AN INTEGRATED KNOWLEDGE MANAGEMENT FRAMEWORK FOR MANAGING SUSTAINABILITY KNOWLEDGE IN THE AUSTRALIAN INFRASTRUCTURE SECTOR

By

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A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

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Faculty of Built Environment and Engineering
STATEMENT OF ORIGINAL AUTHORSHIP

DECLARATION

The work contained in this thesis has not been previously submitted for a degree or diploma at any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signed:

Date:
ACKNOWLEDGEMENTS

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At last, I would like to express my sincere thanks and love to my parents and fiancé who always encourage me, comfort me and accompany me throughout these years of study with infinite patience and deep understanding, despite the long geographic distance between us. I wish to dedicate this thesis to them.
ABSTRACT AND KEY WORDS

In Australia, it has been increasingly accepted that sustainability needs to be at the top of the agenda when contemplating infrastructure development. In practice however, many companies struggle to find effective ways to embrace sustainable ideas and implement them in real projects beyond minimum compliance. One of the reasons is the lack of underpinning knowledge and evidence to demonstrate and measure the linkage between sustainability implementations and the relevant outcomes. This is compounded by the fact that very often there are no common understandings between the stakeholders on sustainability and there is a big divide between research advancement and real-life applications. Therefore it is both feasible and timely to develop and expand the body of sustainability knowledge on infrastructure development and investigate better ways of communicating with and managing it within the infrastructure sector.

Although knowledge management (KM) is a relatively new and emerging discipline, it has shown its value and promise in existing applications in the construction industry. Considering the existing KM mechanisms and tools employed in practice, this research is aimed at establishing a specific KM approach to facilitate sustainability knowledge identification, acquisition, sharing, maintenance and application within the infrastructure sector, and promote integrated decision-making for sustainable infrastructure development.

A triangulation of questionnaire survey, semi-structured interviews and case studies was employed in this research to collect required qualitative and quantitative data. The research studied the unique characteristics of the infrastructure sector, the nature of sustainability knowledge, and evaluated and validated the critical elements, key processes, and priority issues of KM for the Australian infrastructure sector. A holistic KM framework was developed to set the overall context for managing sustainability knowledge in the infrastructure sector by outlining (1) the main aims and outcomes of managing sustainability
knowledge, (2) the key knowledge activities, (3) effective KM strategies and instruments, and (4) KM enablers. Because of the highly project-oriented nature of the infrastructure sector, knowledge can only add value when it is being used in real projects. Implementation guidelines were developed to help the industry practitioners and project teams to apply sustainability knowledge and implement KM in infrastructure project scenarios.

This research provides the Australian infrastructure sector with tools to better understand KM, helps the industry practitioners to prioritize attention on relevant sustainability issues, and recommends effective practices to manage sustainability knowledge, especially in real life implementation of infrastructure projects.

**Key words:** Infrastructure Development, Sustainability, Knowledge Management, Project Management
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<tr>
<td>ABGR</td>
<td>Australian Building Greenhouse Rating</td>
</tr>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
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<tr>
<td>AGIC</td>
<td>Australian Green Infrastructure Council</td>
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<tr>
<td>ALT</td>
<td>Alliance Leadership Team</td>
</tr>
<tr>
<td>AMT</td>
<td>Alliance Management Team</td>
</tr>
<tr>
<td>APQC</td>
<td>American Productivity &amp; Quality Center</td>
</tr>
<tr>
<td>BASIX</td>
<td>Building Sustainability Index</td>
</tr>
<tr>
<td>BEQUEST</td>
<td>Building Environmental Quality Evaluation for Sustainability</td>
</tr>
<tr>
<td>BOOT</td>
<td>Build, Own, Operate, Transfer</td>
</tr>
<tr>
<td>BREEAM</td>
<td>Building Research Establishment Environment Assessment Methodology</td>
</tr>
<tr>
<td>CBR</td>
<td>Case-based Reasoning</td>
</tr>
<tr>
<td>CCF</td>
<td>Civil Contractors Federation of Australia</td>
</tr>
<tr>
<td>CEEQUAL</td>
<td>Civil Engineering Quality Assessment and Awards Schemes</td>
</tr>
<tr>
<td>CEN</td>
<td>European Committee for Standardization</td>
</tr>
<tr>
<td>CIB</td>
<td>International Council for Research and Innovation in Building and Construction</td>
</tr>
<tr>
<td>CoP</td>
<td>Community of Practice</td>
</tr>
<tr>
<td>CRC</td>
<td>Cooperative Research Centre in Construction Innovation</td>
</tr>
<tr>
<td>C-SanD</td>
<td>Creating, Sustaining and Disseminating Knowledge for Sustainable Construction</td>
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<tr>
<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>DESD</td>
<td>Decade of Education for Sustainable Development</td>
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<td>DREAM</td>
<td>Defense Related Environmental Assessment Methodology</td>
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<tr>
<td>EMP</td>
<td>Environmental Management Plan</td>
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<tr>
<td>ESD</td>
<td>Education for Sustainable Development</td>
</tr>
<tr>
<td>FIDIC</td>
<td>International Federation of Consulting Engineers</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GFC</td>
<td>Great Financial Crisis</td>
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<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GRI</td>
<td>Global Reporting Initiative</td>
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<td>Human Resource Management</td>
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<td>ICE</td>
<td>Institution of Civil Engineers</td>
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<tr>
<td>ICT</td>
<td>Information Communication Technologies</td>
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<tr>
<td>KRA</td>
<td>Key Result Area</td>
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<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design</td>
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<tr>
<td>LTMA</td>
<td>Land Transport Management Act</td>
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<tr>
<td>NABERS</td>
<td>National Australian Built Environment Rating System</td>
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<td>Northern Gateway Alliance</td>
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<td>NGO</td>
<td>Non-governmental Organization</td>
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XX
NZTS = New Zealand Transport Strategy
PAB = Project Alliance Board
PM = Project Management
PPP = Public Private Relationship
PPR = Post Project Review
PSM = Project Sustainability Management
QLD = Queensland
QMCA = Queensland Major Contractor Association
R&D = Research and Design
SA = South Australia
SD = Stand Deviation
SK = Sustainability Knowledge
SPeAR = Sustainable Project Appraisal Routine
TBL = Triple Bottom Line
UNCED = United Nations Conference on Environment and Development
UNCSD = United Nations Commission for Sustainable Development
UNEP-IETC = United Nations Environment Program – International Environmental Technology Centre
VIC = Victoria
WA = Western Australia
WCED = World Commission on Environment and Development
LIST OF PUBLICATIONS

**Referred Conference Paper**


**Journal Paper in Process**

Yuan, Mei ad Yang, Jay (2011), Managing knowledge to promote sustainability in Australian infrastructure projects, prepared for publication in *Construction Innovation: Information, Process, Management*.

Yuan, Mei and Yang, Jay (2011), An integrated KM framework for managing sustainability knowledge in the Australian infrastructure sector, prepared for publication in *Construction Management and Economics*.

Yuan, Mei and Yang, Jay (2011), Strategies for managing sustainability knowledge – A case study on the Australian infrastructure sector, prepared for publication in *Journal of Construction Engineering and Management*.
CHAPTER 1
INTRODUCTION

1.1 Research Background

1.1.1 Global Call for Infrastructure Sustainability

Throughout history, civilization has depended on the ability and will of communities, cities and nations to finance, build, operate and maintain infrastructure, the physical backbone of societies. As a result of the previous growth of prosperity, population, and global competition, the demand for infrastructure is creating bottlenecks for economic development in many parts of the world and has become a global phenomenon (ERNST and Young, 2007; Asian Development Bank, 2007). Regeneration of existing infrastructure and development of new infrastructure are at the top of the agenda around the globe. More recently, due to the global financial crisis (GFC), many countries around the world have embarked on infrastructure investment to ease the resulting economic downturn (KPMG, 2009).

Infrastructure in the Australian context typically includes utilities and facilities such as roads, ports, rail, power lines, water pipes, power generation buildings, sewer plants, and other tangible structures (Infrastructure Australia, 2008). They work as a holistic system to provide the basic support for urban activities, playing a fundamental role in determining the efficiency and productivity of the Australian economy.

As a result of the growth of its dispersed population, the resource boom, growing social expectations, international competitiveness and previous decades of relative...
under spending by the private and government sectors, Australia is experiencing a major nation-wide surge in infrastructure development (Mallon and Burton, 2009).

Expanding and regenerating Australia’s infrastructure system has been seen as the principal means for enhancing economic growth and national efficiency and productivity by the recent federal governments (Vella, 2008). The recent GFC and the resulting economic downturn have lifted the importance and urgency of huge infrastructure investment, which is usually seen as an effective means of boosting economy (PKMG, 2010). Under such circumstance, governments and various investors and enterprises from private sectors are under pressure to raise fund to support the ambitious infrastructure roadmap. Meanwhile, there is also growing public and business awareness and appreciations of the need to construct and regenerate the infrastructure projects in a way that protects the environment as well as enhances the social and economic benefits for a wider range of communities (AGIC, 2010).

The logical link is straightforward. The development of infrastructure projects can occupy vast land, have long timespans, consume significant amounts of resources and, typically, cause major disturbance to the natural environment and local community. These factors are closely related to all facets of sustainability issues. Therefore, enhancement of sustainability in infrastructure development can be of crucial importance to not only increase economic benefits but also to reduce adverse environmental, social, and cultural impacts.

1.1.2 Promoting Infrastructure Sustainability – Existing Endeavours and Shortcomings

In Australia, three layers of government and various stakeholders realized that the development of infrastructure to improve standard of living and competitiveness must not come at the expense of the environment and social objectives (Infrastructure Australia, 2008). Governments and organizations are now in quest of infrastructure that is more resource-efficient, cost-effective, environment-friendly and socially acceptable during both the construction and operation phases.
(Ramaswami, 2009). For example, Queensland Department of Infrastructure and Planning has revised the Integrated Planning Act (IPA 1997) and the new version is entitled the Sustainable Planning Act 2009 (SPA2009) with the aim to further emphasize the importance of considering ecological and environmental sustainability during making planning decisions (Queensland Government, 2009).

The industry is responding to sustainability as well. For example, ARUP, a leading international engineering consulting firm, states: “Infrastructure must be sustainable if it is to benefit coming generations and make a positive contribution to the future” (ARUP, 2010).

In fact, sustainability is not a new topic. Over 20 years ago, the emergence of the concept of sustainable development offered the world a new perspective on how to protect environmental systems and enrich the quality of life for this and future generations while booming economic development (WCED, 1987). This concept has profoundly affected various disciplines including the construction industry, which has responded to the sustainability paradigm as evidenced by various publications, governmental strategies and guidelines, industry good practices and a number of facilitating tools. Despite these endeavours, sustainability considerations and real life applications in the construction sector are still at the infant stage. Although many construction organizations will not argue against embracing sustainability with project implementation, industry practitioners are facing extensive challenges to transfer from talk to action, especially in the infrastructure sector. Barriers are various.

It is widely acknowledged that sustainability is still a vague and evolving concept of which people usually have different understandings (Kibert and Rinker, 2007). Various stakeholders, from both private and public sectors and diverse disciplines, are involved in infrastructure development and usually hold different perceptions of sustainability due to their own professional background and priorities. In practice, problems often lie with what should be done, who should do it, and how mutual benefits can be obtained. This is compounded by the fact that very often there are no common understandings between the stakeholders (Yang and Yuan, 2009).
In the highly project-based construction industry, infrastructure sustainability can only be achieved project-by-project. Currently one of the main obstacles for promoting infrastructure sustainability is still the challenge of transforming the principles of sustainable development into practical models (Sahely et al., 2005). It is essential to provide the industry sector with guides and tools to relate whole-society sustainability principles to project-level indicators (FIDIC 2004). However, existing sustainability measurement tools are mainly for the building sector (e.g. Green Star, LEED, NABERS). In fact, research on sustainability in the built environment has mainly focused on buildings, such as commercial office buildings, which have been more successful in raising the bar on sustainability through rating tools, innovations and policies, with up-to-date knowledge and technology captured and encapsulated in these measures.

The literature shows that there were recent research initiatives attempting to address infrastructure sustainability issues by developing relevant assessment systems and implementation processes (e.g. FIDIC, 2004; CEEQUAL, 2008; Ugwu and Haupts, 2007; Ugwu et al., 2006; Sahely et al.; 2005; AGIC, 2009b). However, in contrast with the relatively large amount of literature on the sustainability of buildings, studies and applications of infrastructure sustainability are very limited (Ugwu, 2007; Lim, 2009; and AGIC, 2009b).

Furthermore, although consensus has been reached on the view that sustainability is the right thing to do, in practice, not many companies have positively and wholeheartedly embraced sustainable ideas and implemented them beyond compliance in projects (Myers, 2005). One of the reasons is the lack of the underpinning knowledge and evidence to demonstrate and measure the linkage between sustainability implementations and the relevant outcomes (Wallace, 2005). Pathriage et al. (2007) emphasize that the construction industry needs to intensify its efforts to move to a knowledge intensive mode as better decision-making towards sustainability goals can only be achieved if the stakeholders are informed of the latest concepts, knowledge and expertise across organizational, professional and hierarchical boundaries.
In this research context, “sustainability knowledge” can be defined as the type of knowledge that improves the sustainability of an infrastructure project during its life cycle. Reviewing the literature shows that the current body of sustainability knowledge mainly includes project experience, government policies, assessment tools, and underpinning theory and technologies. However, these are not sufficient and mature enough to facilitate decision-making and to direct construction practices, especially at project level.

