FACTORS AFFECTING BUILDING SERVICES DESIGNS OF CONSULTANTS VS. THAT OF DESIGN & BUILD SUBCONTRACTORS IN MELBOURNE

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ABSTRACT

Building services make up a large portion of a buildings capital cost and are also responsible for majority of its operating cost throughout its life. If designed or installed incorrectly can cause damage, nuisance or death diserving building owners, businesses, developers and main contractors. Building services are being designed by consultant designers or design and build subcontractors and there are some fundamental influences and motivations which may affect the way one designs as oppose to the other.

The aim of this research was to investigate, identify and compare what factors influence a building services design completed by a design consultancy versus a design and build subcontractor in Melbourne, Australia to report on what’s determining the final characteristics and specifications of the designs for each type of organisation.

Through a review of existing literature many aspects that could influence a design have been discovered. There are numerous factors under themes such as procurement, decision making, design aspects and design process. By conducting eight semi structured interviews with four consultant designers and four design and build designers, one from each of the major four building services disciplines electrical, hydraulic, mechanical and fire, and collecting numerical and written qualitative data, this has permitted the comparison of the identified factors between the two organisations to highlight the variances.

The variances signified that consultant designer’s designs appear to be influenced in a larger way by factors such as Communication, Alternatives, Maintenance, Ecologically Sustainable Development / Energy Efficiency, Aesthetics, Whole Life Cost, Redundancy / Back-Up, Safety, Coordination and Standardisation; and design and build designer’s designs appear to be influenced in a larger way by factors such as Capital Cost, Prefabrication, Team Building / Team Work, Relationships, Buildability and Innovation & Creativity.
CONFIDENTIALITY STATEMENT

The author has agreed that all personal and company names of participants in this research will be kept confidential. Confidentiality has been maintained by all participants being referred to as labels e.g. C1 for Consultant Designer Participant 1 and S1 for Design & Build Designer Participant 1.
ACKNOWLEDGEMENTS

I am indebted to many people who have helped and contributed to the preparation of this report during the year it has been in preparation. I give thanks to my supervisor Roger Birchmore and programme leader Kathryn Davies for their leadership and patience. I would like to convey my gratitude to all the participants for their time, patience and honest opinions. Lastly, my appreciation goes to my family, friends and employer for all their support and encouragement.
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GLOSSARY

Back of House: Refers to the rear region of any building type.

Buildability: The term given to how easy or difficult something is to construct.

Building Management System: A computerised system within a building used to control and monitor building services.

Circulation Space: An area of the building used for pedestrian travel.

Design/Bid/Build: The separated procurement system where the project is designed, tendered and constructed in three phases which are completed one after the other. Also commonly referred to as the ‘traditional’ system.

Design/Build: The integrated procurement system where the project is designed and constructed in a single phase.

Duty/Standby: The act of having two exact systems both capable of supplying a 100% of the building service demand, but one operates whilst the other is on standby.

Ecologically Sustainable Development: The term given to a building which aims to meet human needs whilst preserving the environment. Also commonly referred to as a ‘green building’

Front of House: Refers to the front region of any building type.

Green Star: The rating system assigned to measuring how ecologically efficient a building is.

Multi-Disciplinary: A single company which provides services to design multiple building services disciplines.

Prefabrication: The act of constructing building elements or services offsite and delivering it to site complete.

Safety in Design: The act of incorporating safety into a building at the design stage of a project.

Scope of Works: A contractual document that defines the work activities that has been offered and agreed to be undertaken by a company.

Whole Life Cost: An economic assessment of an item considering all significant costs of ownership over its life.
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<td>ACE</td>
<td>Architecture Construction Engineering</td>
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<tr>
<td>BMS</td>
<td>Building Management System</td>
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<td>D/B/B</td>
<td>Design/Bid/Build</td>
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<td>D&amp;B</td>
<td>Design and Build (Same as Design and Construct)</td>
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<tr>
<td>D&amp;C</td>
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<td>ESD</td>
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<td>HVAC</td>
<td>Heating Ventilation and Air Conditioning</td>
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<td>MEP</td>
<td>Mechanical Electrical Plumbing</td>
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<tr>
<td>M&amp;E</td>
<td>Mechanical and Electrical</td>
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<tr>
<td>OH&amp;S</td>
<td>Occupational Health and Safety</td>
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<tr>
<td>RCP</td>
<td>Reflected Ceiling Plan</td>
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<td>Request for Information</td>
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1 INTRODUCTION

1.1 Research Question
The aim of this research project is to pursue and answer the following question…,

“What factors influence a design by a building services design consultancy compared to a design and build subcontractor in Melbourne?”

1.2 Rationale
Building services constitute a significant portion of money within a building. In an average building they account for around 20-30% of the total capital cost, and on buildings that are concentrated in services, such as hospitals and laboratories, building services account for around 40-50%. In addition, they are also responsible for majority of the running costs of a building post construction.

If designed or installed incorrectly, building services can cause excessive amounts of damage, nuisance or even death; disserving building owners, businesses, developers and main contractors and imposing large amounts of unnecessary costs. In the present construction industry with the multifaceted nature of buildings and the high level to which they are designed, it is vital that the building services component is designed and documented to the same high level by expert designers or engineers.

Currently within the construction industry in Melbourne, Australia building services are being designed by either, solely design only consultant designers or design and build subcontractors. Subject to the procurement method of the project, the manner in which these services designers interact in the project is different. For the traditional design/bid/build procurement system, which the construction industry has typically responded to in the past, a design consultant is appointed directly by the building owner, developer, project manager or the project architect. However in the case of a design and build procurement system, a design and build subcontractor is appointed by the main contractor.
Both types of organisations are capable of designing the building services systems, however because of their different positions in the industry and the differing way the two types of companies are structured and function, there are some fundamental influences and motivations which may affect the way one designs as oppose to the other. This is the subject which this research project seeks to answer.

The purpose of this research project was to investigate, identify and compare what factors influence a building services design completed by a design consultancy vs. a design and build subcontractor in Melbourne, Australia. The research aimed to report on what factors are determining the final characteristics and specifications of the designs for each type of organisation.

This research and closing information that comes from it set out to assist people in the construction industry that purchase building services design, such as building owners, developers and main contractors, to make better informed decisions about the nature of the companies they are engaging, the form of the building services design they can expect, and the value of that design.

1.3 Research Framework
This research is categorised under the following chapters…,

- 1 Introduction: Provides the reason, aim and structure of this report.
- 2 Literature Review: To identify prominent factors identified by industry experts that influence a building services design.
- 3 Methodology: The methodology design for this research, including the research method, the design of interview questions, and data analysis method.
- 4 Data: A description and analysis of the collected data through interviews.
- 5 Conclusions: A description of conclusions drawn from data to answer research question.
- 6 References: A bibliography of all sources cited in this report.
- 7 Appendix: Supplementary documents that support this report.

End of Chapter 1.
2 LITERATURE REVIEW

2.1 Introduction
The aim of this research project is to pursue and answer the following question…,

“What factors influence a design by a building services design consultancy compared to a design and build subcontractor in Melbourne?”

To obtain a better understanding of what this question truly entails, the literature found surrounding this topic has been categorised by the following themes. These themes have been identified in the course of reading the literature as areas that are significant, well established and appear to be common topics. These themes have been applied to structure this whole chapter.

- Procurement
- Decision Making
- Design Aspects
- Design Process

The purpose of the literature in this review is not to examine any of the included themes and subthemes in too much depth, but more to identify the prominent factors that have been identified by industry experts that could influence a building services design. There are a lot of factors, and due to the scope of this research and its limited period of time, all factors may not be covered.

Many of the themes and subthemes are directly related and overlap considerably; however this is unavoidable and has been kept to a minimum where possible.

Prior to the examination of literature on the above mentioned themes, it is essential that a definition be provided first. K.C. Lam (2000b) states “As far as building services design is concerned, design can be said to be the concise planning with a purpose and intention of creating the means to provide by electrical, mechanical and equipment for use in buildings”
2.2 Procurement

“Procurement is the framework within which construction is brought about, acquired or obtained.” (Marsh, 2003, p. 1). The subject of procurement and its relation to this research topic is fundamental. It’s fundamental as the main comparison within this research comes about through two different but very traditional procurement systems – design/bid/build (separated), and design/build (integrated). Where services design consultants are typically (but not strictly) appointed in the design/bid/build procurement system and design and build subcontractors (again not strictly) in the design/build procurement system.

Construction industry research in recent years has been largely focused on improving performance from either a management or construction technology perspective. However, as K.C. Lam (2004) identifies, there is a surprising lack of research into the specific area of procurement of building services design and installation, and it has proven difficult to find relevant literature in this area.

With regard to building services and thinking about what makes these opposite procurement systems different and how they influence the way in which services designs are produced. K.C. Lam (2004) mentions that, the design and installation of a building services systems follows the same characteristics of any other engineering type project where specific planning and management is required. However when it comes to deciding on a procurement method in which to acquire the building services system, criteria such as coordination, integration, team building and communication between project personal need to be considered as each will be affected based on the path executed, and the overall success of the project determined as a result. Marsh (2003) presents that “each procurement method available for a project will have different implications for and impacts on, the relationships between client, designers and contractors and on the performance of the project.” (p. 88)

The above highlights that each procurement method selected will have a direct impact on the coordination, integration, team building, communication and relationships of project personal involved with building services. All these criteria will have a bearing on the final outcome of the designs produced, therefore are important to this research.
In order to correctly complete a building services design that will meet the requirements of the client, the project must entail a procurement system which permits the following to take place...,

- Integration with other elements to form a singular system, that is properly planned and co-ordinated for a smooth installation;
- Satisfactory performance in terms of environmental comfort and provision of optimal convenience to users;
- Effective operation of efficiency in both maintenance and energy consumption;
- Cost effectiveness in terms of life cycle costs; and
- A design with necessary levels of flexibility, adaptability, workability, reliability, manageability and safety in mind.

(Marsh, 2003, p. 88)

Based on the points above from Marsh (2003), they are applicable to this research as they provide a form of criteria in which to evaluate both types of organisation against, by establishing the manner in which their designs are being influenced from a procurement point of view. For example, are designers who operate under the separated or integrated procurement systems both achieving cost effectiveness in terms of life cycle costs or effective operation from maintenance? Would both types of designer consider these items? These factors need to be considered.

K.C. Lam (2004) has underlined from research completed in Hong Kong, that presently there are numerous building services procurement issues within the construction industry that need to be considered. These are essential to recognize as the degree in which some of these issues are faced and affect building services design will vary between the differing procurement systems.

- Increasing project complexity with sophisticated building services.
- Increasing client sophistication.
- Fast-tracking pressures on design and construction.
- Separation of design from construction and maintenance.
- Lack of full integration of building services by the design team.
- Lack of effective communication and co-ordination between the key parties.
- Difficulty in managing a large number of specialist contractors by the building work contractors for highly serviced buildings and the approach to co-ordination.
- Inappropriate procurement path for building services.
- Adversarial relationships between members of the building team.
- High cost of co-ordination.

The above mentioned points from K.C. Lam (2004) are applicable to this research as they provide further criteria in which to evaluate both types of organisation against, by ascertaining which of the above issues are encountered, and how they may influence the overall result of the designs from a procurement point of view.

All the previous issues described have been identified as matters which are impeding the performance of building services procurement. K.C. Lam (2004) states, by changing from relationships where project participants are confrontational to ones where participants work as mutual partners, added value can be achieved in building services design and installation; whether it be through the design/bid/build (traditional) or design/build procurement system. Therefore the factor of relationships needs to be seriously considered.

The following sub-sections take an observation of the two most common procurement paths used in industry from a broad construction perspective, however many of the issues and points that are discussed relate directly and impact the design of building services design.
2.2.1 Design/Bid/Build (Separated System)

The separated design/bid/build procurement system is presented by (Masterman, 2002) as one which:

The client appoints independent consultants, on a fee basis, who fully design the project and prepare tender documents upon which competitive bids, often on a lump sum basis, are obtained from main contractors. The successful tenderers enter into a direct contract with the client and carries out the work under the supervision of the original design consultants. (p. 50)

Further to the above, Masterman (2002) presents the following figure illustrating the separated design/bid/build procurement system…,

![Diagram](image)

Figure 1: Contractual and functional relationships, the conventional system of procurement

Referring to the design/bid/build procurement system presented in figure 1, the building service design is undertaken and completed by a design consultant engaged directly by either the client, architect or project manager. During the design phase there is a direct functional working relationship amongst all the designers. The
installation of the building services system is then installed by a domestic subcontractor who is engaged by and solely functions with the main contractor. All communication between the subcontractors and the design consultants must contractually go through the main contractor.

Masterman (2002) discusses that, the separated procurement system is renowned as one where the four main stages of the project are completed one after the other, and that each of these stages are treated individually. Due to this step by step process, the duration of the project is extensive, adversarial relationships form between teams, communication is substandard, buildability suffers, and K.C. Lam (2004) services coordination problems occur. With regard to adversarial relationships, Abi-Karam (1999) comments, that based on history consultants and contractors have never established a relationship where they can work together without confrontation.

K.C. Lam (2004) makes comment that, services coordination under the separated procurement system is more challenging due to the design and construction activities being separated from one another. Marsh (2003) follows by stating, “the designer designs and the contractor builds, with the responsibilities being strictly divided” and that “the building services team is immediately separated – both physically and contractually.” (p. 210). Marsh (2003) further mentions that, as an effect a greater level of coordination is a must and the guarantee that what is designed can actually be built doesn’t exist.

From the above, the separated procurement method has been identified as one which there is adversarial relationships between design and construction, communication is poor, there are issues of buildability and coordination, and level of quality achieved is higher. All of these factors will have an effect on the overall building services designs produced and need to be considered.
2.2.2 Design/Build (Integrated System)
The integrated design/build procurement system is structured as one which “incorporates all of those methods of managing the design and construction of a project where these two basic elements are integrated and become the responsibility of one organisation, usually a contractor” (Masterman, 2002, p. 66).

Further to the above, Masterman (2002) presents the following figure illustrating the integrated design/build procurement system…,

![Diagram](image)

**Figure 2: Contractual and functional relationships, design and build system of procurement**

Referring to the design/build procurement system presented in figure 2, the building services design and installation is undertaken by a design and build subcontractor who is engaged directly by the main contractor. During the design phase there is a direct working relationship amongst all the designers, same as that of the separated procurement system. Once the design team has its design at a stage which is adequate for the installation team, which is not necessarily 100% as the design and installation is overlapped, the design is passed on for installation. All communication between the design and installation teams is internal. K.C. Lam (2000a) presents…,

“Design and Build (D&B) gives a fresh approach for project delivery, it provides the necessary true multi-disciplinary approach and integration because it forms a designer-contractor team at any early stage in the process,
and thus, it vests authority, and so responsibility, for both the design and construction with one organization”.

Masterman (2002) mentions with the single responsibility of design and construction belonging to the contractor, there are less complicated contractual and functional relationships, communication becomes direct permitting mistakes and disputes to be lessened and onerous systems simplified.

From a negative view, Masterman (2002) notes there is a general held view in the construction industry, especially from architects and clients, that the quality and aesthetic value of a building completed under the design and build procurement system won’t produce the same level as that achieved when using other procurement systems, and is better suited to straightforward projects. K.C. Lam (2000a) argues that contractors are very determined by making as much profit as possible and will construct as quickly and cost effective as they can. For this reason architects and clients don’t favour this method so much as they fear quality and aesthetics will suffer as a result. Friedlander (1998) agrees and mentions that the designer working for a contractor on a design and build project can’t be relied on by a client to protect his/her interests as the designer will probably imply a higher level of importance on aspects such as cost and buildability.

Levy (2006, p. 30) comments…,

“One concern voiced by design-build team members is how to develop quality standards during the design and the construction stages. Quality issues during the design stage include: reduction of errors and omissions, coordination of drawings, and avoiding any conflicts between one design discipline and another.”

On the plus side Friedlander (1998) adds that, traditionally design professionals will only provide an average level of service that doesn’t necessarily guarantee a system will work. However under a design and build scenario the designers standard of care changes and they will design and warrant the outcome of the system will be successful.
Masterman (2002) notes the design and build procurement path provides lower costs as a direct outcome of having the design and construction arms working together by producing design drawings that have buildability already incorporated. Rawlinson & Nugent (2007) mention when contractors and designers work together in unison that a greater level of performance will be achieved. K.C. Lam (2000a) says the joint capabilities of the two teams working together will achieve a lot more, and greater level of communication and management will be achieved.

2.2.3 Comparison of Separated & Integrated
Lam (2000) summarises the comparison of both the procurement methods in the context of management of coordination of building services…,

<table>
<thead>
<tr>
<th>Traditional (Separated)</th>
<th>D&amp;B (Integrated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Organization</td>
<td>Integrated design and construction team</td>
</tr>
<tr>
<td>Separation of design from construction</td>
<td></td>
</tr>
<tr>
<td>• Harder integration &amp; coordination of various designers</td>
<td>• Better integration &amp; coordination of all members under one umbrella</td>
</tr>
<tr>
<td>• Difficult to weld the design and construction teams together</td>
<td>• Good teamwork and control with potential long term partnering for future hospital projects</td>
</tr>
<tr>
<td>• Services contractor is not involved in design, and services will have to be coordinated based on contractor’s selection of equipment and plant</td>
<td>• Consultant works with contractors, second coordination after design is not necessary, and both will be involved for detailed design and installation Single point responsibility, contractor must manage all coordination works</td>
</tr>
<tr>
<td>• Coordination is multiple responsibilities (designers and contractors) and allocation of design and construction responsibilities are not always clear</td>
<td></td>
</tr>
<tr>
<td>2. Managerial Issues</td>
<td>Management would be easier due to the integrated team approach</td>
</tr>
<tr>
<td>• Management of separate design and construction teams is difficult</td>
<td>• Coordination must still be managed, but would be carried out by both design and construction teams and the work will be fully completed</td>
</tr>
<tr>
<td>• Management of coordination during design stage is essential, but not fully completed based on ACE condition</td>
<td>• This problem could possible still occur, but D&amp;B directly controls his contractors and work much closer and more efficient</td>
</tr>
<tr>
<td>• Difficult to manage coordination on site with the builder and all subcontractors</td>
<td></td>
</tr>
<tr>
<td>3. Design</td>
<td>• Design must be complete for construction, and both design and construction teams will understand better</td>
</tr>
<tr>
<td>• Fully integrated services and detailed coordinated M&amp;E services drawings are essential, but design is usually incomplete</td>
<td>• Quicker response to coordination problems and solution as the contractor is wholly responsible for design and construction</td>
</tr>
<tr>
<td>• Response to problems and provision of solutions will usually be slow due to separate design and construction teams</td>
<td></td>
</tr>
</tbody>
</table>
4. Contract

- ACE contract for services consultant is a problem, coordination of services is additional duty
- Architect is the lead designer, but coordination of services is passed to his M&E consultant and the main contractor
- Site coordination by all subcontractors but managed and prepared by the main-contractor
- Fosters confrontational attitudes and adversarial working relations due to conflict of interest

- D&B consultant must provide workable drawings, or he will assist the contractor as much as he can
- Both architect and engineers will provide coordinated design and solve coordination problems quickly
- Similar but will be assisted by the M&E consultant and all services contractors
- This problem could possibly still occur, but may be diminished due to the main contractor’s own selected contractors

5. Risk

- In the context of coordination of services, the risk is high as the client is responsible for design, and coordination is a design problem at large

- Builder takes all risks, but subcontractors also take higher risk as the system does not offer good protection in relation to claims for design change and additional coordination works

The above comparison has been kept in its original form as it provides the exact comparison and information required for this research project.

From the Lam (2000) comparison there are several important points which are important to this research. The design and build method appears to offer higher levels of communication and working relationships between members where a partnership is formed, offering better coordination and general integration. It is highlighted that the successful management of the coordination process is essential and must be correctly undertaken at the design stage, and it is just as important under both procurement methods. If incorrectly managed and poorly undertaken, many onsite problems will occur. It is apparent coordination under the traditional separated system is more challenging and requires a higher level of management. Coordination under the design and build is a lot easier due to the joint formation of the design and construction team, but problems will still occur.

Friedlander (1998) presents “The most obvious change distinguishing design/build from traditional design/bid/build projects is that rather than being the owner’s consultant, the design professional is the contractor’s team mate.”
2.3 Decision Making

The theme of decision making has become apparent in the reading of literature as a topic which is important to this research. It’s important as two different types of building service designers are being analysed for the way in which each thinks and makes choices when producing their building services designs. An analysis between a consultant designer and a design and build subcontractor designer.

Maver (1971, p. 154) states

“the science of decision-making is a rapidly growing one and building designers must keep abreast of methodological developments in this field; even more important, however, is the need, which must be met from within the profession, to develop decision-making techniques specifically relevant to the multi-verite problems of the building industry”.

Armstrong (2008) says designs are commenced with primary decision making. It starts with thinking what requirements need to be satisfied. Decision making is defined by Dandy & Warner (1989, p. 214) as “a process whereby one course of action is chosen from a range of alternatives. Decision-making is an essential part of all engineering work, and indeed of professional work generally”. Hatamura (2006) adds that decision making is to choose from numerous selections, where there are many selections possible and the deliberation of each option is needed to set the probability of one option to 1 (100%) and the remaining to 0. It is essentially to choose from many choices.

Hatamura (2006) believes aspects such as experience, preference and the text of handbooks are key drivers of selections made during the decision making process, and that the choices made are heavily influenced by whether the option reflects a previously experienced achievement or failure. Besides experience being the foremost contributor to the thought process, thoughts that come to mind are drawn from personal resources like experience, hunch preference or knowledge.
Hatamura (2006, p. 44) presents the constraints and evaluation that relate to decisions in design. The following figure 3 shows these constraints in the order that they come to the designers mind...

![Figure 3: Constraints associated with design](image)

The above figure incorporates many constraints that would influence the decisions made by a building services designer during the design of system. Therefore this is important to consider.

### 2.3.1 Innovation & Creativity

Marsh (2003) mentions innovation as an aspect of changing an existing system or creating new ones and developing them to increase its efficiency through increasing the output or reducing the demand as required by its end user. Where innovation has an important influence on building services is its need to produce a reduction in capital and life cycle costs and creating a more efficient and cheaper overall system.

Rowlinson et al., (1999) describes innovation as “any idea, technique and/or process, old or new, that is uniquely applied to any aspect of the production of goods and services, such that it either directly or indirectly generates measurable benefits in the form of system or process efficiency, product quality or product type” (Rowlinson, McDermott, International Council for Building Research, & Documentation, 1999).
In the context of building service design, creativity and innovation is thinking outside the typical model to produce new and more efficient building services systems that suit the unique characteristics of the building they are planned for. Designers and their firm’s overall ability to be creative and innovative in today’s industry is particularly important due to the strong influence of environmental sustainability and the need to create resourceful systems. Building services consultant Steve Hodkinson comments “We are usually chosen for a project for the strong creativity and innovation that we bring to the front-end of the job” (Braithwaite, 2010).

Dandy & Warner (1989) note that modern age designers of engineering systems need to research many concepts to solve problems during the design phase and innovation and creativity is a vital aspect. Armstrong (2008) says, this is what differentiates engineering from science. On the flipside, Dandy & Warner (1989) also note, during the creation of a design when a number of varied concepts are being produced, that tried, tested and proven systems must be incorporated also. There is no way to be certain that an innovative and creative design will result in a better system overall, therefore both types of approaches have to be reviewed and compared.

2.3.2 Alternatives
Dandy & Warner (1989) states the greatest design solution will only be discovered by means of creating, comparing and assessing a vast selection of feasible alternatives. This is the most important form of decision making after the task of refining the nature of the design problem. When looking at alternatives, there is never likely to be a single answer on any project and that designers should not research a single solution, but create and compare a wide range. Only after doing so can the best solution be found and applied.

With building services design and the reason that this topic is important to this research is, the approach to identify alternatives by a consultant versus a subcontractor is likely to be different. A consultant is likely to evaluate and compare alternatives based on factors such as performance, reliability, life cycle, quality and brand; and the subcontractor based on factors such as buildability, ease of installation, availability and cost. Of the alternatives identified by any of the designers, the one
that should be implemented should be the one that best matches the client’s requirements, not the designers.

2.3.3 Standardisation
Marsh (2003) mentions, through the implementation of standardisation into a building services system where procedures and products are made typical, benefits are achieved from repeating operations and controlling of spare parts. Standardisation goes against the aspect of creative designs which architects are traditionally fascinated with, however a balance between them should be pursued.

Standardisation is the flipside or opposite of creativity and innovation. There is a premium to pay for creativity, as the more unique the design the more it will cost to design, buy, install and maintain the system. The standardisation of building services originates from not having too many complex interconnected systems that make the overall system difficult to install, understand and keep in working order. Additionally, by keeping products and equipment similar in terms of brand, model, material, finish and installation technique, all contributes to the standardisation of building services. The building services designer needs to keep all these factors in mind.

Marsh (2003) notes, designers typically like to be creative so standardisation usually goes in opposition direction and there’s an opinion that creativity will be lost. It has to be recollected that the correct operation and function of the system is the main priority.
2.4 Design Aspects

Marsh (2003, p. 62) states that “The purpose of design is to construct a workable arrangement of technology that will deliver the technical objectives of the project. Unlike architecture, building services must deliver the described technical performance exactly. To under-deliver leaves the client with a building that is unusable, to over-deliver leaves the client with a building that is too expensive or complex to operate”. Bownass & Bownass (2001) present, meeting the requirements of the client is one of the most fundamental aspects to a design, therefore no matter how well a system functions or how faultless it is, those requirements are always first priority. The optimum design is one which will meet the client’s requirements whilst being compliant with all local statutory requirements.

Marsh (2003) says the client’s requirements for a design will be described briefly in general terms at the commencement of the project. Majority of clients will have common requirements but each placing different levels of importance on each. The objective of the designer’s task is design a system that meets these requirements as closely as possible.

It is presented by Marsh (2003, p. 14) that it is imperative during this stage of design to define exactly…,

- Functional requirements
- Costs limits, both capital and operating
- Quality levels
- Expected maintenance strategies
- Construction time limits

Marsh (2003, p. 120) comments when determining design options for a building services design that an impartial assessment must be undertaken to determine the greatest option that meets the design requirements. Typical criteria which are normal for any project include the following…,

- Durability expressed as probable service life
- Ease of repair
- Ease of replacement
- Energy efficiency
- Environmental issues
- Flexibility (adaptability)
- Lead-time to purchase
- Low maintenance
- Quality
- Reliability

Bownass & Bownass (2001, p. 62) note when looking at the evaluation of design options and determining the best fit solution, success criteria will alter on each and every project although normally the following may be considered…,

- Cost.
- Programme
- Constructability
- Reliability
- Future demand
- Internal environment
- Plant space
- Maintainability
- Sustainability
- Innovation/complexity

Further to and including the above, following are a sequence of design aspects that have been acknowledged in the literature as important factors that a building services designer needs to take into account in the development of a building services design. The connection to this research project for each of the following factors is they have been identified as factors that affect the overall outcome of a design. The underlying question is, which of the designers are more likely to, or to what degree of difference implement and consider each? This list of factors is not exhaustive, but is the key factors that have been acknowledged in the literature. Further factors could be discovered in the latter parts of this research project.
2.4.1 Maintenance
Marsh (2003, p. 64) states…,

“buildings are structurally capable of lasting for over 100 years. No service installation however can feasibly last for more than 25 years because of technological or economical obsolescence. As they are likely to be replaced several times during the life of the building, this must be allowed for”.

K.C. Lam (2000b) notes that if maintenance of building services plant and equipment isn’t considered seriously during the design phase there is a high chance that it will fail to function. A considerable percentage of a buildings operating cost is consumed by the ongoing maintenance of building services. Designers of systems in modern buildings need to embrace the responsibility of incorporating maintenance into their designs as early as possible to permit straightforward maintenance in future.

K.C. Lam (2000b) says one of the primary duties of a building services designer is to incorporate sufficient facilities for services to be maintained in their designs. Designers are responsible for developing systems that require as little maintenance as possible and permitting easy access and maintenance when necessary.

2.4.2 Ecologically Sustainable Development (ESD) / Energy Efficiency
Marsh (2003) states that the design of building services in the current industry has been altered due to sustainability and the aim of achieving lower energy consumption.

