University of Southern Queensland

Faculty of Health, Engineering & Sciences

Assessing the True Cost of Design Variations

A Designer's Perspective

A dissertation submitted by

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Courses ENG4111 and ENG4112 Research Project

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Bachelor of Engineering (Civil)

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Abstract

It is well known within the Australian engineering and construction industry that design variations are prevalent on most projects. They have the ability to be beneficial or detrimental to the design and construction process and are perceived differently between project participants.

This dissertation aims to investigate the major causes, effects and costs of design variations encountered on engineering projects from a designer's perspective.

The research will take an in-depth look at previous research identified through academic and industry literature. An industry case study was carried out on of five different engineering projects, suggested by local government designers. The data was analysed, identifying possible causes for the variation, and the redesign and documentation costs associated with remediating the problem. Results from these case studies suggest that insufficient site investigations prior to the detailed design stages and inadequate communication between stakeholders lead to the design variations encountered.

A questionnaire survey was also developed and distributed to local government designers and private companies within the engineering industry. The questionnaire was designed to obtain the opinions and experiences respondents had in relation to the findings of the literature review. Results from the questionnaire suggest that there is an industry wide view that clients initiate over 50% of design variations. Results also suggest that inadequate design and documentation is encountered frequently by respondents, and that redesign and documentation is a common occurrence which impacts heavily on the designer.

Using the information gather through the case studies and questionnaire survey, recommendations were developed to reduce costs and impacts on future projects. Achievements, limitations and potential future studies were also identified.

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Limitations of Use

Certification

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.

Benjamin Steven Liddell

Student Number: 0050072424

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Finally I would like to recognise the encouragement and understanding of my family and friends throughout my academic career.

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1.0 Introduction

'Variation has become so prevalent in construction that it is hardly possible to complete a project without changes to the plans or the construction process itself.'

(Ssegawa, et al., 2002)

1.1 Outline of the study

The above statement attempts to present the challenges facing the building, engineering and construction industry. It suggests the need to investigate the effects and costs imposed on designers by variations.

1.2 Introduction

Recent global economic conditions have forced industries from all sectors to find innovative and viable solutions to reduce liabilities and unnecessary financial costs. The building and construction industry is not immune to these conditions. The building and construction industry is a key driver for the Australian economy, with an estimated $2.4 trillion worth of construction planned for the next decade (Master Builders Australia, 2014). Longevity of construction organisations rely on the discovery and implementation of best practices for design and construction projects.

The success of a construction project relies on professionals from various fields of study to design, document and construct the client's vision. Due to the interwoven nature of this process, any problems or changes encountered during the life of the projects has the ability to impact all parties involved. Design and construction teams use a variety of processes to communicate and initiate changes or variations to the projects. These processes have been standardised and implemented throughout the construction industry, and are viewed as common practice during the life of a project. Examples include construction variation orders, request for information (RFI), instructions, and variation requests (Bottari, 2014).

This research topic will focus on a particular process which impacts all parties involved; variations and the associated variation/change orders. For the purpose of this paper they will be referred to as variations orders.

Variations are prevalent within the building, engineering and construction industry. Variation orders are a legal means of changing a projects scope of works as defined by the contract documents. They have the ability to be beneficial or detrimental to the design and construction process. Clients, consultants, contractors and subcontractors deal with variations on most major projects. Their opinions on variations are largely determined by past experiences; positive or negative. Some project participants may see them as a means to improve the overall quality or functionality of the design. Others may see them as an unavoidable component of the design and construction process, imposing additional costs and causing schedule delays on the project and the parties involved (Tilley & Gallagher, 1999).

For the purpose of this dissertation, focus will be directed on the negative aspects of variations, primarily the causes of design change and the overall cost implications imposed on designers. Strategies will be formulated to mitigate costs and associated impacts of variations.

1.3 The problem

Building, construction and engineering design consultants are profit driven businesses. The goal of the designer/s is to produce a design and project documentation in the most cost effective and timely manner while satisfying necessary standards and the project brief. The designer/s ability to produce the "perfect" design in a cost and time restrictive environment is near impossible. Along with the unpredictable nature of the construction industry, it is inevitable that design changes and variations will arise during the life of a project. Variations may initiate reviews, redesign, reproduction of drawings, and associated administration costs. The ability of design consultants to quantify the costs of variations imposed on their businesses will help develop strategies to mitigate unnecessary financial burdens.

The fundamental aim for this case study based research project is to reduce the cost impacts of variations on designers in future construction projects. A number of real engineering projects along with a questionnaire survey will provide the data necessary for analysis. Cost impacts can be reduced by identifying the causes of variations, the propagated effects, and determining the actual cost of processing variations in dollar terms.

1.4 Research objectives

In order to reduce the cost impacts of variations imposed on designers in future projects four major research objectives are identified. The objectives are:

- Identify the causes of design variations on construction projects.
- Identify the effects of variations on designers.
- Identify and quantify the costs of variations imposed on designers.
- Develop strategies for reducing the costs and impacts caused by design variations on designers.

1.5 Structure of dissertation

The research project is structured with five main chapters. The information presented in each chapter is as follows;

Chapter one introduces the research project, briefly outlining the problem being investigated, the research objectives and the format in which the project will be structured. A conclusion summarising the main points of interest will conclude the chapter.

Chapter two contains a literature review of all relevant background information relating to variations and variation orders. It discusses in detail the participants involved, causes of design variations, effects of variations on designers, costs imposed on designers, current methods for reducing variation orders, and different processes used in the industry to improve designs. A conclusion summarising major contributions, identifying gaps in research, and relating the literature review to the main topic of discussion.

Chapter three outlines the methodologies that were used to collect the case study data and questionnaire survey data. The parameters used to select projects and the data collected are presented. An outline of each case study will provide context for the reader. Analysis of the data will provide the basis for recommendations and conclusions.

Chapter four discusses the results and data collected from the industry case studies and questionnaire survey. Particular focus is on the overall impact variations imposed on designers. Recommendations and strategies are given to minimise the costs and impacts of design variations.

Chapter five concludes the research project discussing the major achievements to date. It will provide the reader with insight into whether or not project objectives were met and highlight possible limitations that may have inhibited achievements. Further studies are also identified.

1.6 Conclusion

This dissertation aims to determine the main causes of design variations, the effects of these variations, the true costs, and strategies to reduce financial burdens on designers. These aims will be accomplished through a literature review, and analysis of case study data and questionnaire survey data provided by industry sources.

The research is expected to result in a better understanding of the major effects variations inflict on a design consultancy and propose a dollar cost attributed to design variation processes.

A review of literature will identify past and current research conducted on variations. It will highlight common participants in construction projects, common causes of variations, their eventual effects and current strategies for reducing variations and a brief overview of up and coming design processes. It will also identify gaps in current research and highlight the need for further research on the topic.

The outcome of this study will be used for the development of strategies for reducing the impact of variations incurred by designers.

2.0 Literature Review

2.1 Introduction

This chapter will review literature thus establishing the need for a study into the costs implications that variations imposed on designers. The literature reviewed will dissect past and current research on the subject, highlight known causes and effects of variations, and outline current methods for reducing impacts. It will also identify areas of research that require further study and justify the need for this dissertation.

Literature sources were limited to academic journal articles, institutional publications, and industry websites. Literature sourced from journal articles and institutional publications provided a good representation of research achievements to date and highlighted areas that require further study. The claims and findings outlined in these sources have been substantiated through a peer review processes. Journal articles were sourced from online publication index databases. All literature was published in English.

The literature review will be divided into nine main areas.

1. Introduction
2. Participants in construction projects
3. Overview of variation orders
4. Causes of variations in construction projects
5. Effects of variations on designers
6. Cost impacts on designers
7. Reducing variations through early intervention
8. Design processes for designers
9. Conclusion

The research undertaken in this literature review should provide the reader with a better understanding of the major causes of variations, the associated effects, and costs encountered by designers. Current strategies will also provide the reader context.

2.2 Participants in construction projects

This section aims to provide an overview of the major participants that are involved in the variation order process. The relationships between these participants are critical for delivering a project within schedule and cost. Construction project participants will vary between projects and organisations. The diagram below in Figure 1 describes the variety of participants involved in a typical construction project.

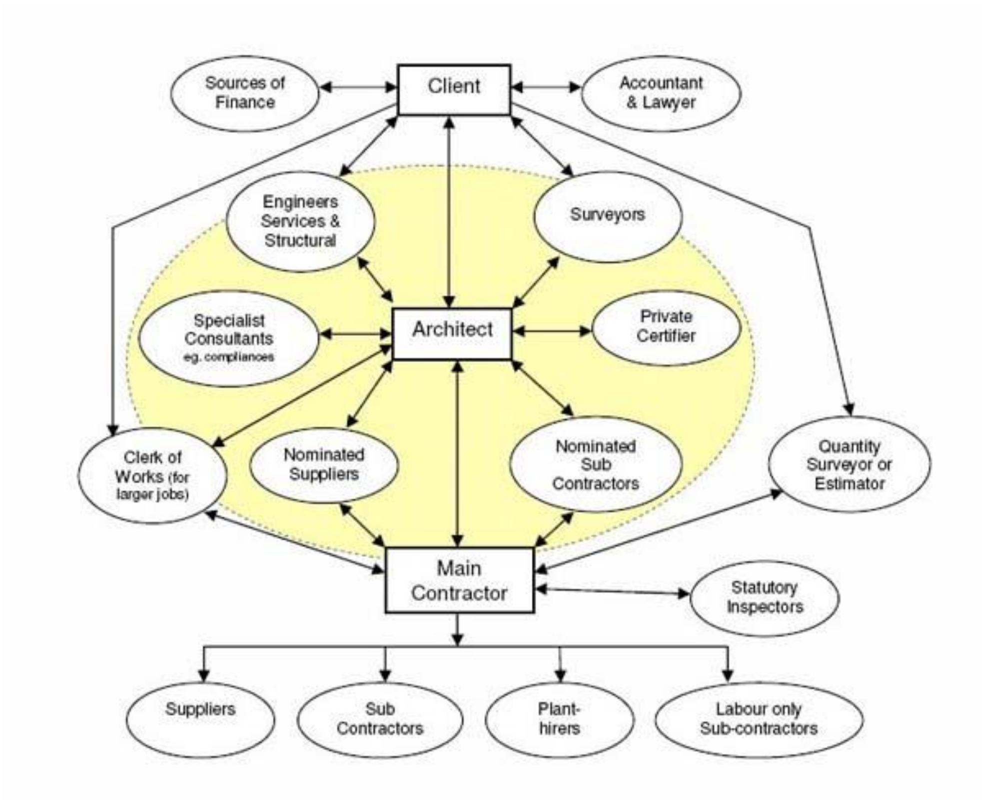

Figure 1: Participants involved in a typical construction project

(Dion Seminara Architecture, 2011)

2.2.1 Client/owner

The client/owner is an organisation or person that commissions and finances the management, design, and construction of a project. Typical clients are federal, state and local governments, public corporations, community groups, and individuals.

Construction projects may include residential, commercial, health-care, industrial, institutional and heavy engineering infrastructure. The client engages consultants to design and produce detailed documentations for the construction project. The contractor is commissioned to build the project to the consultant's design and specifications. The client may or may not be the end user of the final product. (UKessays, 2014).

2.2.2 Superintendent/Project Manager

The superintendent (often an architect) is responsible for facilitating contractual, technical and construction issues between the client and the main contractor. In the public sector an internal engineering department is responsible for the procurement, contract selection and project management. Clients unable to negotiate with the main contractor will need a superintendent to ensure the project will be constructed on schedule and to the required standard.

2.2.3 Consultants

The consultant or design consultant is contracted by the client to design, produce documentation, and provide technical services for the construction of the project. The role and responsibilities of the consultant may differ between projects and countries. Consultants may include architects, engineers of different disciplines, designers, surveyors and scientists. Typical responsibilities of the consultant include feasibility studies, design and documentation, cost-estimates, investigations, and coordination of designs. The consultant may act as an unbiased arbiter for the client and contractor if required. (UKessays, 2014).

2.2.4 Contractor

The contractor or construction contractor is contracted by the client to construct the project using their own resources and subcontractors. They are responsible for completing the project in accordance with the consultants design documentation and completing the project on schedule. Contractors may be companies capable of specialised construction methods, own specialised machinery or have skilled workers at their disposal. Firms with these specialised capabilities would receive subcontracted work. (UKessays, 2014).

2.2.5 Subcontractors

Contractors in control of larger projects rarely have the capability to carry out all facets of construction. The employment of subcontractors can be utilised to provide specialised skills and knowledge. Subcontractors may be nominated by the client at the tender stage.

2.3 Overview of variation orders

2.3.1 What are variations and variation orders?

Design variations/changes and, variation/change orders have been studied extensively throughout the industry. For the purpose of this literature review they will be referred to as *variations and variation orders*. The definition of variations and variation orders has been described by the following authors. A definition by Baker & McKenzie, (Baker & McKenzie, 2013) broke the definition into two parts:

The term 'variation' in the context of construction contracts can mean two things, namely:

a) *A 'variation' or change to the contract terms; and*
b) *The narrower and well known meaning, that is, a physical 'variation' or change to the work (quantity or quality) required to be carried out under the contract.*

A definition provided by Standards Australia (Standards Australian , 1997) states variations are:

a) *Increase, decrease or omit any part;*
b) *Change the character or quality;*
c) *Change the levels, lines, positions, or dimensions;*
d) *Carry out additional work;*
e) *Demolish or remove material or work no longer required by the Principal.*

A definition of a variation order by Duaij (Duaij, et al., 2007) states that:

"A variation order is a written agreement to modify, add to, or otherwise alter the work from that originally set forth in the contract documents at the time of opening bids."

2.3.2 Variation order form

Presented as a formal document, variations orders offer the only legal means of change to provisions after awarding a contract. These conditions may include contract price, schedule of payments, completion date or the plans and specifications. Variations through verbal communication should be avoided. The variation orders must include the following information (Duaij, et al., 2007):

- Projects Name
- Project Number
- Type of variation
- Variation initiator
- Description of the change required
- Justification for the required change
- Referenced project documents
- Cost and time that will be reimbursed
- Start and completion dates
- Signatures

Although there is no standardised variation order form, consultants usually have their forms and procedures that must be followed to process a change (Al-Dubaisi, 2000). Clear and detailed variation orders provide project participants the necessary information for the ensuing discussions. Figure 2 presents an example of a variation order form.

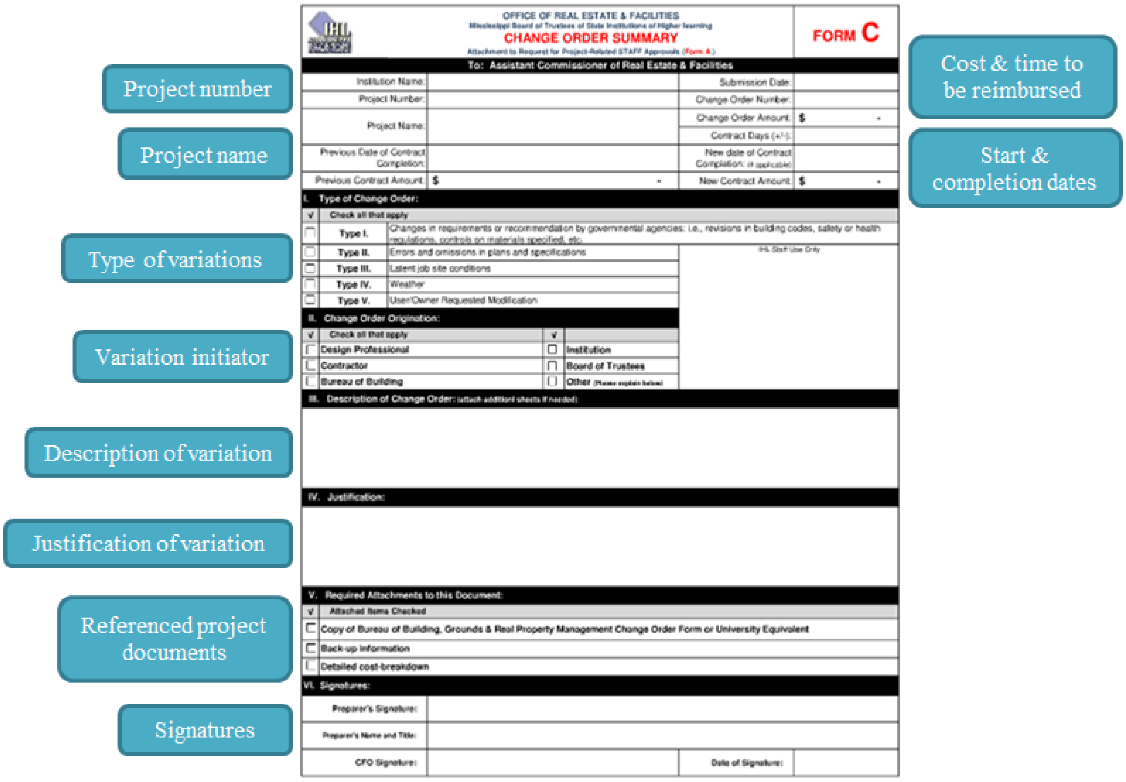

Figure 2: Example of a variation order form (Docstoc, 2010)

2.3.3 Variation order procedure

Procedures and documentation used for variation play an important part in the change management. The process of change is initiated by the project's client, consultant, contractor or other causes. The process utilises forms and guidelines that must be followed to bring in the desired change. Any deviation from the set procedures can result in disputes between the parties involved. The complexity of variation order procedures can pose a problem for large companies. Control systems and the involvement of different technical disciplines can hinder effective variation order procedures. The cost of these procedures can be substantial, with one owner stating that 20% of the project work was directed at developing, processing and negotiating change requests. (Al-Dubaisi, 2000).

Every design consultant will have set procedures and forms to deal with variation orders. The fundamental procedures will consist of the following (Al-Dubaisi, 2000):

- Variation recognition and scope definition
- Variation order initiation and documentation
- Variation order execution and closure

The implementation an effective variation order process is necessary for successful change management. Variations may be initiated by the client, consultant, contractor or external influences. The following outlines the steps taken for a variation initiated by a contractor and roles of the design consultant.

The need for a variation or design change is identified by a contractor or subcontractor. The required change is detailed in a variation request form. This form will usually provide the project's name, project number, clients name, project manager's name, scope of works, impacts on project, and anticipated costs. Sign off by the request initiator and project manager will normally be required. Project changes may be in relation to the constructability of the project, construction methods required, or differing site conditions.

The head contractor will submit a variation request to the project manager (often the architect). The project manager will give an initial assessment of the request and decide if the request needs to be reviewed by the design team.

Following this the project manager will provide instructions to the lead consultant regarding the proposed changes. The lead consultant will collaborate with the primary disciplines affected by the proposed changes. The design team may include structural, civil, mechanical, electrical engineers, architects, designers, and quantity surveyors depending on the nature of the project and the extent of the requested change. The design team will assess the potential impacts on the project's technical feasibility, schedule, and associated costs. The lead consultant will then summarise the findings of the design team and provide recommendations for the client.

At this stage the client will review the findings and recommendations provided by the consultant and will either approve or reject the variations. If approved the design team will need to implement the required changes via a variation order. Design changes may affect 3D computer models, design documentations, drawings and specifications. The designer may need to revisit the site or organise additional site investigations to remediate the change. Once the designer has amended the required changes to the design and documentation, the revised design is packaged and sent to the project manager.

The project manager will instruct the head contractor to carry out the changes outlined in the package. The changes may or may not have an impact to the contractors' schedule or costs. In the event that the contractor disagrees with the changes they can respond with a variation request, notice of a time extension or claim. Once the variation order has been completed the order is closed (Bottari, 2014).

Timeframes for the procedures above are defined in the project's contract. Failure to meet the required timeframes may cause disputes between project participants.

The situation outlined above is shown in Figure 3. It represents one of many possible scenarios which may vary between the parties involved, the nature of the project, organisations involved, and the urgency of the variation.

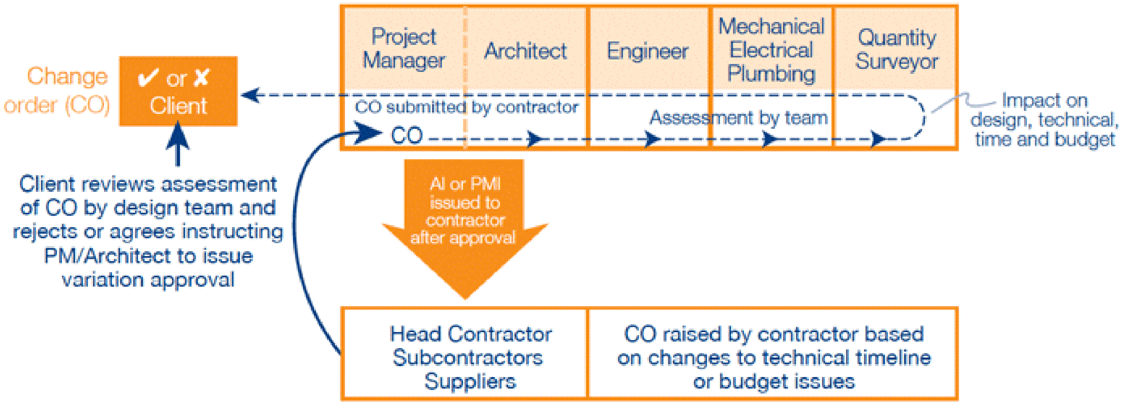

Figure 3: Variation order process (Bottari, 2014)

2.3.4 Valuing variations

The consultant's ability to accurately cost the work associated with variation orders is crucial. The consultant will be required to provide detailed quotation for the works to be undertaken and evidence supporting the basis of the quotation to project participants. This may include measured/estimated quantities, rates, and lump sums. The task of producing large quotations and supporting evidence should be considered, and may have to be included in the final valuation. The cost of variations for consultants can be divided into three components (Law Teacher, 2014):

1. Direct costs
2. Indirect costs
3. Consequential costs

Direct costs are the costs of performing the work required under the variation order. This typically includes the cost of labour for the engineers, and designers employed by the consultant.

Indirect costs may include a company's overheads, administration, supervision, attendance, and profit. These elements are often covered in the conditions of contract.

Consequential costs may include disruptions to work, delay to schedule/activity or inefficiency incurred by completing work out of programed sequence.

The cost of design variations quoted by design consultants should consider all of the above components. An agreement of valuation between the consultant and the client is required before work commences by the consultant.

2.4 Causes of variations in construction projects

In this section we examine the potential causes of variations or design changes in construction projects. Causes have been grouped into four categories.

- Client initiated variations
- Consultant initiated variations
- Contractor related variations
- Other variations

2.4.1 Client initiated variations

2.4.1.1 Nature of client

Variations are commonly initiated by the client or owner during the design phase in construction projects (Oladapo, 2007). Built construction projects involve a number of participants with varying experience and knowledge in the field of engineering and construction (Keane, et al., 2010). In most cases, the client has limited or no knowledge in the field of construction engineering. Inexperienced clients, unfamiliar with standard construction practices, may change budget, scope, design, schedule, or delay variation approvals with little appreciation of the effects of their actions (Engineers Australia, 2005), (Sun & Meng, 2009), (Akinsola, et al., 1997). Clients who work in unison with the practicing professionals can limit the number and effect of variations.

2.4.1.2 Scope or brief

Change in scope or brief by the client is one of the most significant causes of variations in construction projects (Engineers Australia, 2005), (Keane, et al., 2010), (Oladapo, 2007) (Alnuaimi, et al., 2010), (Ismail, et al., 2012). The project's brief sets the foundations of a construction project and need to be executed correctly to minimise design variations in latter stages of a project (Chan & Yeong, 1995). The client's requirements and expectations can change during the life of a construction project. Variations to the project brief can be initiated by the client's finances, desired schedule, omitted information, or simply a change of design requirements (Sun & Meng, 2009). A change in the scope or brief of a project has negative consequences to the detailed design and construction phases. Figure 4 shows a typical brief document cover sheet.