Although knowledge can be borrowed from other sectors (e.g. green building) and industries, industry practitioners within the infrastructure sector are not able to simply “copy and paste” industry best practices or experience from the previous projects due to the unique and complex nature of the infrastructure projects (Kamara et al., 2003). Practitioners in the infrastructure sector have to utilize the existing knowledge and experiences to find creative solutions for future projects with situated and contextual appreciations. During the life cycle of a construction project, a considerable amount of knowledge can be generated. However, due to the fragmented nature and the stressful routine of the industry, only a fraction of knowledge is usually captured, and even less can be maintained and reused in future projects (Tan et al., 2010).

As one of the largest, and one of the most complex, fragmentary and people-intensive sectors, the construction industry cannot provide a positive environment to trigger the sharing and reusing of knowledge and innovations. Generally, the industry is seen as a stubborn, risk averse and highly traditional industry which is often characterized by its adversarial behavior, litigious orientation, poor communication and coordination, poor customer focus and low investment in research and development (R&D) (Barrett et al., 2008). The demanding and often stressful routines of construction works can result in the unwillingness to learn and develop innovative solutions which are essential to move towards sustainability (Wallace, 2005). Moreover, due to the complexity of infrastructure systems, the one-off nature of each infrastructure project, and the long timespan of delivery, it is hard for the stakeholders to deal with the comprehensive but hazy body of knowledge – sometimes, even within a specific project (Tan et al., 2010).
Therefore, promoting the sustainability agenda in infrastructure development is a noticeable exercise. It may not proceed without a knowledgeable, skillful and confident work force, settled objectives, evolving benchmarks and practical guidance. In order to embed sustainability considerations and application in infrastructure projects, there is a genuine desire and mandate to:

- Expand the body of sustainability knowledge for infrastructure development;
- Search for better ways to trigger sustainability knowledge creation, sharing and application across diverse boundaries within the infrastructure sector and to its broader stakeholders; and
- Help the industry to build its capacity to uptake sustainability knowledge at project level and to facilitate better decision-making and implementation to deliver tangible results.

In this research, the knowledge management (KM) approach is seen as a possible solution which can provide a platform for all the stakeholders and the community to share ideas and experiences, to inspire new research and practices, and to promote infrastructure sustainability.

1.2 Linking KM with Infrastructure Sustainability

Although KM is a relatively new and emerging discipline, mechanisms and tools have been developed and employed to better manage information and knowledge in diverse contexts in many sectors of industry and business. It is now a broad and expanding topic contributed to by diverse disciplines and consisting of a multifold mix of strategies, tools, and techniques (Dalkir, 2005). From a functional perspective, KM can be seen as a “systematic approach to manage the use of information in order to provide a continuous flow of right knowledge to the right people at the right time, enabling efficient and effective decision making in their everyday business” (Teece, 2000). That means providing access to information at the time when people need it to facilitate efficient and effective decision-making.
KM has been imported into the construction industry as a fashionable concept as well as a useful tool for some years (Kazi, 2005). The construction management literature discusses the importance and existing implementations of KM in the construction industry.

Like many project-based industries, the construction industry has its own peculiarities which impact upon KM. In the literature, various KM tools and mechanisms are introduced and discussed as possible approaches for KM implementation in the construction industry (e.g. Robinson et al., 2010; Tan et al., 2010; Pathirage and Haigh, 2007; Anumba et al., 2005; Anumba et al., 2005 etc.). Existing studies, ranging from knowledge categorizations, decision support systems, software for KM services and case-based reasoning, have provided inspiring practical experiences in KM implementation. KM is, therefore, increasingly recognized as a vehicle through which an expanded body of sustainability knowledge and improved sustainability performance for infrastructure development is possible.

However, the literature review shows that the majority of the existing KM approaches in construction are addressing just one or some issues within the scope. No research has outlined KM as a solution in a holistic and schematic view.

Few attempts have been made to raise the awareness of sustainability issues in the construction processes by facilitating the obtaining, sharing and application of relevant knowledge (e.g. C-SanD, 2004; Maqsood and Walker, 2007; and Harvard University Graduate School of Design, 2010). These researchers focus on specific tools, such as software, communication techniques and document systems especially at the project level, failing to consider the full cycle of KM process, the environment for KM implementation, and critical issues that drive or compromise its success.

Moreover, managing knowledge is especially important to large scale infrastructure development because of its unique characteristics such as the one-off nature of the projects, long duration of project life cycle, tight schedules,
limited budget, multi-disciplinary stakeholders, dynamic participation of team members and high staff turnover. Although some research described knowledge activities such as capture and reuse of knowledge in project-based scenarios (Tan, 2010; Robinson, 2010; Anumba et al, 2005; Kazi, 2005; etc.), KM solutions specific to big infrastructure development are rare.

It is commonly accepted by the researchers within the field that KM is a multifunctional and multifaceted discipline, contains various components and mechanisms, and has the potential to tackle a variety of issues. Although technology issues are widely recognized in existing KM practices, it is often argued that social and cultural issues are much harder to deal with. Meanwhile, it is also important to recognize the wider economic, political and technological environment within which the KM initiatives take place, as well as the specific aims and problems the organization is tackling (CEN 2004). In fact, KM comprises a variety of components, and understanding of their relationship from a holistic view is helpful.

Based on the noticeable shortcomings of existing KM practice in the construction industry, the researcher is proposing a holistic KM approach to address sustainability issues in the context of infrastructure development. As a useful tool, a KM framework can clearly show and inter-relate the various aspects and components of KM, provide a schematic picture of the interdependence of these components and outline processes of conducting KM activities (CEN, 2004). With regards to the infrastructure sustainability issues, the benefits to gain from a KM framework are plenty. For example, it can help the practitioners to prioritize the most important issues and potential solutions, and facilitate them to position KM programs and initiatives.

With the explosive growth of information and knowledge across various industries, and the resulting fast-growing interest in KM practices, various KM frameworks have been produced, ranging from very general KM frameworks, industry-specific KM frameworks, performance-specific KM frameworks and others (e.g. CEN, 2004; Jafari et al., 2007; Mentzas, 2004; Choi, Jung, and Song,
In general, within a KM framework, major aspects of the discipline are usually outlined, and the important individual elements (e.g. tools, successful factors, effective strategies) are usually illustrated. The structure of these KM frameworks tends to be similar; however, individual elements, their roles and priorities in KM may vary significantly, due to the particularity of the issues they are expected to tackle, the nature of the knowledge they are dealing with (e.g. explicit knowledge, tacit knowledge), the perspectives of their users, and the culture and business model of the organization where KM is positioned (Weber, et al., 2002; Rubenstein-Montano et al., 2001). Thus, existing KM frameworks are not capable of providing accurate direction and suggestions to the infrastructure sector to address sustainability issues.

Therefore, it is fitting for this research to build upon the strengths of existing KM frameworks and adapt them into a specific form, considering the nature of sustainability knowledge and the unique characteristics of infrastructure development. Such a framework will raise sustainability awareness, support better decision-making and communication of understandings during project development, capture project gains and pains, spread best practice, and ultimately promote the uptake of sustainability considerations in real life infrastructure projects. To conclude, this research is aimed at developing a specific KM framework for managing sustainability knowledge in the Australian infrastructure sector and according guidelines to direct industry practice.

1.3 Research Questions

In order to achieve the research aim described in the previous section, four research questions are raised to help the researcher to break down the big research aim into achievable objectives.

**Q1: What are the characteristics of the body of sustainability knowledge?**

Selection of appropriate KM strategies and tools depends largely on the nature of the knowledge that the proposed KM programs deal with (Hansen *et al.*; Haggie
and Kingston, 2003; Dalkir, 2005; etc.). Thus, a good understanding of the existing body of sustainability knowledge for infrastructure development is critical to this research. As limited existing research investigated sustainability from a knowledge perspective – and even less with regards to infrastructure sustainability – identifying and investigating the various forms, locations, characteristics and resources of existing sustainability knowledge constitute a valid platform for this research.

**Q2: What are the important issues that should be addressed when managing sustainability knowledge for infrastructure development?**

According to pervious KM research, various KM strategies and approaches have different focuses. Some of them focus on the knowledge itself, while others focus on the business processes and expected outcomes. The infrastructure sector – as one of the largest and most traditional and highly project-oriented industry sectors – has its unique culture, business patterns and barriers. These unique characteristics and issues of the infrastructure sector may affect the management of sustainability knowledge and, thus, should be investigated.

**Q3: How can sustainability knowledge be effectively managed in the infrastructure sector?**

The proposed KM approach by this research should be able to facilitate the flow of sustainability knowledge among stakeholders within the industry sector and cross project, organizational and disciplinary boundaries, and ultimately help the knowledge be embedded into real projects. Diverse KM activities may take place in this process, and various strategies, techniques and tools can assist these activities. Although previous KM studies have suggested plenty of tools, mechanisms and strategies that are proven to be effective in other disciplines, their suitability, effectiveness, importance and priority for managing sustainability knowledge at its current stage within the infrastructure sector are still uncertain. Thus, investigations of these strategies, processes, tools and activities are principal concerns of this research.
Q4: How can KM promote sustainability knowledge application in real projects?

There is a saying that the value of knowledge doesn’t lie in the knowledge itself; it can only be added when the knowledge is used. In the project-oriented infrastructure sector, sustainability can only be progressed through the increasing uptake of sustainability principles and considerations, project-by-project. Thus, it is essential for this research to investigate the roles of KM at project level and to explore the means of sustainability knowledge application.

1.4 Research Objectives

In order to answer the questions raised for this research, the following research objectives are set.

1. *To investigate the body of knowledge that is relevant to infrastructure sustainability*

This will include investigation of the structures, forms, locations, resources and characteristics of the body of sustainability knowledge for infrastructure development.

2. *To investigate the characteristics of the infrastructure sector as the context for managing sustainability knowledge*

This will include investigation of its business pattern, culture, project development process and main stakeholders, etc.

3. *To identify the main issues which affect the management of sustainability knowledge in the infrastructure sector*

This will include investigation of the barriers, drivers, prior tasks, enablers and possible outcomes of managing sustainability knowledge.
4. To investigate the appropriate approaches which help the infrastructure sector and its practitioners to manage sustainability knowledge

This will include the important KM activities, effective strategies and mainstream enabling tools.

5. To investigate the approaches that facilitate sustainability knowledge application in real project scenarios

This will include the specific processes, important actions, important factors and specific facilitating strategies and tools.

6. To outline the main findings in a holistic KM framework and according guidelines as a major outcome of this research.

1.5 Research Scope

Firstly, the scope of the term “infrastructure” should be clarified at the outset of the research. Usually, infrastructure refers to the physical systems constructed by human beings to support public activities (Frischmann, 2004), including not only engineering facilities such as transport systems, water supply systems and electricity grids, but also basic social facilities such as schools and hospitals. In this research, “infrastructure” only refers to large engineering infrastructure works due to the unique nature of their development processes.

Secondly, it should be distinguished that “sustainable infrastructure” and “infrastructure sustainability” are two different areas of study in the built environment discipline. According to the definitions of the Australian Green Infrastructure Council (AGIC, 2010), “sustainable infrastructure refers to infrastructure that encourages behavioral and lifestyle change towards a more sustainable society” while “Infrastructure sustainability is defined as infrastructure that has been planned, designed, procured, constructed, operated and disposed of in a manner that maximizes value by balancing all the material, social, economic and environmental aspects and impacts across the whole of life cycle of the asset”. This research discusses the knowledge, relevant issues and approaches in regards
to infrastructure sustainability that limit the research scope within the construction industry.

Although two road infrastructure projects are investigated in the last phase of the research to verify the findings, the proposed KM solution is not specific for this type of infrastructure but for the Australian infrastructure sector in general. However, this research is limited to the Australian infrastructure sector. The adoption of sustainability principles in infrastructure sectors differs greatly in different counties, due to their different culture, business pattern, industry structure, regulation, environment and advances in techniques. Thus, the appropriate KM approaches will also differ, highlighting different enablers, core activities and strategies. However, outcomes of this research can be inspiring to other countries and regions seeking better ways to manage sustainability knowledge.

At last, the ultimate goal of this research is to promote the uptake of sustainability principles in real infrastructure projects through the effective management of relevant knowledge in the Australian infrastructure sector. The outcomes of this research will help in addressing issues such as culture, human resources, communication and project performance, which are all important aspects of construction project management. Thus, this research by its very nature lies in the project management discipline.

1.6 Research Approach

Given the objectives set for the research, both qualitative and quantitative data are requested, which can be collected through a combination of different data collection methods. A triangulation of questionnaire survey, semi-structured interviews and case studies was employed in this research. These methods enable the researcher to investigate the issues on managing sustainability knowledge both broadly as the general issues in the industry sector, and in-depth as the specific actions in a specific project. These research methods also maximize the opportunities for industry practitioners participating in the research.
The research can be divided into four main phases.