The impact a building has on its surrounding environment is an aspect the designers need to consider carefully. Dandy & Warner (1989) present, the resources that are available like labour, materials, energy and money are limited, however at the same time there are the high demands of the public. Therefore building services designs need to be devised to operate as efficiently as possible reducing its demand on scarce resources. Rowlinson et al., (1999) state…,

“there is a growing awareness of the impact upon society’s long-term future of the process of developing the built environment. Concepts of ‘sustainable design’ and ‘sustainable construction’, which are part of a ‘green building’ agenda, are becoming more important to customers and clients who wish to appear supportive of, if not actually to be practising, principals of
sustainability. This requires designers and all parties to the development process to learn from past lessons and best practice principles, to promote and develop a sustainable built environment.”

K.C. Lam (2000b) reports, more and more clients want to be seen to be “green” based on the environmental conservation movement that we have all been seeing. This will have a direct effect on the design building services. ("The importance of building services," 2009) presented, as designers it is important that we make evident a building is using as little resources as possible as energy efficiency and sustainability are imposing this aspect through legislation and energy costs.

2.4.3 Redundancy / Back-Up
Redundancy or back-up systems within building services designs are achieved through either designing in further capacity or stand-by back-up systems, just in case something internal or external to the building fails. This system can be utilised to maintain the building functioning normally whilst the failed primary system is being repaired. These types of systems are particularly important in highly serviced and dependant buildings, such as hospitals, emergency services and civil defence buildings. (K C Lam) presents, “the recommended follow-up management (e.g. back up supply) action for each system risk would include improved design such as using a standby facility”

Maver (1971, pp. 97-98) provides an example of such a system, “breaks in the supply of electricity from the local electricity board are not unknown and in certain building types consideration may be given to the provision of an alternative supply by generating electricity on site.” “In non-commercial building types such as a hospital, the consequences of a break in the electricity board supply may be extremely serious but not easily costed and the designer is presented with a difficult design decision.”

2.4.4 Location & Access to Plant & Equipment
For the location and access of major plant and equipment contained in buildings, there are several items that a building services designer needs to take into consideration. Plant needs to be located so it can be accessed, maintained and serviced. Smith &
Hinze (2009, p. 355) state “equipment is only situated in accessible locations if there are no viable accessible locations”. The extent of floor space assigned to a piece of plant needs to be larger than the size of the plant alone, circulation space around the plant is also required to allow people to easily and freely move around the plant for inspections, general maintenance and services.

If large plant is positioned centrally within a building and can’t be easily manoeuvred throughout once majority of the structure and walls are in place, it will need to be brought to site early; this should be noted on the design drawings so the construction team observe it easily. Smith & Hinze (2009, p. 354) state “large equipment located inside the building must be procured early in the project if they are too large to travel through the building once the walls are constructed”.

2.4.5 Building Codes & Standards

Building codes and standards set out the rules and regulations which all in the built environment must adhere to when designing and constructing buildings fit for human use for all new and refurbishment work. Bownass & Bownass (2001) suggest, building codes are strict documents that are well informed by frequent amendments from research on existing buildings that have shown concerning signs. They are highly detailed documents that all relate to one another and necessitate careful reading to comprehend.

Dandy & Warner (1989, p. 36) state…,

“Many of the constraints which apply to engineering design work are legal-technical, and are quantified in codes of design practice and in legislation. Thus, in the design of a city building, details concerning overall height limitations, minimum water and sewerage requirements, vertical transport, and acoustic and thermal insulation, are usually dealt with in relevant ordinances and building acts, while restrictions concerning fire resistance, allowable deformations, and structural safety may be covered in the structural design standards and appropriate codes of practice”.

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Smith & Hinze (2009) provide a couple of practical examples that are experienced in the field. The first, “If a fire water booster pump is required, the building code dictates that it must be tied to emergency power” (p. 339). The second, “fire sprinklers will be required in many routine, and many obscure, code required locations. Regardless, the fire sprinkler subcontractor must be held accountable for identifying and properly accommodating the requirements in their sprinkler system design” (p. 343).

### 2.4.6 Authorities

Designers must design their design to adhere with the requirements of the authorities within the municipality for which the building is to be constructed. For example, for a hydraulic design of a water supply system, particularly the water metering arrangement, it must be in accordance with the requirements of that water authority. Although this research is Melbourne specific, it’s worth noting that producing a building services design in differing municipalities, e.g. QLD, NSW or VIC can have an influence on the end result due to differing authority requirements. The degree of influence between municipalities will vary substantially.

Smith & Hinze (2009) provide a practical example…,

“Canopies at the exterior of the building will require sprinklers unless they are less than four feet from the innermost face of the building. For example, if a door is set back from the face of building, this dimension is measured from the face of door, not the face of the building. This minimum canopy dimension varies in different municipalities, but four feet is a common maximum” (p. 343).

### 2.4.7 Aesthetics

Marsh (2003) mentions that architects and building service designers must work together to create a combined environment where the aesthetics of the building and the technical performance of the services be considered as one.

In the development of creating a building services design, it is common practice for the designer to work closely and collaborate with the project architect. This close working relationship is important for several reasons; firstly the architect has the best
understanding of the overall shape and function of the building, so he/she is the best person to gain first-hand knowledge from about the project. Secondly, you can ensure services are not designed into positions that are visually unwanted, particularly in showcased parts of the building, creating detriment to the overall aesthetics. And thirdly, the architect is responsible for all space planning, so communication back and forth is required to obtain allocated space for building services plant and equipment.

Smith & Hinze (2009, p. 343) provide a practical example “make special note of these canopy sprinklers and ensure that they are designed and installed in an aesthetically pleasing manner. Exterior canopies are commonly regarded as key architectural elements”.

2.4.8 Cost
Dandy & Warner (1989) highlight that in the evaluation of alternate design options, such as a building services system, attaining the lowest capital cost is one of the most important criteria of all. Looking back at procurement methods, Masterman (2002) comments under the traditional separated procurement method that designers have no incentive to monitor the costs of a design. However cost control under the integrated approach is different as it is the design and build subcontractor who is now undertaking the design.

All the activities and sub activities that a subcontractor undertake are all for the purpose of profit (Teets, 1976), and this includes the activity of design for subcontractors who design in addition. As a result, because profit is a big motivator, perhaps the design is solely shaped to maximise this return. Teets (1976) also indicates all tasks embarked on by a subcontractor are in the pursuit of making as much profit as possible, and revenue is sourced through buying plant and equipment at a lower price than costed. Teets (1976, p. 158) notes, this creates a purchasing profit centre. Purchasing at the lowest price is achieved by...,

- Research of equal substitutes
- Pursuing competitive quotations
- Prudent analysis of quotations
- Effective negotiation of purchases
The link from the above to this research project, from the viewpoint of a design and build subcontractor is, the design will be shaped to specify and install upfront something that is already been researched and pursued for competitive quotes and can be obtained for the lowest price possible. As oppose to the traditional approach where the subcontractor will install only what the design consultant has specified, and it costing more.

Marsh (2003) presents “the costs associated with building services can be divided into two distinct categories:”

- **Capital costs:** all costs incurred with the initial design, procurement, installation and commissioning.
- **Life cycle costs:** all costs involved with operation, maintenance, interim replacement and upgrades, and decommissioning. Energy consumption will be the largest element of this cost.

“There are still a few clients who are interested only in the capital costs but those who have an interest in lifecycle costs are interested in the building at all stages; before its being built, whilst its being built and after it has been built.” ("The importance of building services," 2009).

### 2.4.8.1 Capital Cost

Maver (1971) advises, clients and building services designers that create systems based purely on the attention of capital cost is imprudent. Capital cost in the whole of life aspect is a small fraction compared to that of operating costs and selecting plant based on its efficiency is more rational. K.C. Lam (2000b) states “if it is not possible to convince a client that a high initial capital cost should be expended on the basis of a lifetime of saving or profit from that plant then further choices must be made”. In essence, a cheaper upfront piece of plant or equipment is more than likely to cost more in the long run as it will be less efficient to operate and is likely to fail after a shorter duration of time.
Marsh (2003) states, from a procurement perspective the complexity of the supply chain between the building services designer and the merchant will have a large impact on the capital cost of a project. For every extra organisation between design and supply further margins, percentages and handling costs are added to that price, therefore the lesser number of companies that are involved, the shorter the supply chain is, reducing the overall cost.

A design and build subcontractor has a closer relationship to the supply chain than that of a consultant as the subcontractor is the purchaser and installer of the system. As an outcome, the subcontractor will have closer affiliations with suppliers and agreed price rates for plant and equipment that could already be discounted due to it being used on many other projects – not just one.

2.4.8.2 Whole Life Cost
Marsh (2003, p. 71) describes the whole life cycle costs process for a building services designer as “an economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent monetary value”. Marsh (2003) also note, whole life cost analysis provides a real measure and understanding of a building services systems true cost as the operation and maintenance costs make up ten times the initial construction cost. During the design phase any decisions made on the selection of plant and equipment should be analysed and selected based on total cost. An inclination to select based on capital cost creates a high risk of producing a system that is very costly to run. Lower operating costs should be analysed by designers and presented to clients highlighting the payback period justifying why spending more money upfront is a wise decision in the long run.

2.4.9 Monitoring Systems
With the advancement of technology in the built environment and the pressures of environmental sustainability e.g. green buildings, building services systems are now required to be fully monitor able. Monitoring systems with PC like interfaces need to be incorporated by building services designers to exhibit the quantity of resources,
such as electricity or water being consumed and solar or wind energy being gained at any given time, or over duration of time.

Smith & Hinze (2009, p. 350) mentions “a central computer system called a building management system (BMS) allows the building maintenance staff to monitor, and sometimes control, the HVAC system remotely”, however these systems are somewhat costly to buy and install, Smith & Hinze (2009, p. 350) comment “this expensive management system is particularly common and useful for large campuses such as at universities and major industries”.

2.4.10 Safety
Safety in the design of building services systems is another factor that needs to be considered by building service designers. Health and safety in general is a very highly scrutinised issue which is a major concern for all clients and companies. For a designer, there is no point designing in a system that cannot be installed, operated or maintained in a safe manner – this is substandard design principal. Christensen (2010) note that to create a safer environment which reduces fatalities, injuries and illnesses designers need to incorporate a risk assessment and safety approach into the design stage of a project.

Bownass & Bownass (2001, p. 51) present, “techniques for reducing health and safety risks have a prescribed hierarchy ranging from a safe place (the best solution) to a safe person (the poorest solution)”. Smith & Hinze (2009, p. 371) provide a practical example of safety in design, “for safety reasons, running these services underground is recommended to protect the electrical lines from accidental damage”.

It would be of direct benefit to the design and build company for their designers to implement safety in design, as it is their personnel that need to install the system. If they can perform the installation safer, the less likely they are to place themselves in danger, and as a result improve the companies safety records, which are highly reviewed in today’s construction industry.
2.4.11 Existing Conditions / Background Information

Dandy & Warner (1989) present, it is common at the outset of a new project that the designer will discover there is very little background information that led the project to its current state and needs to be attained before any work can commence. Methods of obtaining that information could be through libraries, text books, encyclopedias, data bases, or going to site and carrying out investigative work.

Bownass & Bownass (2001, p. 47) comment “it is the designers unenviable, although necessary, task to review all the applicable sources of information that impact on design”. Smith & Hinze (2009, p. 381) state “unforeseen conditions, especially in older urban environments, may be encountered when the drawings fail to show previously installed utilities or other past building features that are buried in the ground”. Asbuilt drawings are preferred as they are a lot more accurate than previous design drawings or public records.

2.4.12 Design Risk

Ramroth (2007, p. xii) presents…,

“the business of design is not simple. Much of the process and business of designing the built environment is complicated. Some risks have high probabilities of occurring if not properly managed. Risk management is the art and science of recognizing, preventing, and mitigating threats and uncertainties”.

Dandy & Warner (1989) say risk is unavoidable in the design of building services and the amount of risk that is considered acceptable is the challenging job that designer faces. (K C Lam) agreed, mentioning all building services have risk associated with them and one of the major difficulties for the designer is to manage and eliminate that risk. Marsh (2003, p. 28) comments, “risk management is about quantifying the outcome of alternative decisions, ensuring the decisions being made today will provide a satisfactory basis for decisions tomorrow”.

2.4.13 Prefabrication

Gibb (1999) comments that, prefabrication is a contemporary construction technique available in the current industry that offers great cost effectiveness to clients. Its offers
many advantages over conventional onsite construction such as higher quality, reduced time, lower costs and safer installation.

From a building services viewpoint, Marsh (2003, p. 83) presents “prefabrication and preassembly of building services offers the client and the building services team a number of advantages. These can include the three cornerstones of procurement, cost savings, improved quality and reduced on-site programme times”.

Marsh (2003) states when considering prefabrication that a design and build procurement arrangement will permit the designers and contractor to work closely and produce fully worked and coordinated shop drawings. This needs to be deliberated at the early stage of the project in order for it to be properly implemented and benefited from.

2.4.14 Quality
Marsh (2003) defines quality in building services as a system that meets the wants and needs of the client. The level of the design is measured by the ability of the system to meet its requirements. Marsh (2003, p. 87) presents “as far as building services are concerned, quality is the sum of faultless building services, maintainable services, punctual delivery, value for money, ease of maintenance, reliable systems, and being fit for purpose”.

As previously mentioned under procurement, Masterman (2002, p. 63) presents “the generally held view among clients is that the conventional procurement system provides a high degree of certainty that quality and functional standards will be met.” However it is also mentioned by Marsh (2003, p. 88) that having an integrated team such as that in design and build will “allow for improved co-ordination of services that will deliver a project quicker, cheaper and with improved technical quality”.

2.4.15 Technology & Service Life
Marsh (2003) expressed the technology level of building services in the current industry has increased considerably where a number of complex individual systems are being interconnected. Technology is continually being innovated and outdated by
newer and more complex systems, and the key drivers are sustainability where designers are pursuing lower energy more efficient systems and the market is responding.

Marsh (2003, p. 64) also states “Most buildings are structurally capable of lasting for over 100 years. No service installation however can feasibly last for more than 25 years because of technological or economical obsolescence”. Marsh (2003) describes the service life of services will be determined by obsolescence types such as physical life, economic life and functional life.

2.5 Design Process
As part of the complete design process involved in putting together a building services design, there are a number of key factors that can considerably affect the overall result and quality of the design. Civitello & Civitello (2000) note that, designers have a duty to present their system on drawings in a manner that visibly indicates all the requirements in sufficient detail so the work can be accurately carried out without too much difficulty. The system must also be completed carefully in a coordinated manner without overlap.

2.5.1 Scope of Works
The scope of works on a project in essence is a contractual statement of work in the form of an itemised breakdown that is to be completed by a particular company. Civitello & Civitello (2000, p. 3.48) states “the scope of work that must be completed in order to fulfil contractual obligations must be clearly and completely defined”. Work outside of that scope usually constitutes a variation to the contract. Scopes of work are essential to building services design as each design discipline – such as mechanical, electrical and hydraulic has a scope that they must accomplish. What needs to be avoided is gaps and overlaps in those scopes and a clear demarcation and reference between the differing disciplines on the design drawings. Based on research completed in the UK by Price & Gibb (1996), they concluded unclear definition of design responsibilities as a large contributor to poor design interface, and that a lack of information on drawings was due to contractual ambiguity.
Bownass & Bownass (2001, p. 122) mention “if an area contains services detailed by other disciplines, ensure all their appropriate drawings are cross-referenced on the building services layouts.” Subcontractors will often start and stop their work at connection points identified on the drawings (Smith & Hinze, 2009). Smith & Hinze (2009) provide a couple of practical examples…,

- “While the HVAC will provide their own hydronic piping, they will not provide the condensate or other drains from the HVAC equipment to the nearest drain. The plumbing subcontractor will provide these drains” (p. 333).
- “The fire sprinkler subcontractor will begin their system five feet outside the building. The site utilities subcontractor will provide the water service to this connection point.” (p. 339).

### 2.5.2 Coordination

Smith & Hinze (2009, p. 328) states “the MEP coordination process is an important aspect of every project”. K.C. Lam (2004) notes where building services installations have performed badly overall, uncoordinated designs are a large contributing factor. It is only through the efforts of a team that considers the design needs of one another that a completely coordinated and integrated building services design can be achieved.

K.C. Lam (2004) articulates that you can eliminate majority of coordination issues by creating good designs that integrate and coordinate all of the disciplines during the various design stages. Majority of the coordination issues that arise during the construction phase would not exist if the design documents were fully developed.

Price & Gibb (1996) comment, a failure in design and coordination arises primarily due to a lack of information. The areas where coordination problems usually occur are combined service areas and voids. The problems are single service clashes, clashes with building elements such as the structure, steelwork and ceilings; and services simply not fitting in the zones allowed. The consequence of poor coordination is the construction programme has to be rescheduled and extra costs are suffered.
2.6 Summary
At the beginning of this chapter it was specified that the purpose of this literature review was to identify the prominent factors that have been identified by industry experts that could influence a building services design. As a summary the following are the factors that have been identified, which will be implemented for the subsequent sections of this research project. These factors will drive the data collection process by shaping the questionnaire being used in the interviews.

Procurement Theme….,
- Coordination
- Integration
- Team Building / Team Work
- Communication
- Relationships
- Buildability
- Quality
- Cost

Decision Making Theme….,
- Innovation
- Creativity
- Alternatives
- Standardisation

Design Aspects Theme….,
- Maintenance
- Ecologically Sustainable Development (ESD) / Energy Efficiency
- Redundancy / Back-Up
- Location & Access to Plant & Equipment
- Building Codes & Standards
- Authorities
- Aesthetics
- Cost (Capital & Whole Life)
• Monitoring Systems
• Safety
• Existing Conditions / Background Information
• Design Risk
• Prefabrication
• Quality
• Technology & Service Life

Design Process Theme…,
• Scope of Works
• Coordination

End of Chapter2.
3 METHODOLOGY

3.1 Introduction
The aim of this research project is to pursue and answer the following question…,

“What factors influence a design by a building services design consultancy compared to a design and build subcontractor in Melbourne?”

The purpose of this research project is to investigate, identify and compare what factors influence a building services design completed by a design consultancy vs. a design and build subcontractor in Melbourne, Australia. The research aims to report on what factors are determining the final characteristics and specifications of the designs for each type of organisation.

This research and closing information that comes from it sets out to assist people in the construction industry that purchase building services design, such as building owners, developers and main contractors, to make better informed decisions about the nature of the companies they are engaging, the form of the building services design they can expect, and the value of that design.

The purpose of this research methodology chapter, as explained by Naoum (2006) is, an action plan for getting from here to there, where here is defined as the initial questions to be answered, and there is the conclusion about these questions (p. 37). It contains the nuts and bolts of the research project, as it describes what is to be achieved, how it is performed, and the results to be obtained (Holt, 1998, p. 79).

This chapter has been categorised under the following main themes…,

- Research Process
- Research Design
- Reliability & Validity
- Research Ethics
- Research Limitations
3.2 Research Process
This section illustrates the process in which this project has unfolded and the activities and relationships at and between each of the major steps.

![Research Process Flow Diagram](image)

3.3 Research Methodology
This research project aims to identify the major prominent factors that affect a building services design, then to compare those factors and rank them from most important to least important for each of the building services designers. The rankings will then be examined side by side in order to reveal the significant differences and report on how these differences are determining the final characteristics and specifications of the designs for each type of company. Because this project is made up of these sections, the required data will be created from qualitative methods.

As an overview, the purpose of the research is exploratory as it tests and explores aspects of theory (Fellows & Liu, 2003, p. 11), and is diagnosing a situation (Naoum, 2006, p. 40). The time frame is cross sectional “which are observations at one point in time” (Fellows & Liu, 2003, p. 100). The focus of the analysis is on organisations, as the research question is comparing two different types of organisations. The source of data is primary as it will be collected by the researcher. The impact of the researcher is controlling / managing.
The project is founded solely on qualitative data, collected in a word and a numerical form. For the communicative word approach, the data obtained about the factors influencing a building services design will be “based on personal opinions, perceptions, and feelings (Holt, 1998, p. 83) and “the beliefs, understandings and views of people” (Fellows & Liu, 2003, p. 28). However, due to the analyses of such data being considerably difficult, requiring a lot of filtering, sorting and other manipulations to make them suitable for analytic techniques (Fellows & Liu, 2003, p. 28), numerical responses will also be collected for statistical measures and graphical presentation purposes. For the numerical approach, the approach adopted involves making measurements by collecting data (Fellows & Liu, 2003, p. 97) “measured with numbers, and analysed with statistical procedures” (Naoum, 2006, p. 38).

Through the review of the literature, the prominent major factors that affect a building services design, in general, as recognised by industry experts have been identified. These factors will now be implemented and form the basis for the data collection in the subsequent sections of this research project.

From the literature review, two sources of material have exhibited and determined the methodology in which the numerical measurements are to be collected and based on. The first source of material is Bownass & Bownass (2001, p. 63), from their book on building services design methodology. Presented in Figure 5 is their method of evaluating alternate building services design options at the concept design stage of a project, based on typical criteria. As portrayed, each of the criteria have been allocated a numerical weighting - 1 being of low importance and 10 being of high importance, then multiplied by a further numerical score, again from 1 to 10 for each design option, establishing a total score which highlights the most appropriate design option.
The second source of material, which is similar to the first, is Marsh (2003, p. 121), from his book on Building Services Procurement. Presented in Figure 6 is his method of evaluating alternate building services design options. As portrayed, each of the criteria has been allocated a numerical weighting, the higher the rating the higher the importance - to equal a total value of 100; that number is then multiplied by a further numerical weighting for each design option, establishing a total score which highlights the most appropriate design option.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Scoring</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Ease of repair</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Ease of replacement</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>15</td>
<td>14</td>
<td>x</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Environmental issues</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Flexibility</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Lead-time to purchase</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Low maintenance</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Quality</td>
<td>15</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>x</td>
</tr>
<tr>
<td>Reliability</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>total</td>
<td>100</td>
<td>74</td>
<td>x</td>
<td>69</td>
<td>x</td>
</tr>
</tbody>
</table>

Figure 5: Concept design evaluation matrix

Figure 6: Criteria scoring of all options
What’s important and relevant to the collection of the numerical measurements on this project is the way in which both the above literature sources allocated a weighting or score to each of the design factors to quantify its overall importance on a project.

The key characteristic for the overall design of this project is a survey. When looking at the choice of a research method Fellows & Liu (2003, p. 108) presents “the choice is affected by consideration of the scope and depth required”. The survey method has been selected as this project has a broad and general focus as oppose to a specific deep focus used in a case study. The objective is to sample from multiple design consultancies and design and build subcontractors. Kent (2001, p. 7) comment “surveys aim at providing an accurate picture of the attitudes and opinions people hold as a guide to their likely behavior”. This applies to this research topic as the data that is pursued is the attitudes and opinions of building services designers towards factors that influence the overall outcome of their designs.

3.4 Research Sample
The population involved in this research is all Melbourne based building services design consultancies and design and build subcontractors that generate building services designs. This sample was chosen as the research is being operated from within Melbourne, and Melbourne presently has a bigger assortment of separated design, bid, build and integrated design and build procured projects than any other state in Australia. Holt (1998, p. 91) presents, “a sample is a limited number of items selected from a population” as it is unpractical, time consuming and costly to attempt to research an entire population. Naoum (2006, p. 58) states “the term ‘sample’ means a specimen or part of a whole (population) which is drawn to show what the rest look like” and that “the researcher has to ensure that the characteristics of the sample are the same as its population as a whole”.

To obtain the sample of the population involved with this research project, the sampling methods adopted are judgmental sampling and snowball sampling, which are both non-probability sampling methods. Judgmental sampling has been adopted to hand pick the individuals that specifically meet the needs of this study “by choosing a
list of names and addresses of participants with specific characteristics” (Naoum, 2006, p. 59). Fellows & Liu (2003, p. 141) comment that “judgmental sampling may be used; the judgment, which one hopes will be well informed, of a person is used to determine which items of the population should form the sample”. This method was chosen as it is more suited than probability sampling methods due to the nature of this project, and the judgments being made are well informed. Snowball sampling has been adopted also, where previous participants have referred other colleagues or companies that also fit the needs of this study.

The pursued size of the population was four (4) designers from building services consultancies and four (4) designers from design and build subcontractor organizations, providing data from eight (8) designers in total. The following is a table of all participants contacted, how they were contacted and whether they agreed to participate or not – indicating the response rate. Kent (2001) states “it is seldom that all those contacted agree to co-operate”. The more participants that can be contacted the more accurate and representative the final result is of what’s actually occurring for the entire sample population.

The following figure 7 is a table of all participants contacted, the contact method, whether they participated or not, their discipline and what type of organization they are from…,

<table>
<thead>
<tr>
<th>Participant</th>
<th>Contact Method</th>
<th>Participation</th>
<th>Discipline</th>
<th>Organisation Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phone, Email</td>
<td>Yes</td>
<td>Electrical</td>
<td>Consultant Designer</td>
</tr>
<tr>
<td>2</td>
<td>Phone, Email</td>
<td>Yes</td>
<td>Hydraulic</td>
<td>Consultant Designer</td>
</tr>
<tr>
<td>3</td>
<td>Phone, Email</td>
<td>Yes</td>
<td>Mechanical</td>
<td>Consultant Designer</td>
</tr>
<tr>
<td>4</td>
<td>Phone, Email</td>
<td>Yes</td>
<td>Fire</td>
<td>Consultant Designer</td>
</tr>
<tr>
<td>5</td>
<td>Phone, Email</td>
<td>Yes</td>
<td>Electrical</td>
<td>D&amp;B Designer</td>
</tr>
<tr>
<td>6</td>
<td>In Person, Email</td>
<td>Yes</td>
<td>Hydraulic</td>
<td>D&amp;B Designer</td>
</tr>
<tr>
<td>7</td>
<td>In Person, Email</td>
<td>Yes</td>
<td>Mechanical</td>
<td>D&amp;B Designer</td>
</tr>
<tr>
<td>8</td>
<td>In Person, Email</td>
<td>Yes</td>
<td>Fire</td>
<td>D&amp;B Designer</td>
</tr>
<tr>
<td>9</td>
<td>Phone, Email</td>
<td>No</td>
<td>Electrical</td>
<td>D&amp;B Designer</td>
</tr>
<tr>
<td>10</td>
<td>Phone, Email</td>
<td>No</td>
<td>Electrical</td>
<td>D&amp;B Designer</td>
</tr>
</tbody>
</table>

Figure 7: Research Participants
3.5 Data Collection

The data collection method adopted for this project is interviews. This method has been selected for several key reasons. The main reason being to obtain the required qualitative data such as, the opinions, perceptions, feelings, beliefs, understandings and views of people. “The personal interview is a major technique for collecting factual information as well as opinions” and is a suitable technique “when the research requires an explanation as why the respondents are answering or feeling the way they do” (Naoum, 2006, p. 55). The information provided in the interviews will be logged through the application of written notes, and “with the permission of the respondents, tape recording the interview can be very helpful” (Fellows & Liu, 2003, p. 112) the disadvantage of tape recordings is, “transcribing is lengthy, tedious” process (Fellows & Liu, 2003, p. 112).

There are three styles of interviews, “unstructured, structured and semi-structured” (Naoum, 2006, p. 55). The semi-structured approach has been selected as the most appropriate for this project as it provides the correct basis for obtaining the type of information required. It allows the themes and factors identified in the literature review to be structured and discussed, but also allow the flexibility to enquire or probe the respondent to obtain further or more apprehensible information about the question, or even ask further questions. Fellows & Liu (2003) mention that, in a semi-structured interview the inputs of the interviewer are critical, specially probing as the probes will influence the responses obtained (p. 112).

The interviews took place at the respondent’s place of work purely for their convenience and required a period of an hour to complete. Interviews commenced by explaining who the researcher is, what the research project is about, what the purpose of the interview is i.e. how it is providing the key data required, and how the interview was intended to take place, with an explanation of the questionnaire format.

A structured questionnaire was produced and implemented in the interview “designed to influence the direction of the discussion” (Holt, 1998, p. 87) and obtain the data required. This has been included in the appendix of the report. There are two primary styles of questions that can be asked, open or closed. Fellows & Liu (2003, p. 109) present, “open questions are designed to enable the respondent to answer in full” and
“closed questions have a set number of responses” usually one or two words such as yes or no. Largely open questions have been used to obtain people’s opinions and feelings etc. and a few closed questions have been used to gather some information about the participant.

The questions asked in the interview must be relevant and relate to the research project. “A number of sections or categories for the questionnaire” (Naoum, 2006, p. 66) have been created from the themes and factors identified in the literature review. Naoum (2006) comments, “whatever questions you intend to ask, they should not be arbitrary and need to be based on your literature review” (p. 64). “Questions must be clear and precise” (Fellows & Liu, 2003, p. 151), short but comprehensive, non-leading, single, non-presuming, not be ambiguous, be logical in sequence, and be attractive in appearance (Naoum, 2006, pp. 67-68) to ensure the answers received are the correct ones.