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Sunshine Coast
Regional Council

PROJECT BRIEF

Capital Works Manager No.		16069	Project No.	23034
Project Name:	Esplanade – Car / Boat parking area at Boat Ramp		Finance No.	C.B1407 (survey & design only)

Road:	Esplanade	Priority Score	79
Locality:	Golden Beach	Division:	2
Councillor:	Cr Tim Dwyer		

(Northbound view on Esplanade, Golden Beach)

- Project Brief Document Template

Figure 4: Typical brief document cover sheet

2.4.1.3 Project schedule

Changes in project schedule by the client can cause variations in construction projects (Sun & Meng, 2009). Any change to the project's schedule will determine resource allocations by consultants and contractors. Unforeseen resource changes imposed on third parties will incur additional costs.

2.4.1.4 Specifications

Changes to design specifications can cause variations in construction projects (Oladapo, 2007). Specification changes are often prevalent in construction projects with inadequate project objectives. Variations may include changes to the materials, finishes, or procedures used to produce the final product (Keane, et al., 2010). As previously stated, the clients requirements and expectations can change at any time, thus changes in the specifications can impact negatively on a project.

2.4.1.5 Finances

The client's financial problems can cause variations in construction projects (Ismail, et al., 2012), (Sun & Meng, 2009). If the client encounters financial difficulty during the course of the project or has an insufficient budget to begin with the project may lack the required quality, encounter design variations or need the work schedule adjusted (Keane, et al., 2010), (Oladapo, 2007).

2.4.1.6 Project objectives

Inadequate project objectives provided by the client can cause variations in construction projects. If the design consultant is provided limited or insufficient project objectives the design will conflict with the client's expectations causing variations in later stages of the project (Keane, et al., 2010), (Arain & Pheng, 2005).

2.4.1.7 Design decisions

Indecisive decision making by the client can cause variations in construction projects. The inability of the client to effectively and efficiently make and convey design decisions can create variation orders resulting in increases in build costs (Alnuaimi, et al., 2010), (Chang, 2002), (Keane, et al., 2010).

2.4.2 Consultant initiated variations

2.4.2.1 Nature of consultant

Consultants have to work with a number of project participants. The consultant's willingness to accommodate the ideas and desires of the client, other consultants and contractors are necessary for a project's success. A consultant awarded a project through competitive pricing may resort to unethical behaviour such as inadequate quality assurance processes to maximise their fee (Engineers Australia, 2005). It is the consultant's responsibility to act in the best interests of all parties involved (Engineers Australia, 2005). A consultant that acts unethically or is inflexible may cause variations during the life cycle of the project.

2.4.2.2 Design changes and errors/omissions

Changes and errors in designs are one of the major causes of variations in construction projects (Keane, et al., 2010), (Burati Jr, et al., 1992), (Alnuaimi, et al., 2010), (Duaij, et al., 2007). Projects which begin construction before the design is finalised are prone to changes by design consultants. Consultants are often under strict schedules to design and document construction projects (Engineers Australia, 2005). This method of business creates situations where the consultant may intentionally or accidently omit design information. Neglecting a quality design process to satisfy a strict schedule can cause variations and disputes throughout the life of a project. The negative impact of these variations can vary depending on timing. A proper review of final design documentations can prevent design changes.

2.4.2.3 Design documentation

According to a report conducted by Engineers Australia, 60 - 90% of all variations are caused by inadequate design and documentation (Engineers Australia, 2005). Poor quality design documents have created a non-competitive industry, cost over-runs, rework, increased stress, decreased morale, and diminished reputations of consultants (Engineers Australia, 2005). The report also outlined ten root causes for the diminishing quality of project design documents. These include the following:

1. Inadequate project briefs with unrealistic time/cost expectations
2. Lack of integration between parties and project phases
3. Devaluing of professional ethics and business practice
4. Awarding projects to lowest bidder rather than value for money
5. Inadequate knowledge in risk assessment and management
6. Absence of an experienced Design Manager/Coordinator
7. Lack of optimal design documentation skills
8. Lack of skilled/experienced personnel
9. Inadequate use of available technology
10. Lack of open communication

(Engineers Australia, 2005)

Ideally the consultant should provide design documentation detailing every aspect of the design and construction. Unfortunately, a clear and concise set of design documents are a rarity in today's marketplace due to the causes listed above. Inadequate documentation can also cause inaccurate design cost estimates of a project, leading to cost variations (Keane, et al., 2010). The problem is industry wide and needs to be addressed correctly to minimise the negative impacts of variations associated with poor design documentation. Figures 5 shows an example of construction plan issued to construction crews. Figure 6 show a typical estimate which accompanies the plan set.

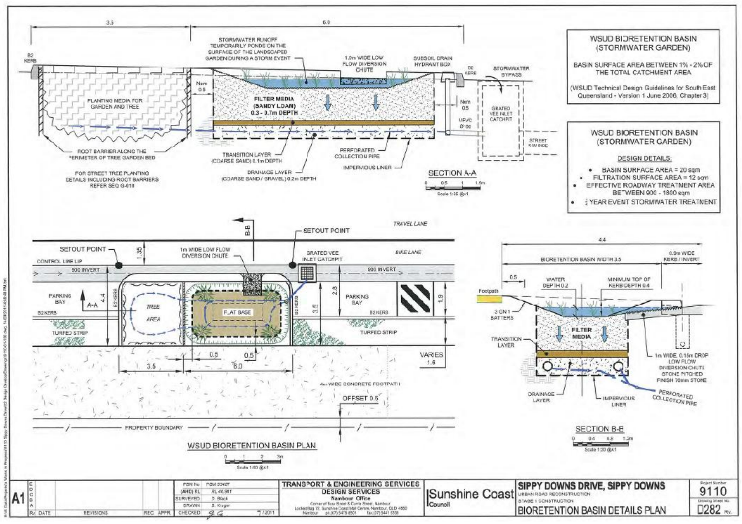


Figure 5: Example of a construction plan

Sunshine Coast Council — *Transport and Engineering* *DESIGN SERVICES* — PRINTED: 5/12/2013

SCC CODE	PROJECT NUMBER 23432 ITEM DESCRIPTION	QTY.	UNIT	RATE	EXTERNAL	INTERNAL	SUB-TOTAL
	SCC FINANCE Number : B.2420						
2317	PRECAST CONCRETE END STRUCTURES TO CULVERTS		lump sum				$500
	PRECAST ENDWALLS, TO SUIT 375mm dia. PIPE (Supply & Place) ROCLA - HWL375H	1	each	$500		$500	
	PAVEMENT DRAINAGE (MRD 2400, Vol 1, MRS 11.03)						
2401	CONCRETE KERB (32MPa/10) (ALL KERBS ASSUMED TO BE MACHINE FORMED)	6	m	$107.00			$642
	BARRIER B2 OR SIMILAR (REFER SEQ R-080)	6	m	$57		$342	
	ALLOWANCE FOR HANDFORMED WORKS (INPUT % LENGTH OF WORKS)	100%	%	$50		$300	
2403	CONCRETE CHANNEL (32MPa/10) (ALL INVERTS ASSUMED TO BE MACHINE FORMED)	14	m	$155.00			$2,093
	INVERT CHANNEL 900mm WIDE (REFER SEQ R-080)	13.5	m	$150		$2,025	
	ALLOWANCE FOR HANDFORMED WORKS (INPUT % LENGTH OF WORKS)	20%	%	$25		$68	
2404	CONCRETE KERB & CHANNEL (32MPa/10) (ALL K&C ASSUMED TO BE MACHINE FORMED)	32	m	$100.00			$3,200
	BARRIER B1, (450mm OR 300mm Channel width) (REFER SEQ R-080)	32	m	$100		$3,200	
2405	CONCRETE KERB CROSSINGS (32MPa/10) (includes 2402) (ALL RAMPS ASSUMED TO BE HAND FORMED)	3.6	m	$450.00			$1,620
	PEDESTRIAN RAMPS, NOMINAL 1.5m DEPTH, 125mm THICK, SL62 MESH (INPUT TOTAL WIDTH) (Refer SEQ R-090 & 091)	3.6	m	$450		$1,620	
2413	CONCRETE GULLIES (32MPa/10) (Includes subsurface junction chamber works) (DAY RATES) (Refer also SEQ D-050 ~ 068 for various styles)	2	each	$1,625.00			$3,250
	ANTI-PONDING KERB INLET (GRATED LID / INSITU CHAMBER) (1230 x 1135 OR SIMILAR)	1	each	$2,500		$2,500	
	PROPERTY DRAIN PIT (GRATED LID / PRECAST CHAMBER) (ROCLA 450x450)	1	each	$750		$750	
	SUBSURFACE DRAINAGE (MRD 2500, Vol 1, MRS 11.03)						
2502	SUB SOIL DRAINS, TYPE D (STD DWG SEQ R-140)	32	m	$35.00			$1,120
	SUBSOIL DRAIN (supply / lay / reinstate, onsite)	32	m	$35		$1,120	
	RETAINING WALLS (MRD 2700, Vol 1 MRS 11.03)						
2721	CRIB OR LINK WALLS (Height Limits as per Manufacturers Specifications)	0.5	m2	$300.00			$150
	SUPPLY OF (CRIB OR LINK, SPECIFY) WALL COMPONENTS (Delivered onsite)	0.5	m2	$150		$75	
	INSTALLATION OF (CRIB OR LINK, SPECIFY) WALL COMPONENTS INCLUDING BACKFILL / COMPACTION	0.5	m2	$50		$25	
	CONSTRUCT UNREINFORCED CONCRETE FOOTING TO WALL (32MPa/10) (0.35m high, 1.8m long, 0.1m deep)	0.1	m3	$500		$50	
	GENERAL EARTHWORKS (MRD 3100, Vol 1, MRS 11.04)						
3100	EARTHWORKS, EXCAVATION / EMBANKMENT / SUBGRADE TREATMENTS	38	m3	$45.47			$1,705
3201	GENERAL EXCAVATION, RIPPABLE MATERIAL (Rate to reflect Material Destination) (DESIGN 8.5m3)	8.5	m3	$30		$255	
3301	GENERAL EMBANKMENT, ON SUITABLE SURFACE (Rate to reflect Material Source) (DESIGN 29m3)	29	m3	$50		$1,450	
3800	LANDSCAPING WORKS (Vol 1, MRS 11.16)		lump sum				$3,613
	Topsoil to Turf, Mulch and Grass Seeding, Supply and Place, Nominal 50mm thick)	9.5	m3	$35		$333	
	TURFING (SUPPLY & PLACE) (Minimum Topsoil, see above, is auto-calculated)	190	m2	$12		$2,280	
	MAINTENANCE (WATERING, WEEDING ETC)	4	weeks	$250		$1,000	
	UNBOUND PAVEMENTS (MRD 4100, Vol 1, MRS 11.05) (not including driveways)						
4103	BASE, UNBOUND PAVEMENT	10	m3	$200.00			$2,000
	Type 2.1 (CBR 80) Compacted Gravel Pavement (75mm x 100m2)	10	m3	$200.00		$2,000	
	DENSE & OPEN GRADED ASPHALT PAVEMENTS (MRD5400 & MRD5500, Vol 2, MRS 11.30 &11.34)						
5500	ASPHALT PAVEMENTS & SEALS / WEARING SURFACES (Refer also 8601 series)	15	tonne	$400			$6,120
	DENSE GRADED, DG10 (Class 320) MIX, (170m2 x Min35mm = 6m3) x 2.55t / m3	15.3	tonne	$400.00	$6,120		
6300	PAVEMENT MARKING (Vol 2, MRS 11.45)		lump sum				$588
	LONGITUDINAL / TRANSVERSE LINE MARKING (Stop / GW / CW / Continuity lines, 150mm to 300mm)	6	m	$5.00		$30	

Location: \\MSC.Internal\User\Data1\bsl\Documents\ — PAGE: 2 of 4

Figure 6: Example of a construction estimate

2.4.2.4 Specifications

Changes to design specifications by the consultant can cause variations in construction projects (Keane, et al., 2010), (Oladapo, 2007). Insufficient investigation into the available materials and construction methods may lead to variations in the design details (Wu, et al., 2005). Inconsistencies within specifications are also common due to the willingness of designers to “copy and paste” specifications from similar projects. It is also common for junior or inexperienced employees to write projects specifications (Kagan, 1985), (Engineers Australia, 2005). Designers with unclear project objectives are pushed to make decisions that the client may not be comfortable with. All these factors increase the frequency and impact of variations.

2.4.2.5 Scope for contractors

An inadequate scope of works for contractors can cause variations in construction projects (Ismail, et al., 2012). Construction sites contain a variety of contractors from different disciplines. A clear and thorough scope for each contractor is needed to limit variations.

2.4.2.6 Site investigation

A thorough and detailed site investigation is needed to reduce the frequency and impact variations on construction projects (Wu, et al., 2005). Site investigations include detailed topographical surveys and geotechnical investigations. These investigations are often seen as wasteful or unproductive by the client, yet they play a crucial role in the operation of a project. Design consultants often reduce the amount of site investigation in an effort to reduce design costs and be awarded the contract (Chan & Yeong, 1995). Topographical surveys provide designers with current ground levels and locations of features relevant to the projects construction. They highlight problematic areas at the project site and are the building blocks for which the design is developed. Dated or incomplete topographical surveys can affects design levels, quantities, schedules, standards applied and construction costs. Inadequate or limited geotechnical investigations can also impact a projects schedule and cost. Geotechnical information gathered by these investigations is often the basis for a structurally safe design that conforms to the necessary standards (e.g. foundation design) (Wu, et al., 2005). Remedial actions during the construction phase may be needed to correct the design. An accurate and detailed site investigation can dramatically reduce the number of variations on a construction project. Figure 7 shows a typical topographical survey used by many designers.

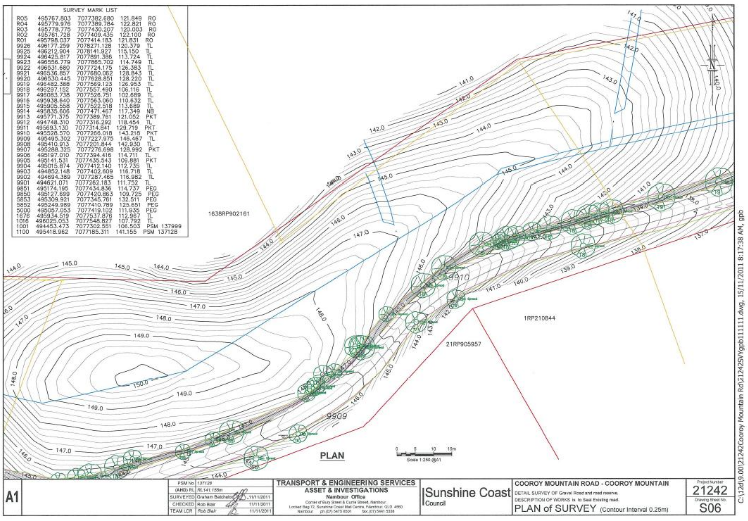


Figure 7: Topographical survey example

2.4.2.7 Contract documentation

Misinterpretation and conflict between contract documents can cause variations in construction projects (Keane, et al., 2010), (Duaij, et al., 2007). Clear and concise contract documents provide all parties with a legal agreement on the scope of the work and expectations of all involved. Inadequate contract documents can impact a projects schedule and costs through variations.

2.4.2.8 Project complexity

The technical complexity of a construction project can be the cause of variations. Construction projects which are unique or push the limits of engineering will be more likely to encounter variations (Keane, et al., 2010), (Sun & Meng, 2009).

2.4.2.9 Experience and knowledge

The inexperience and lack of design knowledge of personal working at a consultancy can cause variations in construction projects (Chang, et al., 2011), (Chang, 2002). Consultants need personnel that are experienced and knowledgeable in all aspects of construction, design and documentation. Poor knowledge of available materials, equipment, and construction methods can increase cost and schedule changes in the construction phase (Keane, et al., 2010). The rise of computer aided design programs has increased productivity of consultants (Engineers Australia, 2005). However, the ability to operate these complex design programs is useless if the operator does not have competent design knowledge. The ability of consultants to effectively adapt and resolve design and construction issues will reduce the risk of variations occurring on the project.

2.4.2.10 Value engineering

Value engineering can be used to minimise a project's cost and should be utilised at the earliest possible time (Keane, et al., 2010). Value engineering relies on experience and knowledge from designers, engineers, project managers, operators, and end users to achieve the most cost effective design. Trying to implement value engineering in later stages of a project can result in variations (Keane, et al., 2010).

2.4.2.11 Technology

Changes in technology can be the cause of variations in long term construction projects (Keane, et al., 2010), (Duaij, et al., 2007). Technology, such as computer aided design (CAD), has increased productivity in design and documentation of construction projects; however, as engineering sciences advance consultants have an evolving palette of materials and construction techniques (Wu, et al., 2005). Changes in materials and methods of construction can cause variations in the design and construction stage. Figure 8 shows one such CAD technology used to design and document projects.

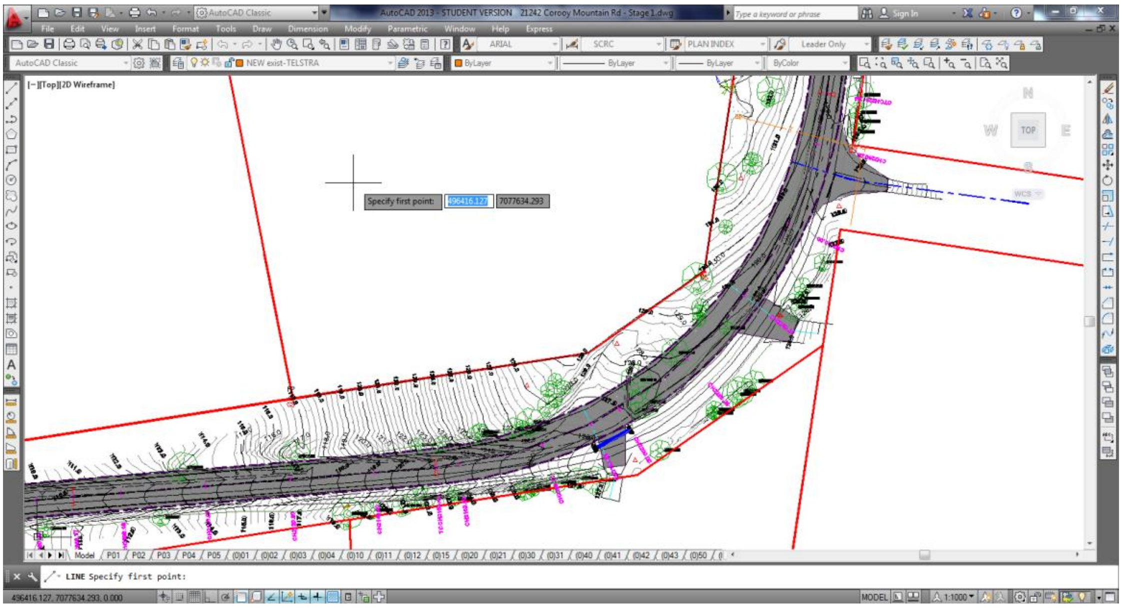


Figure 8: CAD software used for design and documentation

2.4.3 Contractor initiated variations

2.4.3.1 Nature of contractor

Contractors are employed to carry out work for the consultant. It is the contractor's responsibility to act in the best interests of the client. A contractor's desire for profitability can lead to unethical behaviour, variations and increased costs for the client. Variations can be seen as financial rewards for contractors (Keane, et al., 2010).

2.4.3.2 Lack of involvement in design

The lack of involvement in the design process can cause variations in construction projects. The contractor can offer practical knowledge and share past experiences to improve design and construction methods specified in the detailed design (Keane, et al., 2010). Contractors may be able to foresee variations that could occur during the construction phase.

2.4.3.3 Unavailability of equipment

The unavailability of equipment and plant can cause variations in construction projects. Contractors unable to supply the appropriate equipment, machinery or materials to the construction site will cause time and cost variations for the project (Keane, et al., 2010).

2.4.3.4 Unavailability of skills

The unavailability of skilled workers can cause variations in construction projects. Lack of skilled subcontractors and skilled labour has been identified as a possible cause of variations (Keane, et al., 2010).

2.4.3.5 Financial problems

Financial difficulties of the contractor can cause variations in construction projects. Financial difficulties encountered by contractors can affect wages of workers and labour force. Unpaid wages or layoffs may decrease quality of workmanship and increase project schedule (Keane, et al., 2010).

2.4.3.6 Differing site conditions

Differing site conditions can cause variations in construction projects (Alnuaimi, et al., 2010), (Keane, et al., 2010). If site conditions are inconsistent with the description in the design, contractors may not be able to carry out specific construction techniques or construction requirements (Wu, et al., 2005). Alternative methods or machinery may be needed to continue construction. Knowledge of the local conditions at site is also necessary for contractors to successfully complete their work (Keane, et al., 2010).

2.4.3.7 Quality of work

The quality of workmanship by the contractor can cause variations in construction projects. Poor workmanship has been recognised as a common cause for rework and delays in project schedule (Sun & Meng, 2009). The use of subcontractors, over labour supplied by the immediate contractor, can make coordination of work challenging. In some cases complete demolition of the defected work is needed to satisfy quality requirements (Keane, et al., 2010). Additional resources may be needed to keep the project on schedule. Remedial actions may cause variations in the project.

2.4.3.8 Design complexity

As stated in previous sections, the technical complexity of a construction project can be the cause of variations (Keane, et al., 2010). Construction projects which are unique or push the limits of engineering will need contractors with specialised skills and knowledge. Contractors unable to comprehend and construct a complex design efficiently may cause schedule delays and time variations.

2.4.3.9 Lack of experience and knowledge

Lack of experience and knowledge by the contractor can cause variations in construction projects (Sun & Meng, 2009). Contractors awarded the project are expected to be adept in the field of building and construction. Often the cost of an underperforming contractor is larger than the difference in less competitive tender bids (Chan & Yeong, 1995). Contractors may insist on alternative methods and materials specified in project documentation (Wu, et al., 2005). In some cases they may be correct in doing so; however, changes incur cost and schedule changes. The ability of contractors to construct and resolve construction issues will reduce the risk of variations occurring on the project.

2.4.3.10 Lack of strategic planning

Lack of strategic planning by the contractor can cause variations in construction projects (Keane, et al., 2010). Construction of large projects involves the coordination and organisation of various disciplines interconnected with one another (Sun & Meng, 2009). Inadequate strategic planning can lead to poor site and time management, wasted materials, poor use of labour and unnecessary costs. Variations often occur on poorly planned projects.

2.4.3.11 Lack of communication

Lack of communication between the contractor and other parties can cause variations in construction projects. Inadequate communication, cooperation and poor relationships between personnel on site can initiate claims and disputes (Chan & Yeong, 1995). Claims and disputes between contractors and other parties can cause schedule delays.

2.4.4 Other variations

2.4.4.1 Weather

Unforeseen weather events and conditions can cause variations in construction projects (Keane, et al., 2010), (Alnuaimi, et al., 2010). During the life of a project the construction site is exposed to a variety of normal and abnormal weather conditions. The geological location of the project also determines the weather conditions project participants should expect and plan for. Extreme weather conditions experienced in natural disasters can have severe impacts on site conditions and may delay or even terminate work (Wu, et al., 2005). Remedial action is needed to continue construction. Weather conditions are difficult to predict, and are often the main causes for schedule delays and cost variations (Sun & Meng, 2009).

2.4.4.2 Safety

Safety issues can cause variations in construction projects. Noncompliance with safety regulations or substandard designs will need correction to pass quality assurance procedures (Keane, et al., 2010). Substandard designs causing safety issues are easier to correct during the design stage of a project. Redesign and rework of safety issues will cause cost and schedule variations.

2.4.4.3 Regulations

Change to government regulations can cause variations in construction projects (Chang, et al., 2011), (Duaij, et al., 2007). Changes to government policy, law, code, and standards can negatively impact projects if they are implemented after design plans are finalised or construction has commenced (Wu, et al., 2005). Regulations can impact health and safety, planning, employment, environmental and taxation elements of a project (Sun & Meng, 2009).

2.4.4.4 Economics

Changes in economic conditions can cause variations in construction projects. Change in economic conditions at the time of design or construction can increase the frequency and impact of variations (Keane, et al., 2010). Economic downturns that occurred after the global financial crisis effected construction industries globally.