**The first phase** involves an extensive cross-discipline literature review, which covers three main themes: (1) the infrastructure sector and infrastructure development; (2) infrastructure sustainability; and (3) KM theory and practices. Reviewing the infrastructure sector and infrastructure development literature provides an understanding of the culture and business pattern of the industry sector and the sustainability crisis it is now facing; this contributes to Objective 2. Infrastructure sustainability literature outlines the endeavors and shortcomings of sustainability applications in the infrastructure sector; this contributes to Objective 1 and leads to the identification of the research gap. Reviewing the KM literature outlines the KM concepts, activities, relevant strategies and tools, and some existing KM frameworks that this research can use as reference points. A KM framework prototype is developed to guide later studies.

**The second phase** of the research involves a questionnaire survey of industry practitioners. This survey is conducted to qualitatively identify industry opinions on sustainability knowledge and the prior issues, barriers, enablers and knowledge activities that affect management of the knowledge. Findings mainly contribute to Objectives 1, 2 and 3. The questionnaire survey is guided by the KM framework prototype, and a preliminary KM framework is then developed.

**The third phase** involves semi-structured interviews of industry practitioners to collect qualitative data to further explore the identified elements, issues, KM activities and strategies from the questionnaire survey. Findings mainly contribute to Objective 4.

**The fourth phase** involves two real project case studies to explore the management of sustainability knowledge in project scenarios, especially the processes and main actions that apply sustainably knowledge in projects. Findings mainly contribute to Object 5.
During the process, later stage studies further explore as well as validate the results from the earlier stage studies. Finally, the synthesizing of results of these four stages leads to the formulation of the final KM framework for managing sustainably knowledge in the infrastructure sector, and to the guidelines for knowledge application at the project level. This is where the final objective is achieved.

1.7 **Significance of the Research**

As sustainability is increasingly valued within the Australian infrastructure sector, infrastructure stakeholders are making efforts to incorporate more sustainability considerations into infrastructure development. During this process, activities to manage relevant knowledge inevitably happen extensively. Although individuals, project teams and organizations have their own ways of managing the relevant knowledge, definite consciousness, proactive plans and facilitating tools can make their practice more effective and efficient. This is how KM can contribute to and accelerate the progress of infrastructure sustainability.

As stated in the previous section and the later literature review, up to now, KM solutions specifically for the infrastructure sector, or specifically designed to better manage sustainability knowledge are limited. This research can bridge the gap by providing a KM framework that aims to assist the Australian infrastructure sector in addressing sustainability issues. As many issues for infrastructure sustainability should be tackled from a knowledge perspective, the results of this research will provide industry practitioners with a practical introduction for understanding KM, and effective tools and strategies for its facilitation. It is hoped that these efforts will help the industry to develop efficient KM initiatives for managing sustainability knowledge among all stakeholders across various barriers in order to promote sustainability uptake and implementation during project development lifecycles, to trigger innovation, to boost the body of knowledge, and to deliver tangible outcomes. This will ultimately accelerate the industry’s move towards sustainability.
During the course of this research, many industry practitioners were approached for data collection purposes. Some of them appeared to have little knowledge of KM and how it could help them in their work. The researcher utilized these opportunities to introduce industry participants to the KM concepts and techniques as a new but useful management tool to gain business competitiveness. Therefore, it is believed that this research will stimulate not only interested researchers, but also industry practitioners to join an ongoing discussion on KM implementation in this important and unique industry sector.

1.8 Outline of the Thesis

This dissertation consists of eight chapters. A brief summary of each is outlined below.

Chapter 1 comprises the introductory section that states the background and rationale for the direction of this research. It also discusses the research problems and objectives and provides a brief description of methodology and the limitations of the research scope.

Chapter 2 reviews the literature in diverse fields which is introduced in three sections. The first introduces the Australian infrastructure sector and the dynamics of infrastructure development, setting the scene for the research. The second part summarizes the current state of knowledge in regards to infrastructure sustainability. The third part focuses on the main concepts and approaches of KM, providing the theoretical foundation of the study. Existing KM frameworks are highlighted and a link between KM practices and the construction industry is provided.

Chapter 3 describes the research methodology in detail including: the research plan, research methodology and data collection methods. Different research instruments are discussed and three methods are chosen for data collection: questionnaire survey, interview and case studies.
Chapter 4 describes the research work carried out during the questionnaire survey stage. Formulation and conduct of the survey are introduced in detail. Data analysis and extracts of results are then provided, followed by the formulation of the preliminary KM framework.

Chapter 5 describes the processes of interviews in detail, the analysis of data and extracts of results, addressing the issues identified in the previous survey and the “how to” part of the KM framework.

Chapter 6 describes two real-life infrastructure project case studies. Initiatives relevant to addressing sustainability issues and managing related knowledge are investigated and compared with the listed issues and actions identified.

Chapter 7 describes how the issues and recommended actions discussed in the previous chapters are formulated into the KM framework. The final KM framework and according guidelines specific to the Australian infrastructure sector to manage sustainability knowledge are provided in this chapter.

Chapter 8 summarizes the research findings that are related to the research questions. The chapter discusses the research contribution and limitations, and future research outlooks are provided.

1.9 Summary

This chapter provides an overview of this study. To begin with, the research background is described and the research niche is outlined. As there is an urgent need in the Australian infrastructure sector to expand the body of sustainability knowledge and to find better ways of communicating it to, and managing it within the industry, this research proposes to develop a holistic KM framework to outline the important issues that need to be addressed when managing sustainability knowledge in the infrastructure sector. This research aim is later translated into research questions and objectives.
The following chapter introduces the research methods as well as the development process of the KM framework, describing how the research objectives are realized. This is followed by a discussion of the significance and scope of the research. Finally, an outline of the thesis is provided.
2.1 Introduction

The purpose of this chapter is to provide a sound basis for understanding the concept of KM and infrastructure sustainability in the context of Australian construction industry, and envisage the potential usage of KM in infrastructure development to promote sustainability implementation.

In the light of the research questions and research objective raised in the previous chapter, literature from various disciplines are reviewed and presented in three parts: infrastructure development, infrastructure sustainability and KM.

The first part sets the scenario of this research by introducing Australian construction industry and the dynamics of infrastructure development, its culture, challenges etc. Infrastructure development processes and main stakeholders are specifically discussed.

In the second part, to begin with, sustainability concepts and principles are introduced generally before discussing their dynamics and applications in infrastructure development in order to build the logical link between sustainability and infrastructure development. Premised on these discussions, the sustainability research gap in infrastructure development is identified and leads to the formation of the research questions.

The aim of the third part is to set the theoretical framework of this research and clarify the research objectives. To begin with, the origin of KM and its key theories, concepts and ideas are reviewed. Various researchers have studied KM
from different perspectives and dimensions. These dimensions are the focus of
discussion of the first two sections. Three sections are devoted next, to scan the
current KM initiatives and implementation strategies. A thorough review of
existing KM frameworks is also conducted in order to set the KM framework
prototype for the formulation of the subsequent questionnaire survey. At last,
applications of KM in the construction industry, especially few existing endeavors
to address sustainability issues are discussed.

The chapter ends with a brief summary of various concepts discussed in the
chapter. Premised on these discussions, the sustainability research gap in the
infrastructure sector is identified and leads to the formation of the research
questions and the later questionnaire survey in a subsequent stage.

2.2 Australian Construction Industry and
Infrastructure Development

2.2.1 Australian Construction Industry Overview

The construction industry is a vital element of any economy and has a significant
impact on the efficiency and productivity of other industries. In Australia, it
secures the living standard of each citizen and provides the basic support to the
nation’s economy by constructing residential buildings, offices, hospitals,
recreation facilities as well as the essential facilities and utilities such as roads,
bridges, water and electricity supply grids and telecommunication facilities (ABS,
2008). Usually a series of factors will affect the demand for and supply of
construction works, such as populations, economy environment, industry structure,
interest rates, etc.

2.2.1.1 Contribution to National Economy

According to Australian Industry Group (2008), Australian construction
industry’s share of the economy has increased, evidenced by the growth of its
gross industry value from 5.6% in 1996-97 to 7.3% in 2006-07. Since 2000,
growth in the value of construction output has exceeded that of the overall economy, expanding at an average annual rate of 9.7%, and reaching a record value in June 2008 of $79.7 billion. Moreover, this industry employs more than 1 million people which accounts for about 9 per cent of total employment.

Furthermore, the Australian construction industry also has a wider impact on the nation’s economy beyond the direct contribution of construction works due to its close linkage with many other industries and sectors. The Australian Bureau of Statistics (ABS) estimates that an approximate $2.9 million output in the whole economy could be generated from an initial $1 million of extra input in infrastructure development, with additional 9 jobs in the construction industry and 29 in other industries created (The Housing Industry Association, 2010). Especially during and after the global financial crisis (GFC), governments around the world, including Australia, have embarked on major infrastructure investments to cushion the rapid slump of the resulting economic downturn (KPMG Australia, 2009).

In Australia, the construction industry generally takes on constructing work in three areas, including residential building (e.g. houses, departments, etc.), non-residential building (e.g. office building, commercial complexes, cinemas, etc.), and engineering construction (e.g. roads, bridges, water supply facilities, tunnels, etc.). These constructing activities are undertaken by both the private and public sectors. They have different areas of emphasis. The public sector plays the lead role in procuring engineering constructions while the private sector mainly engages in constructing activities of residential and non-residential buildings. However, the private sector may participate in engineering construction area, especially in the projects delivered by Public Private Partnership (PPP). In addition, the public sector leads the role of constructing public facilities (e.g. hospitals, schools, universities, etc.) in the non-residential building area (ABS, 2008). Characteristics of construction activities are summarized in Table 2.1.
Table 2.1: Constructing Activities in Australia

<table>
<thead>
<tr>
<th>Construction Type</th>
<th>Examples</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential building</td>
<td>houses, departments, etc.</td>
<td>Private sector</td>
</tr>
<tr>
<td>Non-residential building</td>
<td>offices, shops, hotels, etc.</td>
<td>Private sector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public sector (public facilities)</td>
</tr>
<tr>
<td>Engineering construction</td>
<td>roads, bridges, water, sewerage, etc</td>
<td>Private sector (PPP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public sector</td>
</tr>
</tbody>
</table>

2.2.1.2 Structure and Culture

The construction industry is one the largest, complex and most people-intensive sectors. In Australia, the construction industry comprises around 320,000 enterprises. Of these enterprises, over 60% are sole traders, with nearly 30% employing between 1 and 4 people (Australian Industry Group, 2008). And as the strong growth in input costs has squeezed construction profit margins, the competence in the construction industry is high.

The construction industry is a highly project-based and fragmentary industry. It is composed of many diverse competing (and collaboration) firms and disciplines, the majority of whom are brought together for a temporary and bespoke project, then disband after project completion.

Furthermore, construction industry is dynamics and diverse. For a very long period, the construction industry has retained its traditional way of executing project development, from design, tendering, contracting and construction. Conflicting interests and priorities held by the diverse stakeholders and fragmentation of control and decision-making have always affected the industry practice (Sherif and Selwyn, 1996). Although new contracting and organizing methods (e.g. PPP/BOOT/alliance) have been adopted in the construction industry, almost everyone is aware that the complexity of modern construction projects—from the many disciplines required to a culture of outsourcing and subcontracting—has resulted in increasing fragmentation (Dainty et al., 2007).
Generally, the construction industry is always seen as a stubborn, risk averse and highly traditional industry which is often characterized by its adversarial behavior, litigious orientation, poor communication and coordination, less of customer focus and low investment in research and development (Barrett et al., 2008).

2.2.1.3 Innovation

The construction industry as a whole has a poor reputation for innovation and has been criticized as being laggard at adopting new technologies when compared to other advanced manufacturing industries such as automotive, shipbuilding or aerospace. Murray and Langford (2003) made such conclusion based on a series of government reports date from 1944-2000 in regards to the nature and culture of the construction industry in UK. The situation in the Australian construction industry is not dissimilar.

According to findings of a 2002 survey initiated by the Australian Construction Industry Forum (ACIF), compared with some other leading countries including the United States, the United Kingdom, Germany and France, Australia in general is slower to innovate, and so does the Australian construction industry. Although the construction industry is always seen as a conservative industry and behaving poor in innovation globally, the Australian construction industry is truly lagging behind (PriceWaterhouseCoopers, 2002).

Moreover, the IBM-Melbourne Institute Innovation Index (2009) shows that, despite the strong increase in the Construction Innovation Index since 2001, in the period under review, productivity in the construction industry has underperformed slightly relative to the average of Australian Industry as a whole (Figure 2.1). The institute recommended that this relatively poor performance is a reflection of the built-in nature of the industry. As the industry is less affected by the foreign competition, it has less incentives and opportunities to learn and adopt the new information and communication technologies (ICT) and other advanced tools and methodologies than other industries.
2.2.2 Australian Infrastructure Scenario

The term “infrastructure” has been used for over 80 years and usually refers to the important engineering structures such as roads, bridges, water and electricity supply facilities, and public facilities such as hospitals, school, and stadiums, for the built environment to function, (Cremasco, 2007). The term has evolved and sometimes refers to different types of structures and social facilities in different courtiers, regions and disciplines.

Australia’s infrastructure has been built up over more than 200 years (Infrastructure Australia, 2008). These important engineering and social infrastructure assets work as a holistic system to provide the basic support for urban activities, providing a foundation for Australia’s economic development and social stability.