In the construction of the questionnaire not all 30 factors identified in the literature review were carried through, only the 18 most important factors which are listed below and presented in a spreadsheet in the Appendix of the report. Reasons for this were…,

- It would take too much time in the interview to question participants on 30 factors at an average duration of 3 minutes each. This would take an interview of 90 minutes excluding the introduction which is far too long.
- Not all the factors will yield specific data relative to the research. For example the factor of Quality that was identified. This is a very broad topic and would not achieve precise data.
- Some factors were identified twice but under different themes. For example the factor of Coordination was identified under the Procurement theme and the Design Process theme. Therefore one was eliminated.
- Other factors didn’t apply to all services disciplines. For example the factor of Existing Conditions / Background Information applies more to the Hydraulics and Fire disciplines than others.
- The factor of Building Codes & Standards is a must for all disciplines, so no point questioning this factor.
• And lastly some factors would be covered in other factors such as Location & Access to Plant & Equipment. This factor will be covered in other factors such as Maintenance, Safety and Aesthetics.

These factors will drive the data collection process by shaping the questionnaire being used in the interviews, and be used for all subsequent section in the report.

Procurement Theme…,
• Team Building / Team Work
• Communication
• Relationships
• Buildability

Decision Making Theme…,
• Innovation & Creativity
• Alternatives
• Standardisation

Design Aspects Theme…,
• Maintenance
• Ecologically Sustainable Development (ESD) / Energy Efficiency
• Redundancy / Back-Up
• Aesthetics
• Capital Cost
• Whole Life Cost
• Safety
• Design Risk
• Prefabrication

Design Process Theme…,
• Scope of Works
• Coordination
In the structured questionnaire prior to each written response is a numerical rating scale system as pictured in the following figure 8 to allow the respondents to rank the importance of each factor on a scale from 1 to 10, 1 being very low importance, 5-6 being low or high medium importance, and 10 being very high importance. The option of no importance or not applicable is also available. The formatting of the numbering system is deliberate so there is no middle value as “respondents may be tempted to ‘opt out’ of answering by selecting the midpoint” (Fellows & Liu, 2003, p. 147). This system has been chosen to reflect the numerical methods identified in the literature review, and to drive the written word responses. This numerical approach is being implemented to simplify the comparison between design organizations and permit the modeling of the data in graphical forms to visually highlight the key differences. “It is a straightforward means of collecting information and the data can be analysed easily” (Naoum, 2006, p. 73).

| Building Services Design Factor Importance - Numerical Rating System |
|---|---|---|---|---|---|---|---|---|---|---|
| – | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| N/A | V Low | Low | L Med | H Med | High | V High |

Figure 8: Numerical rating system for design factors

To ensure that the questions in the questionnaire are precise, and conform to previous comments about what creates a good question, a pilot interview was completed prior to the actual interviews. Naoum (2006, p. 85) mentions, “a pilot study provides a trial run for the questionnaire, which involves testing the wording of the questions”, ensuring that probing is being employed suitably and that the time required of the respondents is not excessive (Fellows & Liu, 2003, p. 156).

The questionnaire was piloted on a colleague who is currently working as a building services designer. The interview took 65 minutes to complete and the followings feedback and observations were made…,

- Be careful that people don’t side track because interview could take a very long time. Length is already boarder line.
The questionnaire remained as it was, however the above comment was taken on board and the questionnaire was used for all data collection interviews. A copy of the questionnaire can be found in the Appendix section of this report.

Two types of data have been obtained in the interviews, nominal data and ordinal data. “Nominal data tend to be qualitative in nature” (Holt, 1998, p. 101) naming a characteristic and can’t be measured, and “Ordinal data are quantitative in nature” and “is used as a means of assigning order or, ranks to the set” (Holt, 1998, p. 101). Although the data appears to be qualitative and quantitative in nature, it is all qualitative, as the numeric data is purely providing a numbered measure against qualitative data for simplistic analysis and presentation purposes. Therefore overall a qualitative method of data analysis is used, with the support of statistical measures. All analysis should provide a summary of the data that clearly highlights the main trends and differences (Naoum, 2006, p. 98) and be used as “a function of satisfying research objectives” (Holt, 1998, p. 99). “The correct choice of analysis is important because…,”

- Wrong analysis will inevitably lead to wrong conclusions
- Important conclusions may go undetected
- Incorrect conclusions may be drawn

(Holt, 1998, p. 100)

As a result of the questionnaire being structured around themes and factors identified in the literature review and the data being collected in this manner, the data analysis approach for this project is typology, a qualitative approach. Under this approach the data is categorized under the same categories, covering all the participants’ responses without any overlap, and the researcher seeks to establish “relationships between them from the data collected” (Fellows & Liu, 2003, p. 96). This is a thematic style of analysis which will draw common threads from the responses “by examining the raw data to search for patterns” (Fellows & Liu, 2003, p. 162).

To analyse and present the ordinal data collected, statistical methods of analysis have been used. The method adopted is a rank correlation format where the ranking of each factor for each for each discipline for each type of organization is placed side
by side in a table, and the difference is expressed as a numerical weighting. This data is then presented in graphs and tables as “visual aids and diagrams can be extremely helpful in analysing data, as patterns and relationships often emerge” (Fellows & Liu, 2003, p. 163). The difficulty with placing numerical measures against qualitative data is that, even if there is a difference in the values, the significance of that difference is hard to determine, this is what the nominal data explains.

**3.6 Data Management**
The recording of data presented in the interviews was executed with the use of written notes taken by the interviewer, and voice recordings with the use of a digital recorder. This was to ensure all data and footage provided in the interview was captured for analysis.

All hand written interview data was scanned into .pdf (portable document format) and is stored on the researcher’s computer. All interview recording audio files is stored on the researcher’s computer also. The objective is to have all information stored electronically to simplify storage, transfer and use of it.

Additional to electronic data being stored on the researcher’s computer, an up to date copy of all data is kept on an external hard drive and on a secured internet storage website called ‘Dropbox’ for back-up purposes. No one other than the researcher and supervisor have access to any of this information.

**3.7 Reliability & Validity**
Reliability and validity in research is referred to by Denscombe (2007, p. 296) as “the bases for judging the quality of research”. The topic of reliability “concerns the consistency of a measure” (Fellows & Liu, 2003, p. 157) and “if someone else did the research would he or she have got the same results and arrived at the same conclusions?” (Denscombe, 2007, p. 298). This implies will another person reach matching results using the exact same methodology presented in this report.

The reliability of this project has been upheld through the research methodology being peer reviewed by the researcher’s supervisor, and the structured questionnaire data
collection tool being pre-tested in a pilot interview to make certain the questions being asked were appropriate to yield the data required, all in a consistent manner. The interviews are all carried out by the researcher only, following the same structured questionnaire procedure with identical themes, factors and questions. There is no relationship between the researcher and seven (7) of the participants, and the remaining one (1) is a design colleague that is employed at the same company. All interviews have been performed at the participant’s place of work in a meeting room.

Denscombe (2007, p. 296) presents that, the topic of validity concerns “the accuracy and precision of the data” and the “appropriateness of the data in terms of the research question being investigated”. Kirk & Miller (1986, p. 21) comment, research cannot be completely controlled and the form of measurement cannot be totally regulated, therefore all measurement is to some extent uncertain.

The accuracy and appropriateness of the data collected has been upheld through, the research design method selected being the most appropriate in accordance with research methods literature in order to obtain the essential qualitative data required to answer the research question. An interview has been adopted as it best provides the rich data desired and permits the observation of body language. The data collection technique has been structured to accord with methods presented in the literature review and to question and measure all factors identified. Pre-testing of the questionnaire numerical rating system in the pilot interview was carried out to ensure it was accurately measuring and analysing the data in the form that was intended.

Looking at how the results of this project can be generalised to other building services designers outside of the selected sample, there are several differing disciplines when it comes to building services design – mechanical, electrical, hydraulic, and fire and that the factors identified in the literature review could also vary in degree of importance between the disciplines as well as the organisations. Through the use of judgemental sampling the researcher has been able to balance the differing disciplines as much as possible to keep the results general to building services designers overall, as oppose to random sampling where a lot more of one particular discipline could be sampled, decreasing the generalised result of the research.
3.8 Research Ethics

Ethics in qualitative research such as this project are “associated with following ethical guidelines and/or gaining ethics approval from professional or academic bodies before commencing data collection” (Mauthner, Birch, Jessop, & Miller, 2002, p. 1). Before the data collection phase of this project an ethics approval process was undertaken by the researcher and reviewed by Unitec New Zealand to ensure the participants involved were not subjected to any harm and their interests were projected.

McNeill & Chapman (2005, pp. 12-14) present, there are six ethical rules that should underpin research…,

- Research participants have a right to know what the research is about and to refuse to take part. This is informed consent;
- The researcher should not engage in deception. Information must not be kept from those taking part in the research;
- Research participants privacy should be safeguarded as much as possible;
- Privacy must be maintained by keeping the identity of the participant’s secret. Information an individual gives to the researcher cannot be traced back to that individual;
- Research participants should be protected from any sort of physical harm;
- Researchers need to think about legality and immorality. Avoid being drawn into situations where the researcher may commit a crime.

All the above mentioned rules are very important; however the ones which are more prominent to this research project are voluntary participation and informed consent; the researcher not deceitfully withholding information; the physical privacy of the participant not being invaded; and protecting the participants identity. The fifth rule is not a concern as participants are in no way being placed in a situation where physical harm is an issue. And the last rule is not a concern as there is nothing illegal about this research project or the way in which the data is being collected.

Informed consent, voluntary participation and avoiding deception was dealt with by all participants being invited to participate based on being presented a research
briefing letter explaining what the research project was about, what the benefits and risks to them were, allowing them to make an informed decision whether to partake or not. Participants were in no form influenced to participate involuntarily.

The physical privacy of the participants has been respected throughout by allowing them to control the length, time and conditions of their involvement. The time and place of the interviews took place at the convenience of the participant and they were acknowledged for taking time out of their busy timetable to partake in this research.

The participant’s identities have been protected throughout by keeping them confidential by the means of keeping their personal details a secret, thus prohibiting any information collected about them to be tracked back. All interviews were agreed upon and completed under the guarantee that confidentiality would be upheld. An explanation in the research briefing letter provided to participants explained that the data (their information) will be reserved by the researcher, and is only perused by the researcher and its supervisor for the purpose of this research project, and will not be provided to any third parties under any circumstances.

3.9 Research Limitations
There is no system of evaluating the level of bias the participants interviewed have, or the influence their current or previous work may have had on their responses. Participants are being asked to respond at a general level, but they are more than likely to be influenced in their response by their current projects, or the types of projects they have been working on recently.

End of Chapter 3.
4 DATA

4.1 Introduction
The aim of this research project is to pursue and answer the following question..., “What factors influence a design by a building services design consultancy compared to a design and build subcontractor in Melbourne?”

The purpose of this section of report is to present the primary data collected in the interview questionnaires and to analyse and discuss that data all to establish some conclusions which will answer the research question.

As previously described in the methodology section, the data presented has been categorised under the same categories identified in the literature review and used in the interview questionnaire. The data has been analysed using a typology approach where patterns and common threads in participant’s responses have been identified.

Data in the form of direct quotes from participants have been presented, and consultant designer responses are identified by ‘C’ and design and build designers by ‘S’.

This chapter has been categorised under the following main themes…,

- Procurement
- Decision Making
- Design Aspects
- Design Process
## 4.2 Procurement

### 4.2.1 Team Building / Team Work

#### 4.2.1.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Role varies depending on procurement of project. D&amp;C we are involved with construction team and construction of project. Traditional we are number of steps away as we stop at design. Rating higher as we work more on D&amp;C type projects than in the past. Industry in Victoria moving this way. 4 or 5 years ago, rating much lower. D&amp;C projects we provide advisory / review role during construction with closer interaction with construction team providing mid-level team building / team work. Traditional projects rating much lower. Once design is completed handed to main contractor, interaction with construction team distant.</td>
<td><strong>Comments:</strong> Team work important for communication and liaising with the team. Helps minimise the risk of design issues. Team work internally of multi discipline company is very high. Create a design and invite trade contractor to view and have opinion on buildability. Work together with the construction team. Liaise with structural and architectural designers and work well as a team to sort space for services and penetration locations. Meetings onsite take place to discuss design.</td>
</tr>
<tr>
<td><strong>Consultant Designer 3 (C3) - Mechanical</strong></td>
<td><strong>Consultant Designer 4 (C4) - Fire</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> Team building and team work within company is very high as we are multi discipline. Open environment with a lot of discussion with other disciplines, team work effective. Communication with external architect’s not high, more paper driven communication as oppose to verbal which is more efficient, team work not as high. Internal architects, if something agreed verbally, they forget and there’s no paper trail. We work against contractors and argue, going against each other creating low level team building. We work together to solve problems, but we always protect the client against contractors variations. Typical in traditional procurement mode, but team building better in D&amp;B mode.</td>
<td><strong>Comments:</strong> Within our multi discipline organisation, members in group close and others distant based on personalities. Outside organisation relationships level drop. Contractors are distant and team building and team work is low. Team building and team work with trade contractor is good, we work together. If a query from site and I know the person, more likely to get phone call then followed by paper work.</td>
</tr>
<tr>
<td><strong>Design &amp; Build Designer 1 (S1) - Electrical</strong></td>
<td><strong>Design &amp; Build Designer 2 (S2) - Hydraulic</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Team building and team work within our organisation is high, and with other contractor’s. High as we know each other, and know what we all have to do; everyone knows each other’s strengths and weaknesses. Team building and team work affected by how well we know other people. Worked with a company before and get along with them, the rating is high. Familiarity of working with someone makes big difference. Depends on people you work with and their personalities. People with positive personalities good to get along with and job go along smoothly.</td>
<td><strong>Comments:</strong> Team building and team work within our organisation high as we know each other and are one company. Not very high because we don’t work from the same position, design and construction is physically separated, we don’t work in the same office. High level of team building and team work with other D&amp;C companies involved with same project, more than multi discipline type office due to non-coordinated designs affecting own back pocket.</td>
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</table>
People with bad attitude and doesn’t want to work with you, team work is low.

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
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<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comment:</strong> You know many individuals from other companies. You have built a relationship with them over time and get much better cooperation and team building compared to working with contractor or consultant you haven’t worked with.</td>
<td><strong>Comment:</strong> Team work amongst subcontractors on D&amp;C projects very good. They all look after one another. All suffered in the past. Jobs hard enough without fighting amongst subcontractors. Level of team building varies from project to project. Some can be high level and some low. Some main contractors hard to work with and others easy.</td>
</tr>
</tbody>
</table>

Table 1: All Data Collected for Team Building / Team Work Factor

### 4.2.1.2 Analysis & Discussion

![Participant Rating Comparison for Team Building / Team Work](image)

Figure 9: Line Graph Comparing Ratings for Team Building / Team Work

The numerical data presented in figure 9 indicates that D&B designers rated their overall level of team building and team work amongst the project team higher than that over the consultant’s ratings; however the difference in the ratings is small and they appear to be similar.

#### 4.2.1.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. Three of the participants provided the same rating, and the
fourth (participant C2) was an outlier with a higher rating. There is no apparent reason in the data collected why participant C2 was higher than the others.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also. Through observation it appeared the more senior and qualified the participant the better the understanding of matters that were taking place around them and their responses were more in depth.

Consultant designers frequently discussed and responded that the level of team building / team work within their own organisation was high as the structure of their companies are multi discipline where all service disciplines involved with the design of a project are working out of the same office for the same company. C2 commented “team work internally of our multi discipline company is very high” and C3 commented “team building and team work within our company is very high because we are multi discipline in an open environment with a lot of discussion with other disciplines all the time, making team work effective”.

Another commonly discussed topic was the level of team building / team work with the construction team onsite. It was discovered that consultant designers are participating more in D&B type projects now than in the past and this has affected their level of team building / team work overall on a project. C1 commented “rating given higher as we are working on more D&C type projects than in the past as this is the way the industry is moving in Victoria. 4 or 5 years ago, the rating would have been much lower”.

The participants expressed that their overall level of team building / team work is higher on a D&B projects than that on D/B/B projects. C3 stated that on a D/B/B project “we tend to work against the contractors and argue, and it seems we always go against each other creating a low level of team building”. However C3 went on to comment that “team building is better in the D&B mode”. C1 agrees with C3 comments by stating “on D&C projects we provide an advisory / review role during construction and have a closer interaction with the construction team providing mid-
level team building / team work environment. On traditional projects that rating would be much lower. Once design is completed it is handed over to main contractor, making interaction with construction team distant.” With regard to the traditionally procured projects, these comments align with Masterman (2002) where he mentioned that due to the step by step process adversarial relationships were formed between consultants and contractors. Abi-Karam (1999) also stated that based on history, consultants and contractors had never established a relationship where they can work together without confrontation.

Participants C2 and C4 made reference to dealing with trade contractors, or also known as subcontractors for their particular disciplines. They felt that they had a good level of team building / team work in general. C4 mentioned “team building and team work with the fire trade contractor is good, we work well together” and C2 agreed by stating “we create a design and invite the trade contractor to view and have his opinion on the buildability. We work together with the construction team.”

4.2.1.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent. Three of the participants provided the same rating, and the fourth (participant S2) was an outlier with a higher rating. It appears that participant S2 gave a higher rating based on this comment “D&C companies such as ours have a high level of team building and team work with other D&C companies involved with the same project, more so than a multi discipline type office due to non-coordinated designs affecting your own back pocket.” None of the other design and build designers specifically revealed this.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.

Design and build designers frequently discussed that the level of team building and team work amongst their own organisation and with other design and build subcontractors is very good. S2 stated “team building and team work within our organisation is high because we know each other well and are all one company”. S1
agreed with this by commenting “team building and team work within our design and construct organisation is high, and same with the other contractors onsite.”

The main reasons that design and build designers responded this way was because they all felt that they knew one another very well; they had a good understanding of what one another has to do; they recognise that jobs are difficult enough without disputing amongst one another; and that by working together the job could be made more profitable. S4 mentioned “team work amongst all subcontractors on D&C type projects is very good. They all look after one another and stick together. We have all suffered somewhere in the past and jobs are hard enough without fighting amongst subcontractors”. S2 agreed and further mentioned “D&C companies such as ours have a high level of team building and team work with other D&C companies involved with the same project, more so than a multi discipline design office due to non-coordinated designs affecting your own back pocket”. This aligns with Rawlinson & Nugent (2007) comment that, when contractors and designers work together in unison that a greater level of performance will be achieved. It also resembles K.C. Lam (2000a) comments that, the joint capabilities of the two teams working together will achieve a lot more.

Another commonly discussed topic was that the level of team building / team work on a project was directly affected by how well you know the other individuals. S3 commented on his rating by saying “the main reason for that level of team building and team work is you tend to know many of the individuals from the other companies that you deal with. You know who they are and have built a relationship with them over a period of time and hence you get a much better level of cooperation and team building compared to say when you are working with another disciplines contractor or consultant that you haven’t worked with before”. S1 back this up with his statement “the level to team building and team work on each project is directly affected by how well we know the other people. If we have worked with a particular company before and generally get along with them, the rating is high. The familiarity of working with someone before makes a big difference to the level.” This is supported by K.C. Lam (2000a) comment that, organisations under the D&B procurement system created good team work and potential long term partnering for future projects.
### 4.2.2 Communication

#### 4.2.2.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
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<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Regardless of procurement methodology, from a communication aspect, we are very much the in between with architectural, the builder, the trades. We need to be able to interact with all facets. We do a lot of interaction. We utilise tools such as Aconex or Team Builder online document handling systems. We use those processes and tools to coordinate that communication process. We don’t have a simple and fast communication channels. Procedures are never that simple when it comes to procurement, especially with trades and building services. There’s always this gap between the trade contractor and us and the builder. It’s not as simple, seamless and effective as it can be. The gap between us and the contractor is part of the contractual process and level of communication.</td>
<td><strong>Comments:</strong> Without communication you wouldn’t resolve issues. You need to communicate with the rest of the team, internally and externally. Communication is key to answer the problems. We use a lot facilities for communication emails, phones, Aconex, other web based systems. Email is best form of communication. Web based systems are slow, uploading and downloading etc.</td>
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<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comments:</strong> We track all communications between each project member because they may have legal impacts. We tend to keep everything. Communication channels are not simple. We talk to the contractor, give verbal advises on site and follow with a report that goes through the client and to the contractor, but that process would take longer. So not necessarily simple and fast.</td>
<td><strong>Comments:</strong> If you know someone well, you sort it out over the phone, and then sort it in writing. This way it doesn’t become a mountain. RFI’s get interpreted wrong, response is incorrect. Keeps going back and forth and becomes a mess. React better on a phone call than on an email. Over phone you can get a better understanding of the issue or question. Email can be interpreted in different ways.</td>
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<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 3</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> A lot of web based communication such as Aconex. Communication paths too onerous. Used to be just send an email out. Now all protect yourself exercise. A lot of he said, she said. We don’t use web based systems in our organisation, it’s all internal through emails and very straight forward.</td>
<td><strong>Comments:</strong> If low it is because builder is not interested in document flow. If high it is because builder realises and understands coordination is important, and a lot more communication. Level of communication with the use of BIM will increase it dramatically and be much higher.</td>
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<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 4</td>
</tr>
<tr>
<td><strong>Comments:</strong> If you know the team members helps the level of communication. If working with team members from scratch takes time to build relationship and level of communication not as strong from the beginning. Within our organisation high level of communication, better levels of information</td>
<td><strong>Comments:</strong> Everything is on these Aconex’s. Disseminating the information takes time. It’s a cover yourself exercise. By sending you all information you are deemed to know about everything. Web based programmes make communication a lot more complicated and less efficient.</td>
</tr>
</tbody>
</table>
transfer that than to external consultant or subcontractors. Processes aren’t as formal. It comes back to relationships; you are working with people year in year out, it’s easier to transfer that information.

Internally and with other subcontractor’s communication very good and very open. Onsite construction guys call and ask questions. Between subcontractors, quick phone call to resolve something and no contractual dramas in the way.

Table 2: All Data Collected for Communication Factor

4.2.2.2 Analysis & Discussion

The numerical data presented in figure 10 indicates that consultant designers rated their overall level of communication amongst the project team higher than that over design and build designers ratings. The difference in the ratings is moderate and there appears to be a noticeable variance.

4.2.2.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was relatively consistent. Three of the participants are placed within a range of one rating, and the fourth (participant C2) was an outlier with a higher rating. It appears that participant C2 gave a higher rating based on a comment that “without communication you wouldn’t resolve issues” and “communication is the key to answer problems” None of the other consultant designers specifically revealed this.
Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was again mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

A regularly discussed subject amongst the consultant designers was that their rating was based on them having to communicate and interact with a lot of different parties involved with the project. C1 commented “being the services consultant, we are very much the in between with architectural, the builder, the trades. We need to be able to interact with all facets of the equation.” C1 mentioned further “I think we as a consulting group we do a lot of interaction, especially between the builder and the architect and then the trade contractor”. C2 agreed and commented “you need to communicate with the rest of the team, internally and externally. From our opinion communication is the key to answer the problems”. K.C. Lam (2004) made comment within the literature review that effective communication between key parties is a current industry issue and needs to be considered.

Consultant designers spoke about using web based project management tools such as Aconex and Team Builder to communicate with the project team. The general expression was they found it useful as all project information was in the one place, such as project contacts, current drawings and communication records. C2 mentioned “We use a lot of facilities for communication such as Aconex and other web based systems. C1 commented “We utilise tools such as Aconex or Team Binder which is online document handling systems and we use those processes and tools to coordinate that communication process”.

The Consultant Designers discussed that their overall rating was lowered due to communication channels with the contractors being complex and slow, and that this was the case on both D&B and D/B/B type projects. Participant C3 stated “communication channels are not simple. When we talk to the contractor we can give verbal advises on site to make things go faster, but when we come back we will always do a report that goes through the client to the contractor, but that process would take longer, so it’s not necessarily simple and fast.” C1 mentioned that “I don’t believe that we have a simple and fast communication channels. I don’t believe the
procedures are ever that simple when it comes to procurement, especially with trades and building services. From an electrical engineering perspective, I don’t believe it to be the case even on a D&C type role, there’s always this gap between the trade contractor and ourselves and the builder, so I think the 7 rating with all the processes that are put in place. It’s not as simple, seamless and effective as it can be.” With regard to the traditionally procured projects, these comments align with Masterman (2002) where he mentioned that, due to the step by step process, communication is substandard.

Further to and directly related to the previous comments, Consultant Designers talked about how the gap between consultants and contractors that slowed the communication flow was generated by their contractual obligations. C1 said “the gap between us and the contractor is part of the contractual process and the level of communication and how the structure is set for any project team”. C3 made a comment that “we keep track of all communications between each project member because there may be legal impacts if something goes wrong and we might have to dig it up all those communication records, so we tend to keep everything.” This is supported by Marsh (2003) comment that, the designer designs and the contractor builds, with responsibilities being strictly divided” and that “the building services team is immediately separated – both physically and contractually.” (p. 210).

Not a common response among the Consultant Designers, but one that is interesting. If there is a relationship between the Consultant and the other project member sending or receiving the information, it is easier to resolve as there is a more open and relaxed level of communication. Participant C4 talked about “if you know someone well, you sort it out over the phone, and then sort it in writing. This way it doesn’t become a mountain. Problem with RFI’s, if it’s not written properly by the contractor and it gets interpreted wrong, and then interpreted response is sent back incorrectly, and then it comes back incorrectly and it keeps going back and forth and becomes a mess. This is where the phone call makes it a lot easier.”

4.2.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was moderately inconsistent as none of the participants provided the same
rating. However the ratings aren’t totally inconsistent as all the rating fall between 3 to 6, where none of them are excessively high or low.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

Design and build designers frequently discussed from a negative point of view, that a lot of the projects they are involved in are using web based project management tools, such as Aconex and Team Binder. These designers felt the use of these websites lowered their level of communication as it was time consuming and tedious. S1 made comment “a lot of web based communication such as Aconex being used now days. Communication paths these days are just too onerous. Before it used to be just send an email out. Now it’s just an exercise of protecting yourself. A lot of he said, she said, no let’s look back at the communication.” S4 completely agreed and stated “where it’s tough these days is everything is on these Aconex’s and there’s a lot of unwanted information that you receive, disseminating the information takes a lot of time. It is an exercise of covering yourself. Web based programmes make communication a lot more complicated and less efficient.”

Another commonly discussed topic amongst the design and building designers was the level of communication within their own organisations and between other subcontractors. The common theme which was a positive one was, that they don’t use web based project management tools, communication was simple and straight forward, transferring information was easy, and no contractual issues to slow things down. S3 commented “Internally within our organisation there is a high level of communication, a better level of information transfer than say communication to external consultant or subcontractors, processes aren’t as formal, it’s come back down to relationships because you are working with people year in year out its easier to transfer that information.” S1 mentioned “in our own organisation we don’t use web based systems, it’s all internal through emails and it is very straight forward.” S4 further backed this by stating “internally and with other subcontractor’s communication is very good and very open. The onsite construction guys just call and
ask questions. Between subcontractors, quick phone call to resolve something and there are no contractual dramas to get in the way.” This is supported by Masterman (2002) who mentions, with the single responsibility of design and construction belonging to the contractor, communication becomes direct, permitting mistakes and disputes to be lessened and onerous systems simplified. It also resembles K.C. Lam (2000a) comments that, the joint capabilities of the two teams working together will achieve a lot more, and a greater level of communication will be achieved.