2.4.4.5 Social cultural factors

Social cultural factors can cause variations in construction projects (Keane, et al., 2010). Communication between project participants and members of the wider community are vital to satisfying all stakeholders (Chang, et al., 2011). Members of the community located near the project may have concerns regarding health and safety, environmental protections, protecting the “local way of life”, business interruptions etc. (Wu, et al., 2005). Community and political pressure, particularly in public sector projects, may cause variations to the design or construction methods.

2.4.4.6 Unforeseen

Unforeseen circumstances can cause variations in construction projects (Keane, et al., 2010). These may include internal forces within organisations (restructures), service and utility providers changing requirements or designs, and other organisations concerned with project impacts (Wu, et al., 2005). Unforeseen problems cannot be predicted and are difficult to control.

2.5 Effects of variations on designers

In this section we examine the potential effects of variations or design changes on designers.

2.5.1 Redesign and documentation

Project redesign and documentation can be an effect of variations for engineering designers. Variation orders requiring change in design, scope or specifications will generally require changes to computer models and drawing documents. Specialised skills are needed to operate the design and drafting packages correctly and efficiently. Changes to the physical layout and design have a flow on effect to the drawings which describe the computer model. The process of making changes to the design and redrafting documentation takes up valuable resource of a design consultant. The review, checking and application of quality assurance procedures to the finished products also require resources and time from professionals.

2.5.2 Increase in overheads

Increase in overheads can be an effect of variations for engineering designers. Variation orders require administration procedures, paper work, emails and reviews before the change can be carried out (Arain & Pheng, 2005). Specialised change management software may be utilised to address changes. The time and cost taken to process one variation order may be small, but, when a project frequently encounters variations, costs can accumulate.

2.5.3 Schedule delay

Schedule delay can be an effect of variations (Arain & Pheng, 2005), (Keane, et al., 2010), (Alnuaimi, et al., 2010), (Sun & Meng, 2009). Many studies have quantified schedule delays due to variations. The study conducted by Kumaraswamy,et al (Kumaraswamy, et al., 1998) of Hong Kong civil engineering projects suggested that 50% of the projects surveyed were delayed due to variations. Any variation takes time to process and review with possible redesigns and remedial work needed. These processes negatively impact the project's schedule and the work program of the designer. Work carried out to adjust designs and documentation due to variations may have a flow on effect to other scheduled designs. This can cause the project to overrun if actions are not taken (Arain & Pheng, 2005). The consultant may choose to utilise the free floats in design schedules to complete the project on time. Figure 9 shows a typical Gantt chart used to program work.

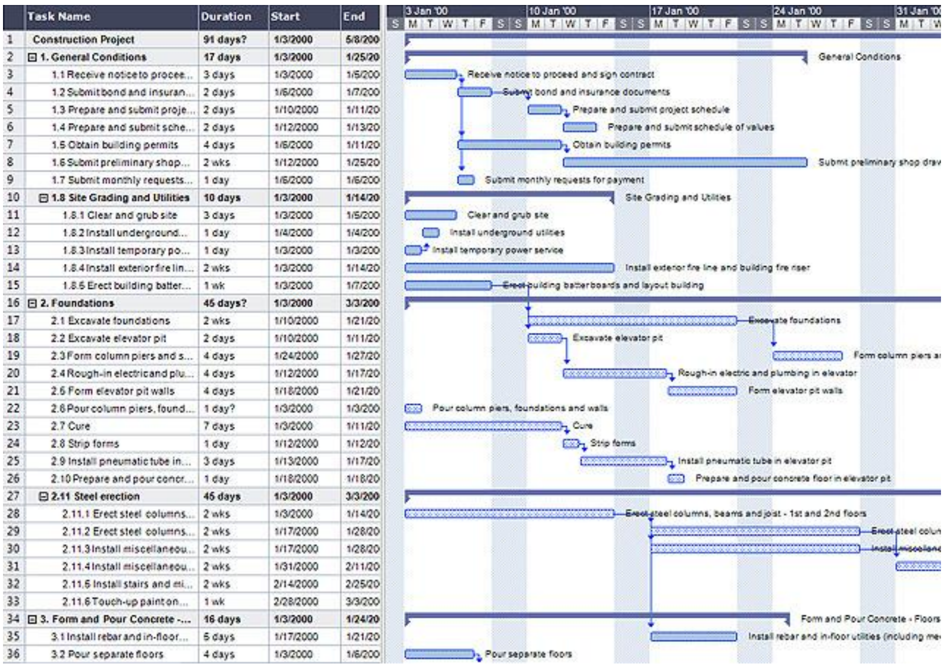


Figure 9: Gantt chart used to program work

2.5.4 Dispute and claims

Disputes and claims between professionals can be an effect of variations (Keane, et al., 2010), (Alnuaimi, et al., 2010). Disputes and claims caused by variations are inevitable in large or complex construction projects (Arain & Pheng, 2005). Disputes between design consultants and the client, or design consultants and the contractor, are a common cause of tensions in professional relationships and are usually the result of a combination of causes. The disputing parties can normally agree on what the change is, however, the cause and cost of the change can create tension. Resolution procedures outlined in the contract, agreed allocation of risks and clear communication will help minimise dispute between project participants. Resolution through negotiation rather than litigation is beneficial to professional relationships and financial interests (Arain & Pheng, 2005).

2.5.5 Reputations

Disputes and claims can negatively impact a company's overall reputation in the industry (Keane, et al., 2010). A design consultant, frequently in dispute, due to variations or poor workmanship, will eventually gain a negative reputation in the engineering and construction industry. In severe cases the company may become insolvent (Arain & Pheng, 2005).

2.5.6 New or additional human resources

Hiring of new or additional personnel can be an effect of variations for engineering consultants. The hiring of new personnel may be caused by underperformance of current employees or the need for additional resources. (Arain & Pheng, 2005). The hiring of additional personnel to carry out design and documentation may be caused by changes of design, increased scope of works, or schedule changes brought on by variations. Hiring of permanent or temporary professionals competent in the field of engineering will incur additional costs to the firm.

2.6 Other effects of variations

2.6.1 Project costs

One of the most common effects of variations is an increase in project costs (Lopez & Love, 2012), (Keane, et al., 2010), (Alnuaimi, et al., 2010), (Sun & Meng, 2009). Any major change to a project's design or schedule will incur costs. An example of variation effects on project costs is related to poor documentation of designs. A report by Engineers Australia (Engineers Australia, 2005) found that poor documentation is contributing an additional 10-15% of project costs. This equates to approximately $12 billion nationwide. Time and costs are closely related (Sun & Meng, 2009). Variations that impact the project schedule are also likely to affect the final cost of a project. It is standard practice for project estimates to include a contingency sum to allow for cost overruns.

2.6.2 Rework and demolition

Rework and demolition can be an effect of variations (Keane, et al., 2010). Alterations or changes during the construction phase will often result in rework or complete demolition of works. Rework will incur increased cost and time to the project schedule. It has been noted that variations during the construction phase have greater impacts to the project than during the design phase (Arain & Pheng, 2005). Steps should be taken to resolve issues during the design phase before construction starts. This may minimise variations thus reducing rework.

2.6.3 Quality of workmanship

Quality of workmanship may decline if variations are frequent in construction projects (Keane, et al., 2010), (Alnuaimi, et al., 2010). If variations affect the work flow of the contractor or subcontractors they may choose to compensate losses in time and costs for poor workmanship and taking risks (Arain & Pheng, 2005).

2.6.4 Productivity decline

Productivity decline can be an effect of variations (Sun & Meng, 2009). Disruptions and delays initiated by variations can have a negative impact on labour productivity. To compensate for variation induced delays, workers may be subjected to overtime for prolonged periods (Arain & Pheng, 2005). A tired and despondent workforce may cause productivity levels to fall, thus affecting the cost of a project.

2.6.5 Logistic delays

Logistics delays can be effects of variations. Delivery times for new materials, equipment and machinery due to design or construction changes can negatively affect a project (Arain & Pheng, 2005). Construction sites in isolated or hard to reach locations are particularly affected.

2.6.6 Delay in payments

Delay in payments to project participants can be an effect of variations. If the project's budget is affected by significant variations, contactors may not be paid on schedule, in turn, affecting payments to subcontractors (Arain & Pheng, 2005).

2.6.7 Procurement delay

Procurement delays can be an effect of variations. Variations during the construction phase of a project that effect materials, or specialised equipment may need revised or new procurement requests (Arain & Pheng, 2005). Delays due to new procurements may affect the project's schedule.

2.6.8 Poor safety conditions

Poor safety conditions can be an effect of variations. Increased workloads or tighter schedules due to variations may promote a relaxed approach to health and safety on the construction site (Keane, et al., 2010). Relaxed health and safety measures increase the risks of accidents and lawsuits. New construction practices, materials and equipment due to variations may also increase risks to unqualified personnel (Arain & Pheng, 2005).

2.6.9 Payment for contractors

Additional payments to contractors can be an effect of variations (Keane, et al., 2010), (Arain & Pheng, 2005). Variations are seen as additional works not specified in the original contract, thus will bring additional income for the contractor (Arain & Pheng, 2005). Additional payments to the contractor impact the client's budget and final build cost.

2.7 Cost impacts on designers

As stated previously the consultant's ability to accurately cost the work associated with variation orders is crucial. Variation orders processed by a design firm can have direct costs, indirect costs and consequential costs that need to be recovered by the firm (Law Teacher, 2014).

Direct costs includes the cost of labour for engineers, designers, drafters, team leaders, and managers employed by the consultant to review, design, draft and mange variations. The time spent by each individual, on any stage of the variation process, is contributing to the overall cost of the variation imposed on the design consultant.

Indirect costs or 'hidden' costs include design consultants overheads, general and administrative expenses. Overheads can include support staff that do not generate revenue for the design consultant. Support staff may include human resources, office administration, IT support, business development, and accounts staff. Indirect costs also include costs associated with renting an office, vehicles provided for staff, specialised computer software, software maintenance, marketing costs and contract personnel (Ankur, 2011).

Consequential costs imposed on design consultants by variations include disruptions to programmed work, inefficiencies cause by disruptions, decline in staff moral (if variations are constant), and the possibility of tarnishing the firm's reputation if disputes arise.

The true cost of design variations imposed on design consultants is not fully understood. While direct costs can be quantified through timesheets etc. the cost of the administration and procedures needed to process variations is not widely known or studied. This research project aims to shed light on the issue.

2.8 Reducing variations through early intervention

The following section outlines elements of the procurement and design phase that should be correctly implemented to reduce the likelihood and impact of variations in later stages of a project.

2.8.1 Contract documents

Well prepared contract documents can reduce the impact of variations in construction projects (Chan & Yeong, 1995), (Keane, et al., 2010). Contract documents act as a communication channel between project participants, thus the quality of this document can influence the outcome of the project. Contractual documents should be clear, comprehensive and accessible by all parties affected. Due to the likelihood of variations it is common for contract documents to detail variation clauses, including payment and time related issues. Clients should have an active role in overseeing contractual agreements.

2.8.2 Consultant selection

Selection of a consultant is often determined by price rather than the ability of the consultant to provide a high level of service required for successful outcomes (Engineers Australia, 2005). Embedded in our culture is the notion that a low price equals value for money. Selection of consultants purely based on price can lead to greater financial consequences in later stages of a project. Current marketplace conditions have pushed consultants to assess and cost projects based on minimalistic principles. As a consequence tensions between contractual parties develop when project objectives and desired outcomes fall short of expectations. The report conducted by Engineers Australia (Engineers Australia, 2005) outlined a strategy for selecting consulting services which is based on value, competency and price. Listed below are bidding and selection objectives.

Clients will:

- Understand the term “value” which includes:
    - The capability to deliver a project with the nominated standard, time and cost restraints.
    - Perform in a non-adversarial manner
    - Maintain social and environmental responsibility
    - Consider whole-of-life implications
- Understand the relationship between time, cost and quality.
- Appreciate the nature of business and the notion that “you get what you pay for”.
- Understand that procuring design and documentation differs from purchasing a commodity.
- Understand the value of developing long-term working relationships with consultants.
- Encourage innovative and creative outcomes through appropriate incentives.
- Acknowledge reputations and demonstrative evidence.
- Understand the risk allocations between participants.
- Implement selection procedures based on value rather than initial price.

Other objectives:

- Consultants will provide bid documents that address selection criteria and validate a value based selection.
- Legislation that recognises that competition based on capability and quality creates a competitive marketplace rather than price alone.
- The opportunity and encouragement for consultants to compete on capability, quality and overall services.

Following these objectives will increase competition, innovation, and quality, and reduce the impact of variations caused by improper selection of consultants.

2.8.3 Project brief

A clear and concise brief can reduce the impact of variations in construction projects. A number of studies (Alnuaimi, et al., 2010), (Chan & Yeong, 1995), (Keane, et al., 2010), (Arain & Pheng, 2005) have suggested that a clear and thorough project brief provided by the client is the most important strategy for reducing the impacts of variations. The client or owner of the project should prepare a precise document outlining their needs and visions before the design phase of a project. This can be achieved by conducting a feasibility study or by surveying the needs of the project's end users. "Getting it right the first time" by Engineers Australia (Engineers Australia, 2005) found that inadequate project briefs contributed to a decline in design documentation. They suggested that project briefs for all significant projects be comprehensive and accurate. Briefs will allow all participants to determine the work required and produce documents that all participants can confidently rely on. They also suggested an industry wide model for completing comprehensive briefs. The report outlined objectives for proper briefing. These include the following:

- Relationships between participants are professional and ethical.
- Administration and management are professional and ethical.
- Detailed descriptions of project context, background, objectives and drivers for the client or owner.
- Scope definition and functional requirements.
- Procedures to complete the project brief.
- A plan outlining realistic costs, schedules and project contingencies.
- Detailed description of engineering and architectural requirements.
- Stakeholder analysis and processes to include project participants in development phase.
- Clients' project management measures.
- Management of necessary permits, approvals and legislation.
- Clients' expectations of disciplines needed.
- Clients involvement in decisions
- Project inputs, documentation and information
- Communication practices for life of project

The Construction Industry Project Initiation Guide for Project Sponsors, Clients and Owners (CIDA 1994) was identified in the report as containing a possible solution for developing project briefs (Engineers Australia, 2005). The CIDA Project Initiation Guide outlined a three-step process to create comprehensive briefs:

1. The concept stage evaluation brief:
    - To identify constraints
    - To describe a range of options
    - To select a shortlist based on analysis by functions/use; cost/benefit
2. The definition stage brief containing:
    - A description of the preferred option
    - Cost targets
    - Time requirements
    - Quality considerations
    - Redefinition of the functional, physical and financial constraints and objectives for the project
3. The project delivery brief which is expected to cover:
    - The enterprise objectives for the project
    - The functional objectives – what the project must do
    - The functional constraints
    - A summary of the feasibility and risk analyses
    - Details of planning approvals
    - The project implementation plan, actions and schedules
    - The procurement plan
    - A cost plan
    - The project documentation, description and illustrative definition

Engagement of specialist or skilled consultant may be required to create the project brief. Participation of the client in the project brief process will expand communications and flow of ideas. Clients of a project need to understand the benefits, possible effects and the rational of having a well-documented and detailed brief. One off clients may require special attention.

2.8.4 Site investigation

A comprehensive site investigation can be used to reduce the impact of variations in construction projects. Studies into the causes of variations suggest that the scope of the initial site investigation may be reduced to please clients and be awarded contracts (Chan & Yeong, 1995), (Chang, et al., 2011). The scope and requirements of the investigation should be determined early in the life of a project. Survey or investigation briefs will allow project participants to determine the information required with the goal of acquiring accurate data that all participants can confidently use. A proper site investigation should include surface and subsurface details. Additional surveys or subsurface investigations post design or during the construction stage can negatively impact a project's cost and schedule.

2.8.5 Detailed design and documentation

Detailed design and documentation can reduce the impact of variations in construction projects (Chan & Yeong, 1995). As stated before, 60 - 90% of all variations are caused by inadequate design and documentation (Engineers Australia, 2005). For contracts based on drawings and specification the design should be completed before tender. This will limit possible claims and disputes in later stages of a project. Coordination of design documentation between disciplines is important (Kagan, 1985). Design drawings and specifications should be reviewed by project participants to avoid conflicts and ambiguities. Trained professionals need to be actively involved in the design from conception to construction. Doing so will reduce technical bottlenecks and reduce the risk of variations. "Getting it right the first time" by Engineers Australia (Engineers Australia, 2005) provided recommendations for improving current project design documentation problems and were grouped around four categorises.

1. Project briefs
2. Bidding philosophy and selection strategy
3. Project delivery
4. Implementation strategy

2.8.5.1 Project briefs

Discussion on project briefs is outlined in section 2.7.3.

2.8.5.2 Bidding philosophy and selection strategy

Discussion on selection strategies is outlined in section 2.7.2

2.8.5.3 Project delivery

It was recommended that the following remedial actions be taken to improve documentation:

- It is suggested that a renewed commitment to the client by the consultant is needed through ethical and professional behaviour, raising professional standards, and taking accountability in day to day operations.
- Acceptance and allocation of risks for the client and consultant according to principles of risk management.
- Appointment of a design manager to monitor performance throughout the projects.
- Appreciation of resources needed to produce optimised designs and quality documentation through design phase.
- A whole industry approach to professional skills shortages.
- Optimising the use of technology to design, document and communicate.
- Improving communication rules and practices.
- Developing process control suitable to nature of project.

2.8.5.4 Implementation strategy

Implementation strategy will not be discussed in this paper.

2.8.6 Communication

Open communication can be utilised to reduce the impact of variations in construction projects (Chan & Yeong, 1995), (Engineers Australia, 2005). Due to the current market conditions time and cost restrictions inhibit the open flow of communication between project participants. These conditions can also create a culture of closed or secretive behaviour resulting in parties becoming divided and self-serving (Engineers Australia, 2005). Modern technology, such as mobile phones and email, has limited face to face communications which was once the basis for common understanding and professional relationships. The report conducted by Engineers Australia (Engineers Australia, 2005) outlined objectives for improving communication which includes:

- Project documentation accessible and intelligible to participants along the supply chain.
- Creation of a communication plan defining the roles of participants and methods to facilitate open communication.
- Face to face communication between participants to ensure strong relationships.
- Using information technology to improve communications.
- Training programs in educational and professional industries designed to build communication and relationship skills.

Open and clear communication is beneficial for all parties involved and is seen as a primary ingredient for successful projects. It lets the client have a better understanding of the design, specifications, finance allocations, and construction of the project.

2.9 Design processes for designers

The following section briefly outlines two design processes; Building Information Modelling and Lean Design Process. These processes are relatively new but have been slowly growing in popularity in different countries and industries.

2.9.1 Building information modelling (BIM) for designers

Building Information Modelling (BIM) has been defined as "a digital representation of physical and functional characteristics of a facility". BIM is a computer modelling software and a process, when used correctly, can offer advantages to all parties in any phase of a construction project. A building information model is a 3D simulation consisting of project components that contain links to information relating to project planning, design, construction and operation (Salman, et al., 2012). The concept of BIM is depicted in Figure 10.

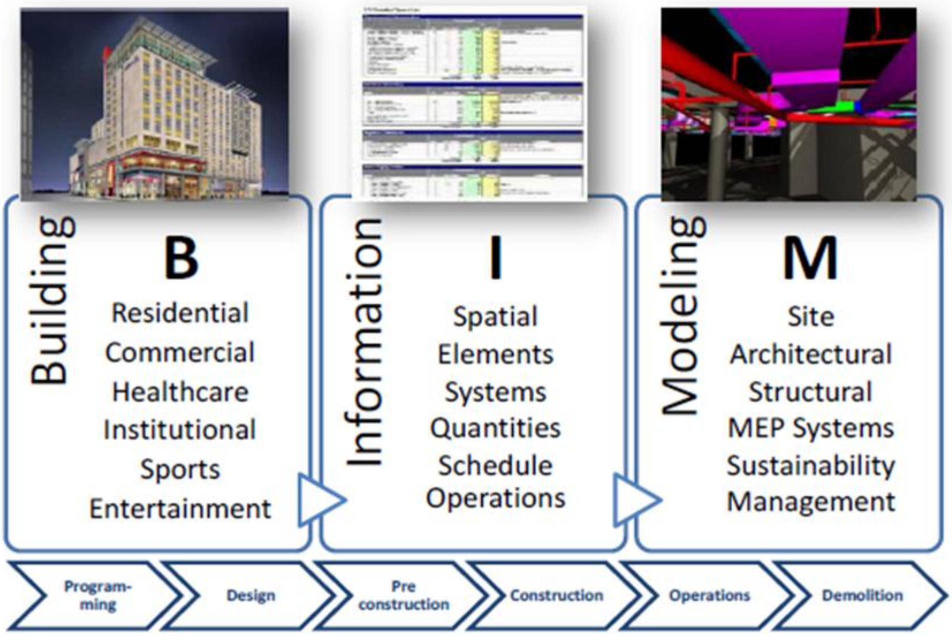


Figure 10: Building Information Modelling concept (Salman, et al., 2012)

A building information model contains all information including the physical characteristics, functionality and life-cycle in separate elements of the model. For example, an elevator within the building model will contain information relating to the supplier, operation and maintenance procedures etc. The BIM process encapsulates all aspects, disciplines and systems within a single digital model. This allows all team members (architects, engineers, designers etc.) to access, refine and adjust the building elements they control. This requires effective communication and collaboration between project participants. Figure 11 outlines a comparison between the traditional and BIM process.

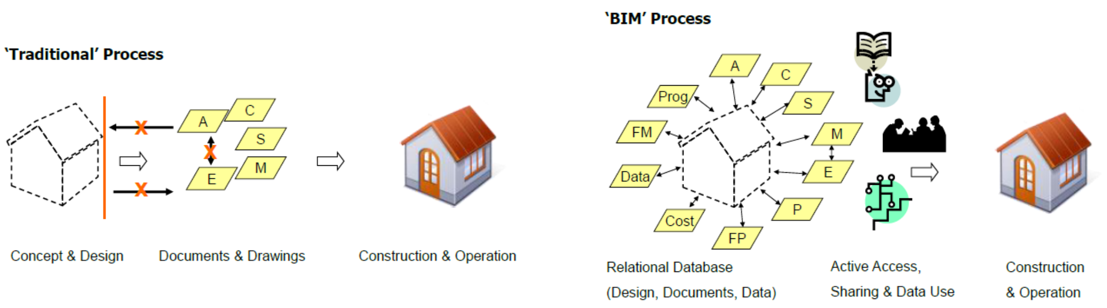


Figure 11: Comparison between the traditional and BIM process

(Salman, et al., 2012)

BIM has applications in project programming, project design, preconstruction, construction and the post construction phase. BIM allows designers to compare multiple design options, create 3D exterior and interior models, use walk/fly throughs, perform building and structural analysis, detect errors, and produce drawings. BIM software has the capability to integrate RFI and variation order information into the model. The integration with smartphones and tablets has allowed contractors to use models to extract necessary information. The capability for any participant to simply click on a particular element to retrieve information about that element is clearly an advantage over traditional CAD systems (Salman, et al., 2012). The benefit to project participants is summarised in Table 1.

Table 1: BIM Application and users (Salman, et al., 2012)

BIM Application	Owners	Designers	Constructors	Facility Managers
Visualization	x	x	x	x
Options analysis	x	x	x	
Sustainability analyses	x	x		
Quantity Survey		x	x	
Cost Estimation	x	x	x	
Site Logistics	x		x	
Phasing and 4D scheduling		x	x	
Constructability analysis		x	x	
Building performance analysis	x	x	x	x
Building management	x			x

The applications provided to designers are substantial. The benefits to designers can include:

- Greater quality of design through detailed analysis of digital models and simulations. These simulations allow clients to grasp a better understanding of the final product and allow input for desired changes.
- Incorporation of sustainable features to predict environmental impacts and performance.
- Complying with regulations and standards through visualisation and analytical checks.
- Ability to graphically assess potential failures, leaks and evacuation plans etc.
- Efficient production of shop and fabrication drawings

Overall BIM has provided the industry with a “revolutionary tool” which has led to improved profits, reduced costs, better management, and improved customer satisfaction (Salman, et al., 2012). A number of countries throughout the world are strongly encouraging the use of BIM. From 2016 the use of BIM will be mandatory for all public infrastructures in the United Kingdom (Howe, 2014). BIM may give engineering and construction companies a significant edge over their competition as they embrace the rise of such technology.