The Australian Green Infrastructure Council (AGIC) (2009a) has provided a list of structures that are considered as infrastructure project from the construction industry perspective in Australia, including:

- Roads, rail, bridges and tunnels;
- Ports, wharves and marinas;
- Airports;
• Distribution grids (pipes, poles, wires);
• Water and waste water supply and infrastructure;
• Waterway or foreshore management; and
• Civil head works for industrial processes.

In fact, due to the influence of infrastructure system on maintaining regional economic growth, productivity, international competitiveness and standard of living, it is well accepted globally that adequate, modern and well maintained systems of infrastructure forms the backbone of today’s economies. For businesses, infrastructure system enables access to places of production and global markets, improves the competitiveness of many other industries, and provides more opportunities to individuals to play a part in economic growth (Greenwood, 2006; Miller, 2007). Existing research has confirmed the positive relationship between infrastructure investment and country’s economic growth (GDP) and concludes that heavy investment on infrastructure projects must be made to ensure a sustained economic growth and to extend resulting benefits to maximum citizens.

2.2.2.1 **Australian Infrastructure Boost**

A strong expansion in infrastructure investment has commenced in Australia, driven by the growth of its dispersed population, the resource boom and the growing social expectations, international competitiveness and previous decades of relative underspending by the private and government sectors. As a result, the engineering construction sector has been one of the strongest performers in the Australian economy over the recent years. As illustrated in Figure 2.2, from 2001 to date, the value of construction work done in Australia continued to grow. While the building sector increased steadily during the period, the engineering construction sector has seen a dramatically growth.
In fact, the infrastructure boost is a global phenomenon. According to ERNST and YOUNG (2007), in Asia, China allocates 9% of its GDP on infrastructure development, while India budgets 3-5% with an intention to increase its allocation to 8%. In Europe, many countries are plagued with their aging infrastructure system and are seeking innovative solutions to tackle the budget constraints. Public Private Partnerships (PPP) is implemented widely to make up funding deficits, especially in the UK, where nearly $55 billion projects are on schedule or underway.

In Australia, the Federal 2009-10 budget increased infrastructure spending, and more than $22 billion will be invested for "Nation Building Infrastructure". As part of that, $8.5 billion towards “nationally significant” infrastructure projects was promised by the federal government, which was estimated as work valued above $35 billion (Australian Government, 2009).

In the year of 2010 to 2011, in order to secure the constant prosperity, the federal government continues to put record investment in infrastructure development across the country, with a stronger focus on transportation infrastructures, such as a national road network and inter-state rail systems. Overall, a budget of around $37 billion is allocated for critical infrastructure (such as road and ports), within which around $22 million will be invested in developing rural and regional transport infrastructure (Australian Government, 2010).
This challenging infrastructure road map is facilitated by the establishment of a statutory authority - Infrastructure Australia - in 2008, to deliver a greater level of state and federal government co-ordination to improve project planning and execution.

### 2.2.2.2 Develop Process and Stakeholders

In regards to infrastructure development process, each project has a life cycle with some variations. In general, a project life cycle begins with the identification of need, moves onto the development of solutions to meet the needs (i.e., design facilities), the financing of facilities, the construction of facilities, the operation of facilities, and ends with decommission of the facilities (Ye and Liu, 2008). Many stakeholders from various disciplines involves in this complex process, including local community, city planner, government agency, designer, surveyor, project manager, contractor and other related institutions etc.

As normally the development of infrastructure requires a very large amount of investment and it takes quite a long term for the investors to get profit, projected funding gaps for infrastructure are usually enormous, which forced the governments to give up the traditional financing approach and seek help from a wide range of resources (Ye and Liu, 2008). In this case, various stakeholders, from both public and private sector and a variety of disciplines and background will involve in infrastructure development. Together with the employment of numerous procurement methods and funding sources, the resulting complexity and fragmentation has great impact on the efficiency of communication among the infrastructure stakeholders (Yang and Yuan, 2009).

Furthermore, as the construction process is always stressful and challenging, project teams usually work under pressure to meet deadline, which makes it extremely difficult for the people to spend their time and creative energy in developing alternative and innovative solutions to carry out tasks, even though they are capable of it (Maqsood, 2006).
Stakeholder means a person, group, organization, or system that affects or can be affected by project or organization. Infrastructure stakeholders are individuals or organization that are either affected by, or affect the development, of the project. Infrastructure is commonly known as a high profile project since it involves multiple stakeholders and has a great impact on its surroundings. These stakeholders include client, designer, general contractor, subcontractor, specialist contractor, project manager, funding provider, consultant, local community, government agency, etc. During the life cycle of infrastructure development, they are involved in the decision making and project implementation processes.

In the pre-development stage, the need for, and benefits of, new infrastructure projects are often disputed by public awareness groups, environmental organizations, politicians, economists, investors and those who are affected by the direct (negative) impacts (such as local communities). Enserink (2000) states that in practice, the early planning stages of large infrastructure projects are restricted to professional and administrative consultation; for the citizens, consultation is restricted to traditional forms of imparting knowledge and to appeal procedures.

In the design and construction stages, tasks are typically carried out by industry professionals. Designers of various disciplines deliver their solution in the format of drawings and documents to contractors and subcontractor, by whom the design will be constructed into physical facilities and structures.

### 2.2.2.3 Sustainability Challenge

Significant environmental and social concerns caused by infrastructure development have come to fore in the wave of infrastructure boom. Infrastructure projects, which can typically cause major disturbance to the natural environment and local community, occupy vast land, span over a long duration and consume significant amount of resources, draw close relevant to all facet of social, economical and sustainable issues (Greenwood, 2006; Yuan and Yang, 2008). 
In Australia, three levels of government and various stakeholders have reached the consensus that the development of infrastructure to improve economic growth and competitiveness must not come at the expense of the environment and social objectives. Such as in Queensland, Department of Infrastructure and Planning has revised the Integrated Planning Act (IPA 1997) and the new version was entitled the Sustainable Planning Act 2009 (SPA2009) to reflect a stronger focus on achieving ecological sustainability as the outcome of planning decisions (Queensland Government, 2009). A number of leading contracting firms and engineering consulting firms have embraced the principles of sustainable development because it is the “right thing to do”.

However ethical imperative is not enough to drive the huge change. While many relevant organizations will not argue against pursuing sustainability, in practice, the infrastructure sector is facing extensive challenges to support the sustainability agenda. Industry practitioners are currently in the position to understand sustainability principles and concepts in regards to their own domains and to translate the sustainability concerns into concrete actions at project-specific levels.

The following section reviews the principles of sustainable development and sustainable construction, followed by the existing body of knowledge with respect to infrastructure sustainability.

### 2.3 Sustainable Infrastructure Development

#### 2.3.1 Sustainable Development

Since the publish of the World Commission on Environment and Development (WCED) report - Our Common Future - in 1987, the concept of sustainable development started to evolve. The Triple Bottom Line (TBL) proposed by the report, which mean the three broad components of sustainable development (social, environmental and economic), is well accepted around the world.
Chaharbaghi and Willis (1999) argue that different professions usually view sustainable development differently according to their own perspective, such as environmentalists might view sustainability as avoiding a catastrophe, a technologists might view it as a problem that can be solved, while the politicians might view it as a rhetorical device.

Generally, sustainable development can be characterized by the opinions listed in Table 2.2.

Table 2.2: Understanding Sustainable Development

<table>
<thead>
<tr>
<th>Key Words</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real &amp; Urgent</td>
<td>• The problems posed by non-sustainable development are real and urgent, e.g. pollution, resource crisis, climate change, poverty, etc.</td>
</tr>
<tr>
<td>Subjective</td>
<td>• Sustainability development is an open-ended word with a diversity of definitions given by different people from different area, purpose and specific context.</td>
</tr>
<tr>
<td>Evolving</td>
<td>• The concept of sustainability is evolving constantly.</td>
</tr>
<tr>
<td>A way of thinking</td>
<td>• It is more a way of thinking and doing things than a certain object to achieve.</td>
</tr>
<tr>
<td>Long-term view</td>
<td>• Achieving sustainability will be a long journey.</td>
</tr>
<tr>
<td>System-thinking and Multi-Disciplinary approach</td>
<td>• Achieving sustainability requires a trans-disciplinary and system thinking approach which need contribution from broad industries and sectors.</td>
</tr>
</tbody>
</table>

According to UK Department of Trade and Industry (2006), an important element in achieving sustainable development is to promote a built environment that minimizes adverse impacts to the environment and surroundings during the construction process (e.g. pollution, disturbance, biodiversity, etc.), while maximizes the contribution to the economic and social objectives (e.g. productivity, cost effectively, improving working environment, etc.)
Sustainable construction can be seen as a construction process that embraces the principles of sustainable development (Chaharbaghi and Willis, 1999; Sage, 1998). Such construction process will address the objectives of economic profitability and environmental and social responsibility evenly as directed by the TBL. Thus, sustainable construction can be seen as a way for the building industry to respond to achieve the goals of sustainable development.

Although noticeable achievement can be seen in construction towards sustainable development, much more has to be done to make all construction works more sustainable. It is widely acknowledged that sustainability is still a vague and evolving concept. Different definitions are held by different stakeholders and different aspects are emphasized in different countries due to their own priorities and special contexts (Kibert and Rinker, 2007). And it is obvious that there is a gap between sustainability criteria and their applications at project level (Sahely and Adams, 2005). A study conducted in the UK construction industry in 2005 on the organizations’ attitudes on sustainability has revealed that, only a small amount of companies have positively and wholeheartedly embraced sustainable considerations and implemented them in their operations. Furthermore, specific sectors in construction, such as infrastructure, are often neglected by researchers therefore need immediate resurrection and adoption of the sustainability agenda (Myers, 2005).

### 2.3.2 Infrastructure Sustainability

As stated in previous section, in broad terms, construction projects can be divided into buildings and infrastructures. Urban infrastructure includes transportation, energy and utilities, and communications assets and networks. Distribution of essential public services to maintain human living standard and continuing economic development is heavily rely on infrastructure systems, which is often seen as backbone of a nation’s economy. The critical role that infrastructure plays in promoting economic growth and improving living standard has been long recognized by governments around the world.
Drawing from the understanding that sustainable construction means the construction process which embraces the basic principles and considerations of sustainable development, sustainable infrastructure can be seen as applying of sustainability principles and considerations into infrastructure projects (Kibert et al, 2007).

In fact, seen from the social respect and the wellbeing of human, especially in developing country, the development and improvement of infrastructure itself is often considered a natural step towards sustainable development. Katherine, Vice President for Sustainable Development of World Bank, said that “By promoting economic growth strategies based on expanded infrastructure which are environmentally responsible and socially acceptable, we are bringing a sustainable future closer to today’s reality” (Sierra, 2007).

The term “sustainable municipal infrastructure” was first introduced by the Federation of Canadian Municipalities, Infrastructure Canada, National Research Council of Canada and Canadian Public Works Association to describe the goal of their InfraGuide project operated from 2001 to 2007. They developed and promoted environmental protocols and encompassed social and ecological factors and indicators in decision-making from the earliest possible phases of infrastructure development, especially in the large scale infrastructure projects to promote sustainability practice (Federation of Canadian Municipalities, 2007). A range of case studies, best practice reports and specific e-learning tools were also developed under InfraGuide project, providing the Canadian perspectives and experience on infrastructure sustainability.

In Australia, it is generally agreed by the industry practitioners that infrastructure sustainability refers to projects that have been delivered according to an infrastructure plan, whereby sustainability solutions are encompassed with design and construction. It is to be noted that, “infrastructure sustainability” is different from “sustainable infrastructure”, which refers to infrastructure planning that offers higher sustainability benefits than an alternative option (public sub-transport system versus inner city highway) (Boyd, 2009).
2.3.3 Endeavours to Promote Infrastructure Sustainability

In the infrastructure sector, by its highly project-based nature, sustainability can only be achieved incrementally, project-by-project. It is suggest that, in order to achieve the goals of sustainable development, the vital first step should be the development of a set of indicators to define project sustainability goals and a process to guide the planning and delivery of projects (Wallace, 2005).

Projects that are intended to make a contribution to sustainability will do so if performance improvements achieved in one or more dimensions of sustainability are not nullified by underperformance in other dimensions. Project sustainability matrix and indicator systems have started to appear in a number of places to transfer general, global sustainability principles into local, project level objectives. Existing indicator systems in different levels and areas are reviewed and listed in Table 2.3.