Not a common response among the design and build designers, but one that aligns with a comment made by consultant designer C4 in the previous section, that if you have a relationship or know the other person, the level of communication is more open and relaxed. C4 said “similar reasons given under team building, if you know the team members previously it helps the level of communication. Where is if you are working with team members from scratch it takes time to build a relationship and hence the level of communication is not necessarily as strong from the beginning of the project.”
### 4.2.3 Relationships

#### 4.2.3.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Relationships we have are one step away from trade contractor there is always a builder, developer or somebody in between. We have professional relationships with contractors or suppliers. Always a third party between us and end party, so communication pathways we provide always goes through those people. Whilst it as cooperative as possible from contractual means, never a friendly relationship; always contractual matters in place. Very good professional relationships with trade contractors and suppliers.</td>
<td><strong>Comments:</strong> Good team relations on most projects. I build trust between team members, I trust their opinions, and they trust me. That’s the relationships I have with the team members. Working with same people through years and projects in past, we understand level of competency within each other, that’s where relationship gets stronger. With trade contractors relations are good. Attitude when I go onsite and talk to contractors at level they feel comfortable. Sit and talk, opens things makes them relaxed and talk very truly.</td>
</tr>
<tr>
<td><strong>Consultant Designer 3 (C3) - Mechanical</strong></td>
<td><strong>Consultant Designer 4 (C4) - Fire</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> Important to keep your relationship with client and major builders as well. Even with traditional projects which we want to keep, we still want more D&amp;C projects from contractors. It’s marketing as far as I’m concerned. We maintain relationships with anyone who can potentially give us projects, like the client or major contractor or external architect. Relationship building is one of the key values that our company holds. We don’t have direct relationship with the trade contractors. I wouldn’t talk to mechanical contractors directly; always talk through builder.</td>
<td><strong>Comments:</strong> Relationships are very different. Some people you get along with some you don’t. The better the relationship the more honest you can be with the other person. More direct. Work together a lot better. Applies across the board. The better the relationship the better things will work in general. There are people internally of our company that I have low relationships with.</td>
</tr>
<tr>
<td><strong>Design &amp; Build Designer 1 (S1) - Electrical</strong></td>
<td><strong>Design &amp; Build Designer 2 (S2) - Hydraulic</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> Clients we have are long term and we get along very well. We respect and work well with other subcontractors. Internally we have our differences, but generally we get along well.</td>
<td><strong>Comments:</strong> Most teams we work with all work towards same target so it pays to get along. Relationships with people you have worked with previously are better. Ability to have non-working discussion and working discussion helps. Good relationships with our guys and builders and clients. We get repeat business. Relationship with guy’s onsite is working relationship, professional relationship, we all respect one another. We all work for same boss, don’t argue with one another, all working for same common goal. Work with same guys on every project. We know what one another is capable of.</td>
</tr>
<tr>
<td><strong>Design &amp; Build Designer 3 (S3) - Mechanical</strong></td>
<td><strong>Design &amp; Build Designer 4 (S4) - Fire</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> Working with the same people, number of years in the industry you know many of your colleagues. Working with people for a</td>
<td><strong>Comments:</strong> Relationships with clients are exceptional as where we get our work from.</td>
</tr>
</tbody>
</table>
number of years, number of projects.

Knowing people helps maintain good working relationship. Built relationship over many years it helps communication. Just get on phone and ask for stuff and information will flow more freely.

Ringing a consultancy you have never worked with, get on phone and response is who are you, why open up and give you information. Walls and barriers come up and want you to be more formal.

Apply to the guy’s onsite. Work with some on number of projects over number of years, they know me, I know them, so information flow more fluent then someone you never worked with.

Not knowing people, relationship more difficult because trust is not there, it is more contractual. If you know someone, you’ve seen their work, there’s a level.

Relationships internally of our company are very high. We are one big family.

Always have a problem with the main contractors. Us and them mentality.

Subcontractors it is fine, you go have a beer with them type relationship.

Table 3: All Data Collected for Relationships Factor

<table>
<thead>
<tr>
<th>Participant</th>
<th>Consultant Designers</th>
<th>D&amp;B Designers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Mechanical</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Fire</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 11: Line Graph Comparing Ratings for Relationships

The numerical data presented in figure 11 indicates that consultant designers rated their overall level of relationships amongst their project teams higher than that over the design and build designers ratings; however the difference in the ratings is small and they appear to be similar.
4.2.3.2.1 Consultant Designers
Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. All four participants provided a rating within a band of 7 to 8 and there are no outliers.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There are very few common responses as most participants had their own point of view providing varying responses.

A common response amongst the consultants lowering their ratings was, they felt there is a gap between them and the construction team, relationship wise, and this was due to contractual reasons and the nature of their engagement where they always had to deal through someone else. Participant C1 mentioned “the relationships we have are always one step away from the end trade contractor because there is always a builder, developer or somebody in between.” C3 followed this by stating that “in many cases we don’t have direct relationships with the trade contractors. I wouldn’t talk to my mechanical contractors directly; we always talk through the builder”. C1 also said “whilst it might be as cooperative as possible from contractual means, it’s never a friendly relationship, there’s always the contractual matters that’s in place.” These comments align with Masterman (2002) where he mentioned that due to the step by step process adversarial relationships were formed between consultants and contractors.

On the flipside of the above, some consultants feel they still have good relations with trade contractors; they work closely with them and have a good open working relationship. Participants C1 and C2 commented that they still had good professional relationships with the trade contractors for their particular discipline. C2 voiced that “with trade contractors my relations are good. I sit with them and talk which opens things and makes them relaxed and talk very truly.” C1 also mentioned “as engineers we have very good professional relationships with all trade contractors”.

A couple of comments that weren’t common but were very interesting as they raised ratings for two participants were. C2 mentioned that “working with the same people
through the years and projects in the past, we understand the level of competency within each other and that’s where the relationships get stronger”.

C3 commented rating was raised as relationships with clients were highly regarded as it was a company key value that was installed within designers. C3 said “one important thing is to keep your relationship with the client” and that “relationship building is one of the key values that our company holds”. Participant C3 did say that he thought it was a marketing tool; C3’s actual words were “it’s really a marketing issue. We try to maintain relationships with anyone who can potentially give us projects, like the client or major contractor or external architect”.

4.2.3.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent. Three of the participants provided ratings within a band of 6 to 7, and the fourth (participant S4) was a minor outlier with a lower rating of 5. It appears that participant S4 gave a lower rating based on this comment “we always have a problem with the main contractors. There is a us and them mentality”. None of the other design and build designers made this comment.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.

Design and build designers frequently discussed that the relationships amongst colleagues in their own organisation was very good. Majority of the individuals have worked with one another over and over on different projects so have developed very good personal and working relationships. They all realise they work for the same employer and work together effectively to achieve the same outcome. S2 made comment that “we all have respect for one another. We are all working for the same boss, so we don’t argue and work for the same common goal. We work with the same guys on every project and we know what one another are capable of.” S4 mentioned “relationships internally of our company are very high. We are one big family”. S3 said that “I have worked with some of our guys on a number of projects or over a number of years, they know me and I know them”. Masterman (2002) mentions, with
the single responsibility of design and construction belonging to the contractor, there are less complicated contractual and functional relationships. K.C. Lam (2004) states, by changing from relationships where project participants are confrontational to ones where participants work as mutual partners, added value can be achieved in the design and installation of building services.

Another commonly discussed topic was that design and build designers felt they had good relations with their clients. These relationships were highly regarded as they are the source of their work. S4 commented “relationships with our clients are exceptional as that is where we get our work from”. S2 said that “we have good relationships with our clients, we get repeat business.” S1 stated “clients we have had are long term and we get along with them very well”.

Participants S1 and S4 made reference to their relations with other subcontractors and commented that this lifted their ratings. S1 said that “we respect and work well with other subcontractors”. S4 also felt this way and mentioned “with the subcontractors our relationships are fine, you have a beer with them type relationship”.

The previous common responses align with literature from, Marsh (2003) who stated that “each procurement method available for a project will have different implications for and impacts on, the relationships between client, designers and contractors and on the performance of the project.” (p. 88)

Further to and directly related to all the previous comments, design and build designers discussed that their relationships with anyone involved on a project was better if they knew and had worked with that individual before. It was better because there is a greater level of trust and understanding of one another, and as a result information flow is greater. S2 stated that “relationships with people you have worked with previously are better. Being able to have a non-working discussion as well as a working discussion definitely helps. S3 also said “just generally knowing people helps maintain a good working relationship. Having built up a relationship over many years it helps communication because you can just get on the phone and ask for stuff and the information will flow through more freely.”
S3 further revealed that, where there is no relationship previously, where you are working with someone new, there are generally more barriers as people tend to be more contractual. S3 said specifically “if you are ringing a consultancy that you have never worked with before, you get on the phone and the response is who are you, why am I going to open up and give you the information you want. The walls and barriers come up and they want to be more formal. By not knowing a person the relationship is more difficult because the level of trust is not there, hence it’s more contractual”.
## 4.2.4 Buildability

### 4.2.4.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> The industry driven by cost. Buildability directly related to financial cost. If project is from a buildability perspective easy and can be done with minimum hassle, results in better financial outcome. Driven by financial means to ensure procurement methodology - materials, product can be easily done, and then turns into better, easier buildable product. We always look how easily it can be procured and how quickly the trade contractors can install it. We look at items that can be procured easily within Australian market, lead time issues, off the shelf.</td>
<td><strong>Comments:</strong> Very important the buildability when you do a design. When I draw a line I make sure it’s possible to build. Common sense, there things involved with plumbing design, the material and requirements of installation, if you have that knowledge, then have an understanding. Go onsite, evaluate the situation and then think will it work, be possible, cost effective, easy to assemble, put together. I go onsite and sort something out. The plumber says, doesn’t work, too hard to put this thing together, there are obstacles in the way, not enough fall, not enough room. It happens.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> We are improving. Few years ago I was a graduate, we design something had a lot of problems during the construction, clashes here and clashes there, the structure and mechanical needed to be redesigned. We are starting to Revit a 3D modelling tool; this will avoid all those clashes. We go onsite twice, once half way through when nothing concealed, see what’s going on behind the ceilings and walls, and second time at completion before handed over and we do tests. In first visit we see real practical side of project, how installed. Incorporate that into future design. Making observations and incorporating lessons learnt into future projects.</td>
<td><strong>Comments:</strong> Buildability, we allow for it, don’t always get it right, it changes. Fire worst affected, mechanical get ducts wrong, duct shifts and affects sprinklers. What we design and coordinate is different to what gets constructed. There are always coordination issues onsite. Our fire drawings aren’t bad. Because of my experience and we over accommodate. For buildability, we have to assume the worst case. Revit is increasing level of buildability because it is all being done in 3D. My experience plays big factor in level of buildability. Learning from mistakes made.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> We work with other subcontractors. It’s the coordination of buildability, that’s the big one. Our buildability is good. Happy with designs we produce. It’s through trial and error of other jobs, what’s been good and what’s been bad and what’s worked. It’s often on jobs we try new things. If you get something wrong you don’t do it again. You always keep developing.</td>
<td><strong>Comments:</strong> If we can’t design buildable, guys can’t work. That’s the idea of D&amp;C; design it so it is able to be installed. The knowledge of our team, all been there and done that. They know, they visualise the installation, from trade experience. Direct input from construction team, because if it’s not buildable they let you know. Feedback from site is key. You get that feedback from the guy’s onsite.</td>
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<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Full D&amp;C contract, we are designing, our team is installing, it is high buildability</td>
<td><strong>Comments:</strong> We have good people; they are good at their job and know what they are doing. There</td>
</tr>
</tbody>
</table>
Table 4: All Data Collected for Buildability Factor

4.2.4.2 Analysis & Discussion

The numerical data presented in figure 12 indicates that D&B designers rated their overall level of team building and team work amongst the project team higher than that over the consultant’s ratings; however the difference in the ratings is small and they appear to be similar.

4.2.4.2.1 Consultant Designers
Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. All four participants provided a rating within a band of 7 to 8 and there are no outliers.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was again mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.
It was frequently discussed by the consultant designers that their ratings were increased as they recognised the level of buildability of a design and its financial successffulness were connected. That if a design was unbuildable there would be significant cost implications. Participant C1 mentioned “if the project is from a buildability perspective easy and understood and can be done with minimum hassle, directly results in better financial outcome”. C2 said that “you evaluate the situation and then you think it is cost effective”.

Buildability ratings were increased by consultant designers through checking and ensuring the product and materials that are specified on the drawings can firstly be procured and secondly be installed easily. C1 commented that “we would look at items that can be procured easily within the Australian market, look at lead time issues, off the shelf. We tend to always look at it from a point where how easily it can be procured and how quickly the trade contractors can install it”. C2 statement aligns that “you evaluate the situation and think will it actually work, will it be possible to do it, is it easy to assemble, put together”.

Consultant designers discussed that the level of buildability of a design was directly affected by how well the coordination of a design had been completed, and how well the other disciplines designs had been completed. Designer C4 said “we don’t always get it right, because it changes. Fire are worst affected, because mechanical get their ducts wrong, the duct shifts and affects all the sprinklers. What we design and what we coordinate with is different to what actually gets constructed. There are always coordination issues onsite with any change that occurs. C3 presented that on previous projects that there were “a lot of problems during the construction phase, clashes here and clashes there, the structure and mechanical all needed to be redesigned.

This reflect comments by K.C. Lam (2004) that, services coordination under the separated procurement system is more challenging due to the design and construction activities being separated from one another. Marsh (2003) follows by stating, “the designer designs and the contractor builds, with the responsibilities being strictly divided” and that “the building services team is immediately separated – both physically and contractually.” (p. 210). Marsh (2003) further mentions that, as an effect a greater level of coordination is a must and the guarantee that what is designed
can actually be built doesn’t exist. Masterman (2002) commented, the separated procurement system is renowned as one where the four main stages of the project are completed one after the other. Due to this step by step process buildability suffers (p. 53),

Further to the previous comments, consultant designer added that buildability was improving due to the introduction of 3D modelling and virtual construction tools such as Revit MEP and Navisworks. These software tools are being used by consultant designers to coordinate differing services and design out clashes prior to the commencement of construction. C3 told that clashes will be reduced and buildability increased as “we are starting to use Revit a 3D modelling tool, this will avoid all those clashes”. C4 agreed by mentioning “Revit is increasing the level of buildability because it is all being done in 3D”.

Other factors that lifted consultant’s ratings for buildability was they are getting to site more during the construction period of a project and can observe any buildability issues, and they can also incorporate more buildability into their designs as their experience is increased and they learn from their mistakes. Participant C3 noted “we normally go onsite twice, once at half way through when nothing is concealed so you can see it and what’s going on behind the ceilings and the walls, and the second time is at completion just before it is handed over and we do some tests. In the first visit we can see the real practical side of the project, how it is being installed. Then incorporate that into our future design. By making observations and incorporating lessoned learnt into future projects”. C2 said “I occasionally go onsite and sort something out and when the plumber says, mate just doesn’t work, too hard to put this down or put this thing together, or there are obstacles in the way, we don’t have enough fall, haven’t got enough room. It does happen”. C4 commented that “my experience plays a big factor in the level of buildability. Learning from mistakes made”.

### 4.2.4.2.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was reasonably consistent. All ratings given are placed at the higher end of the rating scale between 7 and 10. Participant S1 had the lowest of the ratings and was
the only design and build designer to rate lower than the opposing consultant designer, however there is no apparent reason why this is the case.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

Design and build designers often talked about buildability in the sense that it was one of the main reasons for being a design and build company. The designs are being produced to primarily assist the constructors of the same company to install their service as quickly and as easily as possible. S3 mentions “for a full D&C contract where we are designing and our own team is installing, it is a high buildability because we are obviously aiming design to something we know we can build. It would be pretty embarrassing for our company as a designer if we designed something if our own guys can’t build. It defeats the purpose”. S2 agreed and stated “if we can’t design buildable, guys can’t work. That’s the idea of D&C; design it so it is able to be installed”. This aligns with Masterman (2002) who commented, the design and build procurement path provides lower costs as a direct outcome of having the design and construction arms working together by producing design drawings that had buildability already incorporated.

Another commonly discussed topic that raised design and build designers ratings was, that having a trade background or experience helped with creating designs that are buildable. Designer S2 mentioned “the knowledge of our design team that there all been there and done that. They know, they can visualise the installation from trade experience. S4 also said “we have got good people with trade experience, they are good at their job and they know what they are doing”.

Design and build designers felt that receiving feedback from the installers onsite was a big contributor to the buildability level of their designs, and that have a close working relationship really helped. S2 noted “it’s the input from the construction team, because if it’s not buildable they will let you know. The feedback from the site is key and buildability is high because you get that feedback from the guy’s onsite.”
S4 followed this by saying “there is feedback from the installers; we talk to them with regard to what is the easiest, quickest and safest way of installing”. This reflects a comment made by K.C. Lam (2000a) that, “Coordination problems would still exist, but to a lesser extent in D&B due to the integrated nature of design and construction”
### 4.3 Decision Making

#### 4.3.1 Innovation & Creativity

#### 4.3.1.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> Always look even with a standard design; try to make as efficient as possible and creative as possible. Always driven by the developer and the brief and a cost. Try pushing boundaries and thinking outside the box. Something to do with energy efficiency as one of the key items now. As a company one of our key things is innovation. If client doesn’t want something outside of the box and innovative we look at a standard design solution. Always try to make as energy efficient as possible within a standard design. 9 on an ESD type project and 4 for a bare bones standard type project.</td>
<td><strong>Comments:</strong> Requirement of the authorities and of the standards. Cannot go out of those limits. Have to follow those guidelines. Got to be innovative to bring solutions, don’t just photo copy the last job, have to find or do something new that will be the best solution for the job. There is nothing wrong with repeating good systems, if it is proven, if it works. Follow the architect to be in line with the overall design of the building with the latest technology. Be aware of what’s happening with products in the market to utilise it and bring it in to suit the demand.</td>
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<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 4</td>
<td><strong>Rating:</strong> 4</td>
</tr>
<tr>
<td><strong>Comments:</strong> Common for traditional engineering. We follow existing, because gives us the least risk. That is past experience. If something works on one job, we will use the same system on the next job. We try new systems. Do cost estimates and present to the architect or client, but got turned down they are worried about the risk cause we haven’t done this system before. And cost wasn’t so convincing. We look at more innovative systems, but we find all the time we spend on them is a waste. It just turns out to be a no go. We have to go back to those traditional systems. Attend seminars for all new systems and technology and adapt our in-house standards to for this new technology.</td>
<td><strong>Comments:</strong> Low rating, very little people want to take risks. Reasons are because of risk. That is a general consensus within our company and the client. Always stick with tried and tested systems. Innovation and creativity cost more money. You’re always a prototype; therefore client has to give the consent for it. This is not easy to get.</td>
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<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 9</td>
</tr>
<tr>
<td><strong>Comments:</strong> Can keep designing the same thing over and over again, but technology does not allow you to do that. Keep up with technology. If you don’t someone else will. If someone is doing something better, you got to go with them. Important with regard to keeping up with the market and what’s available.</td>
<td><strong>Comments:</strong> Cost efficiency and cheaper alternative. There’s always new products, new systems. Keeping up with technology. Energy efficiency. Save heat losses, trying to offer the client some cost savings on running costs. To be market leader in D&amp;C projects. Clients see you coming up with something new and clever systems saving them money. Important to be seen as an innovator and industry leader.</td>
</tr>
</tbody>
</table>
Design & Build Designer 3 (S3) - Mechanical
Rating: 4
Comments: Focus more on fit for purpose, buildability, functional those types of things, rather than innovation or creativity.
Not risk takers; designs that are more main stream to make easier for our guys to build. Levels of construction become more difficult and hence there is more risk that we don’t build it right and there are more chances of cost blow outs. Because we dive into areas where ours guys onsite aren’t experienced with.

Design & Build Designer 4 (S4) - Fire
Rating: 10
Comments: Get the jump on everyone all the time. Got to look how you can make it better, more efficient and cheaper.

Table 5: All Data Collected for Innovation & Creativity Factor

4.3.1.2 Analysis & Discussion

Participant Rating Comparison for Innovation & Creativity

![Figure 13: Line Graph Comparing Ratings for Innovation & Creativity](image)

The numerical data presented in figure 13 indicates that design and build designers rated their overall level of importance applied to innovation and creativity in their designs higher than that over consultant designer’s ratings. The difference in the ratings appears to be small besides participant S4 who is an outlier. There is no obvious reason why participant S4 is higher than the others.

4.3.1.2.1 Consultant Designers
Examining the numerical data (ratings) provided by the consultant designers, the result was relatively consistent. Two of the participants provided the same rating as each other, and the remaining two participants provided the same rating as each other.
There is however a difference of 3 ratings between them which is interesting. It appears that C1 and C2 gave the same rating because they work for the same organisation, and C3 and C4 gave the same rating because they work for the same organisation. This has occurred due to different company structures and key values affecting the way the participants operate. C1 made comment that “as a company one of our key things is innovation” and participant C4 said “the level of innovation is a general consensus within our company”. This aligns with comments in literature review that, designers and their firm’s ability to be creative and innovative in today’s industry is particularly important.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was again mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

Participants C1 and C2 who both providing a rating of 7 commonly responded that innovation and creativity to them was important and that they would always look to be innovative and creative where possible on a project, even if it was a regular stock standard project. C1 stated that “we would never aim as low as very low. We always look, even with a standard design, to try and make it as efficient as possible and be creative as much as possible. C2 mentioned “you got to be innovative, you have to bring solutions, don’t just photo copy the last job; you have to find or do something new that will be the best solution for the job.”

Following the above and lowering ratings for consultant designers, it was discussed among all participants that repeating previously used systems that had been implemented and proven in the past was important. C3 said “if something works on one job, we will use the same system on the next job.” Participant C2 agreed “there is nothing wrong with repeating good systems, if it is proven and if it works.” Reasons given for repeating previously used systems was it provided the least risk. C4 mentioned “very little people want to take risks”. C3 explained “we want to try new systems. We did some initial cost estimates and try to present this to the architect or to the client, but it didn’t get through, it got turned down as they are worried about the risk because we haven’t done this system before. And also the cost wasn’t so
convincing. We try to look at more innovative systems, but we find all the time we spend on them is a waste. It just turns out to be a no go. We have to go back to those traditional systems.” These findings reflect comments by Dandy & Warner (1989, p. 37) that, during the creation of a design when a number of varied concepts are being produced, that tried, tested and proven systems must be incorporated also. There is no way to be certain that an innovative and creative design will result in a better system overall, therefore both types of approaches have to be reviewed and compared.

Further reasons provided for steering away from innovation and creativity from participant C4 was “it costs more money. Your always a prototype, therefore the client has to give consent for it, but it’s not easy to get.” Participant C1 follows this by stating “if the client doesn’t want something that’s outside of the box and innovative then we would look at a standard design solution.”

A regularly discussed topic that raised ratings for consultant designers was it is important so they are aware of the current market and the technology available. C3 said that “we attend seminars for all new systems and technology.” C2 commented “we have to be aware of what’s happening with products in the market to utilise it and bring it in to suit the demand.”

An uncommon but interesting point raised was that ESD and energy efficiency are drivers of innovation and creativity. Participant C1 stated “there are projects where we always try to push the boundaries and think outside the box, and from electrical engineering it would be something to do with energy efficiency as it’s one of the key items now.” With regard to ratings, participant C1 said “I would be a 9 on ESD projects and a 4 on a standard project”. This reflects a point in the literature review that, innovation and creativity in today’s industry is important due to the strong influence of environmental sustainability.

4.3.1.2.2  Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was very inconsistent as none of the participants provided the same rating and the ratings ranged from 4 to 10. Participant S3 was an outlier in this data set with a low rating of 4. It is obvious from this participants comment’s why this is the case.
S3 stated that “the focus is going to be more on fit for purpose, buildability, functional, those types of things rather than trying to be innovative or creative.” S3 further mentioned that “we are not risk takers; we implement designs that are more main stream, which makes it easier for our guys to build.”

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

A regularly discussed topic that raised ratings for design and build designers was that innovation was considered as being important with regard to keeping up with current technology available in today’s market. S1 commented that “we can keep designing the same thing over and over again, but technology doesn’t allow you to do that. We must keep up with technology.” S2 agreed by mentioning “there’s always new products and new systems, we must keep up with technology.”

Further to and directly related to the previous comments, design and build designers discussed that keeping up with innovation was a must to stay with or ahead of their competitors and be a market leader. S2 said “important to be seen as an innovator and industry leader”. S1 mentioned “if you don’t someone else will. If someone is doing something better, you got to do with them”. S4 stated “you got to try and get the jump on everyone all the time”.

Another commonly discussed topic raising ratings was that innovation was important to create more efficient and cheaper running systems. Participant S2 commented “a big thing is energy efficiency and trying to offer the client some cost savings” S4 stated something similar that “everything you do, you got to look at it and think how you can make it better, more efficient and cheaper.” This supports Marsh (2003) statement that, where innovation has an important influence on building services is, its need to produce a reduction in capital and life cycle costs and creating a more efficient and cheaper overall system. Rowlinson et al., (1999) also described innovation as a system that “either directly or indirectly generated measurable benefits in the form of system or process efficiency”.
### 4.3.2 Alternatives

#### 4.3.2.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> We test internally, process tests a design against another, with electrical engineering, there’s more than one way to a solution. Test a concept design or schematic design, we ask engineers for an alternate process or alternate outcome in getting to end point, so we test to check design is correct, the financial constraints within design are appropriate, and the buildability. Can I do a design and another alternate be more affective, buildable and cheaper.</td>
<td><strong>Comments:</strong> New project at concept stage you give concepts to the client, I will do this way or this way. Give alternate solutions to advise system one is this, the advantages and disadvantages, but system two is this which give these advantages, and make a recommendation. When you give an advice there it is always based on financial, buildable or durability perspective.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 4</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comments:</strong> In mechanical do a lot of the time. Many different systems we can choose from. We compare the initial cost and operational cost and give rating of each, then make recommendations in our report to client; we recommend this system because of these comparisons.</td>
<td><strong>Comments:</strong> We do a lot. Never sure what the client wants. Sometimes what you think is going to work may not. Because not easy to build or what the client wants. Looking at price and client satisfaction.</td>
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<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> One of biggest things for us. As high as we can possibly do it. Important for price difference for same product at the same output. Productivity and ease of installation drives alternatives to get something that’s going to save hours on a job by saving time to install.</td>
<td><strong>Comments:</strong> Most of the time we look at an alternative from cost perspective. Alternatives not compared on buildability, buildability always there. We wouldn’t put forward an alternative if it wasn’t buildable.</td>
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<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comments:</strong> We look at number of design options with the aim of looking at the most cost effective means of implementing the design solution.</td>
<td><strong>Comments:</strong> We are governed by codes, there’s not a lot you can do. There are not many variables. For installations you have a sprinkler every 6 m2 or what have you, you can’t economise on those sorts of things, your real economies are in your install. We look at alternatives from a better installation perspective, because install is where the money is. Driven by cost through the labour content.</td>
</tr>
</tbody>
</table>

Table 6: All Data Collected for Alternatives Factor
4.3.2.2  Analysis & Discussion

The numerical data presented in figure 14 indicates that design and build designers rated their overall level of importance applied creating and comparing alternate design options higher than that over consultant designer’s ratings. The difference in the ratings appears to be small besides participant C3 who is an outlier with a lower rating. It is apparent by the following comment why C3 gave a lower rating “we found that if we do those alternate comparisons it costs the client a lot at concept stage during the project. That’s why for many clients the senior engineers just make a decision this is the system that we are going to use”. No other participant made this comment.

4.3.2.2.1  Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was moderately consistent. Three of the participants provided a rating within a band of 6 to 8, and the fourth (participant C3) was an outlier with a lower rating of 4 for reasons described previously.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.
Consultant designers discussed that they frequently assessed differing design options against one another and recognised that there is usually more than one way to achieve a design solution. Consultant designer C3 stated “in terms of mechanical you do a lot of the time. There are many different types of systems that we can choose from”. C1 mentioned “We test internally, we have an internal process that tests a particular design against another, with electrical engineering there’s more than one way of getting to a scenario or solution”. C4 commented “we do a lot of that. Your never 100 % sure what the client or architect wants. Sometimes what you think is going to work may not”. The above statements align with Dandy & Warner (1989, p. 22) comments that when looking at alternatives, there is never likely to be a single answer on any project and that designers should not research a single solution, but create and compare a wide range. Only after doing so can the best solution be found and applied.

Following the above, consultant designers expressed that they compared alternate design options based on criteria such as capital and whole life cost, buildability, durability, aesthetics and appropriateness so they could present them to the client and highlight the advantages and disadvantages of each system. C1 stated “we do test that purely because, one to check whether our design is correct, second whether the financial constraints within our design are appropriate, and then also getting back to the buildability”. C2 said “you always give alternatives solution to advise system one is this and this is the advantages and disadvantages, but system two is this which give these options or these advantages, and then you make a recommendation. It is always based on financial, buildable or durability perspective”. C3 commented “we compare the initial cost and operational cost and we give a rating of each one, then we make recommendations by putting in our report to the client then we recommend this system because of all these comparisons. We say this system is a winner; we will go with that because the life cycle is going to cost you less”. And C4 presented “with alternatives we are looking at price and client satisfaction”.