2.9.2 Lean design process for designers

Inadequate design and design errors are one of the biggest sources of waste in the construction industry. Variation orders used to correct these issues may increase the overall time and cost of a project. The lean production practice was developed by Sakichi Toyoda. The process was successfully utilised in the design of his automated weaving machine. This device was faster than current models and had the capability to automatically detect errors and stop operations. This method of production eventually led to today's successful Toyota Production System implemented in all Toyota factories. The core goal of this system is to eliminate waste. Waste can be seen as an activity that fails to meet production standards and does not create value within the system. An example of such waste is over production or waste of inventory. The research conducted by Ko & Chung (Ko & Chung, 2014) adapted this process to the building construction industry. Labelled lean design process it aims to identify and eliminated valueless activities thereby increasing the customer or client value.

As stated previously poor design is a form of waste in the construction industry. It wastes time and money of those involved. 40% of variation orders can be linked to designers. Ko & Chung (Ko & Chung, 2014) has taken the lean design process and applied it to a typical building construction organisation, whereby the architect leads the entire design process and is responsible for communication with the client and other disciplines. The lean design process has been divided into three separate, yet connected stages; Preliminary design (1), Basic design (2) and Detailed design (3) (Ko & Chung, 2014).

The preliminary design phase is used to prepare documents and drawings for the design "competition". This may include perspective views of the proposed building and interior, elevation plan and design reports. A number of steps are involved in this phase (Ko & Chung, 2014):

- The architect creating a building system conceptual model with the owner

- Structural engineers creating preliminary structural plans using the architects conceptual model and site investigation data
- Equipment engineers creating a preliminary equipment plan based on the conceptual model and owner requirements
- The next step involves evaluating the preliminary design correctness ratio. The entire team performs checks on the proposed designs and content. Any errors discovered are delegated for correction. The team will use a design correctness ratio (DCR) to evaluate the problems discovered in the preliminary design. Failure to achieve 100% correctness will incur additional corrections. The team cannot progress to the next phase until 100% is achieved.
- Once 100% correctness is achieved the team will integrate the designs and necessary documents for the winning design.

The basic design phase focuses on the integrated winning design (Ko & Chung, 2014). The steps in this phase involve:

- The architect creating a detailed model comprising of further details, flow routes, construction cost estimate etc.
- Structural engineer analysing basic reinforcements, required concrete, roof structure, beams and columns etc.
- Equipment engineer analysing building services such as water pipelines, electrical conduits, elevators etc.
- Once again the DCR is used to evaluate the phase with the addition of the general contractor. The general contractor may provide advice on the overall constructability. Any errors discovered are delegated for correction and the phase will not be able to progress until 100% is reached.
- Once 100% correctness is achieved the team will integrate the designs for a more complete building model.

The detailed design phase is the final phase in the lean design process proposed by Ko & Chung (Ko & Chung, 2014). The aim is to compile designs from all inspections. This phase will involve:

- The architect creating detailed building drawings adding further details from the basic design phase such as specifying brands, models and styles of building components.
- Structural engineers detailing the structural components of the building in detailed plans.
- Equipment engineers detailing the buildings services in detailed plans.
- Once again the DCR is used to evaluate the phase with the design team and contractors. Specialist team may perform conflict and constructability analysis. Any errors discovered are delegated for correction and the phase will not be able to progress until 100% is reached.
- The completed and correct design is compiled by the architect. The owner then hands the completed drawing to the contractor to begin construction

The lean design process example above has been tailored for civil engineering and construction projects, but could also be used in other infrastructure projects. The capability of the individuals involved in this process may influence the quality of outcomes. The process of continuous correction through each phase will limit poor design and errors.

2.10 Conclusion

The literature has a general consensus on many of the topics discussed. Most literature agreed that variations and design changes had negative impacts on a construction project. Research conducted by Arain & Pheng (Arain & Pheng, 2005) offered a comprehensive list of variation effects while research from Keane, et al (Keane, et al., 2010) presented the causes of variations in a logical order.

Despite many articles discussing the causes, effect, and methods for reducing the present of variations, the study into the actual costs of administrating, reviewing, reworking and closing variation orders within a design consultancy had not been explored or quantified. This finding supports the need for this research project.

Forthcoming chapters will present quantitative case study research acquired through interviews and document analysis.

3.0 Methodology

3.1 Overview

In order to achieve the project objectives of determining why design changes are made, severity of impacts and the overall cost implications, the following methodology has been proposed and implemented.

- Obtain a sample of completed engineering projects to conduct a case study.
- Conduct a case study on each of the projects.
- Determine the variation/design change procedure for the organisation.
- Create a questionnaire survey to obtain professionals' views and experiences with respect to causes, impacts, and associated costs of variations.
- Provide the questionnaire to industry sources and receive feedback.
- Using the information gathered, develop strategies for minimising the costs and impacts associated with design variations.

3.2 Data collected through case study projects

In order to determine why design changes are made and the overall cost implications that variations imposed on designers, a number of real engineering projects will be investigated. For the scope of this study and the resources available, case study information will be obtained from the Sunshine Coast Council.

The data obtained for this research project was made available by the Sunshine Coast Council's civil engineering design office. This office is comprised of a number of civil designers capable of designing civil infrastructure ranging in scope and complexity. Designers have access to industry standard design software such as AutoCAD and 12d. Engineering designs are subjected to thorough quality assurance documents and frequent peer review.

3.2.1 Project type

The Sunshine Coast Council's civil engineering design team has the capability to work on medium sized infrastructure projects which include roads, car parks, streetscapes, and drainage structures. Majority of infrastructure projects are designed and constructed by Council employees. For the purpose of this study, projects will vary in infrastructure type.

3.2.2 Project costs

Case study projects range in project costs between $0.28 million to $6.4 million. It is expected that projects within this range will incur design changes at some stage of the project. Design and documentation costs are included in these figures.

3.2.3 Year of construction

Case study projects were designed and constructed between the years 2007 and 2014. Only finished projects were selected for this research to ensure all design documentation was finalised.

3.2.4 Location of projects

Case study projects are located within the Sunshine Coast Council's boundary. Project locations range from rural, beach side and future business hubs. Refer to Figure 12 below for a graphical representation of the project locations within the Sunshine Coast region.

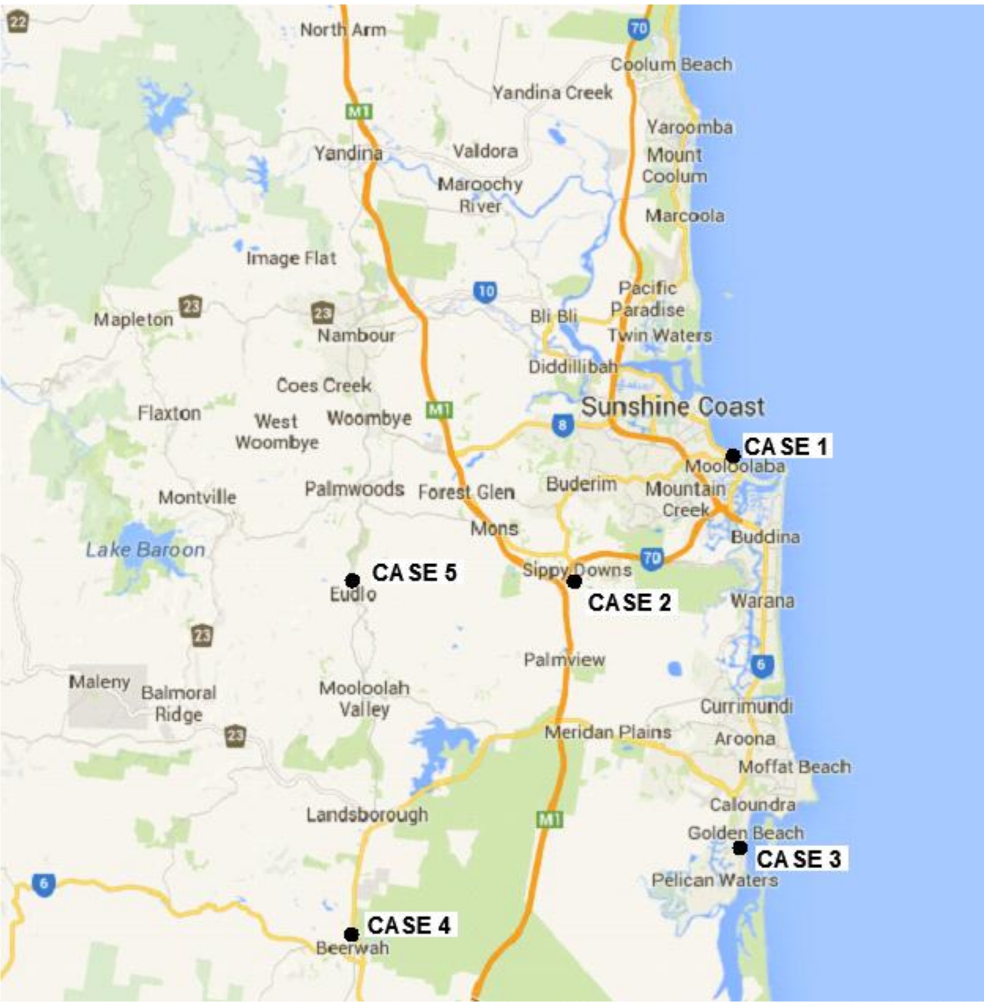


Figure 12: Location of case study projects at the Sunshine Coast (Google Maps, 2014)

3.2.5 Number of projects

Considering the time and resource constraints it was decided that five civil engineering projects will be investigated. The projects selected will be recommended by council's designers for the study.

3.3 Data collection

Case study data for the five engineering projects was provided by the Sunshine Coast Councils design office. Data was collected from the project's design folder and through verbal communication with the designer that worked on the particular project. Causes of variations were derived from emails between project participants, design review meeting minutes and phone conversations with the designer.

3.4 Case study 1 – Streetscape

3.4.1 Project introduction

A streetscape reconstruction project was carried out for the Mooloolaba Esplanade, Mooloolaba. The Mooloolaba Esplanade had grown into a high profile tourist node due to redevelopment of beachfront resorts and restaurants in the immediate area. The project involved the improvement of road infrastructure, pedestrian crossings, landscape works and improved lighting. The upgraded infrastructure provides a missing link between previous refurbished streetscape works while creating an improved public space for residents and tourists alike. Key participants associated with this project include the Maroochy Shire Council/Sunshine Coast Council, Suncoast Cabs and shop owners adjacent to the works. The project was divided into three stages as seen in Figure 13. Stage one included a new roundabout and taxi rank at the northern end of Mooloolaba Esplanade. Stage two included kerb alterations and rearrangement of lighting. Stage three was the major roadway and footpath works between the existing shopfronts and the public open space. The final civil design and construction costs for the project amounted to approximately $310,000. Figure 14 shows an aerial photograph of the Mooloolaba Esplanade.

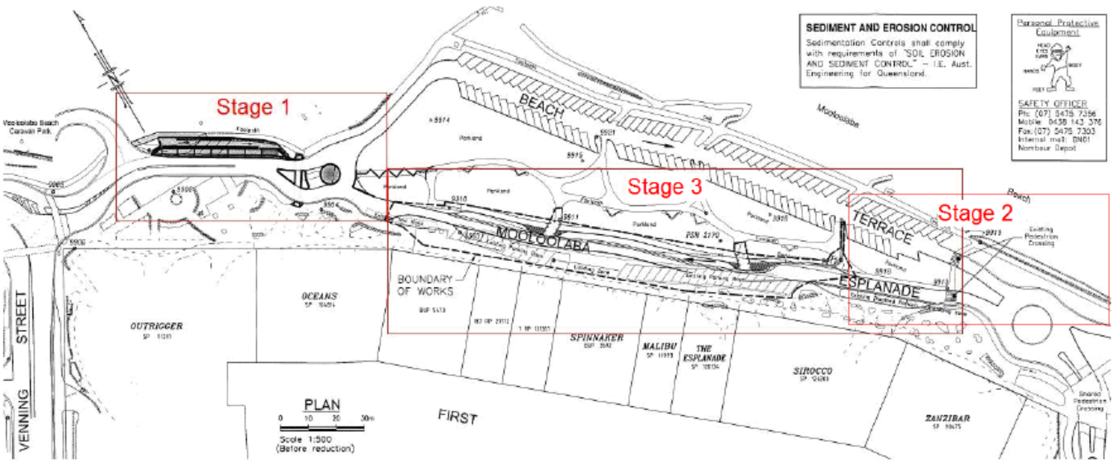


Figure 13: Stages of works - Mooloolaba Esplanade

Figure 14: Aerial photograph of Mooloolaba Esplanade (Nearmap, 2013)

3.4.2 Design variations

The Mooloolaba Esplanade streetscape reconstruction was subjected to a number of design variations during the course of the project. As mentioned above the project was divided into three stages for construction. This was due to insufficient funds for construction in the 08/09 financial year. Design plans for stages one, two and three were completed in November 2007. The variations occurred in stage three of the project. The original design included angled parking bays between the Esplanade footpath and the carriage way. This design utilised kerb and channel to capture the rainfall from the crowned road and pipe it to the existing stormwater system.

In 2007 the Maroochy Shire Council amalgamated with the Caloundra City Council and the Noosa Shire Council. The amalgamation resulted in new staff in the engineering branch and new Councillors. Pressure from the new management meant that the original design completed in 2007 no longer met Council's and the community's desires.

The design variation occurred in early 2009 when the design process continued. The landscape architects discovered that the grades between the shopfronts and the top of the kerb and channel did not meet the disability requirements. It was decided that the kerb and channel and the angled parking bays would be removed and replaced with a concrete edge beam. Doing so created a one way cross fall between the shop fronts and the road. This created an extra five metres of outdoor dining/ footpath space for pedestrians. The news plans were signed by council's Registered Professional Engineer Queensland (RPEQ) in June 2009.

The second design variation occurred at the newly designed pedestrian crossings. The Mooloolaba Esplanade hosts the annual Mooloolaba Triathlon Festival. The triathlon committee had some reservations regarding the width of the pedestrian crossings and its impact on the athletic events. Design review meeting minutes indicate that the designer was to change the width of the pedestrian crossings to satisfy the committees concerns. The alteration of the pedestrian crossings affected the longitudinal section of the kerbs. The final plans were signed by council's Registered Professional Engineer Queensland (RPEQ) in August 2009.

3.4.3 Design and documentation costs

The design and documentation for this project was impacted from the above design changes. The three dimensional computer model on the road surface and kerbs needed to be regraded vertically and horizontally. Subsequently the design and estimate documentation also changed resulting in additional work to be carried out by the designer. The new model, associated plans and estimate were created by a senior designer.

The number of plans issued for construction remained the same with 22 design plans issued. This can be attributed to the fact that the original and new designs were in the same location with similar attributes. The design and documentation costs for the final design were estimated to be $13,500. Speaking directly with the designer it was determined that approximately $6,000 was spent designing and documenting the original design prior to the amalgamation. The design changes relating to the widening of the pedestrian crossing amounted to approximately $1,000.The combined cost of the two changes amounts to $7,000. This represents approximately 2.3% of the overall design and construction costs for the project. Changes to the design after amalgamation and changes to the crossing geometry are representative of poor strategic planning and foresight. The main cause of this design variation was poor communication between the Sunshine Coast's Council and internal and external stakeholders. Figure 15 summarises the main costs associated with project.

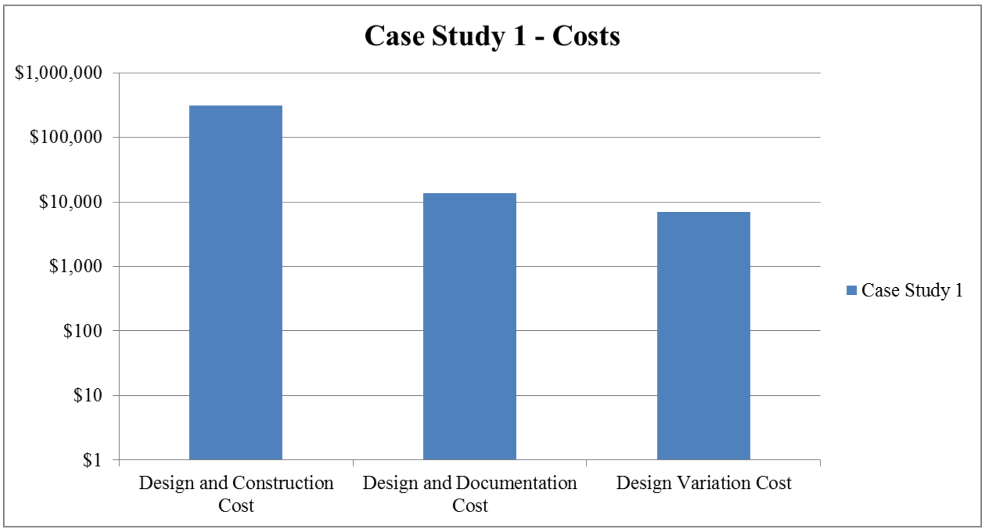


Figure 15: Case study 1 costs

3.5 Case study 2 – Road reconstruction

3.5.1 Project introduction

A road reconstruction project was carried out for Sippy Downs Drive, Sippy Downs as part of the infrastructure upgrades between the University of the Sunshine Coast (USQ) and the future Sunshine Coast Business and Technology Precinct. The project involved the upgrade of a road infrastructure, intersection layout redesign, pathways, drainage and underground power. The upgraded infrastructure provides the residents of Sippy Downs and users of the University a critical connection to the Sunshine Coast Motorway, Siena Catholic College and the Sippy Downs future Business and Technology Precinct. Key participants associated with this project include the Sunshine Coast Council, The University of the Sunshine Coast, and the Department of Transport and Main Roads. The final civil design and construction costs for this stage of the upgrade amounted to approximately \$6.4 million. Figure 16 shows the original University entrance while Figure 17 shows the upgraded entrance.

Figure 16: Original University entrance

Figure 17: Upgraded University entrance

3.5.2 Design variations

The Sippy Downs Drive road reconstruction was subjected to one major design variations during the course of the project. The variation occurred at the eastern end of the drainage system. The original drainage layout was designed to discharge onto the Sunshine Motorway road reserve. The Sunshine Motorway road reserve is controlled by the Department of Transport and Main Roads (TMR) and thus needed prior approval for this to happen. The design and discharge outlet was approved by TMR and the plans were signed by council's Registered Professional Engineer Queensland (RPEQ) in May 2011.

The design changes arose when the University of the Sunshine Coast approached the Sunshine Coast Council and requested that the stormwater discharge be directed on the catchment area of the University. The decision to discharge stormwater into the USQ's stormwater system was done to ensure the existing dams located to the south remain full. The analysis of USQ's existing system was carried out by JFP Urban Consultants who accessed the impact of the additional water. Their analysis proved that the additional catchment could be accommodated with no increase to pipe sizes.

The stormwater design was redesigned and documented. The design changes included a complete redesign of the entire stormwater system to the east of the University entrance. The new construction detailed plans and estimate were signed by Council's RPEQ in September 2011. Construction of the project was completed in 2013.

3.5.3 Design and documentation costs

The design and documentation for this project was impacted from the above design change. The three dimensional computer model of the stormwater pipe system needed to be completely redesigned to ensure water entered the USQ catchment. This included the redesign of catchment pits, manholes and pipe sizes. For the redesign to occur additional survey was needed to obtain accurate existing levels. Design and estimate documentation also changed, resulting in additional work to be carried out by the designer. The new model, associated plans and estimate were created by a senior designer.

The number of plans issued for construction remained the same with only 8 drainage plans issued. This can be attributed to the fact that the original and new designs were similar in length and complexity. The design and documentation costs for the final design were estimated to be $60,000. Speaking directly with the designer it was determined that approximately 10% or $6,000 was spent redesigning and documenting the changes. Considering this figure is only 0.1% of the overall budget, the benefits of implementing the changes outweigh the financial costs. The changes also had an impact on the project's scheduling, with the construction of the project beginning two weeks prior to the design being complete. This approach to design and construction is undesirable in any engineering project.

The main cause of this design variation was the Sunshine Coast's Council lack of strategic planning and communication with community stakeholders. Figure 18 summarises the main costs associated with project.

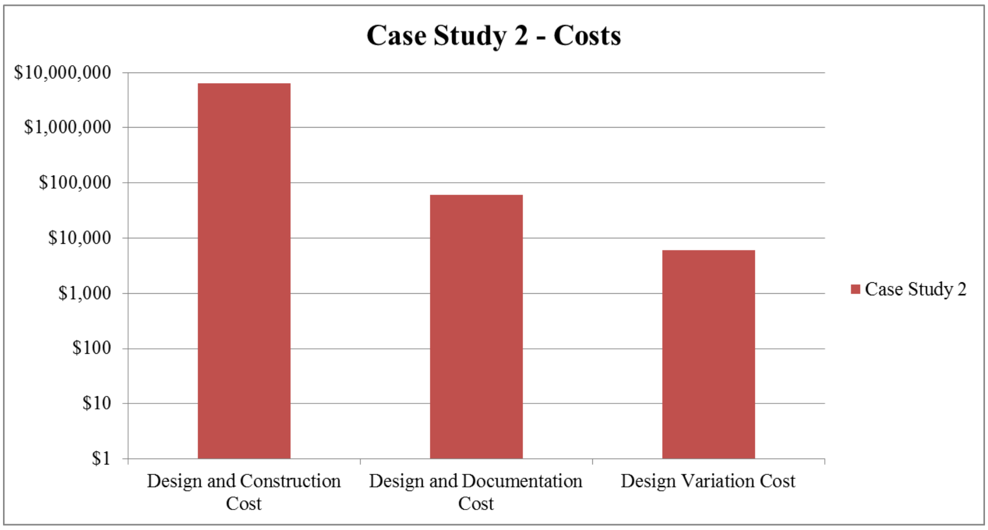


Figure 18: Case study 2 costs

3.6 Case study 3 – Parking facility

3.6.1 Project introduction

A car park reconstruction project was carried out for an existing car park at the Esplanade, Golden Beach. The project involved the extension of an existing car and boat car park utilised by the Boat Club and members of the public. The upgraded infrastructure provides more vehicle parking along the esplanade, better wet weather access and a reduction in maintenance costs required to keep the car park in operational order. Key participants associated with this project include the Sunshine Coast Council and the Boat Club, which is situated adjacent to the car park. The final design and construction costs for the upgrade amounted to approximately $280,000. Figure 19 shows an aerial photograph of the existing car park. Figure 20 shows the existing car park prior to construction.