Defining and demonstrating the conditions and outcomes of sustainable development is a big challenge to decision makers and practitioners. Whole-society’s goals for sustainability tend to be very general and mainly focus on essential issues and broad problems. Together with the lack of practical means of measuring sustainability at the project level within the construction industry, the construction organizations usually found it difficult to relate their construction activities and the performance of their projects to these high-level sustainability principles, and thus hard to gauge their contribution or disturbance to sustainable development (Boswell et al., 2005).
### Table 2.3: Sustainable Development Indicator Classifications

Adapted from: (Wallace, 2005)

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole-society indicators: sustainability of a particular geography or political boundary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>Overall assessment of the current state of the world, mapped to Agenda 21</td>
<td>UNCSD, Pilot Analysis of Global Ecosystems, Millennium Ecosystem Assessment, Ecological Footprint</td>
</tr>
<tr>
<td>Regional and local</td>
<td>Response to Local Agenda 21; assessment of sustainability factors determined to be important to the local population</td>
<td>Pastille, Sustainable Seattle, Santa Monica, NRTEE</td>
</tr>
<tr>
<td><strong>Organizational-based indicators: sustainability of the operation of an organization</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry government or NGO</td>
<td>Indicators of how an organization is performing in terms of a set of sustainability indicators</td>
<td>Global Reporting Initiative</td>
</tr>
<tr>
<td><strong>Investor-based indicators: correlation of corporate sustainability with fanatical performance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project risk assessment</td>
<td>Principles, processes, and indicators for managing project risk</td>
<td>The Equator Principles</td>
</tr>
<tr>
<td>Financial performance indices</td>
<td>Any published index that tracks the financial performance of companies</td>
<td>Dow Jones Sustainability Index, FTSE4Good, Innovest: EcoValue</td>
</tr>
<tr>
<td>Green funds</td>
<td>Funds that hold investment portfolios in companies that believed to have better-than-market returns because of their commitment of sustainability</td>
<td>Domini Social Equity, Triodos Bank</td>
</tr>
<tr>
<td><strong>Project-based indicators: assessment of a project’s contribution to sustainability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project screening</td>
<td>Indicators for screening projects as to their likelihood for achieving sustainability results</td>
<td>World Bank, the Equator Principles</td>
</tr>
<tr>
<td>Project performance</td>
<td>The actual contribution a project makes towards sustainable development; includes efforts made in the construction phase</td>
<td>FIDIC’s Project Sustainability Management, SPeAR, CRISP, BEQUEST, LEED, BREEAM, Green Star, CEEQUAL</td>
</tr>
</tbody>
</table>
According to the International Federation of Consulting Engineers (FIDIC, 2004), in relating whole-society sustainability indicators to project-level indicators, sustainable development:

- demands a whole-society concept based on complete and accepted principles of sustainable development;
- represents a moving target whereby perceived problems and issues will be altered substantially by the course of events and the emergence of new knowledge;
- depends on location due to the fact that many issues surrounding, and impacts of, sustainable development that are significant in one part of the world may be unimportant in another; and
- requires an environment for innovation when consulting engineers are encouraged and free to explore, invest, test, apply and evaluate promising processes, systems and technologies that offer better and more sustainable performance.

Although there are indicator systems right available, sustainability considerations and applications in the infrastructure sector are still at infant stage. Traditionally, research on sustainability in the built environment has been mainly on building, such as commercial office building, which has been more successful in raising the bar of sustainability through rating tools, innovations, and policies, with up-to-date knowledge and technology captured and encapsulate into these measures. Indicator systems currently using in Australia are listed in Table 2.4 all of which are for building assessment.
<table>
<thead>
<tr>
<th>Sustainability Assessment Systems</th>
<th>Founder and Launch Year</th>
<th>Target Industry Sector</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Star</td>
<td>Green Building Council of Australia, 2003</td>
<td>Residential building and commercial office building</td>
<td>Assess the potential environmental impacts</td>
</tr>
<tr>
<td>BASIX</td>
<td>NSW Department of Planning, 2004</td>
<td>New residential developments</td>
<td>Web-based planning tool for assessing the water and energy efficiency at design stage</td>
</tr>
<tr>
<td>NABERS (National Australian Built Environment Rating System)</td>
<td>NSW Department of Environment, Climate Change and Water, 2008</td>
<td>Existing buildings</td>
<td>Measure and compare the environmental performance</td>
</tr>
</tbody>
</table>

Lim (2009) suggested that due to the nature of buildings, these criteria are often treated in “isolation” or under a “single unit”, rather than having to consider the more diversified and myriad impacts of infrastructure projects. Infrastructure projects virtually require a whole new set of sustainability criteria and indicators to reflect their complexity. In other words, an industry-specific assessment tool of its own is imperative in order to advance the sustainability agenda in the infrastructure sector. He proposed a set of sustainability indicators specific for road infrastructure development in Australian context.

However, existing assessment system for infrastructure sustainability is rare. One of the established tools is the Civil Engineering Environmental Quality Assessment & Award Scheme (CEEEQUAL) which is promoted by the Institution of Civil Engineers (ICE) in the United Kingdom and a group of civil engineering organizations in 2003. It was designed to encourage environmental excellence in civil engineering and to improve environmental and social performance of engineering works in each development phase (CEEEQUAL, 2008). The *CEEQUAL Assessment Manual for Projects* contains 200 questions which are split into 12 topic areas: (1) Project Management, (2) Land Use, (3) Landscape, (4)

Another rating system is currently under development in Australia as well, conducted by AGIC and supported by a number of leading organizations in the Australian infrastructure sector. According to AGIC (2009a), this methodology aims at recognizing leading sustainable practice that covers a range of infrastructures.

Sustainability is a broad and subjective concept. To measure sustainability, while project goals set the direction, project indicators enable owners, engineers and stakeholders to gauge progress towards sustainable development by comparing the performance achieved on a project with the intended performance (FIDIC, 2004). These emerging assessment tools for infrastructure sustainability have a great potential to direct industry practitioners a clearer way toward sustainability. However, project complexity, both technical and non-technical, is a big issue in the journey. Currently, designers seeking to incorporate sustainability principles into their projects and advance the state of practice by adding features such as material recycling, resource conservation, re-vegetation, etc. Often these features require additional systems to be brought into the overall design and integrated with other systems (Wallace, 2005). This may require new body of knowledge to underpin the decision making beyond the scope of current industry capacity.

Another well-known methodology is Project Sustainability Management (PSM) which was developed and promoted by the International Federation of Consulting Engineers (FIDIC) as a management strategy for the consulting engineering industry to embrace and apply sustainability considerations at project level. It outlines a process through which the users are able to customize the high-level sustainability principles and relevant indicators with the considerations of the unique characters of their project scope, goals and priorities on sustainability.
Furthermore, it also recommends the process takes into account the changing capabilities of processes, systems, and technologies (Boswell et al., 2005).

2.3.4 Sustainability Gap – from a Knowledge-based Perspective

Although infrastructure sustainability issues are urgent, awareness is raising and some tools and guidance are available, application of sustainability considerations at real projects is still at infant stage.

Ugwu and Haupt (2007) pointed out two barriers that exist among infrastructure stakeholders that constrain sustainability implementation. One is the mindsets of these stakeholders and the education they received which could not effectively support their decision-making to embrace advance sustainability considerations into project development. The other is the short-term focus of these stakeholders and the lack of practical tools that facilitate quantitative analysis of project outcomes.

Wallace (2005) summarized several important conditions that can promote project sustainability performance: (1) a knowledgeable and committed project owner; (2) a high-performance project team; (3) alternative procurement and contracting mechanisms; (4) high but achievable sustainability goals and objectives; (5) access to and willingness to share knowledge and achievements.

It is clear that sustainability goals can only be achieved if construction activities are directed by advanced knowledge such as development pattern, techniques and expertise which can be imported in the form of industry best practice, enforced standards, enhanced development models and academic research outcomes. Moreover, much of the knowledge will be collected from local practices with situated and contextual sustainability appreciations (Pathirage et al., 2007). In the project-oriented infrastructure sector, industry practitioners have to draw on the existing experience to find solutions to the future, with the consideration of the unique context of each project.
In this research context, “sustainability knowledge” can be defined as the type of knowledge which improves the sustainability of an infrastructure project during its life cycle. According to the discussion in the previous section, several types of sustainability knowledge are listed in Table 2.5 as examples, which are assessment tools, government guidelines/police and project experiences.

Table 2.5: Examples of Sustainability Knowledge for Infrastructure Development

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Project Experiences</th>
<th>Government Guidelines/ Polices</th>
<th>Assessment Tools / Indicators</th>
<th>Underpinning Theory / Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Individuals</td>
<td>External resources</td>
<td>External resources</td>
<td>External</td>
</tr>
<tr>
<td>Type</td>
<td>Explicit/tacit</td>
<td>Explicit</td>
<td>Explicit</td>
<td>Explicit</td>
</tr>
<tr>
<td></td>
<td>- Mostly reside in people minds;</td>
<td>- Vague and general.</td>
<td>- Mainly developed from building assessment tools</td>
<td>- Complex and should consider extra systems</td>
</tr>
<tr>
<td></td>
<td>- Hard to track, record and widely share.</td>
<td>- More about environment protection</td>
<td>- More for environment performance assessment</td>
<td>- Many of them are simply not exist currently</td>
</tr>
</tbody>
</table>

During the whole life cycle of a construction project, a large quantity of knowledge will be generated which are highly valuable for future projects. However, in practice, commonly only a small fraction of the knowledge can be identified, captured and properly maintained in an appropriate format for sharing within the industry, not to mention the amount of knowledge that is actually transferred and reused in subsequent projects. Valuable knowledge lost in the complex project development process and fragmented industry sector which contributes to the inefficiency of the construction industry. Therefore, more efforts to ensure new knowledge is identified, captured, shared and utilized are essential to improve the profitability and productivity of the industry (Tan et al., 2010).
Furthermore, the establishment of an environment for innovation is usually seen as a critical prerequisite for success to achieve conditions of sustainability (Wallace 2005). However, in the construction industry, the situation is not optimistic.

Based on the above discussions, from a knowledge perspective, barriers for sustainability implementation in infrastructure project mainly lie in two categories: the body of sustainability knowledge which fails to provide practical and advanced knowledge, and the characteristics of the infrastructure sector, which fails to provide a supportive environment for applying sustainability. These main barriers are listed in Figure 2.3.

Figure 2.3: Barriers for Sustainability Implementation in the Infrastructure Sector - A Knowledge Perspective

To sum up, in order to promote the embracement of sustainability consideration in infrastructure development and to deliver tangible sustainability outcomes, there is a genuine desire and mandate to:

- Expand the body of sustainability knowledge for infrastructure development;
• Search better ways to trigger knowledge creation, sharing and application across diverse boundaries;

• Provide the industry with intensive and up-to-date knowledge and expertise to promote integrated decision making during sustainable infrastructure development.

This research proposes KM as a possible solution. KM theories, concepts, currently initiatives and usage in construction will be discussed in the next section.

2.4 Knowledge Management

The quest for obtaining knowledge and effectively utilizing it is as old as the history of human thought (Spiegler, 2000). Many philosophers have tried to define and understand the nature of knowledge and knowledge sharing, such as Plato, Descarts, Kant and Confucius. Until today, we still employ the methodologies they explored to obtain and construct knowledge as the fundamental guidelines for basic and fundamental research (Maqsood, 2006). Through centuries, politics, teachers, writers and even common citizens did many initiatives to create, transfer and apply knowledge. Thus it could also be argued that KM has been around far longer than the actual term has been in use.

However, it was not until late 1980’s that individuals and organizations began to realize and appreciate the importance of knowledge in the emerging competitive environment (Wiig, 1997). And since then the phase “knowledge management” entered popular usage, evidenced by the extensive KM articles, books and conferences (Dalkir, 2005). All of these are triggered by the invention and dissemination of computer and World-Wide-Web and linked to the profound revolution based on information and knowledge that we are going through.

In 1993, Peter Drucker, who is widely considered to be the father of “modern management”, said: “We are entering (or have entered) the knowledge society in which the basic economic resource...is knowledge...and where the knowledge worker will play a central role.”
Intellectual capital, under the current focus on information and knowledge services is being considered as critical resource, people being the critical asset. Development of new ways to unleashing ideas, intellect, and creative energy is chosen as the core response (Boudreau and Ramstad, 1997).

All the above give the reason why KM is currently receiving considerable attention, from both academic and industry practitioners.

2.4.1 Concepts of Knowledge

The concept of knowledge can be described by a simple word “understanding”. In both theory and practice field, plentiful definitions and taxonomies of knowledge were found based on a range of different perspectives (Alavi and Leidner, 2001; Dalkir, 2005; Kakabadse et al., 2003). Davenport and Prusak (2000) comprehensively states the concept of knowledge as: “a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates in and is applied in the minds of knower. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms.”

• Data, Information and Knowledge

Instead of debating on the definition of knowledge from as epistemological perspective, knowledge is often compared with data and information in the literature (Alavi and Leidner, 2001). A well accepted view is that data is raw material that is directly observable or verifiable; a fact. Information is processed and analyzed data which can be transferred into knowledge when it is combined with specific context and the experience of humans. One of the major attributes of KM relates to the fact that it deals with knowledge as well as information (Dalkir, 2005).

• Tacit Knowledge vs. Explicit Knowledge
Alavi and Leidner (2001) also summarized the existing taxonomies of knowledge, such as tacit knowledge vs. explicit knowledge, individual knowledge vs. social knowledge, declarative knowledge (know-about), procedural knowledge (know-how), causal knowledge (know-why), conditional knowledge (know-when), and relational knowledge (know-with), etc. However, drawing on the work of Polanyi (1962, 1967), the most commonly held view is that there are two dimensions of knowledge: tacit and explicit.

Tacit knowledge refers to the knowledge that possessed only by an individual, such as perspective, know-how, insights, intuitions, skills etc. It is usually hard to be shared to others via words and symbols, but can be transmitted via coaching, and mentoring on a preferably face-to-face basis.