4.3.2.2 Design and Build Designers
Examine the numerical data (ratings) provided by the design and build designers, the result was moderately inconsistent. None of the ratings are the same and they vary within a band of 6 to 10. Participant S4 for the fire discipline provided the lowest
rating which was understandable based on the following comment “we are governed by codes; there’s not a lot that you can do. There are not too many variables. Our real economies are in your install”. This rating also matched the consultant designer of this discipline which justifies this reasoning. However for the other design and build designers there are no obvious reasons why the ratings varied.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.

Design and build designers predominantly discussed that comparing alternatives to them was very important largely from achieving the same outcome at a lower cost. S1 presented that alternatives are “one of the biggest things for us. High as we can possibly do it. It’s important for price difference for the same product for the same output”. S2 said “rating given because most of the time we do look at an alternative from a cost perspective”. And S3 commented “we would generally look at a number of design options, and that maybe just more than one, two or more and with the aim of looking at the most cost effective means of implementing the design solution”. This aligns with Dandy & Warner (1989) that in the evaluation of alternate design options, such as a building services system, attaining the lowest capital cost is one of the most important criteria of all.

Following the above, design and build designers also frequently mentioned alternatives were compared based on productivity to also save costs. S1 revealed “productivity and ease of installation also drives alternatives, if I can get something that’s going to save me x amount of hours on a job that’s a massive saving for us by saving time to install”. S4 also said “we would look at alternatives from a better installation perspective, because the install is where the money is. It is driven by cost through the labour content”. It was anticipated in the literature review section of this report that design and build designers would evaluate and compare alternatives based on factors as buildability, ease of installation, availability and cost. The above statements have shown that this is the case.
4.3.3 Standardisation

4.3.3.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 7</td>
<td>Rating: 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> Two scenarios, project driven by client we do standard design solutions, where green star or ESD driven we go the flipside of the scale.</td>
<td><strong>Comments:</strong> Certain limits that you keep standard. Like water demands, sewer demands, rainwater demand these are standards. Driven by standards and authorities requirements, or even design capacity is to standards, these are fixed items. For ESD you practice innovation to bring something new. A black water treatment plant, something that suits that type of project. Stock standard type projects very much repetitive work and keeps things standard and repetitive.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 8</td>
<td>Rating: 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> It’s a risk thing. Things in past worked out fine, we are comfortable using again. Standard company documents used over and over again.</td>
<td><strong>Comments:</strong> This happens a lot. Less risks because you know it’s going to work. Standard specifications, details, schematics are what you standardise. Use them over and over again. Utilise as much as possible.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 5</td>
<td>Rating: 2</td>
</tr>
<tr>
<td><strong>Comments:</strong> Certain aspects of building industry of our service been doing many years and guys know how to do it. Some things can be innovated, some things stay standard.</td>
<td><strong>Comments:</strong> Always creative and cutting edge. Because of diversity in projects we do, no building the same.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 8</td>
<td>Rating: 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> We standardise design methodologies so internally within company design process is simplified for draftsmen and detailers. Standard way we might design and install something, we know from previous experience it results in satisfactory installation, commissioning outcome and its proven it works. We standardise all installation procedures, methodologies so it helps simplify design processes, tooling onsite, installation procedures.</td>
<td><strong>Comments:</strong> In some aspects there will be standardisation across some of the materials we use. In this trade we are talking steel black pipe which has been used for a hundred years, so stuff like that is just industry standard. The discipline by nature is fairly standard anyway.</td>
</tr>
</tbody>
</table>

Table 7: All Data Collected for Standardisation Factor
4.3.3.2 **Analysis &Discussion**

The numerical data presented in figure 15 indicates that consultant designers rated their overall level of importance applied to standardisation in their designs higher than that over the design and build designers ratings. The difference in the ratings is moderate and there appears to be a noticeable variance. These ratings confirm and agree with the ratings of innovation and creativity which is the flipside to standardisation. Design and build designers rated innovation and creativity higher than consultants and that has been reflected here where it is the opposite.

**4.3.3.2.1 Consultant Designers**

Examining the numerical data (ratings) provided by the consultant designers, the result was relatively consistent. Three of the participants are placed within a range of one rating, and the fourth (participant C2) was an outlier with a lower rating. It appears that participant C2 gave a lower rating based on a comment that hydraulic designs are predominately “driven by standards and authorities requirements, or even design capacity is to the standards, these are fixed items and you can’t avoid them”. No other consultant designer specifically revealed this.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There are very few common
responses as most participants had their own point of view providing varying responses.

Participants C3 and C4 who provided the higher ratings of the consultant designers stated their level of importance given was driven based on design risk. C3 said “it’s a risk thing. We have done things in the past and it has worked out fine, we are comfortable using again. C4 commented “less risks because you know it’s going to work”. These two consultant designers also commented that standardisation in their designs was implemented through continual use and development of in house standards, such as documents and drawings. C3 mentioned “standard company documents are used over and over again”. C4 followed by explaining “standard specifications, details, schematics are what you tend to standardise. Use them over and over again. Try to utilise them as much as possible”.

A common response from participants C1 and C2 was that there level of importance applied to standardisation in designs was affected whether the project was ESD or not. C1 presented “this has two scenarios, where a project might be driven by client requirements we do employ standard design solutions, where it might get to a green star or ESD driven project we go the flipside of the scale”. C2 stated for ESD projects “that’s when you practice innovation to bring something new, but when it comes to stock standard type project it’s very much repetitive work and that’s where you keep things standard and repetitive”.

4.3.3.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was moderately inconsistent. Two participants provided the same rating of 5; however the remaining two participants were at opposite ends of the scale. S2 provided a rating of 2 and S3 a rating of 8. It is clear in the written data presented below why this is the case.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was very mixed. There are very few common responses as most participants had their own point of view providing varying responses.
As previously mentioned, there were two very opposing rankings, S2 with a rating of 2 and S3 with a rating of 8. Participant S2 provided a low rating as being innovative and creative was very important and was applied anywhere possible, S2 actual words were “Always looking for something creative and cutting edge. Mainly because of the diversity in the projects that we do, no building is the same”. Participant S3 provided a high rating as standardising everything from design methodologies to installation procedures within their company was highly regarded, S3 actual words were “from a design point of view we try to standardise design methodologies just so that internally within the company the design process is simplified for draftsman and detailers. We try to standardise all of our installation procedures, methodologies so it one helps simplify the design processes, two simplify the tooling onsite, and standardise our installation procedures”.

Participants S1 and S4 who provided the same rating of 5 had a very neutral feeling towards standardisation, where there are items in their disciplines that are standard and have been the same for years and is driven by the industry, however being innovative is also important. S1 commented “there are certain aspects of the building industry, or of our service where we’ve been doing it for this many years and the guys know how to do it. There are some things that can be innovated and some things that should stay standard”. S4 had a similar statement that “in some aspects there will be standardisation across some of the materials we use. In this trade we are talking steel black pipe which has been used for a hundred years, so stuff like that is just industry standard. The discipline by nature is fairly standard anyway”.

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## 4.4 Design Aspects

### 4.4.1 Maintenance

#### 4.4.1.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 8</td>
<td>Rating: 7</td>
</tr>
<tr>
<td>Comments: Maintenance for electrical services highly important and critical, driven by OH&amp;S in Australia. Consider how easily system can be maintained over the course of its life time. Safety automatically tags on to maintenance, how well system can be maintained as electricity not the friendliest to work with. Give a lot of thought to how system maintained and the level of maintenance and frequency of maintenance. Comes down to the standards. They stipulate maintenance regimes, 3 months, 6 months and yearly.</td>
<td>Comments: When locate plant, have enough access for maintenance and set in specification to keep routine maintenance up to date. In line with the OH&amp;S requirements for the maintenance procedures. Locate plant to have easy maintenance access.</td>
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<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 10</td>
<td>Rating: 10</td>
</tr>
<tr>
<td>Comments: Driven by safety in design. Safety comes first in our design. Safe to construct and safe to operate and maintain, all of them top importance. Maintenance and safety are very much related. Mechanical plant on the floor rather than in ceiling space. If in the ceiling space due to space restrictions, provide access panels to ensure maintenance and access.</td>
<td>Comments: Become big in the last few years, and been thrown back on the designer. Safety and maintaining. In last say 4 years, been something that we have no choice but to look at. We have to do it. It’s part of the BCA. Its legislation driven.</td>
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<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 3</td>
<td>Rating: 7</td>
</tr>
<tr>
<td>Comments: We don’t do maintenance. We don’t have a big maintenance crew. We don’t ever design for maintenance.</td>
<td>Comments: Take into account things have to be removed and replaced. Isolation valves on major pieces of equipment.</td>
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<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 9</td>
<td>Rating: 7</td>
</tr>
<tr>
<td>Comments: Mechanical services contracts require us to carry out maintenance in the warranty period of project which is 12 months or 2 years. If designs cannot be easily maintained by our service division, it’s a cost. There are statutory requirements that have to be complied with. Equipment to be accessed for maintenance easily and without risk to OH&amp;S.</td>
<td>Comments: Maintenance regimes that are code requirements, so there are levels of testing that have to be performed to comply with standards. Access to fire pumps for maintenance is code driven. All the clearance is code driven.</td>
</tr>
</tbody>
</table>

Table 8: All Data Collected for Maintenance Factor
4.4.1.2 Analysis & Discussion

![Participant Rating Comparison for Maintenance](image)

The numerical data presented in figure 16 indicates that consultant designers rated their overall level of importance applied to maintenance in their designs higher than that over design and build designer’s ratings. The difference in ratings appears to be small for the hydraulic and mechanical disciplines; however for the electrical and fire disciplines it is substantial and there is a noticeable variance.

**4.4.1.2.1 Consultant Designers**

Examining the numerical data (ratings) provided by the consultant designers, the result was relatively consistent as they all placed within a band of 7 to 10. Two of the participants provided the same rating, and the remaining two were 2 to 3 ratings lower. There is no apparent reason why this variance occurred, only that maintenance applies more to some services disciplines than others.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.

A very common topic that raised ratings for all consultant designers was that their level of importance applied to maintenance was driven by OH&S and safety in design.
requirements. Creating a design that is safe to install, operate and maintain was highly regarded. Participant C2 said “you need to be in line with the OH&S requirements for the maintenance procedures”. C1 agreed in saying that “maintenance is highly important and critical and gets driven by OH&S in Australia”. Participant C3 mentioned that “maintenance and safety are very much related” and that “if your design is safe to construct and operate then it can be maintained in a safe manner also”. C4 also said “safety and maintaining has become big in the last few years, and been thrown back on the designer”.

Further to and related to the previous points, which raised ratings for consultant designers was, they spoke about maintenance being driven by standards and legislation. C4 commented “we have to do it, its legislation driven”. C1 further mentioned “it comes down to the standards; they stipulate maintenance regimes, 3 months, 6 months and yearly”.

The last and another frequently discussed topic that also raised ratings for consultant designers was that plant and equipment must be designed in a location so it can be easily accessed and maintained over its lifetime. Participant C1 stated “what we try to do is to consider how easily a system can be maintained over the course of its lifetime”. C2 followed by saying “when locating plant, we need to locate it somewhere that it’s accessible for easy maintenance.” C3 mentioned “we would try to put plant on the floor rather than in the ceiling space. But if we had to put it in the ceiling space due to space restrictions, we will provide access panels for access and maintenance”. K.C. Lam (2000b) commented that, designers are responsible for developing systems that require as little maintenance as possible and permitting easy access and maintenance when necessary.

4.4.1.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was moderately consistent as three of the participants placed within a band of 7 to 9. Participant S1 was an outlier in this data set with a low rating of 3. It was evident from this participants comment why this is the case. S1 mentioned that “rating is low as we don’t do maintenance. We don’t have a big maintenance crew. We don’t ever design for maintenance.” However on the flipside, participant S3 had the highest
rating of 9. It was also evident from this participants comment why this is the case. S3 noted “our service contracts involve us carrying out maintenance in the warranty period of the project, hence if we complete designs that cannot be easily maintained by our service division, it is a cost to us”.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was very mixed. There were very few common responses as each participant had their own point of view which applied to the way their company and discipline operated.

A response from participant S4 which also aligns with consultant designers was that their level of importance applied to maintenance was driven by OH&S requirements. S4 mentioned “there are statutory requirements that have to be complied with. Equipment has to be able to be accessed for maintenance easily without risk to OH&S”.

Further to and related to the previous point, which was the only common response among the design and build designers was that maintenance was driven by codes and standards. S3 said “there are maintenance regimes that are code requirements”. S4 further mentioned “access to plant for maintenance is code driven. All the clearances we adhere to are code driven.”

Another response which wasn’t common amongst the design and build designers, but aligned with the consultant designers comments was that plant and equipment must be designed in a location so it can be easily accessed and maintained over its lifetime. Participant S2 stated “it must be taken into account that plant and equipment has to be removed and replaced so easy access is a must”.

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4.4.2 Ecologically Sustainable Development (ESD) / Energy Efficiency

4.4.2.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> As a company aim to be key sustainable consulting groups, we look within ourselves in terms of how well our internal processes are in line with ESD principles as well as designs we do. All projects we do, even standard ones try to be as sustainable as possible. Part of our company mission statement; what we strive for. Want to be known as ESD driven consulting group. Simple as light fitting more efficient than the next. We want to push boundaries. Internal processes, our offices, from an electrical perspective, lighting controls, lighting system, the way they are configured, PC’s shut down when not utilised, after hours non-essential power shuts down. Our internal offices and processes use no so much energy, but ESD wise, we try to be paperless; our internal processes align with mission statement of being green.</td>
<td><strong>Comments:</strong> Build safer environment, environmentally conscious of water savings and reduce the pollution. Designs have water efficient products, design use the green rated green council’s materials rating or reusable type products. Recyclable materials or recyclable systems like rainwater for irrigation or toilet flushing that reduce impact on potable demand. You always look at energy reduction through solar panels.</td>
</tr>
<tr>
<td><strong>Consultant Designer 3 (C3) - Mechanical</strong></td>
<td><strong>Consultant Designer 4 (C4) - Fire</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> Company has dedicated ESD department. Early stage of project get them engaged to work out sustainable features we can introduce, sometimes simple as orientation of building, better glass type, shading, those architectural things, also grey water recycling or using trigeneration. Engineers should always have ESD in mind, that’s going to be the trend. Sustainability is a key value for our company.</td>
<td><strong>Comments:</strong> Saving water from drain down, that’s it. That’s the extent. Recirculating pumps back to tanks. That is standard practice. Use to go to storm water. Nothing else in fire to look at. Just doesn’t apply to this discipline.</td>
</tr>
<tr>
<td><strong>Design &amp; Build Designer 1 (S1) - Electrical</strong></td>
<td><strong>Design &amp; Build Designer 2 (S2) - Hydraulic</strong></td>
</tr>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Becoming important. Being forced on us. Have to look at. Has to be considered. A lot of companies are bleeding edge, not leading edge. Design things and spend next 4 years to fix, because so new. We have issues on current job; it was 6 star, and dealing with issue because of new technology. We installed it, now taking responsibility for it. Generally design based on what I know and to get cheapest outcome.</td>
<td><strong>Comments:</strong> I try implement where possible. Realistic ESD or energy efficiency. Instead of solar hot water plant, putting a 6 star rated gas hot water plant which more efficient than solar. System doesn’t get ESD points, but more efficient.</td>
</tr>
</tbody>
</table>
### Table 9: All Data Collected for Ecologically Sustainable Development (ESD) / Energy Efficiency Factor

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> The way projects are being driven, I don’t think designers necessarily focused towards high levels of ESD unless born upon us by green star requirement. So ESD becoming important because industry forcing upon us. If project didn’t have ESD requirements our rating in design would be low. Industries heading towards higher end score because all buildings will have neighbours rating which is energy efficiency hence ESD initiatives are coming into play.</td>
<td><strong>Comments:</strong> Being jammed down our throat, like ESD for water saving. Installation components being specified from capital recovery on cost of water. You hope there is 250 year life on buildings, there is no payback. It’s got a profile and we are aware of it. Nobody has good solution to how we are going to.</td>
</tr>
</tbody>
</table>

4.4.2.2 Analysis & Discussion

The numerical data presented in figure 17 indicates that consultant designers rated their overall level of importance applied to ESD / energy efficiency in their designs higher than that over design and build designer’s ratings. The difference in ratings for the hydraulic and fire disciplines is nil, and for the mechanical discipline appears to be small; however for the electrical discipline there is a noticeable difference.

#### 4.4.2.2.1 Consultant Designers
Examining the numerical data (ratings) provided by the consultant designers, the result was moderately inconsistent. Two participants provided the same rating of 8; however the remaining two participants were at opposite ends of the scale. C4 provided a rating of 5 and C1 a rating of 10. It is clear in the following written data why this is the case.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

As previously mentioned, there were two opposing rankings, C4 with a rating of 5 and C1 with a rating of 10. Participant C4 provided a medium rating as ESD / energy efficiency was not a driving factor in this discipline, C4 actual words were “in fire it is only saving the water from drain down, that’s it. That’s the extent of it. There is nothing else in fire to look at. Just doesn’t apply to this discipline”. Participant C1 provided a very high rating as ESD / energy efficiency is a factor that is part of the companies mission statement, they want to be known in industry as a company that strives to be a leader in creating green buildings. So much so that even their company’s internal processes are in line with current industry ESD / energy efficient practices. C1 actual words were “as a company our aim is to be, as a worldwide company, is to be a one of the key sustainable consulting groups, we actually look within ourselves in terms of how well we could have our internal processes be in line with ESD principles as well as the designs that we do. It is part of our company mission statement; it is what we strive for. We want to be known as an ESD driven consulting group. Our offices for instance, from an electrical perspective, the lighting controls, the lighting system we use, the way they are configured, PC’s for example shut down when not be utilised, after hours non-essential power shuts down, we try to be paperless, therefore even our internal processes are aligned with our mission statement of being green”.

Further to participant C1 comments above, participant C3 made a similar comment in that sustainability is an important factor to their consulting company and that their company had a dedicated division to provide design advice on the latest ESD / energy
efficient technologies and approaches. C3 mentioned “Sustainability is a key value for our company. Our company has a dedicated ESD department. At the early stage of any project we get them engaged try to work out what sustainable features we can introduce”.

All of the consultant designers are implementing ESD / energy efficient features into their building services designs, and when asked to explain their rating given the following examples were given. C1 “as simple as looking at light fitting is slightly more efficient than the next light fitting which might a couple of dollars dearer. C2 “recyclable materials or recyclable systems like rainwater for irrigation or for toilet flushing that will reduce the impact on potable demand. You are always looking at energy reduction through the use of solar panels”. C3 “orientation of the building or a better glass type, or shading, those architectural things, also sometimes it can be a building services side like grey water recycling or using trigeneration”. C4 “recirculating the pumps back to the tanks. That is standard practice anyhow. Use to go to storm water”. It is evident by the above that all consultant designers are implementing ESD / energy efficiency qualities into their designs.

Following the above, consultant designers commonly responded that the above sustainable features are being implemented to be as ESD / energy efficient as possible, or because they are conscious of the affects their designs have on the environment and are aware it is a movement in the current industry. C3 stated that “ESD is an engineering thing where engineers should always have ESD in mind in design”. C1 mentioned “all the projects we do, even the standard ones we try to be as sustainable as possible”. C2 commented “to build a safer environment, being environmentally conscious and to reduce the pollution”.

The above aligns with Rowlinson et al., (1999) who states..., ”There is a growing awareness of the impact upon society’s long-term future of the process of developing the built environment. Concepts of ‘sustainable design’ and ‘sustainable construction’, which are part of a ‘green building’ agenda, are becoming more important to customers and clients who wish to appear supportive of, if not actually to be practising, principals of sustainability. This requires designers and all parties to the development
process to learn from past lessons and best practice principles, to promote and develop a sustainable built environment.”

4.4.2.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was relatively consistent. Three of the participants provided ratings within a band of 5 to 6, and the fourth (participant S2) was a minor outlier with a higher rating of 8. It appears that participant S2 gave a higher rating based on this comment “I try to implement it where possible within the constraints of the budget”. None of the other design and build designers made this comment.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.

Design and build designers commonly expressed that ESD / energy efficiency is a matter within the industry that is becoming significant and that has to be considered. S1 said that “it is becoming important. It is being forced on us. You have to look at it. It has to be considered now”. S3 also commented “this is the way the projects are being driven. ESD is becoming important because the industry is in fact forcing that upon us”. S4 mentioned “that stuff is being jammed down our throat, like ESD for water saving. It’s got a profile and we are aware of it”. This aligns with Marsh (2003) that the design of building services in the current industry has been altered due to sustainability and the aim of achieving lower energy consumption.

However even though design and build designers recognised this as a movement in the current industry, they are still not focused on it unless it’s a compulsory requirement of a project, and they are designing largely for cost. S3 stated “I don’t think we as designers are necessarily focused towards designing the very high levels of ESD unless it’s born upon us by the green star requirement. If the project didn’t have any specific ESD requirements I would probably say that our rating of that in design would be fairly low”. S1 mentioned “generally I will design based on what I know and to get the cheapest outcome for us”.

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There was a strong opinion amongst the design and build designers which lowered their ratings that there is a need for realistic ESD / energy efficient designs in the market. Realistic in the sense that, they continue to work as intended, they are tried and tested, systems are efficient in practice not just on paper, and payback periods are achievable. S1 commented “there are a lot of companies out there design these things and spend the next 4 years trying to fix the thing, because it is so new. We have some issues on a current job that we did where it was 6 stars, and I am dealing with an issue because of new technology”. S2 presented “realistic ESD or energy efficiency. Instead of putting solar hot water plant in, were putting in a 6 star rated gas hot water plant which is more efficient than the solar. The system doesn’t get any ESD points, but it is more efficient”. S4 stated “you want to hope there is a 250 year life on the buildings, because there is no payback at all. Nobody has really come up with good solution as to how we are going to it”.
### 4.4.3 Redundancy / Back-Up

#### 4.4.3.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Risk type assessment, whether project has mission criticality or not, level of redundancy and back-up systems you provide will increase from a level 5 to level 10.</td>
<td><strong>Comments:</strong> Allow plant to have additional capacity for redundancy, just in case there is an extension or surcharge or high demands greater than what allowed in the design.</td>
</tr>
<tr>
<td>Office scenario or tenancy fit out, a medium level of redundancy consideration given. At higher end of the scale, for hospitals and casinos, multiple levels of redundancy. Driven by mission criticality of project or processes that undertaken. If mission critical process, needs to be maintained whether life threatening or life safety.</td>
<td>Hospital always have 30% extra capacity on hot water system just in case more hot water required there no shortage, or there is extension or extended by adding a new block, you not going to upgrade system for an extra few rooms, the system already has capacity.</td>
</tr>
<tr>
<td>Consultant Designer 3 (C3) - Mechanical</td>
<td>Consultant Designer 4 (C4) - Fire</td>
</tr>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Don’t provide redundancy unless client asks. In many cases give redundancy because thought a little more always better, is benefit to client, in future you have flexibility to extend.</td>
<td><strong>Comments:</strong> Fire all code driven. Duty/standby pumps in most cases. We don’t have a choice. Part of standards for fire. Codes are all driven by the nature of risk involved with this discipline.</td>
</tr>
<tr>
<td>Continuously run plant at 60% load it is not efficient, mostly efficient at 100% load. So if you go for bigger unit which has redundancy but permanently at 60% you losing efficiency and wasting power. So wouldn’t give redundancy unless necessary.</td>
<td></td>
</tr>
<tr>
<td>Minimum redundancies like 30% redundancy on boilers to warm up, 5 to 10% redundancies on chillers for heat loss through pipes, and these all standard redundancies. Sometimes code driven, sometimes its standard design practice.</td>
<td></td>
</tr>
<tr>
<td>Design &amp; Build Designer 1 (S1) - Electrical</td>
<td>Design &amp; Build Designer 2 (S2) - Hydraulic</td>
</tr>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comments:</strong> Only when told through design brief to allow spare capacity. Subject to the design brief. If design brief says they want redundancy, we will give it to them; otherwise we aren’t going to put in something.</td>
<td><strong>Comments:</strong> Depends on the end users requirements or expectations.</td>
</tr>
<tr>
<td>Low, small apartment building. Only an inconvenience if things fail. Have redundancy, but no back-up. Medium, office building costs involved if failure. Staff complaints, going home. Cost implications if there is a failure on businesses. High, Medical. Life or death. Operating theatre run out of hot water couldn’t clean. Driven by budget. If end user expects a lot, they pay a lot.</td>
<td></td>
</tr>
<tr>
<td>Design &amp; Build Designer 3 (S3) - Mechanical</td>
<td>Design &amp; Build Designer 4 (S4) - Fire</td>
</tr>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Hospitals and prisons where you don’t have easy access, systems to be maintained, and need to be very high.</td>
<td><strong>Comments:</strong> Two pumps duty and stand-by, two tap-ins at water main, large water tank to store water in case of failure of public water main.</td>
</tr>
</tbody>
</table>
Office building, very low. The air-conditioning fails not problematic because not stop operation of building if mechanical services down. Determined by impact of failure on type of facility, type of project and impact of failure. All code compliance issues, just complying with it. Level of standards is high due to nature of risk of failure involved, people's lives.

Table 10: All Data Collected for Redundancy / Back-Up Factor

4.4.3.2 Analysis & Discussion

![Participant Rating Comparison for Redundancy / Back-Up](image)

Figure 18: Line Graph Comparing Ratings for Redundancy / Back-Up

The numerical data presented in figure 18 indicates that consultant designers rated their overall level of importance applied to redundancy / back-up in their designs higher than that over the design and build designers ratings; however the difference in the ratings is small and they appear to be similar.

4.4.3.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. Three of the participants provided a rating of 8 and the fourth (participant C3) was an outlier with a lower rating of 5. It appears that participant C3 gave a lower rating based on the following comment “We don’t provide redundancy unless the client asks for that. We also work out for mechanical systems, if you continuously run a plant at 60 % load it is not efficient, it’s mostly efficient at 100 % load. So if you go for a bigger unit which has redundancy but
permanently run at 60% you are actually losing efficiency and wasting power. So I wouldn’t give redundancy unless necessary”.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was again mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

It appears to be common amongst the consultant designers that allowing for redundancy is standard design practice and it is incorporated to cover any system surcharges over and above the design allowance and as a value to the client. C2 mentioned that “allow your plant to have an additional capacity for redundancy that just in case there is a surcharge or high demands greater than what allowed in the design”. C3 said that “give redundancy because we always thought a little bit more is always better, is a benefit to the client”. C3 also said that “there are minimum redundancies, like standard design we give 30% redundancy on boilers to warm up, and we give like 5 to 10% redundancy on chillers just for the heat loss through the pipes, these are all standard redundancies”. C4 said for fire “duty/standby pumps in most cases”.

Further to the previous comments, consultant designers regularly stated that redundancy / back-up was allowed for in designs to cover any building extensions that may be required in future. Participant C2 stated “if there is an extension by adding a new block, you are not going to just upgrade the system for an extra few rooms; the system already has the capacity for it. C3 agree with this by saying “in the future you have the flexibility to extend somehow”.

Consultant designers mentioned that the level of redundancy / back-up allowed was a project type driven decision. C1 presented “for an office scenario or tenancy fit out, definitely a medium level of redundancy consideration being given. At the higher end of the scale, for hospitals and casinos multiple levels of redundancy”. C2 mentioned “in a hospital you always have 30% extra capacity on the hot water system”.

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Further to the previous comments, it was mentioned that it comes down to a risk assessment; the risk in a hospital is high because the impact of a failure is potentially death. It comes down to the seriousness of the operation within the building. C1 said “it is a risk type assessment, whether a project has mission criticality or not, the level of redundancy and back-up systems you do provide will increase from a level 5 to a level 10. If there is a mission critical process, it needs to be maintained, whether it is life threatening or life safety. Where it is a mission critical process in a project, we give a lot of thought to redundancy and back-up”. This aligns with Maver (1971, p. 98) who said, “In non-commercial building types such as a hospital, the consequences of a break in the electricity board supply may be extremely serious but not easily costed and the designer is presented with a difficult design decision.”

Participant C4 who is the fire discipline agreed that it is a risk assessment; however fire was a high risk in all scenarios as a failure of the fire service would mean death in any building, and as a fire service designer they are driven by the standards and codes which are designed to suit the high risk. C4 actual words were “Codes are all driven by the nature of the risk involved with this discipline. We don’t have a choice, part of standards for fire”.