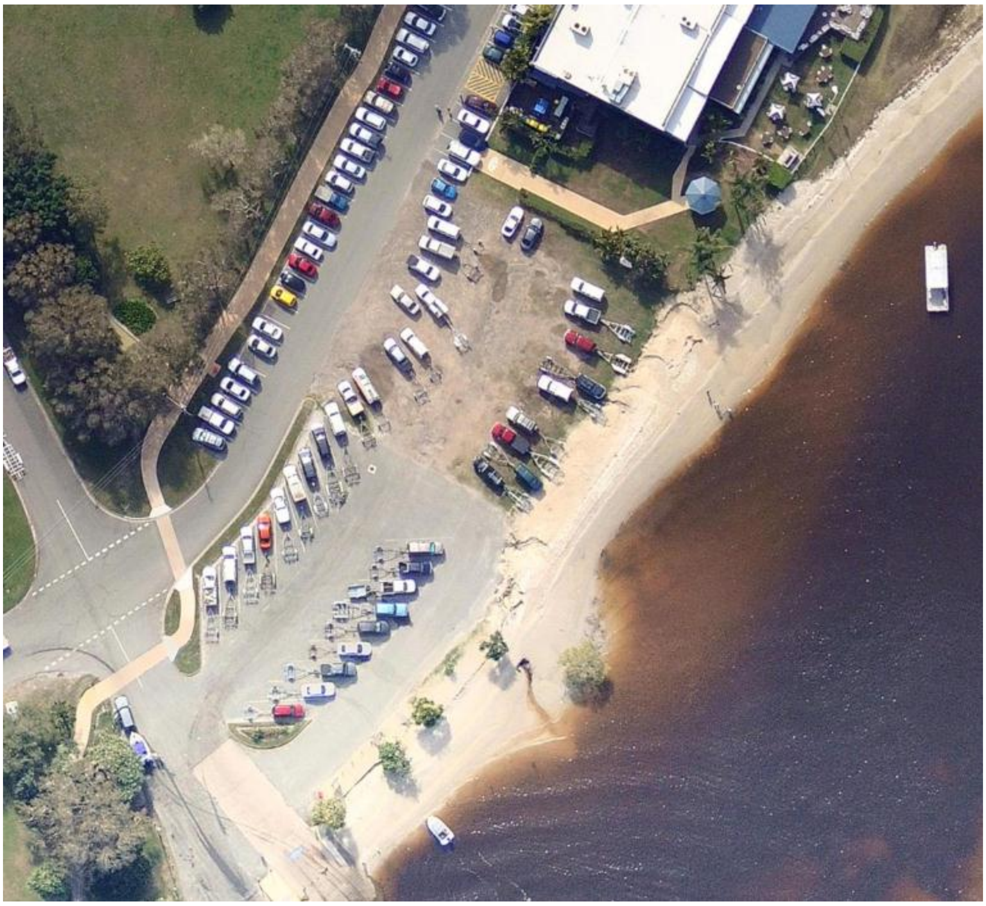


Figure 19: Existing car park - Esplanade, Golden Beach, (Nearmap, 2013)

Figure 20: Car park prior to construction

3.6.2 Design variations

The Golden Beach car park reconstruction was subjected to one major design variation during the course of the project. The key stakeholder for this project was the members of the Boat Club. Early concept layout plans were sent to the club for review late 2012. Comments were made by the club's representative in the weeks following, presenting a number of concerns with proposed layout.

A design review in May 2013 by council's engineering design office agreed that the concept design was to be kept and a full detailed design was to proceed. The original construction detailed plans and estimate were signed by council's Registered Professional Engineer Queensland (RPEQ) in late June 2013. Figure 21 shows the original design.

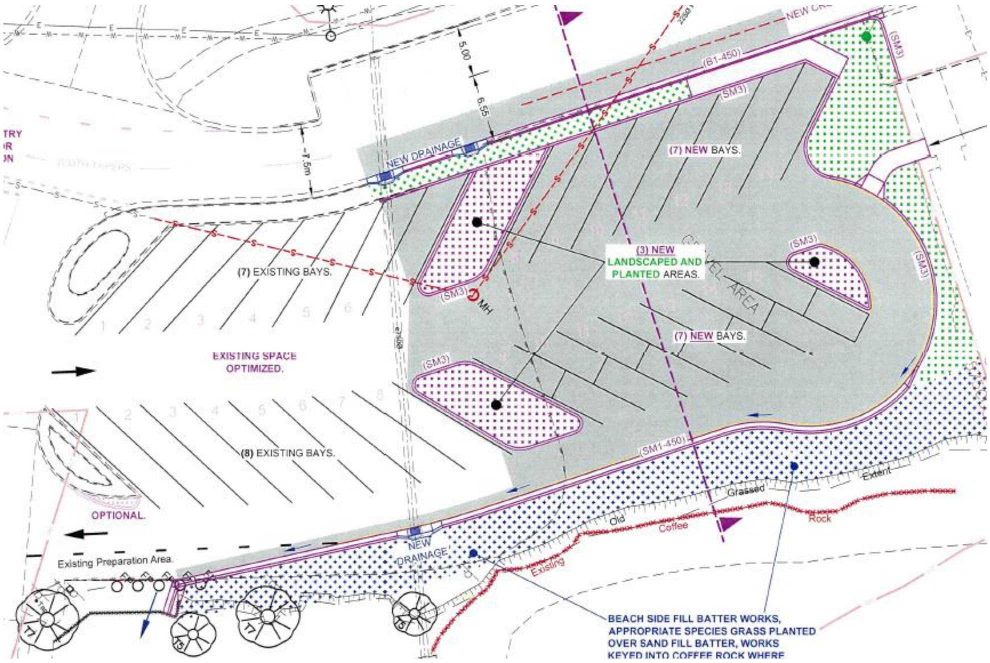


Figure 21: Case 3 - Original design layout

By investigating the email correspondence between participating parties it was determined that a decision to change the design was made between late June and mid July 2013. The decision to change the finished design originated from the Boat Club. A further design review in late July discussed the required changes and the designer was instructed to redesign and create a new plan set and estimate for construction. The design changes included a complete redesign of the circulating layout to a one way design with access from the northern end of the adjacent street. The new design provided 36 boat spaces and 24 car spaces in comparison to the original 29 boat spaces. The new construction plans and estimate were signed by Council's RPEQ in early October 2013. The construction of the car park was started on the 8th of October and was programmed for six weeks dependant on weather. The final design layout is shown in Figure 22.

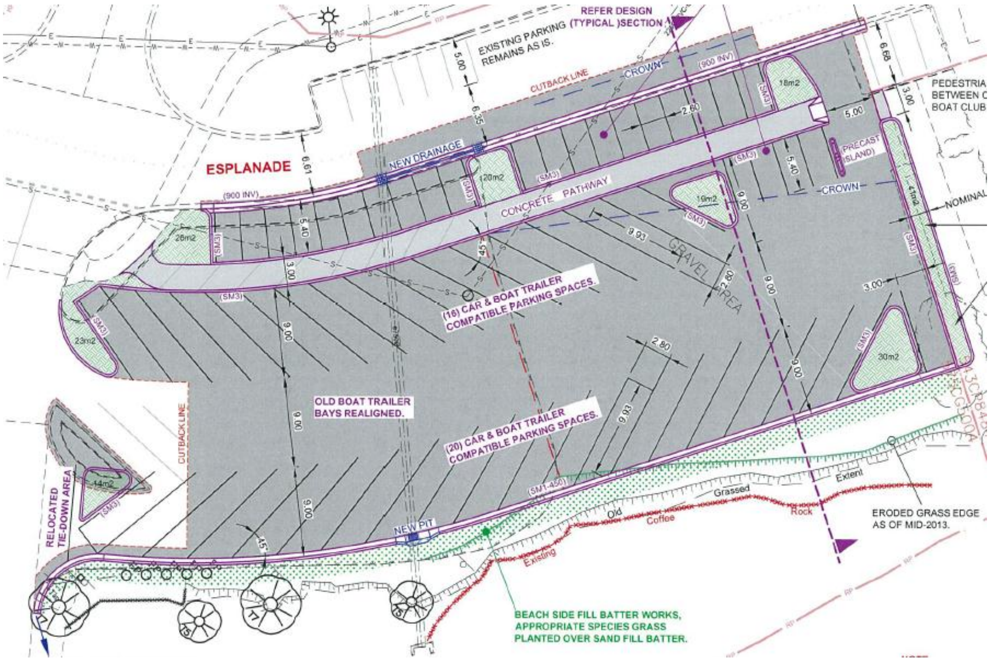


Figure 22: Case 3- Final design layout

3.4.3 Design and documentation costs

The design and documentation for this project was significantly impacted from the above design change. The three dimensional computer model of the original car park design was made redundant due to the car parks drainage design, island layout and kerb and channel levels; therefore a new model was created. The new model was created by a senior designer while a junior member of the design team created the plan set and estimate. The number of plans issued for construction increased from 23 plans to 25 plans. The increase in plans issued was minimal due to the similarity and footprint of the original design and the new design layout. The design and documentation costs for the original design were estimated to be \$6,500. The final design and documentation costs were estimated to be \$8,000, representing an increase of approximately \$1,500. The design changes had a significant impact in the overall cost of the car park reconstruction. The original construction estimate totalled \$205,000 while the new design was estimated to cost \$280,000. The increase in construction costs meant that the new design exceeded the project's budget. Subsequently funds for the project needed to be moved from another source.

The main cause of this design variation was the Sunshine Coast's Councils oversight of the needs highlighted by the community stakeholders. Figure 23 summarises the main costs associated with project.

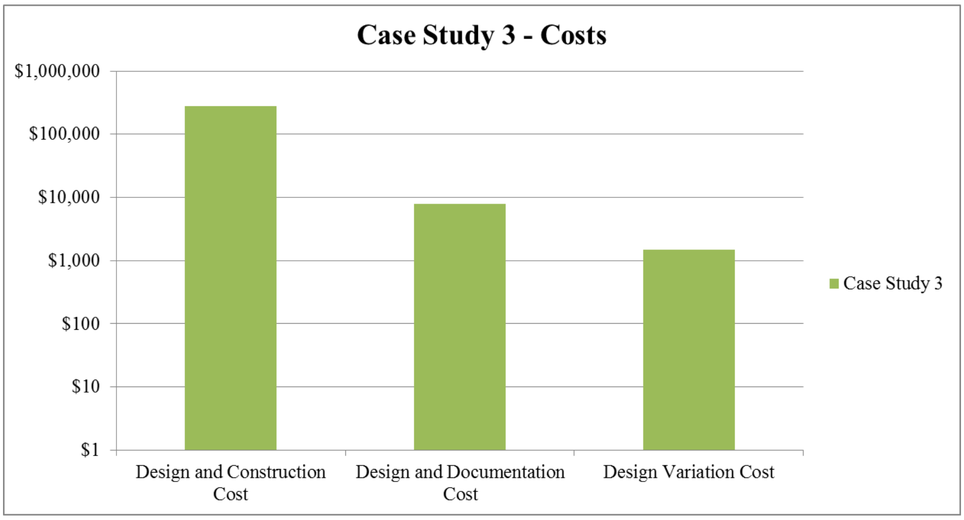


Figure 23: Case study 3 costs

3.7 Case study 4 – Streetscape

3.7.1 Project introduction

A streetscape reconstruction project was carried out for Simpson Street, Beerwah under Council's PLACE+ program. Beerwah is identified as a growing hinterland town located at the southern end of the Sunshine Coast. The project involved the improvement of road infrastructure, pedestrian crossings, landscape works, improved lighting and underground power. The upgraded infrastructure provides the Beerwah community with a pedestrian-friendly town centre that is expected to strengthen local businesses in the immediate area. Key participants associated with this project include the Sunshine Coast Council, Queensland Government and residents of Beerwah. The final civil design and construction costs for this stage of the upgrade amounted to approximately $1.7 million. Figure 24 shows a concept plan of Simpson Street (Main town centre), Beerwah. Figure 25 shows four pictures of the completed works.

Figure 24: Case 2 - Concept streetscape plan

Figure 25: Simpson Street - completed works

3.7.2 Design variations

The Simpson Street reconstruction was subjected to two design variations during the course of the project. The variations occurred at the northern end of the streetscape project on the corner of Simpson Street and Peachester Road. The design changes arose through the discovery of existing services which conflicted with the stormwater design. The original construction detailed plans and estimate were signed by council's Registered Professional Engineer in September 2013. A design review in October 2013 by council's engineering design office made note that the current stormwater design conflicts with existing services discovery during construction. Actions called for the survey team to obtain accurate service locations and depths. The location and depths of the conflicting services were determined by pot holing which found that the services were deeper than expected. The stormwater line was redesigned from a single 600 mm diameter pipe to two 375 mm diameter pipes. Figure 26 shows the original stormwater design while Figure 27 shows the final design.

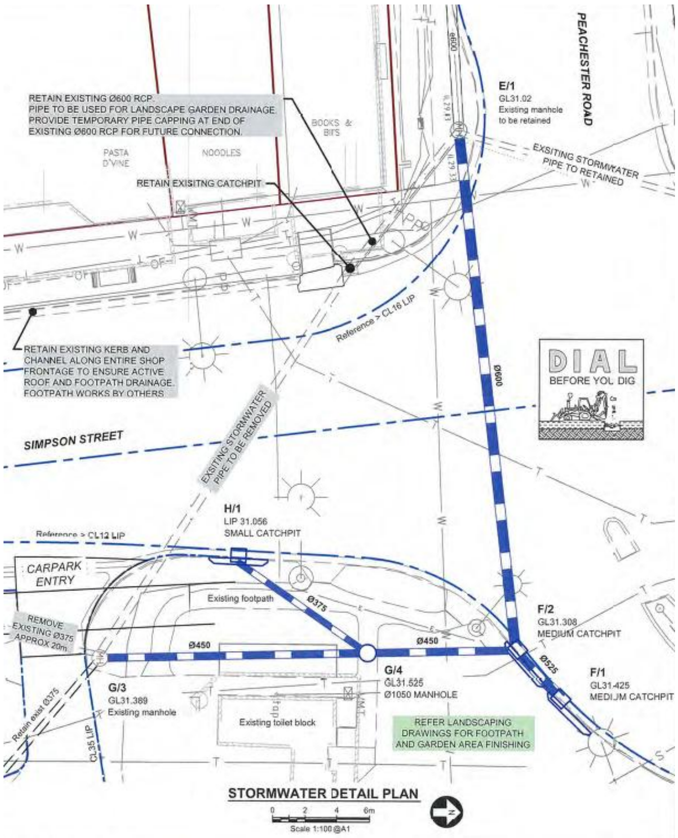


Figure 26: Original stormwater layout

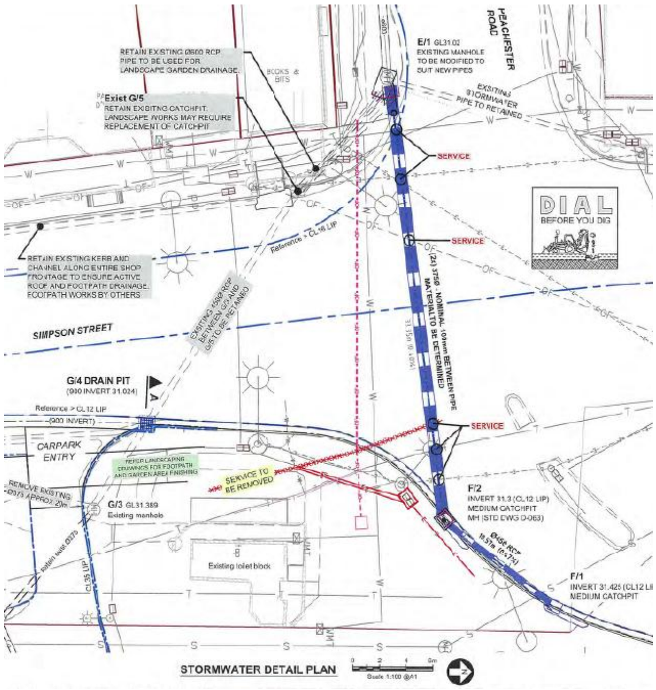


Figure 27: Final stormwater layout

However an investigation into the projects email correspondence found that in early November the construction crew discovered another service conflict during night works. It is stated that the services in conflict were not identified on the Dial Before You Dig (DBYD) plans. Figure 28 shows the exposed services discovered during construction.

Figure 28: Service conflicts discovered during night works

The initial site investigation and detailed survey did not locate the services below the road surface, thus the designer was working with insufficient information. Once again the design was changed to meet the new restrictions by altering the grades of the intersection which had a flow on effect on footpath and kerb and channel levels. The project was completed in early 2014.

3.7.3 Design and documentation costs

The design and documentation for this project was impacted from the above design changes. The three dimensional computer model of the stormwater pipe system needed to be adjusted to clear the existing services. A change in the stormwater pit layout also affected the kerb and channel alignment the south. The new model and associated plans were created by a senior designer.

The number of plans issued for construction remained the same with only 21 drainage plans issued. This can be attributed to the fact that the design changes occurred at the same location and scale. The design and documentation costs for the final design were estimated to be $60,000. Speaking directly with the designer it was determined that approximately 3% or $1,800 was spent redesigning and documenting the two changes. The changes also impacted the projects scheduling, with construction crews having to be relocated to another section of the project while the design was redesigned and documented.

The main cause of these design variation was an insufficient site investigation before the design process commenced. It highlights the fact that the Dial Before You Dig plans cannot be relied upon to give accurate locations of the underground services. Figure 29 summarises the main costs associated with project.

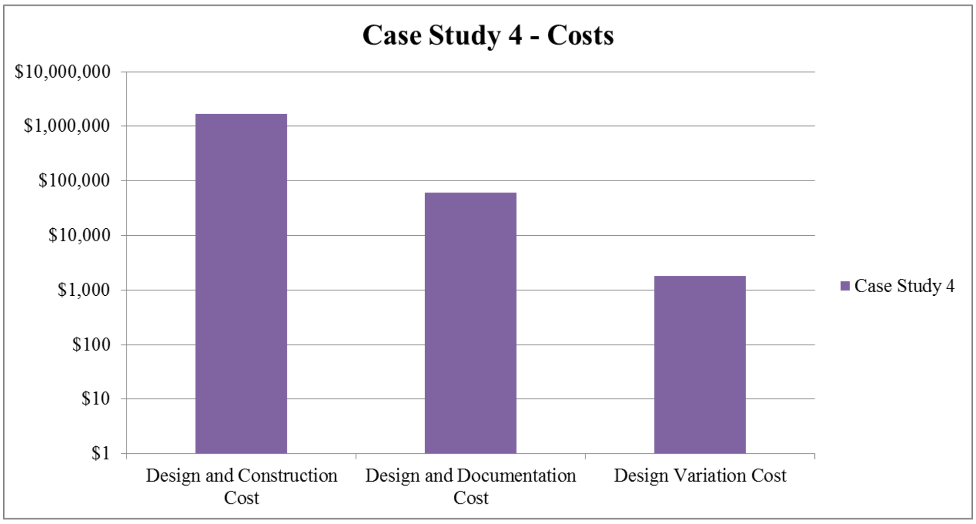


Figure 29: Case study 4 costs

3.8 Case study 5 – Rural road reconstruction

3.8.1 Project introduction

A rural road reconstruction project was carried out for Eudlo School Road, Eudlo under Council's capital works program. Eudlo School road was identified as a vital link for members of the community to access the railway station at Eudlo. The project involved upgrading a 520 metre section of existing gravel road. This included realigning the centreline, improving the vertical and horizontal geometry, tree clearing, intersection improvements and sealing the roads surface. Key participants associated with this project include the Sunshine Coast Council and residents of Eudlo. The final civil design and construction costs for the upgrade amounted to approximately $450,000. Figure 30 shows the upgraded intersection of Eudlo School Road and Sunridge Road. Figure 31 shows a number of photos taken during construction.

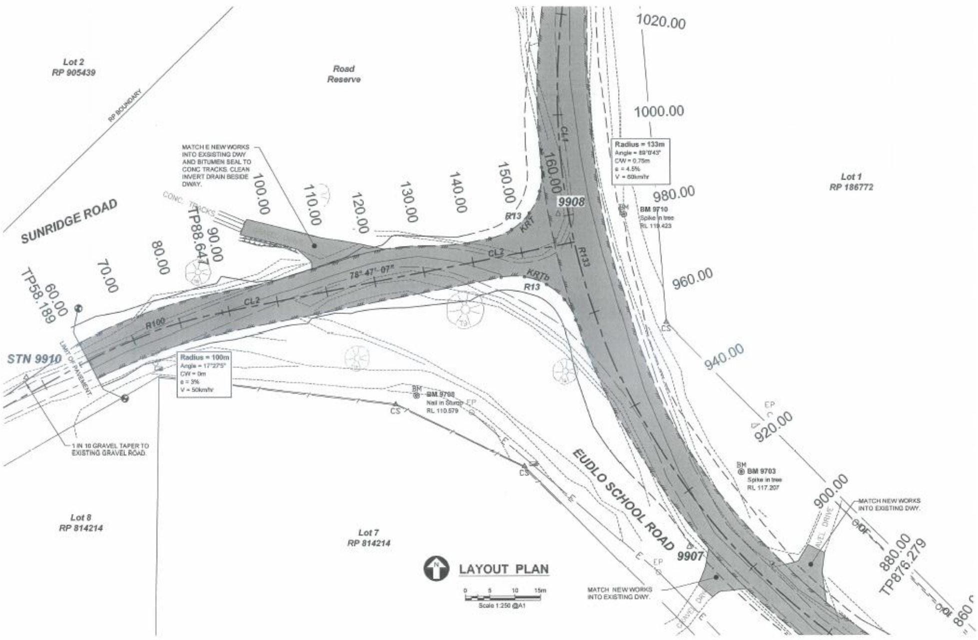


Figure 30: Upgraded intersection on Eudlo School Road

Figure 31: Eudlo School Road during construction

3.8.2 Design variations

The Eudlo School Road reconstruction was subjected to one design variations during the course of the project. The design changes arose through the discovery of a 3.3 metre by 1.4 metre concrete fibre optic chamber in close proximity to the roads shoulder. The original construction detailed plans and estimate were signed by council's Registered Professional Engineer in April 2010 with construction beginning in late April. During the initial earthworks, a large concrete chamber was unearthed just below the natural surface level. The chamber housed fibre optic connections that serviced the surrounding community. The chamber was undamaged during the discovery.

A design review in April by council's engineering design office identified the conflict between the new road alignment and the fibre optic chamber. Actions called for the survey team to obtain an accurate location of the chamber and the fibre optic lines entering and exiting the chamber. The true location of the chamber was determined by obtaining spot levels of the four corners. Figures 32 shows pit location in the new design while Figure 33 shows the location of the chamber on the longitudinal section.

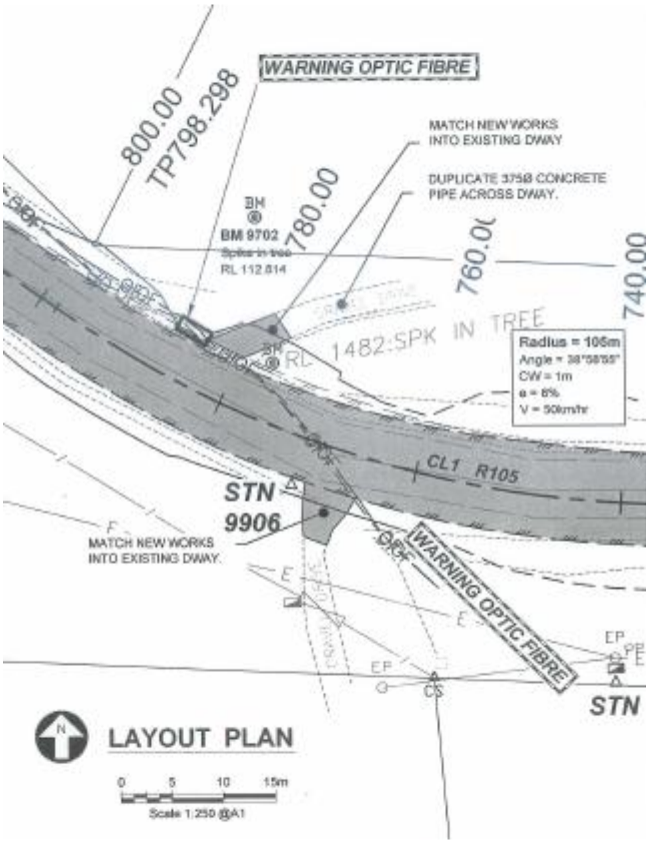


Figure 32: Chamber location in plan view

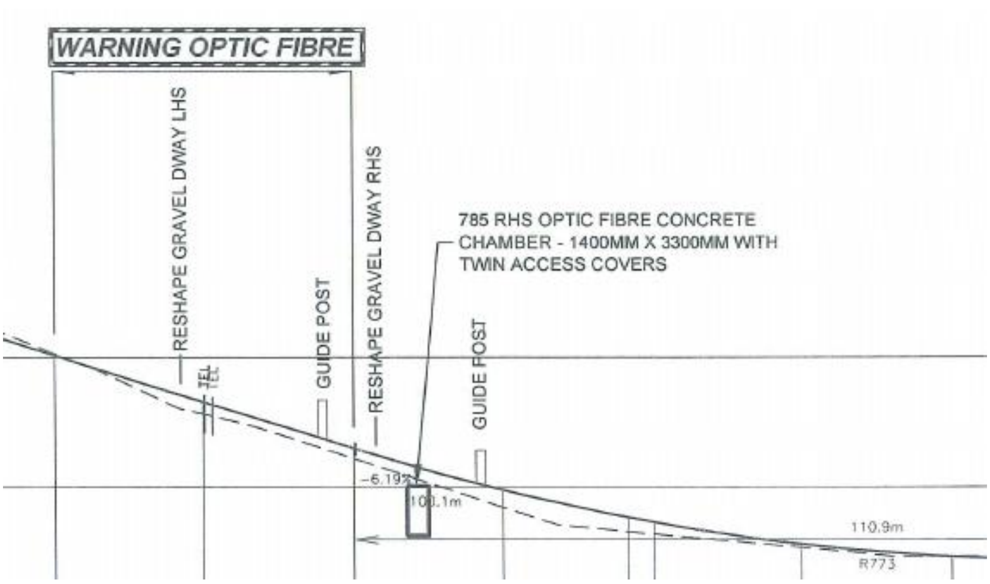


Figure 33: Chamber location in longitudinal view

The fibre optic line was identified on the Dial Before You Dig (DBYD) plans, however the pit was not. The initial site investigation and detailed survey did not locate the chamber. This may have been due to the chamber being covered by soil, thus not visible by the surveyor. The project was completed mid-2010.

