,789	$1,848	$1,908	$1,965	$2,019	$2,064	$2,099	$2,119
	8.75	$1,556	$1,567	$1,587	$1,616	$1,655	$1,700	$1,752	$1,809	$1,868	$1,928	$1,986	$2,039	$2,084	$2,119	$2,139
	9	$1,577	$1,587	$1,607	$1,637	$1,675	$1,721	$1,773	$1,829	$1,888	$1,948	$2,006	$2,059	$2,104	$2,139	$2,160
	9.25	$1,597	$1,607	$1,627	$1,657	$1,695	$1,741	$1,793	$1,849	$1,908	$1,968	$2,026	$2,079	$2,125	$2,159	$2,180
	9.5	$1,617	$1,627	$1,647	$1,677	$1,715	$1,761	$1,813	$1,869	$1,929	$1,988	$2,046	$2,099	$2,145	$2,180	$2,200
	9.75	$1,637	$1,647	$1,667	$1,697	$1,735	$1,781	$1,833	$1,890	$1,949	$2,008	$2,066	$2,119	$2,165	$2,200	$2,220
	10	$1,657	$1,667	$1,688	$1,717	$1,756	$1,801	$1,853	$1,910	$1,969	$2,029	$2,086	$2,140	$2,185	$2,220	$2,240

APENDIX A.2 Plot of Average RFI Cost by Complexity Factor and Construction Value



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