4.4.3.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was relatively consistent as they all placed within a band of 5 to 8. None of the participants provided the same rating, however they are all reasonably close. Fire is the highest which is understandable, as failure is not an option. It is clear in the following written data why the slight variance occurred.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another. The fire discipline responses vary, but that is because they must provide redundancy.

Design and build designers frequently discussed that redundancy / back-up was provided in-line with the end users requirements and what’s being asked in the design brief. S1 said that “when we have been told through a design brief to allow spare
capacity that sort of thing. It is subject to the design brief. If the design brief says they want redundancy, we will give it to them; otherwise we aren’t going to put in something”. S2 mentioned “depends on the end users requirements or expectations. If the end user expects a lot, they will pay a lot”.

Another commonly discussed topic was the level of redundancy / back-up provided was driven by the project type and the impact a failure would have on the end user. S2 presented “low example would be small apartment building where it’s only an inconvenience if things fail. Medium example would be an office building where there are costs involved if there is a failure. Staff complaining and going home. The cost implications if there is a failure on businesses. High example would be medical, life or death. S3 agreed by saying “projects like hospitals and prisons where you don’t have easy access, systems have to be maintained, and it needs to be very high. A traditional office building maybe very low. The air-conditioning fails it’s not necessarily going to be problematic because it’s not going to stop the operation of the building. It determined by the impact of the failure on the type of facility, type of project and the impact of that failure”. 

Not a common response among all design and build designers, but specific to the fire discipline and participant S4. Redundancy and back-up is all code driven and has a high risk associated with it regardless of the project type. S4 commented “they are all code compliance issues, so we are just complying with it. The level of the standards which we design to is high due to the nature of the risk of failure involved, people’s lives. That’s why we have two pumps for duty and stand-by, two tap-ins at the water main, and a large water tank to store water in case of a failure of the public water main”. 

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### 4.4.4 Aesthetics

#### 4.4.4.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 9</td>
</tr>
<tr>
<td><strong>Comments:</strong> Aesthetics is always important to us. For high level of interaction with ourselves and the architect. Lighting used to enhance architecture through colours, shading, levels of light etc.</td>
<td><strong>Comments:</strong> Always a lot of coordination and communication with architect. Design and send without liaising or communication it will fail. More you communicate and liaise with architect more chance system has of working and having problems is low. At initial stages you communicate with architect ask for spacial’s, risers, plant space, lowered ceiling, ceiling space. Give architect all requirements, prior to design after they lock there architectural plans.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> We think for architect, if we do a grill we ask architect is happy with or we use a different finish or different colour. We can’t always think architecturally, looks good or not, think from practical side if works or not.</td>
<td><strong>Comments:</strong> Agree with architects. Want things to look good. You are proud of project even if our stuff is hidden. Sprinkler heads, fire hydrants and hose reels cupboards are exposed. Work with architect to allocate locations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 6</td>
</tr>
<tr>
<td><strong>Comments:</strong> Doesn’t rate for me. Aesthetics annoy me, architects have too much say. Architects spend other people’s money. Important to work with architects to sort RCP reflected ceiling plan, I have no issues with that. Front of house aesthetics is very important, but back of house, car parks etc. not important. Work with architect to sort light fittings. So long as it fits our budget, we push it, it’s all budget driven.</td>
<td><strong>Comments:</strong> Never jeopardise plumbing standards for aesthetics. Not the first thing I think about when I design. Comes down to building or the location in building. If in a car park or somewhere like not too important. But in an entry to car park that’s visible from street you try do something. Back of house vs. front of house. Making sure the system works is more important.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Aesthetics not critical issue for us. A lot of stuff essentially back of house. Mechanical plant concealed whether in a plant room or ceiling space, so aesthetics not critical. Only thing where aesthetics high is things that are seen. Fit out items like grills, registers. That’s were aesthetics very important to ensure set out correctly, they aren’t unattractive, evenly spaced, that type of thing, symmetrical. That part is important, what is actually seen in the room.</td>
<td><strong>Comments:</strong> Important in foyer areas, got to make it look good. Don’t put up bent pipe, or second hand pipe. Latest reflected ceiling information to be part of our planning, for set outs so our fit off is right. Coordinate sprinkler location on ceiling with other services.</td>
</tr>
</tbody>
</table>

Table 11: All Data Collected for Aesthetics Factor
4.4.4.2 Analysis & Discussion

The numerical data presented in figure 19 indicates that consultant designers rated their overall level of importance applied to aesthetics in their designs higher than that over the design and build designers ratings; however the difference in the ratings is small and they appear to be similar. The biggest differences are the hydraulic and mechanical disciplines.

4.4.4.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. Three of the participants provided a rating within a band of 8 to 9 and the fourth (participant C3) was an outlier with a lower rating of 5. It appears that participant C3 gave a lower rating based on the following comment “we are not architects, so we can’t always think architecturally, if that looks good or not, always think from the practical side if it works or not”.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was little. Many of the responses are common and agree with one another.
Consultant designers frequently discussed and displayed that they work with and have a high level of interaction with architects. They feel that aesthetics is important and communicate and coordinate design related issues frequently. C1 comment was “aesthetics is always important to us. High level of interaction with ourselves and the architect”. C2 said “always a lot of coordination and communication with the architect. The more you communicate and liaise with the architect the more chance the system has of working and having problems is low. C4 presented “I agree with architects. You want things to look good. Then you are proud of the project even if most of our stuff is hidden”. This reflects Marsh (2003) that architects and building service designers must work together to create a combined environment where the aesthetics of the building and the technical performance of the services be considered as one.

Further to the previous comments, reasons provided by consultant designers for working closely with the architect were enhancing aesthetics, obtaining spacial’s and locations for services. C1 mentioned “lighting used to enhance architecture through colours, shading and levels of light”. C2 told “communicate with the architect and ask for the spacial’s, risers, plant space and ceiling space. Give the architect all the requirements, prior to you commence your design after they lock there architectural plans”. C3 revealed “if we do a grill we will ask the architects are you happy with that or we will use a different finish or different colour”. C4 said “sprinkler heads, fire hydrants and hose reels cupboards are exposed. Work with the architect to allocate these locations”.

4.4.4.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was moderately consistent as all of the participants placed within a band of 6 to 8 and there are no outliers.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.
The responses to this factor from the design and build designers was a two sided response. These designers felt aesthetics was important in some aspects and not in others. A common response was where services are at the front of the building (front of house) they are very important, however when they are at the back of the building (back of house) not so much. S1 replied “front of house aesthetics is very important, but back of house, car parks etc. not important”. S2 agreed by saying “it comes down to the building or even the location in the building. If it’s in a car park or somewhere like that it’s not too important. But if it’s in an entry to a car park that’s visible from the street you would try and do something about it. Back of house vs. front of house”. S3 said “aesthetics probably not a critical issue for us. A lot of our stuff is essentially back of house type gear. The only thing where aesthetics is high is the things that are seen”. This aligns with Smith & Hinze practical example “make special note of these canopy sprinklers and ensure that they are designed and installed in an aesthetically pleasing manner. Exterior canopies are commonly regarded as key architectural elements” (p. 343).

Reasons provided by design and build designers that aesthetics wasn’t important and lowered their ratings were, aesthetics are annoying, considered not important, it costs money and function of building service over aesthetics is more important. S1 said “doesn’t rate for me. Aesthetics just annoy me, as architects have too much say. Architects like to spend other people’s money. So long as it fits our budget, we will push it, it’s all budget driven”. S2 comments were “it’s not the first thing that I think about when I do a design. Never jeopardise plumbing standards for aesthetics. Definitely making sure the system works is more important”. S3 presented “most mechanical plant is concealed whether it’s in a plant room or ceiling space, so the aesthetics is not critical”.

Reasons provided by design and build designers that aesthetics was important and lifted their ratings were the coordination and specification of exposed services such as light fittings, grills, registers and sprinklers. S1 said “it is important to work with the architects to sort RCP reflected ceiling plans and that type of thing, I have no issues with that sort of thing. We work with the architect to sort types of light fittings”. S3 mentioned “fit out items like grills, registers. That’s were aesthetics is very important to ensure their set out correctly, so that they aren’t unattractive, evenly spaced, that
type of thing, symmetrical”. S4 replied “the latest reflected ceiling information needs to be in and part of our planning, for the set outs so our fit off is right. Coordinate sprinkler location on ceiling with other services”. 
4.4.5 Capital Cost

4.4.5.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 9</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Targeting budget, you establish a budget or cost at outset of project, track against that, management of cost and design within that budget is very high, otherwise you won’t have project in the end.</td>
<td><strong>Comments:</strong> Always working on a budget. You have budget when the project starts, number one comment from the team leaders, the project have X$ to spend. Have to design system within budget requirement. You have to find a system that’s within budget and working to requirements and still operates.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 5</td>
</tr>
<tr>
<td><strong>Comments:</strong> On most projects we have done capital cost isn’t much of a worry. Seems most clients have sufficient budget to what we decide. We do costing’s for clients at stages of design. Mechanical do cost plans ourselves. Talk to supplier to find price and do those ourselves. We talk to suppliers and ask for budgets. Don’t worry about overall price much but if we can design cheaper we will do that without affecting performance.</td>
<td><strong>Comments:</strong> Fire has little control over capital cost. Only thing can do is code compliant and only way you make savings is by taking short cuts. If you need ring main, then you put a ring main in. If you don’t you will need a dispensation from fire authority.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Whole industry is dollar driven. So doing things cheaper is way forward. All about making money. There’s always someone who reckons they can do it cheaper.</td>
<td><strong>Comments:</strong> Boss sits in the big office. If the boss doesn’t make money we don’t have a job. Specification of plant and equipment is always driven by capital cost. As long as it works and functions and it’s going to do its intended job. If it is full D&amp;C project, I pick and choose plant and equipment. We choose whatever we like. Approval of cheapest alternative is simple because in house, don’t have to ask, not a finger pointing exercise at the end if doesn’t work, as a company we take full responsibility, there no one to blame.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 9</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Capital cost for obvious reasons is very important particularly if design and construct and we doing the design and hence constructing very important that we design within our budget.</td>
<td><strong>Comments:</strong> Aim to make as much money as possible. We have loyalties to some suppliers, but at same time we still check and compare.</td>
</tr>
</tbody>
</table>

Table 12: All Data Collected for Capital Cost Factor
The numerical data presented in figure 20 indicates that design and build designers rated their overall level of importance applied to capital cost in their designs higher than that over consultant designer’s ratings. The difference in ratings appears to be small for the electrical and hydraulic disciplines; however for the mechanical and fire disciplines it is substantial and there is a noticeable variance.

4.4.5.2.1 Consultant Designers
Examining the numerical data (ratings) provided by the consultant designers, the result was moderately inconsistent. Two participants provided medium ratings of 5 and the remaining two participants provided very high ratings of 9 and 10. It is clear in the following written data why this is the case.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There were very few common responses as each participant had their own point of view.

Looking at the two medium ratings, participant C3 provided this rating based on not being concerned about capital cost when undertaking designs believing that most clients have adequate budgets to cover what is designed. C3 stated “capital cost isn’t
so much of a worry. Seems that most clients have a sufficient budget to cover what we decide. I don’t worry about the overall price too much, but if we can design a system in a cheaper way we will do that in a cheaper way without affecting the performance”. This reflects Masterman (2002) who mentions under the traditional separated procurement method that designers have no incentive to monitor the costs of a design.

Participant C4 provided this rating based on being restricted by the fire code and not being able to control cost. C4 commented “fire has very little control over capital cost. The only thing you can do is code compliant and the only way you make savings is by taking short cuts”.

A common response among the two consultant designers C1 and C2, who provided the high ratings, was they are working to budgets. They are tracking costs and regard working to those budgets highly. C1 said that “establish a budget or a cost at the outset of the project and track against that, management of the cost and how we can design within that allocated budget amount is very high, otherwise you won’t have project in the end”. C2 replied “you are always working on a budget. So you have to design a system that is within that budget requirement. You have to look somewhere to find a system that’s within the budget and it is working to the requirements and still operates properly”.

Despite participant C3 providing a medium rating, the participant expressed that estimates were undertaken at varies stages during design and they were obtained by speaking to suppliers. C3 spoke “we do costing’s for clients at different stages of design. Mechanical services have to do cost plans ourselves. We have to talk to each supplier to find the price, and we just do those ourselves. We talk to suppliers and ask them for budgets”.

4.4.5.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent. Three of the participants provided very high ratings of 10 and the fourth (participant S3) provided a high rating of 9, so very little variance.
Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

It was a very common response among all the design and build designers that capital cost is very important in order to meet their budget and make money. S1 stated “the whole industry is dollar driven. So doing things cheaper is the way forward. It’s all about making money. There’s always someone who reckons they can do it cheaper”. S2 said “because the boss sits in the big office. If the boss doesn’t make money we don’t have a job. Specification of all plant and equipment is always driven by capital cost. As long as it works and functions and it’s going to do its intended job”. S3 mentioned “capital cost for its obvious reasons is very important particularly if it’s a design and construct project and we are doing the design and hence constructing it is very important that we design something that is within our budget”. S4 commented “aim is to make as much money as possible”. This reflects Teets (1976) who mentions all tasks embarked on by a subcontractor are in the pursuit of making as much profit as possible, and revenue is sourced through buying plant and equipment at a lower price than costed.
### 4.4.6 Whole Life Cost

#### 4.4.6.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 9</td>
</tr>
<tr>
<td><strong>Comments:</strong> Don’t do a lot of life cycle analysis for clients. Occasions where proposing alternatives we inclined to make sure client understands benefit of going for energy efficient system or a design which is outside the box, do analysis to show life cycle or payback based on life cycle of a product or design, how it stacks against a standard option.</td>
<td><strong>Comments:</strong> Need to look at those items closely. Need to look they fit the budget and make sure is a good system. Major projects need to look at whole life of materials is long lasting, less maintenance and reliable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 0</td>
</tr>
<tr>
<td><strong>Comments:</strong> We think about efficiency in design. How to improve efficiencies. Selecting a chiller, efficiency of a chiller called COP. When discussing alternative design options, discussed we compare alternate designs based on life cycle costs.</td>
<td><strong>Comments:</strong> Doesn’t apply to this discipline. Pumps on standby most of the time. Pump is tested every month. Sprinklers get tested every 25 years. Hydrants get tested every 6 months. Selection of fire pumps and fire equipment not based on whole life cost. Has to do the job it has to do, and it gets tested regularly. System just sits in limbo, so not applicable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 5</td>
<td><strong>Rating:</strong> 3</td>
</tr>
<tr>
<td><strong>Comments:</strong> When it comes to these things, we won’t put in cheapest light fitting that’s something we never do, especially on a design and construct, because comes back to haunt you.</td>
<td><strong>Comments:</strong> We want the product to last 12 months. Needs to last the warranty period, we don’t go super cheap, and for reputation. If your systems fall over after 12 months, you’re not going to get repeat work if it’s a common occurrence. Goes against capital cost. Usually cheaper life cycle cost means expensive capital.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 0</td>
</tr>
<tr>
<td><strong>Comments:</strong> We have a reputation to uphold. Important we provide a design and installation that is fit for purpose and reasonable standard and quality so doesn’t prematurely fail or have to be replaced. Comes down to design decision, quality of equipment, the brand of equipment, make sure don’t design cheap and nasty equipment that we know is suspect.</td>
<td><strong>Comments:</strong> Doesn’t apply to us. Our system just stands still until it is required. If our system is operating then there is a problem.</td>
</tr>
</tbody>
</table>

Table 13: All Data Collected for Whole Life Cost Factor
The numerical data presented in figure 21 indicates that consultant designers rated their overall level of importance applied to whole life cost in their designs higher than that over the design and build designers, however the difference in ratings appears to be small for the electrical and mechanical disciplines, there is a nil difference in the fire discipline, and for the hydraulic there is a noticeable difference. Interesting outcome was both organisation types rated fire as N/A as they expressed this factor simply did not apply to their discipline.

### 4.4.6.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was relatively consistent when excluding the fire discipline that provided a rating of N/A. Two of the participants placed with a band of 8 to 9 and the third (participant C1) was an outlier with a lower rating of 6. It appears that participant C1 gave a lower rating based on the following comment “we don’t do a lot of life cycle analysis for our clients”. None of the other consultant designers made this comment.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There were very few common responses as each participant had their own point of view.
The only common response amongst the consultant designers was they completed whole life costing when comparing alternate design options to highlight to a client the differences between one system and another i.e. which one would cost more or less over a period of time. C1 said that “there are occasions where if we are proposing alternatives for instance or if we inclined to make sure the client understands the benefit of going for an energy efficient system or a design which is outside the box, we do analysis to show that life cycle or payback based on the life cycle of a particular product or design how it stacks up against a standard option. C3 commented “back when discussing alternative design options, it was discussed that we compare alternate designs based on life cycle costs”. C3 comment under the alternative factor was “we compare the initial cost and operational cost and we give a rating of each one, then we make recommendations by putting in our report to the client then we recommend this system because of all these comparisons. We say this system is a winner; we will go with that because the life cycle is going to cost you less”. This reveals Marsh (2003) description of whole life cycle costing as “an economic assessment of competing design alternatives, considering all significant costs of ownership over the economic life of each alternative, expressed in equivalent monetary value” (p. 71).

Further to the previous comments, participant C3 added when considering the whole life cost of a design that the efficiencies of plant and equipment are evaluated. C3 stated “we think about efficiency in our design. We think about how to improve efficiencies, like selecting a chiller, the efficiency of a chiller is called COP”.

The fire service participant commented that this factor is not applicable as their systems don’t generally operate unless they are being tested or there is a fire; they are always in standby mode awaiting for a fire to occur. C4 actual words were “doesn’t really apply to this discipline. Pumps are on standby most of the time. Pump is tested every month. Sprinklers get tested every 25 years. Hydrants get tested every 6 months. Selection of fire pumps and fire equipment is not done based on whole life cost. The system just sits in limbo, so it is not applicable”.

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4.4.6.2.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was relatively consistent when excluding the fire discipline that provided a rating of N/A. Two of the participants placed with a band of 5 to 6 and the third (participant S2) was an outlier with a lower rating of 3. It appears that participant S2 gave a lower rating based on the following comment “because it goes against capital cost. Usually cheaper life cycle cost means expensive capital”. None of the other design and build designers made this comment.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

The only common response amongst the design and build designers was about not specifying the absolute cheapest plant and equipment in order to prevent it failing in a short period of time and affecting the company’s reputation. S1 responded “we won’t put in the cheapest light fitting that’s something we will never do, especially on a design and construct, because it comes back to haunt you”. S2 said “not very low because we at least want the product to last 12 months. It needs to at least last the warranty period, so we don’t go super cheap, and for our reputation. If your systems are seen to fall over after 12 months, you’re not going to get much repeat work if it’s a common occurrence”. S3 presented “we have a reputation to uphold. So it’s important that we provide a design and installation that is fit for purpose and is a reasonable standard and quality so that the equipment doesn’t prematurely fail or have to be replaced”.

Further to the previous comments, participant S3 added that the specification of plant and equipment to avoid it failing in a short time was undertaken by selecting reputable brands that were known to last. S3 stated “comes down to design, decision comes into place that the quality of the equipment, the brand of the equipment, make sure that we don’t design around cheap and nasty equipment that we know is suspect”.

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Identical to the consultant designers, the fire service participant commented that this factor is not applicable as their systems don’t generally operate unless they are being tested or there is a fire; they are always in standby mode awaiting for a fire to occur. S4 actual words were “this doesn’t apply to us. Our system just stands still until it is required. If our system is operating then there is a problem”.

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4.4.7 Safety

4.4.7.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 10</td>
<td>Rating: 10</td>
</tr>
<tr>
<td>Comments: We are in compliance with relevant regulations and standards.</td>
<td>Comments: Number one priority that you design safe. Number one with OH&amp;S requirements. Safe to operate and safe to maintain.</td>
</tr>
<tr>
<td>Organising plant rooms and switchboard cupboards and like in manner there’s means of escape through clearances, head heights, and consideration at design stage so not trying to add on safety as add on component in construction stage, but thought of in design stage.</td>
<td>OH&amp;S requirement to put equipment at certain levels to reduce risk of tripping and being harmed. Location of hot water units so not a risk item during maintenance.</td>
</tr>
<tr>
<td>We carry out safety in design process early to ensure our designs are in compliance with OH&amp;S requirements.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 10</td>
<td>Rating: 10</td>
</tr>
<tr>
<td>Comments: Related back to maintenance. Safe to construct, safe to operate, safe to maintain.</td>
<td>Comments: Something that is legislated. Driven by legislation. If someone losses their life you have to live with it, peace in mind you have done what you can to reduce risk.</td>
</tr>
<tr>
<td>Every project we do a safety design checklist. Identify risks like fall from height. Equipment on roof close to roof edge where the maintainer or operator may fall, ask architects to provide parapet or hand rail.</td>
<td></td>
</tr>
<tr>
<td>More codes coming out in terms of safety. Used to be engineering concern now you follow the codes.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 10</td>
<td>Rating: 5</td>
</tr>
<tr>
<td>Comments: Whole industry and whole company relies on it. A must in the industry now as legislation driven. Producing work method statements to explain how to install something safely.</td>
<td>Comments: Legislation, you have to look at it. The legislation is new and still getting used to idea of looking at it and making it a priority. It’s new that it’s mandatory.</td>
</tr>
<tr>
<td>When we design, only look at safety from an installation point of view. Not operation or maintenance.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating: 9</td>
<td>Rating: 10</td>
</tr>
<tr>
<td>Comments: We have got legislation. Obligated by law to occupation health and safety act to design and install plant and equipment that is safe.</td>
<td>Comments: Minimise unsafe installation practices, use access equipment that will get you to area or consider actually scaffolding big foyers or those sorts of things.</td>
</tr>
<tr>
<td>If we design something that kills somebody, we go to jail. Statutory obligation; also a moral obligation to design installations that are safe. Safe to install, safe to maintain, and systems have to be safe to use by the end operator.</td>
<td>After installation typically our service doesn’t need to be touched as there are no moving parts or hidden valves or panels like other services.</td>
</tr>
</tbody>
</table>

Table 14: All Data Collected for Safety Factor
4.4.7.2 Analysis & Discussion

![Participant Rating Comparison for Safety](image)

The numerical data presented in figure 22 indicates that consultant designers rated their overall level of importance applied to safety in their designs higher than that over the design and build designers ratings; however the difference in the ratings appears to be small besides participant S2 who is an outlier with a lower rating. It is very apparent by the following comment why S2 gave a lower rating “reason only a 5 and not a 10 because the legislation is only new and still getting used to the idea of looking at it and making it a priority. It’s new that it’s mandatory”. No other participant made this comment.

4.4.7.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. All four participants provided a rating of 10 and there are no outliers.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.
A frequently discussed subject amongst the consultant designers was safety is a very important issue to comply with the latest regulations, standards, legislation and OH&S requirements. C1 commented “so we are in compliance with the relevant regulations and standards. We do carry out safety in design type of process early on in house to ensure that our designs are in compliance and in line with the OH&S requirements. C2 said that “it is number one within the OH&S requirements. C3 replied “as long as you follow the codes you are alright. C4 stated “something that is legislated. Driven by legislation.

Further to the previous comments, it was also a regularly discussed that in order to meet the above codes and standards etc. that safety had to been incorporated in a building at the design stage and not added or attached as an extra during construction; a term given for this was safety in design. C1 noted that “organising plant rooms and switchboard cupboards and like in such manner that there’s means of escape through clearances, head heights, and these get put into consideration at the design stage so when you’re trying to build it you’re not trying to add on safety as an add on component in the construction stage”. C2 said “the number one priority is that you design safe”. C3 followed saying “on every project we do a safety design checklist. This checklist would help you identify risks, like is there a likelihood of fall from height, and if there is, like if we have equipment on the roof which is close to the roof edge in which case the maintenance where the maintainer or operator may fall, we will ask the architects to provide a parapet or hand rail to fix this”. This reveals Christensen (2010) that to create a safer environment which reduces fatalities, injuries and illnesses, designers need to incorporate a risk assessment and safety approach into the design stage of a project.

Consultant designers also spoke about a link between safety and construction, operation and maintenance. In that, when designing in a piece of plant ensuring it can be installed or constructed in a safe manner, the person who has to operate the plant can do so in a safe manner, and when the plant requires repairs or general maintenance it can be completed in a safe manner. C3 said “safe to construct, safe to operate, safe to maintain. C2 also stated “it is safe to operate and safe to maintain”.
4.4.7.2.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent as three of the participants placed within a band of 9 to 10 and the fourth (participant S2) was an outlier with a lower rating of 5 as explained previously.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

Similar to the consultants, a frequently discussed subject amongst the design and build designers was safety is a very important issue to comply with the latest regulations, standards, legislation and OH&S requirements. S1 replied “it’s a must in the industry now as it is legislation driven”. S2 said “legislation, you have to look at it”. S3 presented “we are obligated by law to the occupation health and safety act to design and install plant and equipment that is safe. If we design something that inadvertently kills somebody, we go to jail. There is a statutory obligation; there is also a moral obligation to design installations that are safe”.

It was a common response from the design and build designers that there is a link between safety and construction. When designing in a piece of plant ensuring it can be installed or constructed in a safe manner. S1 mentioned “when we design, we only look at safety from an installation point of view. Not operation or maintenance. S4 commented “you try to minimise potentially unsafe installation practices”. S1 also referred to producing work method statements to document how their company proposed to safely install a component of their service. S1 actual words were “producing work method statements to explain how we are going to install something safely”.

Not a common response among the design and build designers but one which aligns with the consultant designers, participant S3 spoke about a link between safety and construction, operation and maintenance. S3 words were “so the designs are safe to install, safe to maintain, and systems have to be safe to use by the end operator”.

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### 4.4.8 Design Risk

#### 4.4.8.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Two phases in electrical. Whether we are a D&amp;C basis or a traditional full tender and design documentation. D&amp;C perspective is about a 4 or a 5. There is a level of risk in the design, designs not fully developed, so there is a level of design risk. Traditional design, fully detailed design and it’s probably about a 9. Ultimately we reduce the risk and scope the project on behalf of our client so level of risk in design should be very low.</td>
<td><strong>Comments:</strong> Projects like health projects or schools or university, public utilities design need very high redundancy in design, a lot of standby backups so risk of system failing should be minimal in that sort of environment. Standby system for a day or something like that will reduce your risk in design.</td>
</tr>
</tbody>
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<thead>
<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 9</td>
</tr>
<tr>
<td><strong>Comments:</strong> We design smart systems like laboratory gas alarm system. When failure happens warns the occupants and addresses the risk. Or interlock control on a boiler and heating hot water pump, if the pump runs or starts, if the pump fails, the boiler will automatically stop, otherwise it will overheat. Primarily control risk by implementing smart systems on critical items in designs that eliminate risks. We imply high level of importance to design risk to ensure we eliminate it.</td>
<td><strong>Comments:</strong> Same reasons as safety and maintenance. Where innovation and creativity step in, because it is a design risk. If it is innovative it is a high risk.</td>
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</tbody>
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<thead>
<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> New technology. If new technology hasn’t been certified. Varies brands come on market, new brands come out of Asia, and new brands come out of Europe they haven’t been tried and tested. It’s important; it’s a risk if it fails. No contingency on cabling, we size it right. Size exactly what need to be. It’s only allowed if design brief asks for it.</td>
<td><strong>Comments:</strong> Not dealt with in form of contingencies; dealt with through good design, or highly calculated design, highly efficient calculations. Instead of by some form of contingency, it’s by not taking guesses.</td>
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</table>

<table>
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<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 9</td>
<td><strong>Rating:</strong> 7</td>
</tr>
<tr>
<td><strong>Comments:</strong> Consistently have high rating. Not in our interest to design that going to be questioned, or not fit for purpose. Designers use engineering qualifications, if claim made against business due to design not meeting intent or an insurance claim made against business, the insurance company want who designed it. Comes into standardising designs and how we design things is important in eliminating the risk in design. Typically contingencies of 10-15%. It’s a risk thing, if risk is low it will have a lower percentage of safety, if the risk is high it will have a much higher factor of safety.</td>
<td><strong>Comments:</strong> Over design in terms of pipe sizing. We won’t push it to the nth degree. Give it at least 10% or 15% over what’s required. We manage by just knowing what we are doing through experience and knowledge gained over many years.</td>
</tr>
</tbody>
</table>

Table 15: All Data Collected for Design Risk Factor
4.4.8.2 Analysis & Discussion

The numerical data presented in figure 23 indicates that design and build designers rated their overall level of importance applied to design risk in their designs higher than that over consultant designer’s ratings. The difference in ratings appears to be small and they appear to be similar. The largest variance is between the fire discipline designers where the consultant designer rated it higher than the design and build designer. It is apparent by the following comment given by participant S4 why the rating was lower “we manage by just knowing what we are doing through experience and knowledge gained over many years”. No other participant made this comment.