Explicit knowledge refers to the knowledge that can be easily articulated in formal language and codified, shared, and stored in a variety forms, such as documents, scientific formulae, manuals, procedures, etc.

Stickiness can be characterized as a property of knowledge which makes the transferring of knowledge from one mode to other or from one individual to other difficult.

Rather than providing an explicit classification of knowledge, Davenport and Prusak (2000) tried to develop an understanding of knowledge by explaining various dimensions of knowledge. They propose seven dimensions of knowledge, including: tacit vs. explicit, teachable vs. not teachable, articulated vs. not articulated, observable in use vs. not observable, schematic vs. rich in context, simple vs. complex, and documented vs. undocumented.

- **Objective vs. Subjective (or Functionalist vs. Interpretive)**

Moreover, a twofold typology of knowledge is identified within the debate of KM: objective and subjective. An objective approach sees knowledge as an object that can be discovered and distributed. In contrast, a subjectivist approach advocates
that knowledge is essentially linked to human experience and identified through the social practice of knowing (Shelbourn et al., 2006). There is also another very similar expression. Ulrike Schultze (1998) identifies the follow two perspectives that are twofold opposites: functionalist perspective and interpretive perspective.

### 2.4.2 Knowledge Management: Definitions and Perspectives

Through the literature study, no well accepted definition regarding to “what is KM” can be obtained due to its multi-disciplinary nature. KM now is a broad and expanding topic contributed by diverse disciplines (e.g. cognitive science, IT technologies, organizational science, library and information sciences, document and information management, etc.) and a multifold mix of strategies, tools, and techniques (Alavi and Leidner, 2001; Dalkir, 2005; Kakabadse et al., 2003; King et al., 2002; McInerney, 2002). Researching the theory and literature of this field, many approaches to KM have been identified and categorized in various ways. Figure 2.4 illustrates some of the diverse disciplines that have contributed to KM.

![Disciplines that Contribute to KM](Source: Dalkir, 2005)

From the business perspective, the purpose of KM is forma a positive environment for learning and working within the organization to promote the continuous sharing, using, creating and expanding of individual and organization knowledge asset with an ultimate aim to increase business value (Kikawada and Holtthouse, 2001). Dalkir (2005) views KM as a systematic and collaborative
approach that is positioned to manage the enterprise’s intellectual assets through facilitating its creation, capture and usage.

From the technology/process perspective, the following definition of KM was quoted on Microsoft’s website: “Knowledge management is the use of technology to make information relevant and accessible wherever that information may reside. To do this effectively requires the appropriate application of the appropriate technology for the appropriate situation. Knowledge management incorporates systematic processes of finding, selecting, organizing, and presenting information in a way that improves an employee’s comprehension and use of business assets” (Brown and Duguid, 2000).

Moreover, from an objective perspective, Teece (2000) considers KM as a systematic approach to manage the flow of information in order to provide access to the right knowledge at the time people need it to facilitate efficient and effective decision-making. Thus, in this view, KM is task-oriented.

As mentioned above, there are a range of disciplines have influenced and contributed to the field of KM in theory and practice. Regardless of the various definitions and perspectives on KM in the existing literature and practices, it is increasing considered as not only a fashionable topic in the management field, but more as an integrated and effective approach of understanding and exploring the critical role of knowledge in the modern business environment and better ways of utilizing it (Mentzas, 2004).

### 2.4.3 KM Cycle and KM Approach

Diverse terms are used to refer to the similar KM processes or stage in the field of KM by different researchers due to the difference in perspective, focus, priority and level of detail. Major presentations can be encompassing the capture, creation, codification, sharing, accessing, application, and reuse of knowledge within and between organizations. Based on the various models, Dalkir (2005) developed a KM cycle which identified KM in 3 major steps: Knowledge Capture and/or
Creation, Knowledge Sharing and Dissemination and Knowledge Acquisition and Application, as illustrated in Figure 2.5.

![Figure 2.5: KM Cycle Stages](Source: Dalkir, 2005)

The identifications of KM cycle of KM processes set a foundation for KM implications that focus on knowledge processes and enablers. The adopters of the new discipline have followed different approaches to trigger and facilitate knowledge flow within the cycle with varying emphasis on technological, culture, and organizational and managerial issues. However, as many researchers identified (Hansen et al., 1999; Rubenstein-Montano et al., 2001; Mentzas, 2004), according to the two-fold typology of knowledge – objective and subjective; it is easy to notice that two main perspectives of KM are usually employed.

The objective approach views knowledge as an independent object that can be captured, stored, distributed and measured. Thus the main focus of this approach is to build products and artifacts to contain and represent knowledge, which usually relies on the management of documents through IT-based solutions. Examples include: knowledge map, knowledge taxonomies and formal knowledge structure; database and archives for best practice, former business cases and lesson-learned, etc. Therefore, based on its focus and main methods, this approach is also entitled as “content-centered”, “codification”, “product” or a “people-to-document” approach.
On the contrary, abolishing the idea of managing the knowledge, the subjective approach emphasizes the means of facilitating and motivating the process of knowing. It views knowledge as something closely tied to the person who owns it, and thus views KM as a process of social communication, in which new knowledge is created and existing knowledge is shared. This approach also considers Information Technology (IT) and Information and Communication Technology (ICT) as very important tools for their ability to facilitate person-to-person contacts and communication of knowledge. This approach has also been referred to as “collaboration”, “personalization”, “process” or a “people-to-people” approach. Table 2.6 compares the differences between these two KM approaches.

<table>
<thead>
<tr>
<th>Define Knowledge</th>
<th>Objective Approach</th>
<th>Subjective Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mostly explicit</td>
<td>- Mostly tacit</td>
<td></td>
</tr>
<tr>
<td>- An object that can be stored and distributed</td>
<td>- Associated to people and context</td>
<td></td>
</tr>
<tr>
<td>View KM</td>
<td>- A systematic way to deliver the knowledge to the people who need it</td>
<td></td>
</tr>
<tr>
<td>- Facilitate communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>- Link people to documents</td>
<td></td>
</tr>
<tr>
<td>- Link people to people</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of IT</td>
<td>- Heavy investment in IT, Database, search and retrieval tool, etc.</td>
<td></td>
</tr>
<tr>
<td>- Moderate investment in IT, ICT, discussion forum, etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the choosing and adoption of appropriate KM approach, it is suggested that the nature of the industry, organization characteristics, the peculiarity of its products and services, organizational culture should be considered (Hansen et al., 1999). However, there are more calls for an integrated approach that reflect both the object and the subject perspective. Since each perspective identified important elements for successfully the implementation of KM initiatives, such as knowledge repositories and retrieval technology, knowledge codification etc. from the “object” approach and emphasis on organizational culture, net-working, team developing etc. from the “subject” approach.
2.4.4 KM Techniques: from both Social and Technical Perspective

In order to support different KM processes, various strategies are employed by the organizations including both IT tools and non-IT tools. The non-IT tools do not depend on IT although still can be facilitated by it. KM techniques are not new; many organizational have been implementing these for a long time under the umbrella of management approaches such as organizational learning and organizational learning. Examples of the KM tools can be seen in Table 2.7.

<table>
<thead>
<tr>
<th>IT-Tools</th>
<th>Non-IT Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data and text mining,</td>
<td>Brainstorming,</td>
</tr>
<tr>
<td>Groupware,</td>
<td>Communities of practice (CoP),</td>
</tr>
<tr>
<td>Internet,</td>
<td>Face-to-face interactions,</td>
</tr>
<tr>
<td>Extranet,</td>
<td>Post project reviews,</td>
</tr>
<tr>
<td>Knowledge bases,</td>
<td>Recoumment,</td>
</tr>
<tr>
<td>Taxonomies and ontologies,</td>
<td>Coaching and mentoring,</td>
</tr>
<tr>
<td>KM software,</td>
<td>Apprenticeship,</td>
</tr>
<tr>
<td>IT based database, etc.</td>
<td>Training, seminars, workshops, etc.</td>
</tr>
</tbody>
</table>

CoP is an important KM strategy used across the area of organizational learning, KM, social networking, professional development and others and is worth extra introduction.

According to Wenger et al. (2002), communities of practice (CoP) are “groups of people who share a concern, a set of problems or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis”. As a powerful and effective KM strategy, CoPs are becoming increasingly important in many organizations, as stated by the American Productivity & Quality Center (APQC) (2001): “CoPs are becoming the core knowledge strategy for global organizations. As groups of people who come together to share and learn from face-to-face and virtually, CoPs are held together
by a common interest and are driven by a desire and need to share problems, experiences, insights, templates, tools, and best practices”.

CoP is a specific kind of community. It is different from other types of groups like projects team and formal departments mainly because it allows cross-functional and multi-disciplinary integration. While project team members are assigned to a project to accomplish a specific task and thus usually work within their professional domain, members of the CoPs are self-selected based on their personal interests and expertise. They are getting together based on their common interest, regardless of their disciplines, positions and functional department, to create, expand, exchange knowledge, and to develop individual capabilities.

Forms and structure of CoPs can be various, there are three fundamental components are contained in all of them: (1) a domain of knowledge, which creates the common ground for the group of people and defines the main topic and a range of critical issues; (2) a community of people who care about the domain, which creates the social structure of learning and communications; and (3) a shared practice which refers to the specific knowledge that the communities develops, such as the tools, ideas, solutions, guidelines etc. that are valuable to the domain (Wenger et al., 2002).

Main conditions to secure the success of a CoP include: (1) endorsement and support by the senior management level; (2) active core members; (3) defined membership with clear but different roles and responsibilities; (4) supporting tools such as database, forum, website and other collaboration facilities; and (5) regular measurement (APQC, 2001).

2.4.5 KM Implementation: Strategy and Success Factors

Since the inception of the KM in last decades, organizations have undertaken various KM related initiatives to survive the furious market competition and development of knowledge economy. As they acknowledged that both explicit and tacit knowledge are important for the organization and both must be
recognized as providing value to the organization, the goal of the initiatives, then, is to (1) leverage knowledge and reduce the size of the organizational knowledge gaps; and (2) improve organization’s performance.

The current main stream practices of KM are predominated by the information systems and human resource management (HRM) perspectives. Information system perspective address KM through the usage of IT and ICT tools to facilitate the transferring and storage of information and knowledge, while the HRM perspective emphasizes on motivating and facilitating the individuals to expand and use their personal knowledge to accomplish their tasks in work for business success (Tan et al., 2010).

In fact, in practice, a combined consideration of both the soft and hard approach is proven to be more effective. On one hand, the goals of leveraging knowledge through IT/ICT alone is often hard to achieve, as the important culture and human issues cannot be solved by the IT/ICT tools. On the other hand, HRM approach could heavily benefit from the usage of ICT tools which provide faster and broader access to information and various efficient means to facilitate communication.

According to Krogh et al. (2001), knowledge strategy can be seen as the adoption of KM processes and approaches to either expand the existing knowledge or create new knowledge in order to achieve specific goals. It should focus on the dynamic knowledge process, rather than the static content it is dealing with. They proposed four general knowledge strategies according to different combination between “existing knowledge domain” and “new knowledge domain”, and “transfer” and “creation” as shown in Figure 2.6, including: (1) leveraging strategy, which refers to transfer knowledge to add to existing knowledge asset; (2) expanding strategy, which refers to create new knowledge based on existing knowledge asset; (3) appropriating strategy, which refers to use new knowledge from outside the company to build up a new knowledge domain; and (4) probing strategy, which refers to create new knowledge within the company.
In order to choose the appropriate KM strategy, it is suggested that the organization should have a good understanding on the status of organization knowledge asset, the goals want to achieve, expected outcomes through KM implementation, and the knowledge environment (e.g. organizational culture, capabilities of the employees, etc.). Furthermore, the choice of KM strategies should be coupled with other strategic activities within the organization to ensure adequate attention, resource allocation and priority (Krogh et al., 2001).

The growing body of literature recommended how KM strategies should be developed (Hansen et al., 1999; Krogh et al., 2001; Schwartz, 2006). Robinson (2010) summarized a series of actions for developing and implementing a KM strategy as:

- Deciding what key knowledge to share about processes, people and products/role of learning;
- Deciding with whom to share (member of the project, internal and/or external organizations – e.g., suppliers, clients, individuals or groups of specialist);
- Deciding how to share (what KM tools- technical or technologies – to use);
- Deciding which implementation issues to address – resources needed, reform and results monitoring systems;
- Deciding how to evaluate the effectiveness and efficiency of KM strategy or initiatives;
In practice, KM initiatives may fail due to various barriers, such as:

- Learning, understanding, and sharing knowledge can be very time-consuming. People may not have time and priority to conduct these activities.
- Some organizations and individuals believe that “knowledge is power” and protect their knowledge asset to keep competitive advantage.
- Various culture, subculture, and discipline languages may exist in one organization, which prevent the effective communication of information.
- Apathy about knowledge sharing may build in an individual’s mindset or an organization’s culture, which affect their behaviours.

Failures of the KM initiatives have led to another important question for implementing KM – what are the key factors to secure their successful. Davenport and Prusak (2000) argue that KM is predominantly a human interaction exercise with ICT as providing a supportive and facilitate role. They suggest the ratio of 1/3 technology and 2/3 people-related issues as being a useful guideline for successful KM initiatives. However, it is popular in the business environment currently to take a “technical-push” strategy to address KM implementation, investing heavily on expecting the IT tools to solve the problems related to knowledge sharing, application and creation” (CEN, 2004b).