3.8.3 Design and documentation costs

The design and documentation for this project was impacted from the above design changes. The location of the chamber meant that the design required geometry changes. The three dimensional computer model of the road was adjusted and included changes to the horizontal, vertical geometry. These changes had a flow on effect on the design documentation and estimate. The longitudinal and cross sections that are produced from the horizontal and vertical grading were also updated.

The number of plans issued for construction remained the same, with only 27 plans issued. This can be attributed to the fact that the design changes occurred at the same location with no scope change. The design and documentation costs for the final design were estimated to be $12,000. Speaking directly with the designer it was determined that approximately 8% ($960) was spent redesigning and documenting the changes.

The main cause of this design variation was an insufficient site investigation before the design process commenced. It highlights the fact that the Dial Before You Dig plans cannot be relied upon to give accurate locations of the underground services.

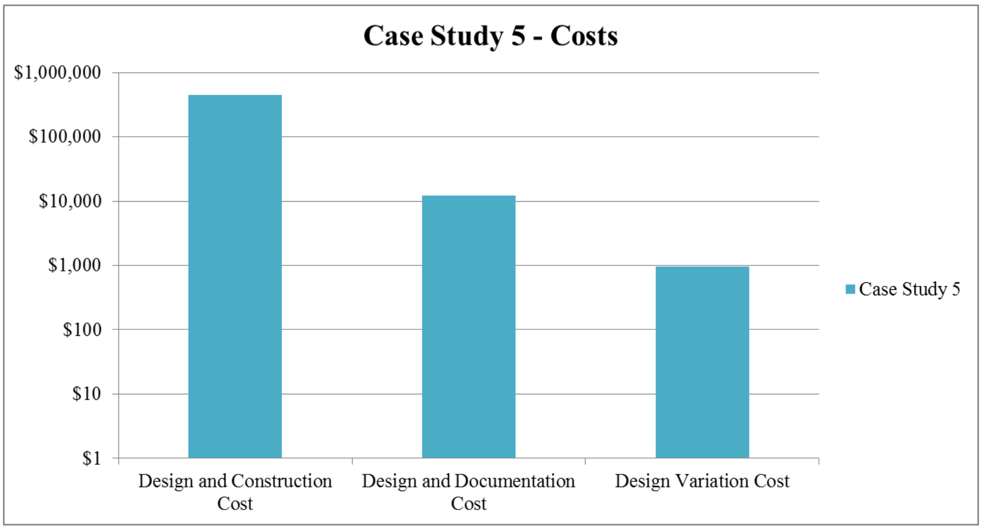


Figure 34: Case study 5 costs

3.9 Design variation process

The design variation process within the Council's civil design office is shown in Figure 35. The process begins with identifying the need for a design variation. This may be raised by the construction engineer, construction superintendent etc. The project manager who controls the project will be contacted and provided information about the required change or conflict. The project manager subsequently contacts the design team leader. The design team leader manages the work and scheduling of the office designers. The design team leader will assess the requested design change and decide if the change is a simple amendment to the drawings or will require additional scrutiny by the design review team and Registered Professional Engineer. If the latter is required, he will contact the design office administrator, who will place the project onto the next design review meeting agenda. The weekly design review meeting consists of a group of professionals that review current and potential projects. The speciality of each member differs with the designer, design team leader, traffic engineer, project manager, project coordinator and the design manager (RPEQ) present at each meeting. The team reviews the validity of the design change and the resources required to remediate the problem. It may be decided that the design change is unnecessary or unrequired to meet the objectives of the project. If unnecessary the request will be closed. If the variation is approved and requires no additional information the designer will be tasked with making the necessary changes to the design model, design drawings, estimate and quality assurance documents. If the designer requires additional information to make the required changes, such as the location of services, the surveyor will be contacted by the team leader or designer with details of the request. Once the additional information is obtained and the changes made by the designer, the design team leader is informed to arrange the project be added to the next design review agenda. The new design drawings and estimate will be required to be signed by the design manager before release. Once signed, a scanned copy of the plans and estimate will be provided to the project manager who will then distribute the plans to the construction crew.

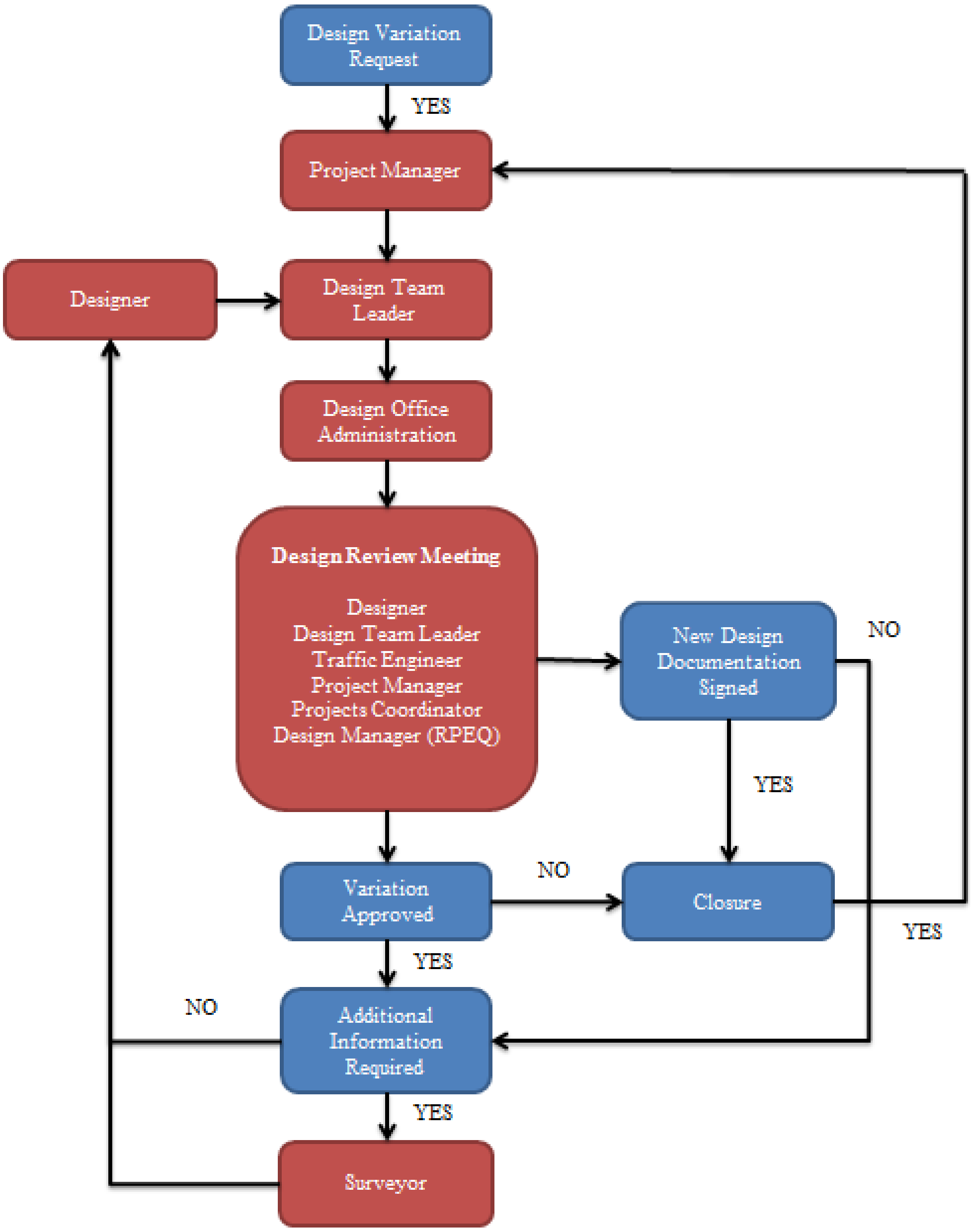


Figure 35: Design variation process

3.10 Data collected through questionnaire survey

Gaining access to case study data of private design firms was difficult due to confidentiality agreements with their clients. It was decided that a questionnaire survey would be utilised to obtain data required for this study. Questionnaire surveys have been used in previous studies relating to variations orders and design changes in construction projects.

Questionnaire surveys are a common method for conducting quantitative research. Quantitative research is known as a reliable and objective method of conducting research, with results providing data that can be statistically analysis to generalise a finding. Quantitative data is used to test theories or hypotheses and assumes the sample is representative of the wider population. Typically less detailed that qualitative data it has the risk of omitting the desired response from the respondent. (Surrey, 2014)

Questionnaires or social surveys are a common method of obtaining standardised data from large number of people. They are used to collect data in a statistical form, and have been categorised into three types of survey (Surrey, 2014)

1. Factual surveys (government census)
2. Attitude surveys (opinion poll)
3. Explanatory surveys (test new theories and hypotheses)

The questions asked within surveys are often used to make generalisations about the researchers field of interest, therefore the questions must be carefully selected and worded. Questions within the survey can be presented in the following forms (Surrey, 2014):

- Open ended
- Closed
- Fixed choice
- Likert scale

Questionnaire should consist of the same set of questions asked in the same order and wording to ensure the data collected is uniform. Closed and fixed choice questions may unintentionally force the respondent into a choice they cannot quantify or explain. For the purpose of this research closed and fixed choice questions will not be used. The method of collecting data through a questionnaire can include (Surrey, 2014):

- Formal interview with the respondent.
- Postal questionnaire.
- Telephone questionnaire.
- Email questionnaire
- Internet based questionnaire
- Paper based (letter drop)

3.10.1 Advantages of questionnaires

Questionnaire surveys have a number of advantages over other data collecting methods. Advantages may include:

- Potential for large amount of information to be collected from a wide range of respondents within a short amount of time.
- Cost effective.
- Results can be easily quantified.
- Results can be compared to previous research.
- Specialty software or equipment not required.
- Data collected can create new theories or test existing hypotheses.

3.10.2 Disadvantages of questionnaires

Questionnaire surveys also have a number of disadvantages. Disadvantages may include:

- Cannot account for respondent's emotions, behaviour, feelings etc.
- Truthfulness and effort of respondent can be questioned.
- Rely on the respondent's interpretation of questions.
- Questions represent what the researcher believes is important.

3.10.3 Design of questionnaire survey

The questionnaire survey created for this research project was developed from the literature review and discussions with my research supervisor. The literature review identified a number of central topics relating to the causes, effects and costs that design variations imposed on designers. These topics were the central basis for this questionnaire.

The questionnaire was divided into six main sections and included:

1. About the project
2. Instructions for questionnaire
3. Profile of organisation/respondents
4. Main questions
5. Additional information
6. Contact information

The first section briefly outlines the aims of the project, giving the reader some context in which to approach the following sections of the questionnaire.

The second section provides the respondent with instructions on how to complete the survey. Colour coding, examples and simple phasing is used to ensure the respondent is able to complete the survey to the best of their abilities.

The third section aims to gather data on the organisation or respondent completing the questionnaire. Information collected includes, the name, location and type of organisation, the position held by the respondent (engineer etc.) and how many year of professional experience they have.

The fourth section consists of the main research questions developed from the literature review. The first five questions relate to the main causes and effects of design variations on designers. Respondents were asked to indicate the frequency and impact of each cause and effect using a five point Likert scale. The scale was constructed utilising Microsoft Words ability to customise drop boxes. A sample of the drop down box is shown below in Figure 36.

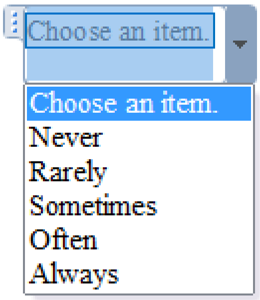


Figure 36: Likert scale drop box

The Likert scales used throughout the questionnaire include the following:

Frequency

1. Never
2. Rarely
3. Sometimes
4. Often
5. Always

Impact

1. Very low

2. Low
3. Moderate
4. High
5. Very high

Helpfulness

1. Not at all helpful
2. Slightly helpful
3. Moderately helpful
4. Very helpful
5. Extremely helpful

Agreement

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly disagree

The use of a five point Likert scale provides the respondent with a neutral position on the question. Other questions require the respondent to specify approximate percentages to the given question.

The fifth section allows the respondent to provide additional information that may be useful to this research. This may include past experiences and overall opinions of design variations.

The final section thanks the respondent for their time and effort spent completing the questionnaire. Personal contact details are provided to provide a method of contact if they have further queries.

Data obtained by the questionnaire was analysed using the Relative Importance Index (RII) method. This method is used to calculate the strength of index familiarity, frequencies and agreements of the specific question. This equation has been used in previous studies. It provides a percentage score that indicates the strength of the score in relation to other questions asked. The higher the percentage score the more important the question was to the respondent. The Relative Importance Index equation is given as follows (Oladapo, 2007):

$$Relative\ Importance\ Index\ (RII)\ \% = \left(\sum_{i=1}^{5} w_i \times f_i\right) \times \frac{100}{5n}$$

w_i is the weight given to the ith rating.

$i = 1, 2, 3$, 4 or 5

f_i is the response frequency of ith.

n is the total number of responses.

A number of design firms were contacted by telephone and asked if they were interesting in completing the questionnaire. If the company showed an interest in providing information an email was sent with a brief introduction explaining the purpose and importance of the study. The questionnaire was sent to 25 respondents from structural, civil, architecture and local government design offices.

A copy of the questionnaire survey can be viewed in Appendix B.

4.0 Results and Discussion

4.1 Introduction

The following section presents the data obtained through engineering case studies and the questionnaire survey distributed to industry sources. Results from the questionnaire survey have been sorted and analysed in Microsoft excel and presented in a simple table format for the reader. Patterns and discrepancies in the data will be discussed and conclusions drawn. Strategies for reducing the cost impacts of variations imposed on designers will be recommended.

4.2 Case study discussion

The case studies presented in section 3.4 provide an insight into the causes, effects and costs design variations imposed on construction projects designed by local governments. Local government designers often work in collaboration and for a number of external stakeholders including, specialist consultants, telecommunication, electricity, water, and sewer companies, local residents and community groups. Council's primary stakeholder or clients are local residents and community groups which utilised and are often impacted by new engineering projects.

Designers are employed to design sustainable, cost effective and safe engineering solutions for identified issues. These design ethics are no different to a designer working for a private company; however designers working for a local government are exposed to political pressures rarely encountered by private companies. The two main causes of design variations highlighted were inadequate communication and insufficient site investigation.

Inadequate communication can be attributed to the design changes found in case studies one, two and three. The communication between the civil designer and the internal stakeholder (landscape architect) in case one was vital to ensuring the overall design was safe for all end users. A breakdown in communication provided a design which was inadequate for disability compliancy and overall functionality. This may be caused by the departmentalisation nature of Council's infrastructure branch. Case two and three identified inadequate communication between Council and the community stakeholders. A change in the stormwater network on Sippy Downs Drive and a complete redesign of the Golden Beach car park justify the need to include and inform stakeholders affected by the project early in the design process. The Sippy Downs Drive design change may have been avoided if the University was informed about the design and was able to voice their requests to divert the stormwater runoff into their system. The Golden Beach car park complete redesign was caused by Council's oversight of the concerns highlighted by the key stakeholders in the design concept stage of the project. The opportunity to change the layout of the car park in the design stage would have cost considerably less in design and documentation costs.

The second cause of design variations identified was insufficient site investigations prior to the design stage of the project. Initial site investigations for local government projects include a topographical survey carried out by a surveyor. Surveyor's use Dial Before You Dig plans to locate above ground and underground services. These plans highlight the fact that certain services are located within the area and are not relied upon for accurate design, unless located by the surveyor. If it is identified that services may conflict with design features, the services may be found using a number of techniques such as potholing and cable location devices. Case studies four and five encountered design changes arising from the discovery of underground services during the construction phase. In case study four, the services discovered were not identified on the Dial Before You Dig plans and thus were not located in the initial site survey. The chamber encountered in case study five was identified on the Dial Before You Dig plans, yet was not located by the surveyor due to the chamber buried under a layer of soil. Conflict with services can be minimised by locating the services and depths during the initial topographical survey. This may increase the cost of the initial survey, however the consequences experienced in the construction phase will be designed out by the designer.

The cost of the design changes varied between project due to the scope of and the complexity of the variation. The cost of the variation as a percentage of total design and construction costs ranged between 0.1% - 2.3 % while as a percentage of total design and documentation costs resulted in a range from 3% - 51.9%. Figure 37 shows the associated cost between the five case studies.

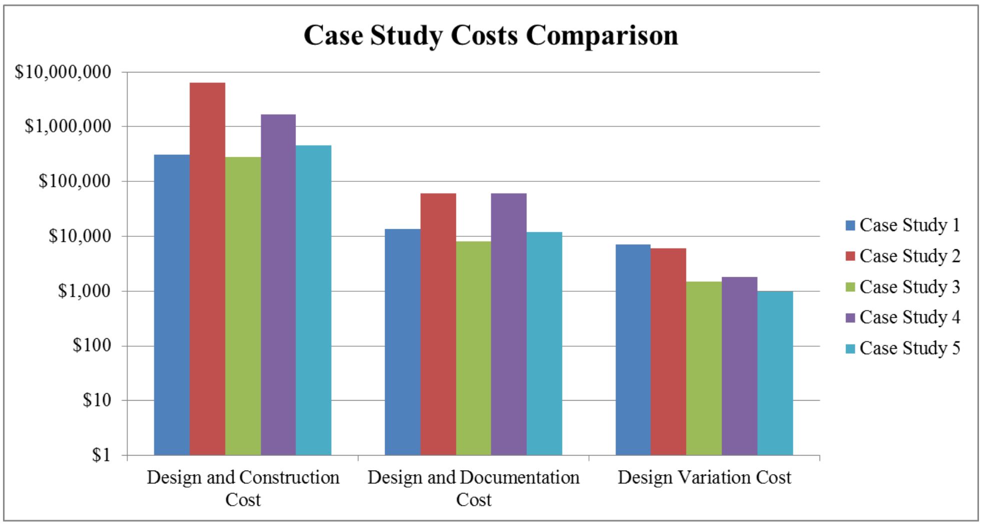


Figure 37: Case study cost comparison

4.3 Questionnaire survey data

The data collected by the questionnaire survey was divided into four sections which include the following:

1. Profile of responses
2. Government data
3. Private company data
4. Combined data

Separating the data collected attempts to determine patterns and possible connections within the responses.

4.3.1 Profile of responses

4.3.1.1 Location of organisation

The location of the organisations that responded to the questionnaire survey was distributed between Queensland, New South Wales and Tasmania. The proportion of respondents from each state is shown in Figure 38. The majority of respondents were located in Queensland.

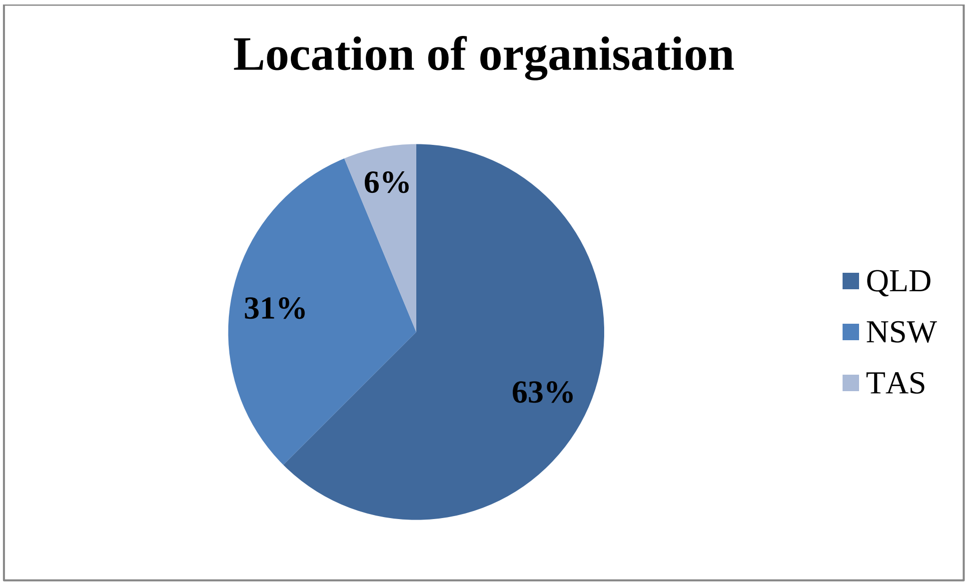


Figure 38: Location of organisations

4.3.1.2 Type of organisation

The type of organisation that responded to the questionnaire survey was distributed between government and private companies. The proportion of respondents from each type of organisation is shown in Figure 39. The majority of respondents worked for government organisations.

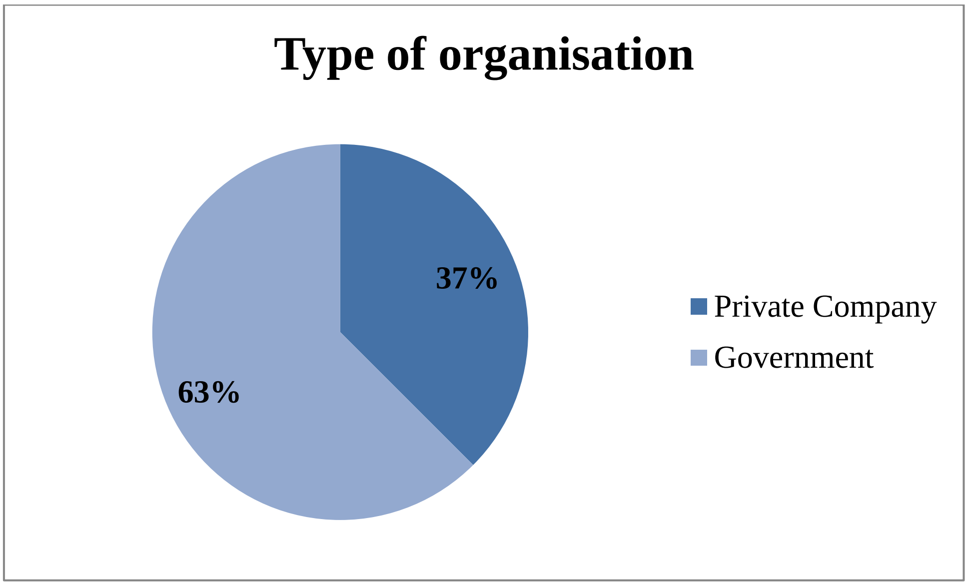


Figure 39: Type of organisation

4.3.1.3 Position in organisation

The position of the respondent in the organisation that responded to the questionnaire survey was distributed between designers, engineers, management and others. The proportion of respondents from each position within the organisation is shown in Figure 40. The majority of respondents were designers.