4.4.8.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was moderately consistent as all of the participants placed within a band of 7 to 9 and there are no outliers.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There are no common responses as each participant had their own point of view.
Participant C1 explained that design risk was a two sided scenario which depending on how complete the design was, and this varied whether C1 was working on a D&B type project or a traditional D/B/B type project. For a D&B type project, C1 commented “from a D&C perspective is probably about a 4 or a 5. Because there is a level of risk in the design, designs not fully developed, so there is a level of design risk”. For a traditional type project, C1 commented “look at a traditional design, fully detailed design and it’s probably about a 9. Ultimately we try to reduce the risk and scope the project on behalf of our client so that we have the level of risk in the design is should be very low”.

Participant C2 explained that design risk depending on the type of project, whether it’s public or private, a school or hospital building, and the impact of a risk occurring on that project. C2 said that “projects like health projects or schools or university these are the areas, public utilities that need very high redundancy in design they need a lot of standby backups so the risk of the system not failing should be minimal in that sort of environment”.

Participant C3 explained that design risk is covered through incorporating smart systems on high risk items that either electronically warned building occupants of a failure, or automatically shut a system down to avoid it causing damage or harm. C3 mentioned “primarily we control design risk by implementing smart systems on critical items in our designs that eliminate risks. So we imply a high level of importance to design risk to ensure we eliminate it before our drawings go out”. An example given by C3 was “like interlock control on a boiler and heating hot water pump, if the pump runs or starts, if the pump fails, the boiler will automatically stop, otherwise it will overheat”.

Participant C4 explained that design risk was related to safety, maintenance and innovation and creativity. Safety and maintenance with regard to, if the design was created so the system can be installed, operated and maintained in safe manner that eliminates design risk. Innovation and creativity with regard to, being innovative and creative is a high risk because the system could fail. So by not being innovative and creative and keeping things standard this further eliminates risk. C4 replied “same
reasons as safety and maintenance. That is where innovation and creativity step in, because it is a design risk. If it is innovative it is a high risk”.

4.4.8.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was relatively consistent as they all placed within a band of 7 to 10. None of the participants provided the same rating, however they are all reasonably close.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

A regularly discussed topic amongst the design and build designers was contingencies and how they were or weren’t being applied to designs to mitigate design risk. Some designers are designing to the exact requirements of the system and allowing no contingencies, and others are ensuring there is spare capacity by allowing small contingencies. S1 stated “no contingency put on cabling, we size it right. Size exactly what they need to be. It’s only allowed if design brief asks for it”. S2 expressed “it’s not dealt with in the form of contingencies; it’s dealt with through good design, or highly calculated design, highly efficient calculations”. On the flipside S3 said “typically we would be looking at contingencies of 10-15%”. S4 mentioned “when designing, we over design a little bit in terms of pipe sizing. We won’t push it to the nth degree. We don’t push it too far; we give it at least 10% or 15% over what’s required.

Another common response from the design and build designers was avoiding new technology that hadn’t been proven to last and keeping things standard as a method of reducing design risk. S1 comments were “if new technology hasn’t been certified. Varies brands come on the market, new brands that come out of Asia, and new brands that come out of Europe they haven’t been tried and tested. It’s important; it’s a risk to us, if it fails”. S3 presented “standardising the type of designs and how we design things is actually important in eliminating the risk”.

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Participants S3 also said another important reason for eliminating design risk was to avoid designs being questionable and their professional credentials being put on the line and ruined. S3 words were “we would consistently have a high rating. It’s not in our interest to put a design that we think is suspect or its going to be questioned, or not fit for purpose, as designers our engineering qualifications are on the line, if there’s a claim made against the business due to design not meeting the intent or there is an insurance claim made against the business, the insurance company is going to want to know who designed it”.
### 4.4.9 Prefabrication

#### 4.4.9.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 6</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Rating driven by the switchboard; do your switchboard offsite, bring it in, connect it up and way you go. Fully detailed and shop drawn and fabricated switchboard offsite, they can come to the site. From this level we do consider it. It’s the nature of the electrical engineering discipline.</td>
<td><strong>Comments:</strong> Cold water booster pumps, prefer them pre-assembled, commissioned, tested, put on skid. Solves problems and saves time onsite with installation. Easier to preassemble and commission and bring it on a skid together. Only make in and out connections on site, save plumbers getting it wrong. Manufacturers of plant and equipment prefer to preassemble own equipment. Reduces failures onsite. Safer like that, if fabrication onsite, sometimes cold, sometimes too hot creating issues onsite. Manufacturers have all the facilities, they do it; they test it, its fail proof. They have better tools and facilities to assemble and commission correctly.</td>
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<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 3</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> If system we don’t specialise in like steam system, with steam boilers, pumps, pressure regulation, which we are not good at, we will go to supplier who supply whole package and we do all interconnection between different components, the controls. If we are familiar with and its standard practice, we will get individual system components from suppliers. In mechanical we never do prefab because we know mechanical contractors are capable of doing individuals.</td>
<td><strong>Comments:</strong> Fire pump prefabbad as we wouldn’t want someone putting together onsite. Built by company in factory. The risk of assembling control valves, pumps is to high allowing local trade to assemble onsite. If something wrong with prefabricated unit, you get manufacturer onsite to sort. It’s a risk mitigation strategy. Prefabrication is good for coordination and spacial allowances. Prefabbed unit you know size of it, if you work out how all goes together, becomes a problem because you don’t know how big each component is.</td>
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<tr>
<th>Design &amp; Build Designer 1 (S1) – Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 0</td>
<td><strong>Rating:</strong> 0</td>
</tr>
<tr>
<td><strong>Comments:</strong> Doesn’t apply to us. We don’t do anything prefabricated. Switchboards are made offsite, but it’s more of a product that we buy and its industry standard.</td>
<td><strong>Comments:</strong> Not plumbing industry way of doing things, not trade practice. Can be built on or offsite. Still has to be done by a plumber, so there is no cost advantage.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 9</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Mechanical services have a high rating. Nature of our industry 70% of work is ductwork so always prefabricated, designed and shop drawn to be fabricated. Its nature of our business, otherwise have to have sheet metal folding machines and building duct onsite. Highly important to speed up the processes and make it cost effective. Likewise with pipework, particularly steel pipework, where possible it’s prefabricated, because cost of welding in a factory is half of the cost of site labour.</td>
<td><strong>Comments:</strong> 90% of all our work is prefabbad. So it is very important. We go through a shop drawing process and have all pipework created offsite. It’s cheaper to have it made offsite because you don’t have to pay site allowance, or you get rained out, too hot, too cold.</td>
</tr>
</tbody>
</table>

Table 16: All Data Collected for Prefabrication Factor
4.4.9.2 Analysis & Discussion

The numerical data presented in figure 24 indicates that consultant designers rated their overall level of importance applied to prefabrication in their designs higher than that over the design and build designers ratings. All the disciplines have a moderate difference and its being driven by the design and build designers whose ratings went from one extreme to the other. The difference in the ratings overall is moderate and there appears to be a noticeable variance. All ratings and comments given by all designers for this factor were vastly driven by their particular discipline.

4.4.9.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was moderately consistent. Three of the participants provided a rating within a band of 6 to 8 and the fourth (participant C3) was an outlier with a lower rating of 3. It is apparent by the following comment why C3 gave a lower rating “if it is something we are familiar with and its standard practice, we will get individual system components from suppliers. In mechanical we never do prefab because we know mechanical contractors are capable of doing individuals”. No other consultant designer made this comment.
Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

Consultant designers commonly provided examples of where they would implement prefabricated features into their designs. This revealed that prefabrication is applicable to all disciplines. C1 stated “driven by the switchboard; if you do your switchboard offsite, bring it in; connect it up and way you go. So fully detailed and shop drawn and fabricated switchboard offsite, they can come to the site”. C2 commented “cold water booster pumps, we would prefer them pre-assembled, commissioned, tested, put on a skid”. C3 revealed “a steam system, with steam boilers, pumps, pressure regulation, which we are not so good at, we will go to a supplier who can supply the whole package”. C4 said “the fire pump would be prefabbled as we wouldn’t want someone putting this together onsite. Built by a company in a factory”.

Further to the previous comments, reasons provided by the consultant designers for incorporating prefabrication was it saved time onsite, reduces failures, reduces risk, reduces commissioning, avoids onsite environmental impacts, higher quality assembly, easier coordination and easier space allocation. Participant C2 comment was “solves half of the problems and saves a lot of time onsite with installation. It’s easier to preassemble and commission and then bring it on a skid together. Only make in and out connections on site, save plumbers getting it wrong. Onsite, sometimes cold, sometimes too hot creating issues onsite. Manufacturers of the plant they have all the facilities, they do it; they test it, its fail proof. They have better tools and facilities to assemble and commission correctly”. C4 mentioned “the risk of assembling control valves, pumps is to high allowing local trade to assemble onsite. If something goes wrong with a prefabricated unit, then you get the manufacturer onsite to sort issue. It’s a risk mitigation strategy. Good for coordination and spacial allowances”. This reflects Marsh (2003) who said “prefabrication and preassembly of building services offers the client and the building services team a number of advantages. These can include the three cornerstones of procurement, cost savings, improved quality and reduced on-site programme times” (p. 83).
4.4.9.2.2 Design and Build Designers

Examining the numerical data (ratings) provided by the design and build designers, the result was very inconsistent. Two participants provided high ratings in a band of 9 to 10, and the remaining two participants were at the opposite end rating it N/A. It is clear in the following written data why this is the case.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also. The written data is very two sided as per the numerical data.

Design and build designers S1 and S2 who both provided ratings of N/A commonly said that prefabrication didn’t apply to their disciplines as it wasn’t the way their industry operated. S1 words were “doesn’t apply to us. We don’t do anything prefabricated. Switchboards are made offsite, but it’s more of a product that we buy and its industry standard”. S2 stated “not plumbing industry way of doing things, not trade practice. Can be built on or offsite. Still has to be done by a plumber, so there is no cost advantage”.

On the flipside design and build designers S3 and S4 who both provided very high ratings commonly said it was very important because it was the way their industry operated. A large percentage of their work is shop drawn and prefabricated. S3 stated “for mechanical services this has a high rating. By nature of our industry 70% of our work is ductwork so that is always prefabricated and is designed and shop drawn to be fabricated. Likewise with pipework, particularly the steel pipework, where possible it’s prefabricated”. S4 commented “90% of all our work is prefabbed. So it is very important. We go through a shop drawing process and have all pipework created offsite”. The above reveals Marsh (2003) when considering prefabrication that a design and build procurement arrangement will permit the designers and contractor to work closely and produce fully worked and coordinated shop drawings.

Further to the previous comments, further reasons provided by S3 and S4 for incorporating prefabrication was it’s in the makeup of their business, saves time,
saves money and avoids onsite environmental impacts. S3 mentioned “it’s the nature of our business, otherwise we would have to have sheet metal folding machines and building duct onsite which we don’t want to do. So it’s highly important to speed up the processes and make it cost effective. The cost of welding in a factory is half of the cost of site labour”. S4 replied “it’s cheaper to have it made offsite because you don’t have to pay site allowance, or you get rained out, too hot, too cold”.
4.5 Design Process

4.5.1 Scope of Works

4.5.1.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Highly important we have an agreed scope of works with clients and therefore clearly defined scope when doing design so we know what to design, and what to target for.</td>
<td><strong>Comments:</strong> Don’t know the scope then you don’t know what you doing. Just a stab in the dark. Someone asks you to do a little job. That job could become a big job. Need to know what you have to do and what is your limit, where does your involvement stop.</td>
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<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 7</td>
<td><strong>Rating:</strong> 8</td>
</tr>
<tr>
<td><strong>Comments:</strong> Very important, but not always the case. We always prefer a clear scope at beginning, but not always the case. It’s changing. Have to make some allowance for scope changes, you think it’s not going to change, but we all know it happens.</td>
<td><strong>Comments:</strong> Creates less confusion, less overwork, could be designing something not being paid for. Less risks of leaving something out. Not assuming where design is required and not required. Reduces risk for design and construction, because designed and installed in the correct locations and doesn’t need to be removed or added in at a later date.</td>
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<tr>
<th>Design &amp; Build Designer 1 (S1) - Electrical</th>
<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 3</td>
</tr>
<tr>
<td><strong>Comments:</strong> Get it right. Make sure what we are designing is what asked for, and no more, no less. At the start, then there’s things they might ask for during course of project they might not have asked for, and say scope going to change, where going to do this and that, part and parcel with design and construct agenda. No variations with D&amp;C. Give GMP figure, they say can you build this for me, I say yes. Unless the client changes the scope of works for whatever reason, the brief changes.</td>
<td><strong>Comments:</strong> Scope of works document provided by the builder / client. Makes easier to get out of doing things. Once it is shown on your drawings, you don’t have a case to argue. If you leave off and make it ambiguous site guy might be able to say builder’s responsibility even if yours. So you pass scope on easier. That’s why sometimes not bad to have it grey area.</td>
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<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> You need to have a very clear scope. If not clear, means there is a risk that design is not going to meet users expectations, and risk of litigation or dispute in general if there is a perception design has not meet the scope.</td>
<td><strong>Comments:</strong> It’s important. Bulk of our jobs will come in and consultants will start them. A consultant cost of original design was high, so the builder sacked the consultant once the project was novated and then went D&amp;C. We then offered a cheaper cost by wiping out so much unneeded stuff.</td>
</tr>
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</table>

Table 17: All Data Collected for Scope of Works Factor
4.5.1.2 Analysis & Discussion

The numerical data presented in figure 25 indicates that consultant designers rated their overall level of importance applied to having a clearly defined scope of works marginally higher than that over the design and build designers. The difference in ratings appears to be small and they appear to be similar. The largest variance and a clear outlier in the data set is participant S2. It is apparent by the following comment given by participant S2 why he was lower “If you leave it off and make it ambiguous the site guy might be able to say it is the builder’s responsibility even if it was yours. So you can pass some of the scope on easier. That’s why it’s sometimes not too bad to have it as a grey area”. No other participant made this comment.

4.5.1.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was moderately consistent. Two participants provided very high ratings of 10 and the remaining two participants provided high ratings of 7 and 8.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was very mixed. There are few common responses as each participant had their own point of view.
All of the consultant designers rated and agreed that having a clearly defined scope of works was very important to them. C1 stated “it is highly important that we have an agreed scope of works with our clients and therefore a clearly defined scope when doing our design”. C3 agreed “it is very important”. However it was also discussed that it wasn’t always clear and it was likely to change throughout the project. C3 mentioned “we always prefer to have a clear scope at the beginning, but it’s not always the case. It’s changing. I probably would have to make some allowance for scope changes, you think it’s not going to change, but we all know it happens”. C2 added “someone asks you to do a little job, that job could become a big job”.

A frequently discussed topic amongst the consultant designers was bases why having a clearly defined scope were important. Reasons given were so you know what you have to complete, where your design limits are and it reduces risk of missing items. C1 replied “so we know what to design, and what to target for”. C2 mentioned “if you don’t know the scope then you don’t know what you are doing. It’s just a stab in the dark. Need to know what you have to do and what your limit is, where your involvement stops”. C4 added “creates less confusion, less overwork, you could be designing something totally that you’re not being paid for. Less risks of leaving something out. So you’re not assuming where design is required and not required”. This aligns with Civitello & Civitello (2000) statement “the scope of work that must be completed in order to fulfil contractual obligations must be clearly and completely defined” (p. 3.48).

4.5.1.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent. Three participants provided very high ratings of 10 and the fourth (participant S2) was an outlier with a lower rating of 3 as previously explained.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was very mixed. There are few common responses as each participant had their own point of view.
Largely design and build designers rated and agreed that having a clearly defined scope of works was important. Reasons given were so you know what you have to complete, where your design limits are, reduces risk of missing items and being sued. S1 said “make sure what we are designing is as per what they have asked for, and no more, no less”. S3 commented “you need to have a very clear scope. If the scope is not clear, then that means there is a risk that the design is not going to meet the intended users expectations, and therefore there’s always risk of litigation or dispute in general if there is a perception that the design has not meet the scope”.

Similar to the consultant designers, it was discussed by participant S1 that the scope is likely to change throughout the project, however under design and build contracts variations or extra fees couldn’t be charged unless it was a change to the original client briefing document. S1 comments were “there are things that they might ask for during the course of the project that they might not have asked for, and say the scope going to change, where going to do this and that, it’s just part and parcel with design and construct agenda. There are normally no variations with D&C, unless the client changes the scope of works for whatever reason the brief changes.”
## 4.5.2 Coordination

### 4.5.2.1 Data Collected

<table>
<thead>
<tr>
<th>Consultant Designer 1 (C1) - Electrical</th>
<th>Consultant Designer 2 (C2) - Hydraulic</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 8</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> I would like to say that it is very high, but it is not. It is about a high. High level of importance put in place for making sure internally services are coordinated so people tapping into the correct points, interfaces between each service is proper, architecturally an on-going process with architect we make sure services corresponds with the architectural. No clashes is ultimate goal, it’s never there, not possible, definitely internally we do, electrical do what we can with hydraulic department. Being multi discipline company provides advantage for coordination of disciplines.</td>
<td><strong>Comments:</strong> Important element of design process to make sure systems can be put together and work. Liaise with other parties for design requirements and your requirements. You want something; say putting pipe threw a two metre beam. If not coordinated it’s not buildable. Coordination starts with architect, the authorities, and other consultants during the design phase.</td>
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<tr>
<th>Consultant Designer 3 (C3) - Mechanical</th>
<th>Consultant Designer 4 (C4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 9</td>
</tr>
<tr>
<td><strong>Comments:</strong> Making sure cable tray under your duct so they can access it, I lift my duct up. As I get more knowledge I tend to think more for others for design to be better for other disciplines. We do little sketch and send to drafter because when they do Revit they can see, they can avoid clashes. I personally think it is very important. Being multidiscipline helps, we learn from others. We all in same office, we talk all the time. Other individual companies have to talk over the phone without something to look at.</td>
<td><strong>Comments:</strong> Coordination is important because it restricts variations. The architect can plan his aesthetic ceiling layouts. Reflected ceiling plans. Revit 3D modelling tool is making you think harder about coordination.</td>
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<table>
<thead>
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<th>Design &amp; Build Designer 2 (S2) - Hydraulic</th>
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</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 10</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> Getting better. Very important, but doesn’t get done very well, that’s the issue. We all rate it very high. Some companies we work for the coordination is overboard. The documentation, designing and overlays that sort of thing. Important because otherwise you end up doing things twice. Not pull things out and reinstall.</td>
<td><strong>Comments:</strong> Construction team, for the whole D&amp;C team, it is high. Not always all done, some left to be coordinated onsite. If you don’t coordinate you can’t build it. Level depends on guy onsite. Guys with high capability you give plain undetailed and they will sort onsite. Guys with low capability you give fully detailed and coordinated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design &amp; Build Designer 3 (S3) - Mechanical</th>
<th>Design &amp; Build Designer 4 (S4) - Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating:</strong> 9</td>
<td><strong>Rating:</strong> 10</td>
</tr>
<tr>
<td><strong>Comments:</strong> What like to achieve, and see in industry is lower. If services aren’t coordinated, costly and time consuming to reroute the duct and often means have to get prefabricated ductwork remade so importance to us very high. Important to maintain relations with other designers on project. If services coordinated in timely manner before site installation works start then helps minimise disputes onsite because nobody likes moving their services.</td>
<td><strong>Comments:</strong> Biggest problem are the plumbers because don’t do shop drawings. The problem is we are always last in. if plumbing isn’t designed write and coordinated properly it causes a lot of problems and goes pear shaped. It is getting better, we seeing more and more shop drawings from plumbers and it is helping.</td>
</tr>
</tbody>
</table>

| Table 18: All Data Collected for Coordination Factor |  |

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4.5.2.2 Analysis & Discussion

The numerical data presented in figure 26 indicates that design and build designers rated their overall level of importance applied to coordination in their designs higher than that over consultant designer’s ratings. The difference in ratings appears to be small and they appear to be similar.

4.5.2.2.1 Consultant Designers

Examining the numerical data (ratings) provided by the consultant designers, the result was very consistent. Three of the participants provided a rating within a band of 9 to 10 and the fourth (participant C1) was a minor outlier with a lower rating of 8. It is apparent by the following comment why C1 gave a lower rating “during the design process I would like to say that it is very high, but it is not. It is about a high. I don’t think we have no clash which is the ultimate goal, it’s never there, it’s not possible”. No other consultant designer made this comment.

Examining the written data (comments) provided by the consultant designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.
In line with the ratings provided, all consultant designers agreed in their comments that coordination is very important and is an essential element in the design process to ensure a project was buildable and reduce variations during the construction phase. C2 replied “this is an important element of the design process to make sure that all systems can be put together and it works”. C3 presented “I personally think it is very important”. C4 said “coordination is important because it restricts variations”.

Consultant designers frequently discussed and responded that the level of coordination within their own organisation was high due to being a multi discipline company where all disciplines are working out of the same office, they talk to one another, learn from one another, have internal meetings, physically have the project in front of them, and it is a very easy and efficient process to coordinate. Participant C1 comments were “I would definitely say that being a multi discipline company provides an advantage for coordination of disciplines. High level of importance put in place for making sure internally our services are coordinated. Electrical engineers do what we can with hydraulic department. Internally we do have meetings to clarify those”. C3 added “I think being multidiscipline helps, we learn from others. We are all in the same office, so we talk all the time. Other individual companies have to talk over the phone without something to look at”.

Consultant designers frequently gave examples of the coordination process and their general methods to ensure it was completed adequately. They discussed items such as clear demarcation or interface points, alignment with architectural and structural disciplines, eliminating clashes between services, interacting with other designers, discussions with authorities and generally thinking of other disciplines whilst designing. C2 presented “liaise with all the other related parties for their design requirements and your design requirements so all systems work and you can put it together. You want something, say putting in a pipe and you go through a two metre beam. If it’s not coordinated it’s not buildable. Coordination starts with the architect, the authorities, and the other consultants during the design phase”. C1 mentioned “interfaces between each service is proper, architecturally an on-going process with the architect that we make sure that services are corresponds and correlates with the architectural”. C3 commented “making sure a cable tray is under your duct so they can access it, so I have to lift my duct up. Think more for others for the design to be
better for other disciplines”. This reflects K.C. Lam (2004) that you can eliminate majority of coordination issues by creating good designs that integrate and coordinate all of the disciplines during the various design stages.

Another topic that was discussed lightly, which was covered under the buildability factor, is coordination is improving due to the introduction of 3D modelling and virtual construction tools such as Revit MEP and Navisworks. C4 stated “Revit 3D modelling tool is making you think harder about coordination”. C3 mentioned “when we do Revit we can see and avoid clashes”.

4.5.2.2.2 Design and Build Designers
Examining the numerical data (ratings) provided by the design and build designers, the result was very consistent. Three of the participants provided very high ratings of 10 and the fourth (participant S3) provided a high rating of 9, so very little variance.

Examining the written data (comments) provided by the design and build designers, the level of variation amongst the responses was mixed. There are common responses in some cases, but at the same time each participant had their own point of view which provided varying responses also.

In line with the ratings provided, all design and build designers agreed in their comments that coordination is very important to avoid rework, ensure buildability and minimise disputes. S1 said important because otherwise you end up doing things twice. Not having to pull things out and reinstall”. S2 replied “if you don’t coordinate you can’t build it. S3 commented “if the services have been coordinated in a timely manner before the site installation works start then it helps minimise disputes onsite because nobody likes moving their services”. This aligns with K.C. Lam (2004) where building services installations have performed badly overall, uncoordinated designs are a large contributing factor.

Design and build designers frequently gave examples of coordination issues that they come across. They discussed items such as, it’s not completed very well or it is overboard, ramifications are time consuming and costly, rework, causes anger, other disciplines, and no shop drawings. S1 stated “very important, but doesn’t get done
very well, that’s the issue. Some companies we work for the coordination is overboard”. S3 presented “optimally what we would like to achieve, and practically what we actually see in industry is lower. If services aren’t coordinated, it’s costly and time consuming to have to reroute the duct services and it often means we have to get prefabricated ductwork remade. It all causes frustration and anger onsite because there is time loss, money lost”. S4 commented “biggest problem we have are the plumbers, because they don’t do shop drawings. The problem is we are always last in. if plumbing isn’t designed right and coordinated properly it causes a lot of problems and goes pear shaped”. This reflects Price & Gibb (1996) that as a result of poor coordination that the construction programme has to be rescheduled and extra costs are suffered.

*End of Chapter 4.*
5 CONCLUSIONS

The aim of this research project is to pursue and answer the following question…,

“What factors influence a design by a building services design consultancy compared to a design and build subcontractor in Melbourne?”

5.1 Most Different Results

5.1.1 Communication

Consultant designer’s level of communication is created through interacting with a large number of parties involved on a project, internally and externally of their own organisation. Their rating was also increased because they have embraced new web based project management systems such as Aconex and Team Binder. However their rating was lowered due to slow and complex communication channels with onsite contractors due to contractual obligations.

Design and build designer’s level of communication is created by simple and straightforward communication within their own organisation and with other subcontractors, as processes aren’t as formal and contractual, and transferring information is simple. Their rating was decreased due to a lot of projects now implementing web based project management systems such as Aconex and Team Binder, and they felt the use of these systems only lowered communication as they are time consuming and tedious.

Communication amongst design and construction teams affects an overall building services design if it inhibits adequate coordination and information flow to take place. Consultant designers have a higher level of communication overall as they appear to be interacting with all parties involved in a project and have adopted the use of web based project management systems better than that of design and build designers. However, design and build designers have a much better level of communication with the construction team than consultant designers.
In conclusion, communication influences both organisations building services designs, but consultant designers appear to be achieving a significantly higher level overall.

5.1.2 Alternatives
Consultant designer’s level of importance applied to creating and comparing alternate design options is largely created through recognising that there is usually more than one way to achieve a design solution and creating and comparing different design options based on criteria such as capital and whole life cost, buildability, durability, aesthetics and appropriateness. Their rating was further increased because they are completing these evaluations a presenting them to their clients and advising the advantages and disadvantages of each system.

Design and build designers level of importance applied to creating and comparing alternate design options is largely created through creating and comparing different design options based on achieving lower cost and productivity rates.

The written and numerical data for this factor don’t appear to line up. Design and build designers gave higher numerical ratings than the consultant designers, however it appears only because design and build designers place a high level of importance on cost, and they place a similar level on creating and comparing alternatives to achieve those costs. Whereas looking at the written (comments) data provided by consultant designers it appears they are applying a higher level of importance to creating and comparing alternatives. They are identifying the best possible system for their clients by evaluating alternatives on performance, visual, suitability and cost aspects.

In conclusion, alternatives influence both organisations building services designs, but consultant designers appear to be achieving a significantly higher level overall.

5.1.3 Maintenance
Consultant designer’s level of importance applied to maintenance in their designs is largely driven by the requirements of OH&S, safety in design, standards and
legislation. Their rating was further increased as easy access and maintenance of their systems over the course of its lifetime was highly regarded.

Design and build designer’s level of importance applied to maintenance in their designs is largely driven by the structure of their company and whether they had a maintenance arm to cater for maintenance contracts. Their level was also driven by the requirements of OH&S, standards and legislation. Easy access and maintenance of plant and equipment was also mentioned by one participant.

Maintenance affects an overall design if the system being implemented is designed to require little maintenance during operation, the ease of maintenance and the straightforward replacement of plant and equipment is accommodated. Both organisations are accommodating maintenance in their designs; however consultant designers appear to be regarding it more important in their designs due to their higher awareness and following of OH&S, safety in design, standards and legislation requirements.

In conclusion, maintenance influences both organisations building services designs, but consultant designers appear to be achieving a significantly higher level overall.

5.1.4 Ecologically Sustainable Development (ESD) / Energy Efficiency

Consultant designer’s level of importance applied to ESD / energy efficiency in their designs is largely driven by implementing ESD / energy efficient features into their designs because they are aware of this topics movement in the industry, understand its impact on the environment and have generally embraced it as something they need to think about every day. Their ratings are further increased as in some cases it’s driven by their company structure and its key values.