European Committee for Standardization (CEN) indicated that in order to successfully implement KM, organizations and practitioners should focus more on the soft issues, such as: cultivating organizational culture, facilitating communication, identifying leadership, supporting communication, providing personal motivations, etc. Technologies should be seen as an enabler and too for facilitating communication, providing a media for knowledge storage, etc. (CEN, 2004b). Five important enablers for KM initiative success are suggested by CEN, including organization culture, structures and processes, information technology, skills and motivation, and management support.
2.4.6 Existing KM Frameworks

As many researchers and industry adopters indicated, successful KM is a balancing act, which involves not only technology issue, but also social and cultural issues which are in fact more important but harder to address. Meanwhile, it is also important to consider the wider economic and technological issues that push the organizations to innovate and improve constantly.

Weber et al. (2002) considered a framework as a holistic and concise description of the major elements, concepts and principles relating to a specific domain. In their opinion, main aspects that should be outlined in a KM framework include: the main elements of KM, their relationships and principles of their interactions. In this case, a KM framework can be used as a reference for KM understanding and implementing. More benefits can be gained by developing such KM frameworks, such as providing the practitioners with a consistent language, offering a source of ideas for designing KM programs, providing a checklist to address the most important issues, especially to tackle the non-technical aspects of KM (Robertson, 2002).

With the explosive growth of interest in KM, various KM frameworks have been produced in order to help the real world’s organizations to implement KM; however a codified, generally accepted framework has not been established (Oliver, 2003; Robertson, 2002; Weber et al., 2002; Rubenstein-Montano et al., 2001).

Rubenstein-Montano et al. (2001) reviewed 26 existing KM frameworks by the year of 2001 and classified them into a twofold typology, prescriptive and descriptive. Prescriptive frameworks generally illustrate the KM procedures (or KM cycle in some literature) without explaining how the procedures can be conducted or facilitated. On the contrary, descriptive frameworks provide specific details to describe KM. The authors indicate that the majority of frameworks they reviewed are prescriptive and thus tend to be task-oriented. They emphasize placing KM in a larger context of systems thinking so that influencing factors on
its success or failure can better be recognized and understood. They also provide suggestions on what a general framework should include: (1) the framework should be both prescriptive and descriptive, by naming the KM procedures and provide details of how to accomplish them; (2) KM activities should be closely linked to organizational strategies and goals; (3) KM activities should be pre-planned; (4) mechanisms for feedback and continues learning should be set to make KM evolving.

Weber et al. (2002) also discussed the existing KM frameworks from a dissimilar perspective from Rubenstein-Montano et al. (2001). They distinguished KM frameworks into two types: holistic and explanatory. In their view, holistic KM frameworks share similar structures and aims, which usually illustrate all key aspects of KM and consider the relationship and role of individual elements, such as technology, people, strategy, process and tools. However, due to the property and perspectives of their creator, different frameworks will emphasize different individual elements. Explanatory frameworks usually are designed to explain certain aspects of KM to address a particular issue or to emphasize a particular approach. Usually elements within a explanatory framework may constitute to part of a holistic KM framework.

Here are several examples of existing KM frameworks which were designed for various purposes, and thus, emphasized different elements of KM.

- **Example A: a holistic KM framework**

The European KM Framework can be seen as a good example of general framework developed by CEN in 2004. This framework aims to help general organizations to positions KM programs by outlining the key components of KM and providing a schematic picture to show the relationship of these various aspects. It describes the overall context for KM implementation at both organizational and personal level with an aim to help organizations to understand and successfully implement KM in practice.
As illustrated in Figure 2.7, The KM Framework proposes three layers for KM: (1) implement KM basing on business processes including all participants and their knowledge; (2) core knowledge activities (which is also called KM cycle in literature) which are identified as knowledge identification, creation, storage, sharing and use; and (3) enablers for KM implementation which are divided into two categories, which are personal and organizational knowledge capabilities. This framework also emphasizes that KM initiatives should center on the business focus of the organization and add value to it.

The personal knowledge capabilities proposed by CEN include ambition, skills, behavior, experience, tools and time management, etc., while organizational knowledge capabilities include the mission, vision and strategy, the design of processes and organizational structures, measurement, understanding of the culture, the use of technology and infrastructure, etc.

![Knowledge Management Framework: A European Perspective](image)

**Figure 2.7: Knowledge Management Framework: A European Perspective**
(Source: CEN, 2004a)

- **Example B: an industry specified KM framework**

As an adaptation example of KM framework to a specific industry, Jafari et al. (2007) provide us an example (as shown in Figure 2.8) through the investigation of the role of KM in Iran aerospace industries and the development of a KM framework specially designed for aerospace industries towards a knowledge-based organization.
- **Example C: performance specific KM framework**

Moreover, specific KM frameworks are developed to integrate with specific issues which usually aim at improving some aspects of the organization’s performance. Mentzas (2004) developed the following strategic KM framework (as shown in Figure 2.9 and Figure 2.10) which is knowledge asset based.
Some other examples include: a framework for the integration of KM and business process management (Choi, Jung, and Song, 2004); a KM framework for
innovation capacity audit (Biloslavo, 2005); a KM maturity road map for corporate sustainability (Robinson et al., 2006); and a strategic KM framework for leveraging knowledge innovation (Sung, 2006) etc.

2.4.7 KM in Construction

The construction industry is a highly project based industry in which improvement can only be achieved project-by-project. KM facilitates continuous improvement through project learning and innovation (Robinson et al., 2010). From a project context, KM is a process of capturing, storing, sharing and applying the different types of knowledge, whether tacit or explicit, by making them easily accessible and usable so that time is saved, performance is improved and innovation is facilitated in the planning and design development, construction and operational phases of big construction projects.

According to Robinson et al. (2010), project-based organizations have three distinct mode of leaning: inter-project, intra-project leaning and cross-sectoral or supporting learning.

- Inter-project learning takes place across projects by sharing lessons learned in precious projects to develop new knowledge for improving the performance of future projects. Documents relating to precious projects such as drawings, cost plans, bulls of quantities, specification, work program and project reports are often archived for future reference.

- Intra-project learning takes place within a project by the creation and sharing of knowledge design the project life cycle. Intra-project learning provides an immediate and direct opportunity to influence an ongoing project as lesson learnt in earlier phases can be applied into subsequent phases for improvement. However, such benefits are not always fully realized as time is always a major constraint as a project progress through different phase.

- Cross-sector or support learning takes place outside the project sector environment.
According to Tan et al. (2010), majority of inter-project learning and intra-project learning are around reusable project knowledge. In the same project, project knowledge generated from the earlier stages can be used in subsequent stages. For a different project, project knowledge can be referred in order to prevent the same mistakes, to avoid “reinventing the wheel” and to make improvement.

Tan et al. (2010) also listed several types of important project knowledge, including: knowledge about process, knowledge about clients, knowledge about cost, knowledge about relevant policies and regulations, knowledge about suppliers and contractors, knowledge about industry best practices, knowledge about lessons learned, “know-who”, etc.

In the modern fast-changing and high competitive business environment, knowledge is leading an increasing significant role in sustaining an organization’s competitiveness and performance in many industries. KM has also been imported into the construction industry as a modish concept as well as a useful tool for some years (Kazi, 2005). There is evidence that the importance of KM has been recognized by the construction industry by the various methods, models, and tools supported by real-life case studies providing insights into the management of knowledge in the construction industry.

As a project-oriented industry, the construction industry has its unique characteristics that influence KM practices. Following statements were found in the literature which generally outlined the knowledge activities and KM implementations in the construction industry.

- A large portion of the construction knowledge is tacit in nature and exists in the minds of the industry practitioners from various background and disciplines (Khalfan et al., 2002).
- However, in the construction industry, such tacit knowledge is a more important factor affecting an organization’s ability to remain competitive (Pathirage and Haigh, 2007).
• Due to the multi-disciplinary nature of the construction industry, various stakeholders and team members usually have difficulties in sharing understandings. This is one of the mains barriers that constrain knowledge sharing across functional and disciplinary boundaries within the industry (Anumba et al., 2005).

• Usually knowledge generated from projects is not well organized and maintained. Losing important knowledge on projects at the end of the project when the project team is disbanded is a common problem in the construction industry. Such knowledge includes such as lessons learned and best practices that embedded in the operational procedures and technical solutions. (Kamara et al., 2002).

• Conducting Post-project review (PPR) is a common approach employed in the construction industry to capture knowledge generated in the projects. However, in practice, it is constrained by the insufficient time allocation due to the demanding routine of the project development process (Anumba et al., 2005).

• In the construction industry, knowledge sharing is heavily based on informal communication and collaboration. Industry practitioners usually identify and obtain knowledge through networking and “know-who” (Kamara et al., 2002).

Despite the shortcomings of the current KM practices in the industry which are, for most of the time, not entitled a formal KM tag, Anumba et al. (2005) proposed that many benefits can be gained through KM implementation. Such as:

• **Boosted innovation** – KM can boot innovation by providing a clear strategy for managing knowledge.

• **Improved project performance** – Practitioners will work more effectively and efficiently if they are provided up-to-date knowledge and best practice. Moreover, continuous improvement will be accelerated if lessons learned form one project can be transferred and used in future projects.
- **Enhanced communication** – KM can promote knowledge sharing across various disciplinary, organizational, functional and cultural boundaries, which sets a better platform for understanding.

- **Improved industry capacity** – KM can boot knowledge sharing, which will also enhance the dissemination of industry best practice across projects and organizations.

Practical means of implementing KM in the construction industry through various mechanisms and tools are developed and used in the industry to some extent. Studies ranging from the implementation of decision support systems, external provision of KM services, internal exertion of KM, learning histories, innovation, and so forth provide enriching practical experiences in KM implementation in the construction industry.

However it is obvious that despite these efforts which separately deal with just one or some aspects of KM, such as explore culture as important enabler of KM application and innovation development, or address the issues of capturing, storing, and transferring knowledge in the construction industry, there is no research outlines KM as a solution in a holistic and holistic view.

Furthermore, there is still very limited KM approaches brought forward with the aim to bring an awareness of sustainability issues in construction processes, and even less on how to ensure that knowledge is readily available to individuals, project teams, and companies at the project level.

### 2.4.8 Linking KM with Sustainability in Construction

A few earlier academic studies have attempted to link KM with the construction industry with the aim to promote sustainable development.

**Soft System Methodology as a KM Tool in Construction**
Venters and Cushman (2004) have employed Soft System Methodology (SSM) as a method to understand the knowledge environment of the construction industry. This research also brought the awareness on promoting sustainability practices in the construction process.

Maqsood and Walker (2007) used SSM in case studies to identify innovation diffusion initiatives within a construction organization. The noticeable gap between the advancement of academic knowledge and its implementation was emphasized by this research.

A Knowledge-driven Management Approach to Environmental-conscious Construction

Chen et al. (2003) presented a knowledge-based management prototype entitled E+ for environmental-conscious construction projects, which tried to integrate the existing environmental management tools into construction practices. This tool aimed to facilitate selectively reusing the retrievable knowledge in construction engineering and management areas assembled from previous projects for the best practice in environmental-conscious construction.

Creating, Sustaining and Disseminating Knowledge for Sustainable Construction: Tools, Methods and Architecture (C-SanD)

This research project proposed a software tool to facilitate the capture, retrieval and creation of knowledge with an aim to promote sustainable construction. “Sustainability Management Activity Zone” (SMAZ) was the main output of this project, which is a web-based portal for managing sustainability knowledge in construction. SSM was used in this project to identify and understand the critical issues on managing sustainability knowledge (Shelbourn et al., 2006). With an aim to facilitating knowledge management at project level, SMAZs were designed to integrate with the development processes of the project as following. It also outlined a process to embed sustainability considerations into project plans and construction, including a serious of stages such as: prepare Sustainability Mission
Statement, scope sustainability issues, prepare sustainability plan, undertake sustainability assessment, monitor progress and conduct project reviews.

**Sustainability Community of Practice (CoP)**

Wallace (2005) recommended that establishing a sustainability CoP that across all disciplines and functional departments should be the first move for the engineering firms that what to embedding the sustainability principles and delivering sustainability services.

Rydin et al. (2007) discussed the interrelationship between knowledge and practice of sustainable construction in the UK’s planning departments. The concept of CoP framed the analysis of this research. Results showed that limited KM practice found in the UK’s construction industry. It suggested that relevant knowledge should be translated into more systematic and transferable forms to promote its flow and application.

**Zofnass Program for Infrastructure Sustainability**

A program entitled Zofnass is currently ongoing at Harvard University with the mission to define and quantify sustainability for large scale infrastructures and urban development through developing and promoting methods, process and facilitating tools. It is developing a rating system for sustainable infrastructure to assist environmental sustainability measurement and to facilitate decision-making towards more sustainable projects for a wide range of infrastructure stakeholders, such as designers, contractors and operators (Harvard University Graduate School of Design, 2010).