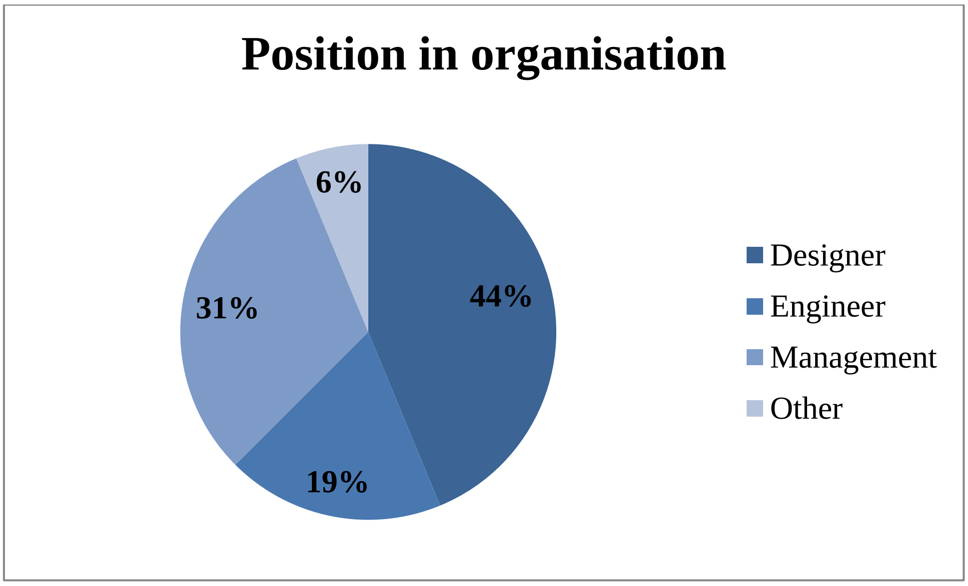


Figure 40: Position in organisation

4.3.1.4 Years of professional experience

The years of professional experience of the respondent that responded to the questionnaire survey ranged from 1 - 5 years' experience up to 20+ years. The proportion of respondents within each band of experience is shown in Figure 41. The majority of respondents had more than 20 years of professional experience.

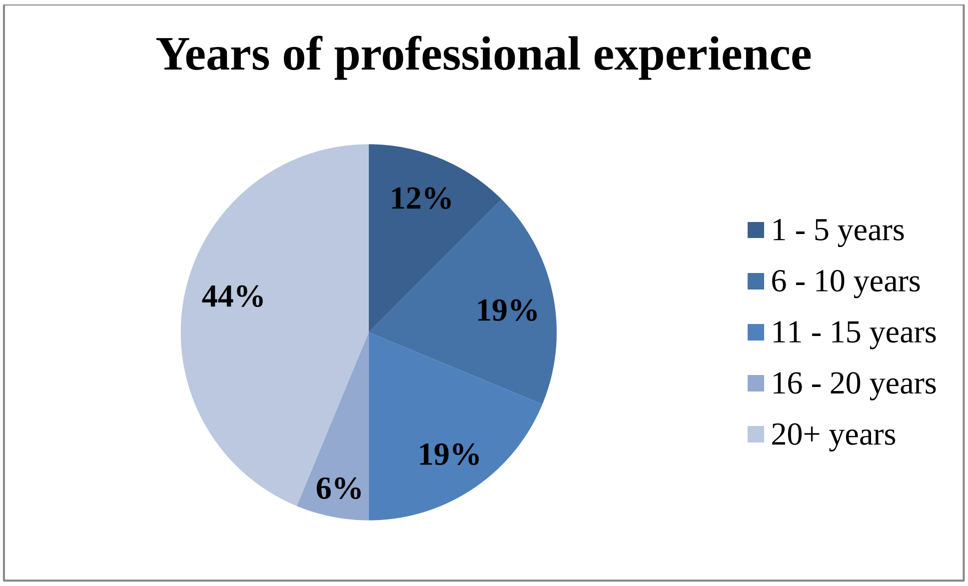


Figure 41: Years of professional experience

4.3.2 Government data

The following section presents the results obtained from government designers and engineers. The tables shown in this section present the response frequency and overall ranking of the following:

- Client, consultant, contractor and other initiated causes of design variations.
- Effects of design variations on designers.
- Initiators of design variations.
- Indirect costs associated with design variations.
- Median response value for the discussed causes and effects.

4.3.2.1 Government data - Frequency

Respondents were asked to indicate the frequency of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 2 show that the changes to project scope or brief by the client, inadequate design documentation by consultants, poor quality of work by the contractor, social cultural factors and redesign and documentation were experienced the most by respondents.

Table 2: Government Data - Frequency

Government Data - Frequency

Reason	Response Frequency					Relative Importance Index (%)	Rank
	1	2	3	4	5		
Client initiated causes of design variations							
Change to project scope or brief	0	0	3	6	1	76	1

Change to project schedule	0	2	5	2	1	64	2
Change to project funding	0	0	9	1	0	62	3
Change to project objectives	0	2	5	3	0	62	3
Consultant initiated causes of design variations							
Inadequate design documentation	0	3	3	4	0	62	1
Insufficient site investigation	0	4	5	1	0	54	2
Lack of experience or knowledge	0	6	3	1	0	50	3
Changes of specifications	1	5	4	0	0	46	4
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	1	3	5	1	0	52	2
Poor quality of work	0	1	8	1	0	60	1
Inappropriate design	0	6	4	0	0	48	3
Lack of experience or knowledge	0	8	2	0	0	44	4
Lack of strategic planning	1	4	3	2	0	52	2
Other causes of design variations							
Change to regulations	0	9	1	0	0	42	3
Change to economic conditions	0	5	5	0	0	50	2
Social cultural factors	1	3	5	1	0	52	1
Effect of design variations on designers							
Redesign and documentation	0	0	6	4	0	68	1
Increase in overheads	0	3	6	1	0	56	3
Project schedule delay	0	1	7	2	0	62	2
Disputes and claims	0	7	3	0	0	46	5
Develop a negative reputation within industry	1	4	5	0	0	48	4

4.3.2.2 Government data - Impact

Respondents were asked to indicate the impact of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 3 show that the changes to project objectives by the client, inadequate design documentation, lack of experience or knowledge by consultants, inappropriate design for the contractor, social cultural factors, and redesign and documentation were perceived to impact government respondents the most.

Table 3: Government Data - Impact

Government Data - Impact

Reason	**Response Frequency**					**Relative Importance Index (%)**	**Rank**
	1	**2**	**3**	**4**	**5**		
Client initiated causes of design variations							
Change to project scope or brief	0	2	4	3	1	66	2
Change to project schedule	0	3	7	0	0	54	4
Change to project funding	0	4	3	3	0	58	3
Change to project objectives	1	0	1	6	2	76	1
Consultant initiated causes of design variations							
Inadequate design documentation	0	2	4	4	0	64	1
Insufficient site investigation	0	3	3	4	0	62	2
Lack of experience or knowledge	0	1	6	3	0	64	1
Changes of specifications	2	2	5	1	0	50	3
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	2	4	1	3	0	50	4
Poor quality of work	2	0	7	1	0	54	3
Inappropriate design	1	1	2	6	0	66	1

Lack of experience or knowledge	1	1	6	1	1	60	2
Lack of strategic planning	3	2	3	2	0	48	5
Other causes of design variations							
Change to regulations	2	4	3	1	0	46	2
Change to economic conditions	3	4	2	1	0	42	3
Social cultural factors	2	0	6	2	0	56	1
Effect of design variations on designers							
Redesign and documentation	0	1	1	5	3	80	1
Increase in overheads	3	2	3	2	0	48	5
Project schedule delay	1	4	3	1	1	54	4
Disputes and claims	0	5	3	1	1	56	3
Develop a negative reputation within industry	1	1	4	1	3	68	2

4.3.2.3 Government data - Initiators

Respondents were asked to indicate to the nearest 5% the proportion of design variations initiated by each project participant. The results in Table 4 show the average responses from the respondents. It was determined that 51% of respondents perceived clients to initiate the majority of design variations while other causes are ranked last with 8%. Design consultants and contractors were indicated to initiate similar amounts with 22% and 20% respectively.

Table 4: Initiators of design variations

Initiators of design variations

Project Participant	Average Percentage
Clients	51 %
Designers/Design Consultants	22 %
Contractors	20 %
Others	8 %

4.3.2.4 Government data – Valuing variations

Respondents were asked to indicate if to the following variation items were considered when valuing a design variation. If the response was yes they were required to allocate a percentage to that item in relation to the overall cost of total design and documentation costs. The results in Table 5 show that the median value for each item amounts to:

Variation management administration	5% to 10%
Design variation review	2.5% to 5%
Additional site visits	0% to 1%
Communication with project participants	1% to 2.5%
Documentation stationary	0% to 1%

Table 5: Valuing design variations

Valuing design variations

Variation Item	Response Frequency				
	0% to 1%	1% to 2.5%	2.5% to 5%	5% to 10%	10% +
Variation management administration	1	0	1	3	0
Design variation review	0	2	2	2	1
Additional site visits	3	0	0	0	0
Communication with project participants	1	4	0	0	0
Documentation stationary	2	0	0	0	0

4.3.2.5 Government data – Median Likert values

The results in Table 6 show the median Likert score for the frequency and impact of each of the identified causes and effects.

Table 6: Median responses

Reason	Frequency	Impact
Median Responses		
Client initiated causes of design variations		
Change to project scope or brief	Often	Moderate
Change to project schedule	Sometimes	Moderate
Change to project funding	Sometimes	Moderate
Change to project objectives	Sometimes	High
Consultant initiated causes of design variations		
Inadequate design documentation	Sometimes	Moderate
Insufficient site investigation	Sometimes	Moderate
Lack of experience or knowledge	Rarely	Moderate
Changes of specifications	Rarely	Moderate
Contractor initiated causes of design variations		
Lack of involvement in design (Non D&C projects)	Sometimes	Low
Poor quality of work	Sometimes	Moderate
Inappropriate design	Rarely	High
Lack of experience or knowledge	Rarely	Moderate
Lack of strategic planning	Rarely–sometimes	Low–mod
Other causes of design variations		
Change to regulations	Rarely	Low
Change to economic conditions	Rarely–sometimes	Low
Social cultural factors	Sometimes	Moderate
Effect of design variations on designers		
Redesign and documentation	Sometimes	High
Increase in overheads	Sometimes	Low–mod
Project schedule delay	Sometimes	Low–mod
Disputes and claims	Rarely	Low–mod
Develop a negative reputation within industry	Rarely-sometimes	Moderate

4.3.3 Private company data

The following section presents the results obtained from private engineering companies. The tables shown in this section present the response frequency and overall ranking of the following:

- Client, consultant, contractor and other initiated causes of design variations.
- Effects of design variations on designers.
- Initiators of design variations.
- Indirect costs associated with design variations.
- Median response value for the discussed causes and effects.

4.3.3.1 Private company data - Frequency

Respondents were asked to indicate the frequency of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 7 show that changes to project scope/brief and project schedule by the client, inadequate design documentation by consultants, lack of involvement in design and poor quality of work by the contractor, changes in economic conditions, and redesign and documentation were experienced the most by respondents.

Table 7: Private Company Data - Frequency

Private Company Data - Frequency

Reason	Response Frequency					Relative Importance Index (%)	Rank
	1	2	3	4	5		
Client initiated causes of design variations							
Change to project scope or brief	0	0	3	3	0	70	1
Change to project schedule	0	0	3	3	0	70	1

Change to project funding	1	1	1	2	1	63	2
Change to project objectives	0	2	3	1	0	57	3
Consultant initiated causes of design variations							
Inadequate design documentation	0	0	4	2	0	67	1
Insufficient site investigation	0	2	1	3	0	63	2
Lack of experience or knowledge	0	3	3	0	0	50	3
Changes of specifications	1	3	1	1	0	47	4
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	0	2	2	2	0	60	1
Poor quality of work	0	1	4	1	0	60	1
Inappropriate design	1	2	3	0	0	47	4
Lack of experience or knowledge	0	4	1	1	0	50	3
Lack of strategic planning	0	3	2	1	0	53	2
Other causes of design variations							
Change to regulations	1	3	1	1	0	47	3
Change to economic conditions	0	1	5	0	0	57	1
Social cultural factors	1	1	3	1	0	53	2
Effect of design variations on designers							
Redesign and documentation	0	1	0	4	1	77	1
Increase in overheads	1	0	3	0	2	67	2
Project schedule delay	0	1	2	3	0	67	2
Disputes and claims	0	1	4	1	0	60	3
Develop a negative reputation within industry	3	1	2	0	0	37	4

4.3.3.2 Private company data - Impact

Respondents were asked to indicate the impact of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 8 show that the changes to project schedule by the client, insufficient site investigation by consultants, poor quality of work by the contractor, change to economic conditions, and redesign and documentation were perceived to impact respondents the most.

Table 8: Private Company Data - Impact

Private Company Data - Impact

Reason	Response Frequency					Relative Importance Index (%)	Rank
	1	2	3	4	5		
Client initiated causes of design variations							
Change to project scope or brief	1	0	2	3	0	63	2
Change to project schedule	0	0	2	3	1	77	1
Change to project funding	1	1	3	0	1	57	4
Change to project objectives	1	2	1	0	2	60	3
Consultant initiated causes of design variations							
Inadequate design documentation	0	2	0	4	0	67	2
Insufficient site investigation	0	0	1	5	0	77	1
Lack of experience or knowledge	0	1	5	0	0	57	3
Changes of specifications	2	2	2	0	0	40	4
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	2	0	2	2	0	53	5
Poor quality of work	0	0	4	2	0	67	1
Inappropriate design	1	1	1	3	0	60	3
Lack of experience or knowledge	1	1	2	2	0	57	4
Lack of strategic planning	1	1	0	4	0	63	2
Other causes of design variations							
Change to regulations	2	2	2	0	0	40	3
Change to economic conditions	1	0	2	3	0	63	1

Social cultural factors	2	0	3	1	0	50	2
Effect of design variations on designers							
Redesign and documentation	0	0	1	5	0	77	1
Increase in overheads	1	1	2	2	0	57	4
Project schedule delay	1	0	3	2	0	60	3
Disputes and claims	0	0	4	1	1	70	2
Develop a negative reputation within industry	2	0	2	1	1	57	4

4.3.3.3 Private company data - Initiators

Respondents were asked to indicate to the nearest 5% the proportion of design variations initiated by each project participant. The results in Table 9 show the average responses from the respondents. It was determined that 58% of respondents perceived clients to initiate the majority of design variations while other causes are ranked last with 6%. Variations initiated by design consultants and contractors were 24% and 12% respectively.

Table 9: Initiators of design variations

Initiators of design variations

Project Participant	**Average Percentage**
Clients	58
Designers/Design Consultants	24
Contractors	12
Others	6

4.3.3.4 Private company data – Valuing variations

Respondents were asked to indicate if to the following variation items were considered when valuing a design variation. If the response was yes they were required to allocate a percentage to that item in relation to the overall cost of total design and documentation costs. The results in Table 10 show that the median value for each item amounts to:

Variation management administration	5% to 10%
Design variation review	2.5% to 10%
Additional site visits	2.5% to 5%
Communication with project participants	2.5% to 10%
Documentation stationary	0% to 1%

Table 10: Valuing design variations

Valuing design variations

Variation Item	Response Frequency				
	0% to 1%	**1% to 2.5%**	**2.5% to 5%**	**5% to 10%**	**10% +**
Variation management administration	0	2	0	3	0
Design variation review	0	1	2	2	1
Additional site visits	1	1	2	1	1
Communication with project participants	1	1	1	2	1
Documentation stationary	3	0	0	0	0

4.3.3.5 Private company data – Median Likert values

The results in Table 11 show the median Likert score for the frequency and impact of each of the identified causes and effects.

Table 11: Median responses

Median Responses		
Reason	**Frequency**	**Impact**
Client initiated causes of design variations		
Change to project scope or brief	Sometimes-often	Mod-high
Change to project schedule	Sometimes-often	High
Change to project funding	Sometimes-often	Moderate
Change to project objectives	Sometimes	Low-mod
Consultant initiated causes of design variations		
Inadequate design documentation	Sometimes	High
Insufficient site investigation	Sometimes-often	High
Lack of experience or knowledge	Sometimes-often	Moderate
Changes of specifications	Rarely	Low
Contractor initiated causes of design variations		
Lack of involvement in design (Non D&C projects)	Sometimes	Moderate
Poor quality of work	Sometimes	Moderate
Inappropriate design	Rarely-sometimes	Mod-high
Lack of experience or knowledge	Rarely	Moderate
Lack of strategic planning	Rarely-sometimes	High
Other causes of design variations		
Change to regulations	Rarely	Low
Change to economic conditions	Sometimes	Mod-high
Social cultural factors	Sometimes	Moderate
Effect of design variations on designers		
Redesign and documentation	Often	High
Increase in overheads	Sometimes	Moderate
Project schedule delay	Sometimes-often	Moderate
Disputes and claims	Sometimes	Moderate
Develop a negative reputation within industry	Never-rarely	Moderate

4.3.4 Combined data

The following section presents the results obtained from government and private engineering organisations. The tables shown in this section present the response frequency and overall ranking of the following:

- Client, consultant, contractor and other initiated causes of design variations.
- Effects of design variations on designers.
- Initiators of design variations.
- Indirect costs associated with design variations.
- Median response value for the discussed causes and effects.

4.3.4.1 Combined data - Frequency

Respondents were asked to indicate the frequency of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 12 show that changes to project scope or brief by the client, inadequate design documentation by consultants, poor quality of work by the contractor, social cultural factors, changes in economic conditions, and redesign and documentation were experienced the most by respondents.

Table 12: Combined Data - Frequency

Combined Data - Frequency

Reason	Response Frequency					Relative Importance Index (%)	Rank
	1	2	3	4	5		
Client initiated causes of design variations							
Change to project scope or brief	0	0	6	9	1	74	1

Change to project schedule	0	2	8	5	1	66	2
Change to project funding	1	1	10	3	1	63	3
Change to project objectives	0	4	8	4	0	60	4
Consultant initiated causes of design variations							
Inadequate design documentation	0	3	7	6	0	64	1
Insufficient site investigation	0	6	6	4	0	58	2
Lack of experience or knowledge	0	9	6	1	0	50	3
Changes of specifications	2	8	5	1	0	46	4
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	1	5	7	3	0	55	2
Poor quality of work	0	2	12	2	0	60	1
Inappropriate design	1	8	7	0	0	48	4
Lack of experience or knowledge	0	12	3	1	0	46	5
Lack of strategic planning	1	7	5	3	0	53	3
Other causes of design variations							
Change to regulations	1	12	2	1	0	44	2
Change to economic conditions	0	6	10	0	0	53	1
Social cultural factors	2	4	8	2	0	53	1
Effect of design variations on designers							
Redesign and documentation	0	1	6	8	1	71	1
Increase in overheads	1	3	9	1	2	60	3
Project schedule delay	0	2	9	5	0	64	2
Disputes and claims	0	8	7	1	0	51	4
Develop a negative reputation within industry	4	5	7	0	0	44	5

4.3.4.2 Combined data - Impact

Respondents were asked to indicate the impact of client, consultant, contractor and other initiated causes of design variations. A Likert scale ranging from 1 to 5 was used. The results in Table 13 show that the changes to project objectives by the client, insufficient site investigation by consultants, inappropriate design for the contractor, social cultural factors and redesign and documentation were perceived to impact respondents the most.

Table 13: Combined Data - Impact

Combined Data - Impact

Reason	Response Frequency					Relative Importance Index (%)	Rank
	1	2	3	4	5		
Client initiated causes of design variations							
Change to project scope or brief	1	2	6	6	1	65	2
Change to project schedule	0	3	9	3	1	63	3
Change to project funding	1	5	6	3	1	58	4
Change to project objectives	2	2	2	6	4	70	1
Consultant initiated causes of design variations							
Inadequate design documentation	0	4	4	8	0	65	2
Insufficient site investigation	0	3	4	9	0	68	1
Lack of experience or knowledge	0	2	11	3	0	61	3
Changes of specifications	4	4	7	1	0	46	4
Contractor initiated causes of design variations							
Lack of involvement in design (Non D&C projects)	4	4	3	5	0	51	4
Poor quality of work	2	0	11	3	0	59	2
Inappropriate design	2	2	3	9	0	64	1
Lack of experience or knowledge	2	2	8	3	1	59	2

Lack of strategic planning	4	3	3	6	0	54	3
Other causes of design variations							
Change to regulations	4	6	5	1	0	44	3
Change to economic conditions	4	4	4	4	0	50	2
Social cultural factors	4	0	9	3	0	54	1
Effect of design variations on designers							
Redesign and documentation	0	1	2	10	3	79	1
Increase in overheads	4	3	5	4	0	51	5
Project schedule delay	2	4	6	3	1	56	4
Disputes and claims	0	5	7	2	2	61	3
Develop a negative reputation within industry	3	1	6	2	4	64	2

4.3.4.3 Combined data - Initiators

Respondents were asked to indicate to the nearest 5% the proportion of design variations initiated by each project participant. The results in Table 14 show the average responses from the respondents. It was determined that 53% of respondents perceived clients to initiate the majority of design variations while other causes are ranked last with 7%. Variations initiated by design consultants and contractors were 23% and 17% respectively.

Table 14: Initiators of design variations

Initiators of design variations

Project Participant	Average Percentage
Clients	53
Designers/Design Consultants	23
Contractors	17
Others	7

4.3.4.4 Combined data – Valuing variations

Respondents were asked to indicate if to the following variation items were considered when valuing a design variation. If the response was yes they were required to allocate a percentage to that item in relation to the overall cost of total design and documentation costs. The results in Table 15 show that the median value for each item amounts to:

Variation management administration	5% to 10%
Design variation review	2.5% to 5%
Additional site visits	1% to 2.5%
Communication with project participants	1% to 2.5%
Documentation stationary	0% to 1%

Table 15: Valuing design variations

Valuing design variations

Variation Item	Response Frequency				
	0% to 1%	1% to 2.5%	2.5% to 5%	5% to 10%	10% +
Variation management administration	1	2	1	6	0
Design variation review	0	3	4	4	2
Additional site visits	4	1	2	1	1
Communication with project participants	2	5	1	2	1
Documentation stationary	5	0	0	0	0

4.3.4.5 Combined data – Median Likert values

The results in Table 16 show the median Likert score for the frequency and impact of each of the identified causes and effects.

Table 16: Median responses

Reason	Frequency	Impact
Client initiated causes of design variations		
Change to project scope or brief	Often	Moderate
Change to project schedule	Sometimes	Moderate
Change to project funding	Sometimes	Moderate
Change to project objectives	Sometimes	High
Consultant initiated causes of design variations		
Inadequate design documentation	Sometimes	Mod-high
Insufficient site investigation	Sometimes	High
Lack of experience or knowledge	Rarely	Moderate
Changes of specifications	Rarely	Low-mod
Contractor initiated causes of design variations		
Lack of involvement in design (Non D&C projects)	Sometimes	Low-mod
Poor quality of work	Sometimes	Moderate
Inappropriate design	Rarely	High
Lack of experience or knowledge	Rarely	Moderate
Lack of strategic planning	Rarely-sometimes	Moderate
Other causes of design variations		
Change to regulations	Rarely	Low
Change to economic conditions	Sometimes	Low-mod
Social cultural factors	Sometimes	Moderate
Effect of design variations on designers		
Redesign and documentation	Often	High
Increase in overheads	Sometimes	Moderate
Project schedule delay	Sometimes	Moderate
Disputes and claims	Rarely-sometimes	Moderate
Develop a negative reputation within industry	Rarely	Moderate

4.4 Questionnaire survey discussion

This section of the report discusses the results obtained by the questionnaire survey by identifying possible patterns and discrepancies in the data. It may be noted that the response rate from private companies was less than ideal. Table 17 presents the highest RII items (shown in red) for the government and private company respondents.