Design and build designers level of importance applied to ESD / energy efficiency in their designs is largely driven by being aware of the topic and its significance, but not focusing on or implementing it unless they have to. Their ratings were decreased because they believe there is a need for realistic ESD / energy efficient systems, not ones that just look good on paper.
ESD / energy efficiency affects an overall design if the system being implemented is designed to reduce the consumption of limited resources such as energy and materials, all in support of developing a more sustainable built environment. Both organisations are well aware of the matter; however consultant designers appear to have embraced it better and are regarding it more important in their designs.

In conclusion, ESD / energy efficiency influences both organisations building services designs, but consultant designers appear to be achieving a significantly higher level overall.

5.1.5 Aesthetics
Consultant designer’s level of importance applied to aesthetics in their designs is largely created through regarding aesthetics as being important and having a high level of interaction with the project architects to communicate and coordinate design related issues on a frequent basis.

Design and build designer’s level of importance applied to aesthetics in their designs is largely created through regarding it as a two sided scenario, where front of house it is important and back of house not so important. Their ratings were lifted where aesthetics was regarded important such as the coordination and specification of exposed services, however their ratings were lowered as their general regard was aesthetics is annoying, not important, it costs money, and the function of services over aesthetics is more important.

Aesthetics affects an overall design if the system being implemented is designed through the collaboration of the architect and building services designer to create a combined environment where the aesthetics of the building and the technical performance of the services be considered as one. Both organisations are regarding it in their designs. The written and numerical data for this factor don’t appear to line up. Consultant designers gave slightly higher numerical ratings overall than the design and build designers, however looking at the written (comments) data provided by the
consultant designers it appears they are applying a higher level of importance than suggested.

In conclusion, aesthetics influences both organisations building services designs, but consultant designers appear to be achieving a significantly higher level overall.

### 5.1.6 Capital Cost
Consultant designer’s level of importance applied to capital cost in their designs is made up through some mixed responses. Their ratings were decreased as half of the consultant designers were not concerned about capital cost, either because they had no control over it or they believed their clients had sufficient budgets to cover whatever was designed. Their ratings were increased as the other half considered it very highly and are establishing, tracking and working to budgets thoroughly.

Design and build designer’s level of importance applied to capital cost in their designs is solely made up of ensuring they meet the budget and made as much money as possible. Their ratings were increased further as the specification of plant and equipment is predominantly driven by minimum capital cost.

Capital cost affects an overall design if the system being implemented is designed to minimise capital cost through the specification of inexpensive plant, equipment and materials. Both organisations are working to budgets to minimise capital cost, however design and build designers appear to be achieving a higher level as they have an incentive to make more money.

In conclusion, capital cost influences both organisations building services designs, but design and build designers appear to be achieving a significantly higher level overall.

### 5.1.7 Whole Life Cost
Consultant designer’s level of importance applied to whole life cost in their designs is largely created through undertaking whole life costing to compare alternate design options to underline for clients the differences. Their ratings were increased further as the evaluation of plant and equipment efficiencies are also being considered.
Design and build designer's level of importance applied to whole life cost in their designs is created through not specifying the cheapest plant and equipment available to avoid it failing in a short duration. Their ratings were increased further by specifying plant and equipment that had reputable brands and were known to last.

Whole life cost affects an overall design if the system being implemented is designed to minimise whole life cost through an economic assessment of alternate design options allowing for all important costs of ownership over the systems life. Only consultant designers are truly implementing whole life cost into their designs.

In conclusion, whole life cost only influences consultant designers building services designs; therefore appear to be achieving a significantly higher level overall.

5.1.8 Prefabrication
Consultant designer’s level of importance applied to prefabrication in their designs is made up through implementing prefabricated components into their designs, such as switchboards, domestic and fire water booster pumps and hot water generation plants. These items are being introduced to save time onsite, reduce failures, reduce risk, reduce commissioning, avoid onsite environmental impacts, achieve higher quality assembly, easier coordination and easier space allocation.

Design and build designer’s level of importance applied to prefabrication in their designs is a two sided scenario. It’s either not implemented at all, which appears to be for the case for the electrical and hydraulic disciplines, or it is totally implemented, which appears to be for the case for the mechanical and fire disciplines. The electrical and hydraulic disciplines don’t apply it because it’s not the manner in which their industry operates. The mechanical and fire disciplines do apply it because it is all about the manner in which their industry operates, 70 – 90% of their work is shop drawn and prefabricated before it arrives onsite. The mechanical and fire disciplines use prefabrication as it’s in the nature of their business, it saves time, it saves money and it avoids onsite environmental impacts.
Prefabrication affects an overall design if the system being implemented has been designed to incorporate components that are prefabricated or preassembled offsite in a factory and delivered to site ready for installation. Both organisations are implementing prefabrication into their designs, however even though consultant designers did rate it higher overall, and the electrical and hydraulic design and build designers rated it N/A, the level and seriousness that the mechanical and fire design and build designers implement this factor exceeds all the consultant designers.

In conclusion, prefabrication influences both organisations building services designs, but design and build designers appear to be achieving a significantly higher level overall.

5.2 Most Similar Results

5.2.1 Team Building / Team Work
Consultant designer’s level of team building / team work is largely created through their own company being multi discipline and having an effective internal working environment. Their rating was also increased further because they are now involved more in D&B type procured projects than in the past and their involvement with the construction team is higher than previously. However their rating was lowered due to adversarial dealings on D/B/B procured projects.

Design and build designer’s level of team building / team work is created through an effective internal working environment where the designers and constructors are the same company; they all know one another very well, they have a good understanding of what one another have to do, and they operate from the same position to achieve the same goal. Their rating was increased further as they work closely with other subcontractors which they have built relations with over time working on the same projects.

Team building / team work affects an overall building services design if it inhibits communication and information flow amongst the design and construction teams and disallows adequate coordination to take place. Both organisations have a high level of
team building with the design team, however design and build designers have a higher level with the construction team.

In conclusion, team building / team work influences both organisations building services designs, but design and build designers appear to be achieving a slightly higher level overall.

5.2.2 Relationships
Consultant designer’s level of relationships is largely driven by them having good professional relations with trade contractors and internally within their own multi discipline organisations. Their ratings were increased further by working with the same people and developing stronger relationships, and having good relations with their clients. Their ratings were lowered by the fact that there is a gap between them and the construction team and this was due to contractual reasons and the nature of their engagement.

Design and build designer’s level of relationships is created through them having very good relations with colleagues in their own organisation by working together over and over again on many projects, and through the fact they all work for the same employer and are aiming to achieve the same goal. Their ratings were increased further by having good relations with their clients and other subcontractors. Relationships were also stronger where they had worked with another colleague previously and had developed a level of understanding and trust, resulting in greater information flow.

Relationships affect an overall building services design where participants become confrontational as oppose to helpful and slow or prohibit the transfer of information. Both organisations appear to have good relations with their clients and other designers, however design and build designers have a higher level with the construction team and other subcontractors.

The written and numerical data for this factor don’t appear to line up. Consultant designers gave higher numerical ratings than the design and build designers, however the written (comments) data provided by consultant designers was very inconsistent.
and weak versus the written data (comments) provided by the design and build designers which was very consistent and strong, signifying that design and build designers level of relationships is actually higher.

In conclusion, relationships influences both organisations building services designs, but design and build designers appear to be achieving a slightly higher level overall.

5.2.3 Buildability
Consultant designer's level of buildability incorporated into their designs is largely created through recognising that unbuildable designs have cost implications, and they are conscious of and check that all products and materials specified can be purchased in a reasonable time frame and installed easily. Their ratings where further increased by being aware that the level of coordination completed during design will have a direct bearing on buildability, and whilst this isn’t as good as it could be, it is improving through the use of 3D virtual construction tools such as Revit MEP and Navisworks. Consultant designers are also attending site to review installations to review and improve on any buildability errors created by their designs.

Design and build designer's level of buildability incorporated into their designs is created through it being one of the primary reasons for being a design and build company, through producing buildable designs for your own construction team to install their services as quickly and easily as possible. Their ratings where further increased by their designers having a trade background or experience which allowed them to better visualise their designs. Design and build designers also through their close relationships with the onsite installers receive a lot of rich feedback on how to design to make installations easier, faster and safer.

Buildability affects an overall building services design if it inhibits the onsite installers to build it. Whether it is through not being able to purchase the product or material or the lead time being unreasonably long; or through not being able to install the product or material because coordination hasn’t been completed, there is inadequate space or it is unsafe. Both organisations have a high level of buildability
incorporated into their designs, however design and build designers are achieving a higher level due to it being a fundamental aspect to the operation of their company.

In conclusion, buildability influences both organisations building services designs, but design and build designers appear to be achieving a slightly higher level overall.

5.2.4 Redundancy / Back-Up
Consultant designer’s level of importance applied to redundancy / back-up in their designs is largely made up through providing additional capacity in their system to cover system surcharges and any minor building extensions in future. Consultant designers are designing the level of redundancy / back-up to suit the building type and the risk level of the operation within that building. The fire service is a high risk on all buildings and the level of redundancy being provided matched that risk.

Design and build designer’s level of importance applied to redundancy / back-up in their designs is largely made up through provided what the design brief asked for and in-line with the end users requirements. Design and build designers are also designing the level of redundancy / back-up to suit the building type and the impact a failure would have on the end user. The fire service was also a high risk on all buildings and the level of redundancy being provided matched that risk.

Redundancy / back-up affects an overall design if the system being implemented is designed to have extra capacity or a stand-by back-up system so the building can continue to operate normally in the event of internal or external failure or an unexpected spike in demand. Both organisations appear to be providing adequate levels of redundancy in their designs; however consultant designers are incorporating it without being instructed as its standard design practice, and they appear to be going over and above what is required to facilitate future expansion.

In conclusion, redundancy / back-up influences both organisations building services designs, but consultant designers appear to be achieving a slightly higher level overall.
5.2.5 Safety
Consultant designer’s level of importance applied to safety in their designs is largely driven by ensuring their designs comply with OH&S legislation. Consultant designers are complying with legislation through the implementation of safety in design practices where risks are identified and designed out at the design stage. Their ratings where further increased as they are designing their services to be constructed, operated and maintained in a safe manner.

Design and build designers level of importance applied to safety in their designs is largely driven by ensuring their designs comply with OH&S legislation also. Design and build designers are predominantly designing their services so they can be constructed in a safe manner very well. They are also considering safe operation and maintenance of services, but more so if their company is involved with maintenance.

Safety affects an overall design if the system being implemented is designed upfront to comply with OH&S legislation through ensuring the service can be constructed, operated and maintained in a safe manner. Both organisations appear to be incorporating safety into their designs through recognising OH&S legislation; however consultant designers are achieving a higher level overall through the use of safety in designs techniques and ensuring their services are safe to construct, operate and maintain, not just safe to construct.

In conclusion, safety influences both organisations building services designs, but consultant designers appear to be achieving a slightly higher level overall.

5.2.6 Design Risk
Consultant designer’s level of importance applied to design risk in their designs is made up through some very mixed responses. Design risk was managed through completing fully detailed drawings where all risks had been identified and dealt with. They were also managed through providing redundancy, back-up, smart electronic warning and shut down systems, and through creating safe and standard designs.

Design and build designer’s level of importance applied to design risk in their designs is largely made up through providing contingencies over and above the system
demand, and executing highly efficient calculations. Their rating was increased further by only using tried and tested brands and technology, and standardising designs.

Design risk affects an overall design if the system being implemented has been designed through recognition of the threats and uncertainties in the system and those risks have managed and mitigated as much as possible. Both organisations rated this factor highly and are recognising risks and managing them; however they are managing them in different ways and the researcher is inconclusive as to which one is truly higher or lower.

In conclusion, design risk influences both organisations building services designs, but the researcher is inconclusive as to which is achieving a higher level overall.

5.2.7 Scope of Works
Consultant designer’s level of importance applied to having a clearly defined scope of works is made up through considering it very important to have a clearly defined scope so they know what they have to design, where their design limits are, and it reducing the risk of missing items.

Design and build designer’s level of importance applied to having a clearly defined scope of works is made up through considering it very important to have a clearly defined scope so they know what they have to design, where their design limits are, reducing the risk of missing items and being sued.

A scope of works affects an overall design if the scope is unclear and design responsibilities are not completely defined, causing drawings to be incomplete and clear demarcations between services non-existent. Both organisations rated this factor highly and recognise it importance equally. Design and build designers had a more consistent high rating, however consultants had more consistent comments. There is nothing clear in the data that separates the two organisations.
In conclusion, the scope of works influences both organisations building services designs, but both appear to be achieving the same level overall.

5.2.8 Coordination
Consultant designer’s level of importance applied to coordination in their designs is largely created through regarding coordination as very important and to ensure buildability. Coordination is being achieved by ensuring their designs have clear demarcation points, they align with architectural and structural disciplines and eliminated clashes through interaction with other designers and authorities. Their rating was increased further through the use of 3D virtual construction tools such as Revit MEP and Navisworks.

Design and build designer’s level of importance applied to coordination in their designs is largely created through regarding coordination as very important to ensure buildability, avoiding rework and minimising disputes. They expressed numerous coordination issues and impacts such as, it’s not completed very well, its overboard, ramifications are time consuming and costly, causes rework, causes anger and other disciplines – either having poorly developed designs or no shop drawings.

Coordination affects an overall design if the system being implemented has not taken into consideration during the various design stages proper integration and coordination of services. Thus affecting the buildability of the system through clashes with other services, the building structure, steelwork and ceilings; and services not fitting into allocated zones. Both organisations regard coordination very important and aware of the issues that surround it, however only consultant designers expressed how they were achieving coordination in their designs and therefore appear to achieving a higher level overall.

In conclusion, coordination influences both organisations building services designs, but consultant designers appear to be achieving a slightly higher level overall.
5.3 Most Unexpected Results

5.3.1 Innovation & Creativity
Consultant designer’s level of innovation and creativity is largely driven by their company structure and its key values which influence the way its designers operate. Some companies install a high level of importance into their designers where they try to be as innovative and creative as possible, and others don’t where repeating previously used systems which had been implemented and proven in the past is important. Implementation of tried and tested systems was unexpectedly being adopted more as efforts to implement innovative designs are going to waste as clients never accept them as the level of risk and associated costs are too high. Majority of consultant designers believe it is important to be aware of the current market and technology that is available.

Design and build designers level of innovation and creativity is largely created through their companies trying to stay inline or ahead of their competition and being seen as an industry leader. This is being achieved by keeping up and being aware of the current market and technology that is available and not just implementing the same designs over and over again. These designers are trying to create more efficient and cheaper systems for their clients where practically and economically viable. Implementation of systems that are purely fit for purpose, buildable and functional was not highly regarded and was an unexpected outcome.

Innovation and creativity affects an overall design if the system being implemented is a unique design that aims to gain operational efficiency versus a standard previously used system that is primarily fit for purpose, buildable and functional. Both organisations are carrying out innovation and creativity in their designs, however design and build designers appear to be regarding it more important in their designs. This result is unexpected as it was thought consultant designers rating would be higher due to the number of green star (ESD) projects and that they only provide an intellectual service where innovation and creativity would set them apart.
In conclusion, innovation and creativity influences both organisations building services designs, but design and build designers appear to be achieving a higher level overall.

5.3.2 Standardisation
Consultant designer’s level of standardisation is largely driven by minimising risk through repeatedly using proven standard company documents such as specification, details and schematics over and over again. Consultant designer’s level of standardisation is lowered when working on ESD type projects where innovation and creativity is important.

Design and build designers level of standardisation is largely driven by repeating standard trade practices that have been in use and understood for many years. Their ratings were further increased where companies are creating standardised methodologies for design and installation procedures, however their ratings were lowered where companies felt innovation and creativity was more important.

Standardisation affects an overall design if the system being implemented is a standard design that aims at not having too many interconnected systems making it simple to install, understand and keep in working order; and by keeping products, materials and installation techniques similar. Both organisations are carrying out standardisation in their designs; however consultant designers appear to be regarding it more important in their designs. This result is unexpected as it was thought design and build designers rating would be higher to keep things repetitive to keep costs down and focus on operation and function.

In conclusion, standardisation influences both organisations building services designs, but consultant designers appear to be achieving a higher level overall.
5.4 Further Research

Majority of the questions in this research project are how important is each factor to the designer? What was discovered is, just because something is rated very important doesn’t necessarily mean it’s been completed very well. As someone’s high rating could equally be another’s medium rating as people interpret questions differently or give ideal answers. So, further research could be how well are these factors actually being achieved? Go to site, ask project managers how smoothly the installation has gone for example from a coordination perspective – compare a consultant designed project to a design and build subcontractor designed project. Participant S3 comment for coordination factor was “9 is optimally what we would like to achieve, and practically what we actually see in industry is lower, is probably realistically 7 or 8 In terms of the level coordination we see occurring in the industry”.

Do multidiscipline design organisations produce better coordinated designs than that of separated? Or what other clear advantages are there of being a multi discipline office vs. being separated?

Does having a trade background in a particular service discipline make you a better building service designer? It has been mentioned by many participants that it does. Does it really?

Safety in design is a relatively new topic in the industry. How well are building services designers achieving it?

It is common for there to be gaps in the scope of building services contracts. What is the impact of those gaps? Are they easily dealt with?
The last question in the questionnaire to all participants was “Are there any other factors that affect building services designs that has not been covered that you feel is important? Or do you have any other comments that maybe relative to this research project?”

Participant C1 said...,

“from the maintenance as built perspective of a building, we design one way, but if the users don’t understand how the building is meant to be utilised, any type of energy efficiency or water efficient system that has been put through might be irrelevant because its not be utilised properly. I think key items from building consultant or being a consultant in the building industry is to ensure that the end client understands the design intent. I always look at the sustainability and energy efficiency as a journey, they have to use it in the same way that we intended, so that needs to marry up, it’s probably one of the key items that needs to be looked at from a, that’s influencing the building industry now. The end client might not know that the system are meant to operate in a certain manner, and while the facility is there, he might ignore it, really communicate that, that’s one of the key items as an engineer and as a company need to take a key interest in. The as built scenario, the as built form operates in as built design intent”.

The above has potential for further research for sustainable buildings from a building services perspective. Are the building services systems designed into green buildings operating and saving energy or water as intended at the design stage because the end client or building operator is using the system as intended? Or not? If not, why don’t they use the system as intended? Do they understand the system?

End of Chapter 5.
6 REFERENCES


*End of Chapter 6.*
7 APPENDIX

The following chapter contains all supplementary material that has been used in the creation of this report.
<table>
<thead>
<tr>
<th>Literature Review - Themes &amp; Factors for Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procurement Theme</strong></td>
</tr>
<tr>
<td>Coordination, Integration, Team Building / Team Work, Communication, Relationships, Buildability, Quality, Cost</td>
</tr>
<tr>
<td>No, No, Yes, Yes, Yes, No, No</td>
</tr>
<tr>
<td>Joined with Coordination under Design Process.</td>
</tr>
<tr>
<td>Relative &amp; gains useful data</td>
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<tr>
<td>Relative &amp; gains useful data</td>
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<tr>
<td>Relative &amp; gains useful data</td>
</tr>
<tr>
<td>Factor too broad, Won't get answer specific to research</td>
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<tr>
<td>0</td>
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<tr>
<td><strong>Decision Making Theme</strong></td>
</tr>
<tr>
<td>Innovation &amp; Creativity, Creativity, Alternatives, Standardisation</td>
</tr>
<tr>
<td>Yes, No, Yes, Yes</td>
</tr>
<tr>
<td>Relative &amp; gains useful data</td>
</tr>
<tr>
<td>Joined with Innovation as per Lit Review.</td>
</tr>
<tr>
<td>Relative &amp; gains useful data</td>
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<tr>
<td>0</td>
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<tr>
<td><strong>Design Aspects Theme</strong></td>
</tr>
<tr>
<td>Yes, Yes, Yes, No, No, Yes, Yes, Yes, No, Yes, Yes, Yes, Yes, Yes, No, No, No, No</td>
</tr>
<tr>
<td>Relative &amp; gains useful data</td>
</tr>
<tr>
<td>Not a major factor. Part of Maintenance &amp; Safety, &amp; Aesthetics. Ignored.</td>
</tr>
<tr>
<td>Not a major factor. Both organisation types must adhere to these.</td>
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<tr>
<td>Not a major factor. Research is Melbourne based. Ignored.</td>
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<tr>
<td>Relative &amp; gains useful data</td>
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<tr>
<td><strong>Design Process Theme</strong></td>
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<tr>
<td>Scope of Works, Coordination</td>
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<tr>
<td>Yes, Yes</td>
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<td><strong>Comment</strong></td>
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<tr>
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<td>54</td>
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</table>

**Purpose of Document:** There are too many factors to present in the interview to keep it within a 1 hour duration. The purpose of this spreadsheet is to review all factors identified in the literature review and decide which ones are to remain, and which ones can be ignored and excluded from the interview and subsequent sections of the report.
INTERVIEW QUESTIONNAIRE DOCUMENT

MATHEW YANEZ (1195432)
INDUSTRY PROJECT
**PROCUREMENT THEME:**

The following questions are taken from the view of procurement systems in the construction industry and how they relate to building services design.

**Team Building / Team Work**

Looking at the procurement method of the projects which you are involved in, please circle your rating for the level of team building and team work present amongst the project team/s.

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</table>

1 (V Low) = No team building activities. Members don’t know each other and are distant. Members don’t work together as a team. Members operate from separate positions.

10 (V High) = A lot of team building activities. All members know one another and are close. Members all work together as a team. Members operate from the same position.

Following the above, please explain why you feel this level of team building and team work is present amongst the project team/s. 

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Communication

Looking at the procurement method of the projects which you are involved in, please circle your rating for the level of communication present amongst the project team/s.

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1 (V Low) = No communication amongst members. Communication channels are complex and slow. Procedures are difficult.

10 (V High) = A lot of communication amongst members. Communication channels are simple and fast. Procedures are straightforward.

Following the above, please explain why you feel this level of communication is present amongst the project team/s.

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Relationships

Looking at the procurement method of the projects which you are involved in, please circle your rating for the level (nature) of the relationships between you and the project team/s.

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</table>

1 (V Low) = No relationships. Very adversarial & challenging type relationships. No cooperation or partnering.

10 (V High) = Good relationships. Very collaborative & supporting type relationships. Very cooperative

Following the above, please explain why you feel this level (nature) of relationships exists between you and the project team/s.

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MATHEW YANEZ (1195432): INDUSTRY PROJECT
Buildability

Looking at the procurement method of the projects which you are involved in, please circle your rating for the level of buildability you are able to incorporate into your designs.

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1 (V Low) = Design not buildable at all. No inclusion or assurance of buildability.

10 (V High) = Design completely buildable. High inclusion and assurance of buildability.

Following the above, please explain why you feel this level of buildability is able to be incorporated into your designs.

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DEcision MAKING THEME:

The following questions are taken from the view of the decision making process and how it relates to building services design.

Innovation & Creativity

Looking at your decision making process (thought process) during the development of a building services design, please circle your rating for the level of importance applied to innovation & creativity in your designs.

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</table>

1 (V Low) = Not important. Not considered at all. Always look for standard designs. Always design with proprietary (off the shelf) systems and products.

10 (V High) = Very important. Always thinking outside the typical model (box). Always looking for new and more efficient systems.

Following the above, please explain why this level of importance is applied to innovation & creativity in your designs.

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Alternatives

Looking at your decision making process (thought process) during the development of a building services design, please circle your rating for the level of importance applied to creating and comparing alternate design options in your designs.

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1 (V Low) = Not important. Not considered at all. The first design solution is the only option considered.

10 (V High) = Very important. Never a single design solution considered. Wide range of alternatives created and compared.

Following the above, please explain why this level of importance is applied to creating and comparing alternate design options in your designs.

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**Standardisation**

Looking at your decision making process (thought process) during the development of a building services design, please circle your rating for the level of importance applied to standardisation in your designs.

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1 (V Low) = Not important. Not considered at all. Always look for creative non-standard designs. Always design with customised systems and products.

10 (V High) = Very important. Repeating operations highly considered. Never use creative non-standard designs. No complex interconnected systems making system difficult to install, understand or maintain. Always design with proprietary (off the shelf) systems and products.

Following the above, please explain why this level of importance is applied to standardisation in your designs.

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DESIGN ASPECTS THEME:
The following questions are taken from the view of design aspects and how they relate to building services design.

Maintenance

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to maintenance in your designs.

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1 (V Low) = Not important. Not considered at all. Never consider maintenance in designs.

10 (V High) = Very important. Always implement systems which require little maintenance during operation and facilitate ease of maintenance. The straightforward replacement of services such as plant is always allowed for.

Following the above, please explain why this level of importance is applied to maintenance in your designs.

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Ecologically Sustainable Development (ESD) / Energy Efficiency

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to ecologically sustainable development (ESD) / energy efficiency in your designs.

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1 (V Low) = Not important. Not considered at all. Never implement ESD / energy efficient systems into designs.

10 (V High) = Very important. ESD / energy efficient systems are always considered and implemented in designs where possible.

Following the above, please explain why this level of importance is applied to ecologically sustainable development (ESD) / energy efficiency in your designs.

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Redundancy / Back-Up

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to redundancy / back-up in your designs.

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</table>

1 (V Low) = Not important. Not considered at all. Never implement redundancy or back-up systems into designs.

10 (V High) = Very important. Always implement systems which incorporate redundancy or back-up just in-case something fails.

Following the above, please explain why this level of importance is applied to redundancy / back-up in your designs.

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Aesthetics

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to aesthetics in your designs.

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1 (V Low) = Not important. Not considered at all. Never work with or communicate with architect.

10 (V High) = Very important. Always work with architect to create an aesthetic combined environment where services are never placed in visually unwanted positions. A lot of communication with architect to obtain allocated space for plant and equipment.

Following the above, please explain why this level of importance is applied to aesthetics in your designs.

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Capital Cost

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to capital cost in your designs.

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1 (V Low) = Not important. Not considered at all. Specification of plant, equipment and material never driven by capital cost.

10 (V High) = Very important. Minimum capital cost is highly considered and evaluated. Specification of plant, equipment and material driven by capital cost.

Following the above, please explain why this level of importance is applied to capital cost in your designs.

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Whole Life Cost

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to whole life costing in your designs.

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1 (V Low) = Not important. Not considered at all. Specification of plant and equipment never driven by whole life cost.

10 (V High) = Very important. Full whole life costing analysis of all energy consuming plant and equipment. Specification of plant and equipment driven by whole life cost.

Following the above, please explain why this level of importance is applied to whole life costing in your designs.

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Safety

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to safety in your designs.

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1 (V Low) = Not important. Not considered at all. Never implement safety into designs.

10 (V High) = Very important. Always implement safety into designs. Always design systems that can be installed, operated and maintained in a safe manner. Always incorporate safety and risk assessment and mitigation into design.

Following the above, please explain why this level of importance is applied to safety in your designs.

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Design Risk

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to design risk in your designs.

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1 (V Low) = Not important. Not considered at all. Risk is not managed or eliminated.

10 (V High) = Very important. Managing and eliminating risk in design is highly considered. All risk is dealt with by some form of contingency.

Following the above, please explain why this level of importance is applied to design risk in your designs.

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Prefabrication

Looking at general design aspects of developing a building services design, please circle your rating for the level of importance applied to prefabrication in your designs.

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1 (V Low) = Not important. Not considered at all. System components never designed as prefabricated or preassembled units.

10 (V High) = Very important. System components always designed as prefabricated or preassembled units where possible to either save costs, improve quality or reduce onsite programme times.

Following the above, please explain why this level of importance is applied to prefabrication in your designs.

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DESIGN PROCESS THEME:
The following questions are taken from the view of the design process and how it relates to building services design.

Scope of Works

Looking at the general design process of developing a building services design, please circle your rating for the level of importance applied to having a clearly defined scope when undertaking your designs.

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1 (V Low) = Not important. Not considered at all.

10 (V High) = Very important. Scope of works must be defined in an itemised breakdown. Definition of design responsibility must be clearly described.

Following the above, please explain why this level of importance is applied to having a clearly defined scope when undertaking your designs.

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Coordination

Looking at the general design process of developing a building services design, please circle your rating for the level of importance applied to coordination in your designs.

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1 (V Low) = Not important. Not considered at all. Design completed in isolation. No meetings & discussions with other designers or construction team.

10 (V High) = Very important. Design thoroughly coordinated with other services and building elements such as structure, steelwork and ceilings. No clashes at all. Frequent meetings & discussions with other designers and construction team.

Following the above, please explain why this level of importance is applied to coordination in your designs.

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Are there any other factors that affect building services designs that has not been covered that you feel is important? Or do you have any other comments that maybe relative to this research project?

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