Table 17: Highest RII values

Highest RII Values – Frequency and Impact

Reason	Gov.		Private company	
	F	I	F	I
Client initiated causes of design variations				
Change to project scope or brief				
Change to project schedule				
Change to project funding				
Change to project objectives				
Consultant initiated causes of design variations				
Inadequate design documentation				
Insufficient site investigation				
Lack of experience or knowledge				
Changes of specifications				
Contractor initiated causes of design variations				
Lack of involvement in design (Non D&C projects)				
Poor quality of work				
Inappropriate design				
Lack of experience or knowledge				
Lack of strategic planning				
Other causes of design variations				
Change to regulations				
Change to economic conditions				
Social cultural factors				
Effect of design variations on designers				

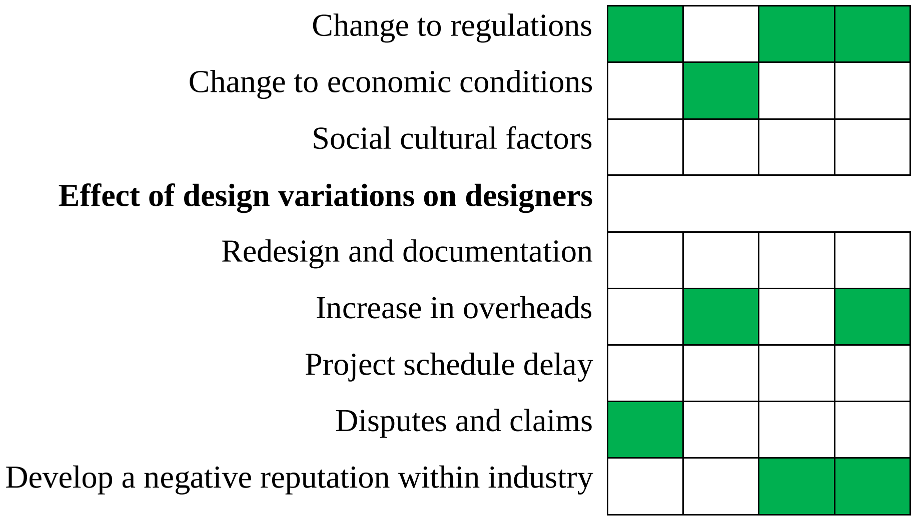
Redesign and documentation				
Increase in overheads				
Project schedule delay				
Disputes and claims				
Develop a negative reputation within industry				

Table 18 presents the lowest RII items (shown in green) for the government and private company respondents.

Table 18: Lowest RII values

Lowest RII Values – Frequency and Impact

Reason	**Gov.**		**Private company**	
	F	**I**	**F**	**I**
Client initiated causes of design variations				
Change to project scope or brief				
Change to project schedule				
Change to project funding				
Change to project objectives				
Consultant initiated causes of design variations				
Inadequate design documentation				
Insufficient site investigation				
Lack of experience or knowledge				
Changes of specifications				
Contractor initiated causes of design variations				
Lack of involvement in design (Non D&C projects)				
Poor quality of work				
Inappropriate design				
Lack of experience or knowledge				
Lack of strategic planning				
Other causes of design variations				



4.4.1 Highest RII scores

A change in the project scope or brief by clients was identified by both sets of respondents as the highest RII score. Project scopes and briefs are used by designers in both the public and private sector. In the public sector the scope or brief will be provided when a new project is identified for construction. The new project will have been identified on either a 5 year or 10 year capital works program. The scope is usually provided to the designer by someone with competent design and documentation skills. A well-defined scope will provide the designer with the majority of the information needed to correctly complete detailed design and documentation. Government designers answer to a number of internal and external stakeholders or "clients". These may include different departments, councillors, community organisations and many others. Changes to the project scope are often changed by internal stakeholders from external requests. The scope of brief provided to designers in the private sector is usually provided by the client. This may include other consultants, architects, and companies or individuals outside the engineering field.

Inadequate design and documentation provided by consultants was identified by both sets of respondents as the highest RII score. On various Council projects, design consultants are commissioned to design and document project plans. In recent years design consultants have provided council with less than adequate plans. Inadequacies include poor designs that are not practical, omission of critical data, poor drafting and overall substandard documents. It is widely known in the industry that design and documentation standards have been falling for a number of years. As stated in previous sections of this report, 60 - 90% of all variations are caused by inadequate design and documentation (Engineers Australia, 2005). The problem is industry wide and will continue to effect projects until standards are improved.

Poor quality of work by contractors was identified by both sets of respondents as the highest RII score. On any given construction site there may be multiple contractors working on constructing the designer's vision. This may range from a simple kerb and channel, to erecting concrete or steel columns for a high-rise. Designers in the public and private sector may need to redesign parts of a project due to poor workmanship. One example of this happening is a kerb and channel alignment constructed by a contractor. The contractor set the kerb lip 150 mm off the design alignment. It was decided that the designer would rework the surrounding traffic lanes, islands drainage pit to accommodate the poor workmanship. This case was for a local government streetscape project. The private sector would not be so forgiving for this mistake.

Redesign and documentation was identified by both sets of respondents as the highest RII score for effects on designers. This was true for the frequency and perceived impact. Design variations will generally create extra work for designer. Design consultants and government designers may use a range of software to design projects in their area of speciality. Design variations may propagate changes to 3D models, construction plans, estimates and quality assurance documents. It is accepted within the industry that redesign and documentation is inevitable with design variations and cannot be avoided. Designers can limit their exposure to design variations by addressing the items discussed in section 2.7.

4.4.2 Lowest RII scores

Change to the projects objectives by the client was identified by both sets of respondents as the lowest RII score. It has been discussed previously that a change in scope or brief was frequently experienced by all designers. The projects size, cost, schedule may change, however the objectives of the project rarely differ from the original objective. An example of this is case study three. The objective, providing a car parking facility for the community did not change, however the scope of the project did. The objective of an engineering project is rarely changed without a rational purpose.

Change of specifications by the consultant was identified by both sets of respondents as the lowest RII score for frequency and impact. Specifications are usually standardised documents that have been industry proven for a number of years. This may be specifications for the type of concrete used within a construction element or the construction of a road pavement. Specifications for a one off product or material are not conducted without scientific merit. Changes to specifications are rarely encountered during the course of a project thus reflect the scores provided by all questionnaire respondents.

Change to regulations was identified by both sets of respondents as the lowest RII score. Regulations may include changes to government policy, law, code and standards. Much like specifications, regulations rarely change within the timeframe of a project. If a change was to occur within a regulation the change will most likely be insignificant and could be dealt with swiftly by the designer. A change in regulations would affect both public and private sector designers working within the same speciality.

Increase in overheads was identified by both sets of respondents as the lowest RII impact score. Design variations increase the design and documentation work required by the designer, therefore increasing the overheads on the organisation. The overheads of a designer carrying out design variations per hour of work are minimal and will usually be claimed by the consultant when valuing the variation. Overheads within the public sector are not viewed with concern. This may be due to the fact that government organisations are not profit driven companies.

4.4.3 Highest frequency and impact RII scores

Change to the project schedule by the client was identified by the private company respondents as having the highest RII score for frequency and impact. Private companies are profit driven organisations. We are all familiar with the phase, “time is money”, and for designers working in the private sector this statement rings truth. A delay in project schedule may affect construction timelines and can have a flow on effect to other projects. Government respondents ranked the frequency of schedule change second while the impact was ranked fourth. This may be due to the fact that government projects are scheduled in 5 and 10 year capital works programs. If schedule delay is experienced, designers and construction crews can be shuffled to other projects within the program or the project can be delayed until the design is ready.

Inadequate design documentation provided by consultants was identified by the government respondents as having the highest frequency and impact. As previously discussed, local governments sometime approach private design firms for design services. Many designers within the public sector have had negative experiences with design models and plans provided by design consultants. This may be caused by the consultants “cutting corners” in the detailed design process. An impact of such events can include the government civil design team having to redesign the project, thus wasting taxpayer’s money.

Poor quality of work by contractors was identified by the private company respondents as having the highest RII score for frequency and impact. As previously stated, a number of different contractors can be present on a construction site at any one point. Private companies may recognise the frequency and impact of contractor initiated changes due to the size and scope of projects. Private firms have the ability to design large scale projects, many times the size and budget of local government projects.

Change to economic conditions was identified by the private company respondents as having the highest RII score for frequency and impact. A downturn in the local or global markets can negatively affect private companies. The global financial crisis of 2007 impacted markets throughout the world. Private companies are more exposed to clients facing financial difficulties. They may also be more likely to experience job cuts due to a downturn in the economy. The public sector is not immune to these problems. Annual infrastructure budgets were significantly reduced from 2007 onwards, causing projects to be downsized or cut completely.

Social cultural factors were identified by the government respondents as having the highest RII score for frequency and impact. Projects designed and constructed by council designers are exposed to a number of social cultural factors. The intimate relationship between the council and the surrounding community opens projects to an increase amount of political pressure and influence on the final outcome of a project. Private companies are sheltered from such pressures. Social cultural impacts that have the ability to affect private companies and government designers are the discovery of indigenous artefacts or sites with significant cultural heritage.

Redesign and documentation was identified by the government and private company respondents as having the highest RII score for frequency and impact. As previously stated within this section and within the literature review, redesign and documentation is very common and is an accepted effect of design variations. No designer within the industry is immune to redesign and documentation changes.

4.4.3 Lowest frequency and impact RII scores

Change to regulations was identified by private company respondents as having the lowest RII score for frequency and impact. As stated previously regulation changes may include changes to government policy, law, code and standards. Private companies see the frequency and impact of such an event having no substantial effect on their business. This view is mirrored by the government respondents for frequency only.

Developing a negative reputation within the industry was identified by private company respondents as having the lowest RII score for frequency and impact. It is known within the industry that design variations are a common occurrence which cannot be avoided. This known fact can attribute to the low RII score provided by private company respondents. Government respondents are shielded from such claims or reputations due to the in house relationship with construction crews and design teams.

From this discussion above a number of conclusions can be determined;

- Government and private company respondents believed a change to project scope or brief was the most frequent client initiated cause.
- Government and private company respondents believed inadequate design documentation was the most frequent consultant initiated cause.
- Government and private company respondents believed redesign and documentation was the most frequent and greatest impact of design variations.
- Government and private company respondents believed change to project objectives was the least frequent client initiated cause.
- Government and private company respondents believed changes of specifications was the least frequent and smallest impact consultant initiated cause.
- Government and private company respondents believed change to regulations was the least frequent other initiated cause.
- Government and private company respondents believed increase in overheads was the smallest impact of design variations.

- Private company respondents believed change to project schedule was the most frequent and largest impact client initiated cause.
- Government respondents believed inadequate design documentation was the most frequent and largest impact consultant initiated cause.
- Private company respondents believed poor quality of work was the most frequent and largest impact contractor initiated cause.
- Private company respondents believed change to economic conditions to be the most frequent and largest impact other initiated cause.
- Government respondents believed social cultural factors to be the most frequent and largest impact other initiated cause.
- Government and private company respondents believed redesign and documentation to be the most frequent and largest impact of design variations.
- Private company respondents believed developing a negative reputation to be the least frequent and smallest impact of design variations.

This section provides a simple analysis of the patterns discovered in the responses from government and private company designers. A number of correlations can be drawn between the two sets of data suggesting that the issues identified are industry wide and are not confined into public and private sectors.

4.5 Assessing the costs imposed on designers

To determine an approximate dollar cost for processing variations, the design variation process outlined in section 3.9 will have to be addressed. Due to simplistic nature of the design variation process within the Sunshine Coast Council and having no formal variation management software the uncaptured costs will be quite small. The project manager, once receiving the variation request from the initiator (usually in the form of an email) will provide the information to the design team leader. Their time spent on a particular project is captured within a time billing sheet which is required to be completed every week. The time sheet contains every project currently undertaken by the council. Users are required to allocate an approximate hourly figure against the projects they have worked on each day. Hourly values placed against projects are conservative estimates.

The department administrator that schedules the project into the design review meeting may also take meeting minutes. The length of the meeting with regards to the variation can vary depending on the scale of the change and participants involved. Once the meeting is complete the meeting minutes are required to be emailed to the participants affected, filed within the project folder system and placed into Council's document management software. The administrative officer does not allocate hours towards a particular project. The time spent completing these tasks are therefore not captured into the total costs of a project. According to the *Queensland Local Government Officers Award,* the hourly wage for a level 3 administration officer ranges from \$30.89 to \$33.27 per hour. These figures are the base wages for the employee and do not consider the overheads of undertaking the work. Overheads may include cost to run computers, using the document management system, paper for minutes etc. The time taken to schedule the project for review, placing documents into the system and sending emails is relatively small. The time spent recording meeting minutes for a project can vary in length with no defined time limit. An estimate for completing the scheduling, filing the minutes into the system and sending an email to the relevant participants is approximately 30 minutes. It can therefore be determined that the cost of processing a design variation is approximately;

$$\left(\$32 \times \frac{1}{2} hr\right) + (\$32 \times time\ spent\ taking\ minutes) + overheads$$

The participants within the design review meeting and surveyors also allocate time spent on particular projects into a time billing sheet.

4.6 Recommendations to limit costs and impacts

Strategies for reducing the costs and impacts of design variations on designers were derived from the case study analysis and the questionnaire survey. The case study investigation identified administration costs that were not captured in the cost of the design variation process. This cost was found to be relatively small in comparison to the overall design and documentation costs associated with variations. Suggesting strategies to reduce this administration cost is not practical due to the small cost and exposure the employee has to the entire variation process. Therefore strategies will focus more on minimising the likelihood and impact of design variations. The main issues identified by government respondents in the case studies and questionnaire survey were change to project scope or brief by the client, inadequate design and documentation provided by consultants, poor quality of work by contractors, social cultural factors and redesign and documentation impacts. The following strategies are recommended:

- Define a detailed and thorough project scope or brief in the early stages of the project. Ensure the brief is reviewed by all internal stakeholders involved in the project. Changes to the project scope prior to the detailed design stage will significantly reduce the impact of changes later on. The creation of a thorough brief may be achieved using the three-step process outlined by the CIDA Project Initiation Guide.

- Select design consultants with a proven record of quality designs and documentation. Additional costs may be incurred by selecting a consultant with a proven track record, but as the saying goes "you get what you pay for". The additional costs will in many cases outweigh the final costs of reviewing, correcting and possibly redesigning a project due to poor design and documentation. If possible provide the consultant with quality assurance documents for which the design is required to meet. Clear and concise communication with the consultant is also crucial for client/designer relations.

- Select a skilled and knowledgeable contractor that is known for quality workmanship. Doing so may incur additional upfront fees. The contractor is required under the contract to perform to a high standard. If rework or demolition of inadequate construction elements occurs, it should not initiate redesign work for the designer. Rework or demolition costs are incurred by the contractor.

- Conduct a thorough investigation regarding possible cultural heritage or indigenous sites within the vicinity of projects. This may identify possible future conflicts. Allowing conflict provisions in the projects estimate will reduce the impact of possible discoveries during the course of construction. Providing a comprehensive public consultation process for larger projects may reduce impacts during the design and construction stages of a project. Keeping the community and stakeholders up to date with major design decisions will reduce risk of possible conflicts.

- Utilise the latest industry software programs to redesign, reproduce plans and update estimates. Design programs within the engineering industry are continually advancing. The majority of a designer's time is spent drafting design plans for construction. The designer's ability to efficiently and effectively rework design plans will reduce the overall time spent on a project. The use of standard drawing templates and drawing elements can reduce the work required by the designer. Many design programs have the ability to produce plan quality construction elements automatically. Utilising these capabilities will reduce time spend on projects, thus reducing design costs.

5.0 Conclusions

The causes, effects and costs imposed on designers due to design variations were investigated and conclusions were drawn accordingly. Recommendations are made to minimise the frequency and impact of design variations using processes outlined in the literature review.

5.1 Achievements

This research project was completed by following the methodologies outlined in section three. The objectives for this research outlined in section one were met despite a number of setbacks.

The case study data made available from the Sunshine Coast Council provided an insight into the problems facing local government designers and ongoing issues facing the industry. A key element in obtaining usable information from the council was the presence of a professional relationship with a number of the designers and the design team leader. The ability to talk directly with the designers of projects was crucial in obtaining the information discussed in the case study analysis.

Questionnaire surveys were provided to industry sources over a short period of time. This situation is not ideal; however was dealt with efficiently with good results obtained. Personal telephone communication with potential private companies helped to portray the importance of the research and the urgency of the information required. A large number of designers and former colleagues also provided completed questionnaire surveys within a short time frame. The information provided was used to compare results of private company responses. This comparison between local government designers and private sector designers sheds light on different opinions and highlight issues that are industry wide. From the results obtained through the questionnaire survey a number of conclusions were drawn. Government and private company respondents agreed that over 50% of design variations are initiated by the client with consultants, contractors and other cause following. A number of correlations were made between frequency and impact of causes affecting public and private designers. Both parties agreed that, change of scope or brief, inadequate design and documentation and redesign and documentation was frequent within the entire industry. They also agreed that changes to project objectives, change to specifications, change to regulations and an increase in overheads were the less frequent and often had the least impact. The areas where the parties disagreed were the frequency and impact of economic and social cultural factors. From this data recommendations were made to reduce the frequency and impact of variations.

5.2 Limitations

The limitations experiences during the course of this research inhibited the objectives stated in the project specifications. The short fallings encountered are identified below.

The original project methodology included obtaining case study data from companies within the engineering and construction industry. The company in question needed to have designed projects of substantial size with significant number of design variations. Access to the projects variation register would be vital to determine the number of variations, causes, costs etc. Access to the company’s designers would also be needed to conduct structured interviews. Gaining access to such companies was difficult. Due to the commercial and sometimes sensitive/confidential arrangements with their clients they were not able to disclose the type of information to third parties. One company showed potential interest in providing research data, but quickly changed their mind once the request for access to their designers and “non-existent” variation register was discussed.

Another limitation was the number of respondents from the private sector interested and willing to complete the questionnaire survey. A number of companies were not interested in any involvement in the research while others accepted the questionnaire but did not respond. On a follow up with those companies it was determined that the respondents did not reply due to time restraints and high workloads at this time of year. Fortunately a large numbers of designers within the Sunshine Coast Council have worked within the private sector throughout their extensive careers. Their experiences and knowledge would have been used when completing the survey.

Another limitation was the relatively simple variation design process within the Sunshine Coast Council. Unlike private design consultants, the majority of the design work is done within the limits of council. This means that communication and administrative costs associated with dealing with multiple external parties is simply not present. None the less, an approximate cost per design variation was derived.

5.3 Further Work

The possibility for further work on the topic of design variations is substantial. Design variations are not going away any time soon and have the ability to inflict additional costs on private design firms and government organisation. Further research may include:

- Investigating design variations from the perspective of the client.

- Investigating design variations using case study data from private design firms. The physical size and budget of projects designed is larger thus typically encountering increased numbers of design variations.

- Investigate the relationship between design variations and RFIs.

- Investigate the relationship between the number of design variations and the type of construction undertaken e.g. commercial, residential, government projects

- Investigate design and documentation quality assurance measures throughout the industry.

- Determine if the implementation of BIM has impacted the frequency of design variations.

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Appendices

Appendix A – Project specification

University of Southern Queensland

FALCULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR:	**Benjamin Steven LIDDELL**
TOPIC:	*ASSESSING THE TRUE COST OF DESIGN VARIATIONS – A DESIGNER'S PERSPECTIVE*
SUPERVISOR:	Paul Tilley
ENROLMENT:	ENG 4111 – S1, 2014
	ENG 4112 – S2, 2014
PROJECT AIM:	This project aims to investigate the effects of variations on construction projects from a Designer's perspective.
PROGRAMME:	**(Issue A, 18 March 2014)**

1) Research background information relating to design variations and the overall cost implications.
2) Evaluate current methods of reducing cost impacts of design variations.
3) Obtain case study data from industry sources, with particular focus on the reasons why design changes are made and the overall cost implications that variations impose on designers.
4) Provide recommendations on how the cost impacts of design variations can be reduced.
5) Submit an academic dissertation on the research and case study findings.

Appendix B – Questionnaire survey

Questionnaire – Accessing the true cost of design variations from a designer's perspective

About the Project

The project involves obtaining questionnaire data from industry sources, with particular focus on the reasons why design changes are made and the overall cost implications that variations impose on design firms. The aims of the research project are:

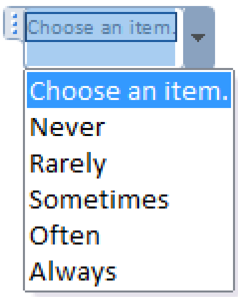
- Identify the causes of design changes/variations on construction projects.
- Identify the effects of variations on designers.
- Identify and quantify the costs of variations imposed on designers.
- Develop strategies for reducing the cost impacts imposed on designers.

Instructions for Questionnaire

Please type response into **red boxes** provided in questionnaire: Example.

Please click on the relevant **green boxes** provided in questionnaire: ☐

Please choose a response from the **blue boxes** provided in questionnaire: Choose an item.



Section A - Profile of organisation/respondents

1) Name of organisation: Enter name of organisation here.

2) Location of organisation: Enter location here.

3) Type of organisation:

Private Company ☐ Government ☐

4) Position in organisation:

Designer ☐ Engineer ☐ Architect ☐ Management ☐ Other: Enter position here.

5) Years of professional experience:

1 – 5 years ☐ 6 – 10 years ☐ 11 – 15 years ☐ 16 – 20 years ☐ 20+ years ☐

Section B – Questionnaire

6) Indicate the frequency and impact of the following *client* initiated causes of design variations:

	Frequency	Impact
Change to project scope or brief	Choose an item.	Choose an item.
Change to project schedule	Choose an item.	Choose an item.
Change to project funding	Choose an item.	Choose an item.
Change to project objectives	Choose an item.	Choose an item.

7) Indicate the frequency and impact of the following *other consultant* initiated causes of design variations:

	Frequency	Impact
Inadequate design documentation	Choose an item.	Choose an item.
Insufficient site investigation	Choose an item.	Choose an item.
Lack of experience or knowledge	Choose an item.	Choose an item.
Changes of specifications	Choose an item.	Choose an item.

8) Indicate the frequency and impact of the following *contractor* initiated causes of design variations:

	Frequency	Impact
Lack of involvement in design (Non D&C projects)	Choose an item.	Choose an item.
Poor quality of work	Choose an item.	Choose an item.
Inappropriate design	Choose an item.	Choose an item.
Lack of experience or knowledge	Choose an item.	Choose an item.
Lack of strategic planning	Choose an item.	Choose an item.

9) Indicate the frequency and impact of the following *other* causes of design variations:

	Frequency	Impact
Change to regulations	Choose an item.	Choose an item.
Change to economic conditions	Choose an item.	Choose an item.

Social cultural factors	Choose an item.	Choose an item.

10) Indicate the frequency and impact of the following effects on *designers*.

	Frequency	Impact
Redesign and documentation	Choose an item.	Choose an item.
Increase in overheads	Choose an item.	Choose an item.
Project schedule delay	Choose an item.	Choose an item.
Disputes and claims	Choose an item.	Choose an item.
Develop a negative reputation within industry	Choose an item.	Choose an item.

11) To the nearest 5%, what proportion of design variations are initiated by each project participant. Please ensure sum of responses = 100%

Clients	Choose an item.
Designers/Design consultants	Choose an item.
Contractors	Choose an item.
Others	Choose an item.
Total / 100	

12) Indicate if the following are captured in valuing design variations and the approximate percentage of total costs. If Yes please provide approx % value.

	Yes or No	% of Total Costs
Variation management administration	Choose an item.	Choose an item.
Design variation review	Choose an item.	Choose an item.
Additional site visits	Choose an item.	Choose an item.
Communication with project participants	Choose an item.	Choose an item.
Documentation stationery (paper, printer ink etc.)	Choose an item.	Choose an item.

13) Do you use BIM? If Yes go to Q14. If No go to Q16.	Choose an item.

14) Please indicate how helpful the following applications of BIM are in the design and construction process:

Visualisation	Choose an item.
Option analysis	Choose an item.
Sustainability analysis	Choose an item.
Quantity survey	Choose an item.
Cost estimation	Choose an item.
Site logistics	Choose an item.
Phasing and 4D scheduling	Choose an item.
Constructability analysis	Choose an item.
Building performance analysis	Choose an item.

Building management	Choose an item.

15) Overall what is your level of agreement for the following statements:

The BIM process helps mitigate variations	Choose an item.
Overall the BIM process improves the design process	Choose an item.
Request for information (RFIs) increase the occurrence of design variations	Choose an item.

Section C – Additional Information

16) Please provide additional information you think will be useful for this study.

Enter response here.

Thank you for supporting my research and participating in this questionnaire. Please save and send to email provided below:

Ben Liddell – 0410 4600 43
w0072424@umail.usq.edu.au