The above discussions have outlined the existing research that addressed sustainability issues for construction from a knowledge perspective. They have shown the important role of managing relevant knowledge and the potential of KM in promoting sustainable practice in construction projects.
Moreover, within the construction industry, managing relevant knowledge can be of more importance to the large scale infrastructure development because of the unique characteristics of each project, i.e. multi-disciplinary teams, dynamic participation of team members, heavy reliance on previous experience, the one-off nature of the projects, long period of project life cycle, tight schedules, limited budget. However, up to the present, no such KM solutions specifically designed for infrastructure development have been provided.

2.5 Summary

Infrastructure development can cause major impacts on the environment, society and local economy. As the global realm of sustainability develops and evolves, it is increasingly accepted that sustainability issues should be put at the top of the agenda when contemplating infrastructure development. In Australia, as the response to the unprecedented demands and to ensure the future prosperity, infrastructures are invested and delivered at a speed has not been seen in history. The call for infrastructure sustainability is critical and urgent.

While the logical link has been established between infrastructure and sustainability, industry practitioners are facing challenges to support the sustainability agenda to transfer from talk to action. In order to embrace sustainability principles, the industry need to move to a knowledge-intensive mode and there is an underlying need for technical, social and innovation changes.

This chapter reviews the current body of knowledge on infrastructure sustainability, the mechanics of infrastructure development and the culture and characteristics of project-based industry. The urgent needs to expand the body of knowledge and find better ways to manage it within the sector to trigger innovation and improve project performance are highlighted.

KM is considered to be a possible solution. The principle and theories of KM and its application in the construction industry are reviewed. Furthermore, KM framework is specifically discussed which can relate the various components of
KM (people, process, technology, etc.) to each other and provide a schematic picture of how these various aspects depend on each other. Base on these review and discussion, a specific KM framework, considering the characteristics of sustainability knowledge, infrastructure development process and the nature of the project-based industry, will be developed in later stages of the research.
CHAPTER 3
RESEARCH DESIGN

3.1 Introduction

This chapter firstly explains the philosophical foundation that underpinned the selection of research methodology. Then it outlines the research design and justifies the selection of research methods, namely questionnaire survey, semi-structured interviews and case studies, which are considered appropriate for investigating the research questions. Furthermore, the process of executing each selected method is proposed to direct subsequent data collection and analysis.

3.2 Understanding the Philosophy of Research

Fellows and Liu (2008) describe research as a careful search and investigation and term it as a “voyage of discovery”. The purpose of research is to contribute to the existing body of knowledge and to facilitate the learning process. It is an organized, data-based, critical investigation into a specific problem and the process is affected by contextual factors. The aim of research is to discover truth and construct reality.

Creswell (2008) states that when designing a research, intersection of philosophy, strategies of inquiry, and specific methods should be involved, and the interaction of the three components is illustrated in Figure 3.1.
3.2.1 Paradigms of Research

Dainty (2008) emphasizes that establishing a philosophical position and orientation towards the inquiry is fundamental to a research. According to Guba and Lincoln (1998), a paradigm can be seen as the cluster of basic beliefs and perspectives that a researcher holds in a particular scientific discipline. It will influence the researcher on “what should be studied”, “how research should be done” and “what methods should be used” (Brman, 2004). Therefore, selections of paradigm are different in various disciplines, for different inquires and will result in the generation of different types of knowledge.

As per Creswell (2008), in the field of modern social science, there are four different views of research paradigms that can be broadly categorized as “postpositivist worldview”, “social constructivist worldview” “advocacy and participatory worldview”, and “pragmatic worldview”.

- The postpositivist worldview
Postpositivist (also called positivism / postpositivism / empirical science in the literature) assumptions only recognizes non-metaphysical facts and observable phenomena, which is seen as the representation of the traditional form of research (Fellows and Liu, 2008; Creswell, 2008). It holds a deterministic philosophy in which causes probably determine effects or outcomes. Thus it seeks to test correlations between variables in the world that is external and objective thus is more likely to adopt quantitative methods for data analysis. The main principle of using this paradigm is the separation of researcher (subject) and research object.

- **The social constructivist worldview**

The main underpinning theme of the “social constructivist” paradigm is that the world is not objective and exterior, and the real world is determined by people rather than by objective and external observable facts (Easterby-Smith *et al.*, 2002). Thus it is particularly valuable for research in management discipline by indicating the reality is constructed by the persons involved. Thus it is more likely to feature in qualitative studies (Fellows and Liu, 2008).

- **The pragmatic worldview**

As a paradigm, pragmatism places “the research problem”, rather than the theory, at the central position and the researchers would apply all available approaches to understand the problem and find solutions to it (Patton, 2007; Creswell, 2003).

In practice, researchers holding this worldview will use multiple methods of data collection to best answer the question, will employ both quantitative and qualitative sources of data collection, will focus on the practical implementation of the research, and will emphasize the importance of conducting research that best address the research problem (Creswell, 2006). It is also the philosophical underpinning for mixed methods studies.
3.2.2 Research Methodology

Paltridge and Starfield (2007) observed that second-language young researchers in particular are often not fully aware the distinction between methodology and methods where it is relevant. In fact, research methodology (or called strategies of inquiry/research strategies) refers much more than individual research method. A method usually gives systematically details to the process of conducting a study with this method (e.g. how to conduct a questionnaire survey.) In contrast, research methodology provides a generic framework to describe the philosophical positions and rational the underpinned the inquiry (Dainty, 2008; Paltridge and Starfield, 2007; Creswell, 2008). Thus, the research methodology will enormously influence the actual selection, position and conduction of research methods.

Generally, three broad classifications of research strategies can be found in the literature: quantitative, qualitative, and mixed-method strategies (Creswell, 2008).

In a broad view, quantitative research is underpinned by the postpositivistic paradigm and refers to the systematic investigation of quantitative properties. It usually employs methods (e.g. experiment, questionnaire) that can yield numeric data and use mathematical measures to analyze it. During the research process, the researcher should be objectively separated from the subject. On the contrary, qualitative research heavily focuses on interactive process with an aim to understand human behavior.

The third one, mixed methods strategy is underpinned by the pragmatic paradigm. As it employ two or more research techniques, qualitative and quantitative approaches may be employed to reduce or eliminate disadvantage of each individual approach whilst gaining the advantage of both, and of the combination – a multi-dimensional view of the subject, gained through synergy. Thus, triangulation can be very powerful to gain insights and results, to assist in making inferences and in drawing conclusions.
Fellows and Liu (2008) emphasize that triangulation may be used for entire studies (such as by investigating a topic from several, alternative paradigms or/and research methodologies) or for individual part(s) of a study. Figure 3.2 illustrates how quantitative and qualitative data can be combined to investigate research questions and draw conclusions.

In construction management research community, methodological pluralism is often pursued. Dainty (2008) reviewed the 107 papers published in Vol. 24 of *Construction Management and Economics* in order to investigate the employment of various methodology in construction management research. The result shows that 12(11.2%) papers adopted a mixed-method approach, while qualitative methods, quantitative methods and review paper are 9(8.4%), 76(71.0%) and 10 (9.4%) respectively. Thus the construction management discipline tends to be firmly rooted within the traditional positivist paradigm. Mingers (1997) suggests many factors may influence individuals’ selection of research paradigms, such as the institutional, physical and geographic boundaries.
Although mixed-method approach is not a predominant methodology in construction management discipline, it is suggested that plenty benefits can be brought by adopting a “multi-methodological” research design, especially for the social science research within the construction management discipline (Dainty, 2008). For example, it enables the researcher to better understand the complex mechanisms and relationships that influence the industry practices, to gain richer insights and a more complete understanding of the way that industry practitioners “do” management in the construction industry.

3.2.3 Pragmatic Paradigm and Mix-method Strategy

Given the possibility of using qualitative, quantitative and mixed methods approaches, Creswel (2008) advices the most important criteria that affects the choice of one approach over another is the research problem.

As stated in Chapter 1, this research roots in the neglected, problematic and unprincipled status of sustainability practice in Australian infrastructure sector, which is a highly project-based and complex industry which involves various stakeholder. This research aims at developing a holistic KM framework for the infrastructure sector to manage sustainability knowledge.

In order to propose such framework, theory of KM and existing frameworks should be investigated. Integrated with the unique characteristics of sustainability knowledge and the Australian infrastructure sector, KM theory and related concepts can be proposed and then be tested, and usually quantitative methods should be adopted for this purpose. However, quantitative methods often fail to provide rich contextual information, insights and reasons behind the data. As this research also hope to provide applicable suggestions and guidelines to the industry practitioners, investigations on the important issues cannot be avoided. Thus qualitative methods are needed to collect industry practitioners’ attitudes, insights, suggestions and current good practices on managing sustainability knowledge.
To sum up, in order to answer the research questions and achieve the research objectives stated in Chapter 1, this research may start with quantitative methods in which existing KM theories and relevant concepts can be tested, followed by qualitative methods involving detailed exploration with industry practitioners and real infrastructure projects. In this approach, the later stage qualitative methods are used to elaborate and expand the findings from the earlier quantitative methods, fitting the characters of sequential mixed methods. Diverse types of data can provide best understandings of the research problem and possible solutions.

3.3 Research Design

Generally speaking, “research design” can be seen as a framework that illustrates the ways of collecting and analyzing data with the aim of achieving the research objectives and answering the research questions. Development of the research design is underpinned by the philosophy foundation (the chosen paradigm) and is essential to secure the contribution that the research is expected to make (Bryman, 2004).

Fellows and Liu (2008) point out that the critical consideration is the logic that links the data collection and analysis to yield results, and hence, conclusions, to the main research question being investigated. Therefore, the research design must take into account the research questions and determine what data are required, and how the data are to be analyzed.

Research design directs the research strategy by defining an action plan for getting the initial research questions to the conclusions (Wellman and Cruger, 2002). It can be considered as the structure of research -- it is the "glue" that holds all of the elements in a research project together. It helps to structure the research methodology into logical steps through appropriate stages.

According to the detailed research objectives and questions stated in Chapter 1, this research requires a combination of qualitative and quantitative methods and
using primary and secondary data. The quantitative technique is used to test KM theory and concepts to confirm its relevance to the management of sustainability knowledge in the infrastructure sector, and identify the priory issues. The qualitative technique is used to collect rich contextual information, to seek good industry practices, to identify the possible best solutions and gain deep understandings of the sustainability and KM issues in project scenario.

### 3.3.1 Selection of Research Methods

Once the research approach is determined, then specific research methods for collecting, analyzing and interpreting data should be carefully chosen. Literature suggests that methods are driven by research approach as well as how to integrate the participants (Kelly, 2004). As discussed in the previous section, this research adopts the mix-methods research approach, thus both quantitative and qualitative methods are required.

**Quantitative Methods**

Various quantitative methods or strategies that usually fall in the positivist paradigm include laboratory experiments, field experiments, archival analysis, forecasting future research, simulation, game/role playing and surveys (Galliers, 1992 and Yin, 2003).

Based on the literature review, potential important enablers, barriers, knowledge activities and approaches, outcomes and important issues for managing sustainability knowledge in the Australian infrastructure sector have been identified. The research requests the quantitative method to test on these items in order to identify the most important and relevant elements with regards to the research objectives. Research questions in this stage include what (e.g. what are the import enablers for managing sustainability knowledge), how much (e.g. importance of a KM activity, influence of an enabler), and who (e.g. influential stakeholders), etc. Such information can only be provided by the industry practitioners.
In the light of the requirements of the research, questionnaire survey among industry practitioners is considered in the first phase of the study. Questionnaire survey is a popular method in both construction management area and KM area, especially in studying KM's application in various industries due to its ability to reach a large number of respondents and to quantitatively analyze large numbers of variables. For example, Singh et al. (2006) used a postal questionnaire survey to investigate the impact of KM practices in Indian manufacturing industries, and a Five-likert scale is adopted to formulate the close-ended questions. Furthermore, Wong (2006) also used a questionnaire survey to study the KM practices in Hong Kong quantity surveying firms.

**Qualitative Methods**

Various qualitative methods or strategies that usually fall in social constructivist paradigm, including interview, case study, archival analysis, subjective argumentative, action research, ground theory, and descriptive / interpretive (Galliers, 1992 and Yin, 2003).

This research requires qualitative methods to further explore the important issues that identified through the quantitative study and to investigate “how to” address these issues. Interview method is selected as it allowed the researcher to directly discuss with knowledgeable industry practitioners in order to gain insights, suggestions, and existing effective practices. In fact, interview remains a popular method of data gathering by those researching in the built environment disciplines for its ability to yield both quantitative and qualitative data, as well as to provide an opportunity for the researcher to closely communicate with the participants, probe questions and then, gather in-depth insights (Haigh, 2008).

Furthermore, as this research also aims to help the infrastructure sector to apply sustainability knowledge and implement KM in real project, thus relevant issues at project level should also be investigated. Case study is a natural option for this purpose.
**Triangulation of the Three Methods**

The selected data collection methods range between a broad but shallow study at one extreme and a narrow and deep study at the other, or an intermediate position which can be illustrated as in Figure 3.3. Thus, through the combination of these three methods, together with literature review, the researcher is able to obtain broad and in-depth data in order to best achieve the research objectives.

![Figure 3.3: Breadth and Depth of Three Question-based Research Methods](Source: Fellow and Liu, 2003)

Table 3.1 summarized the key features of these three methods, and the research questions they are expected to answer.
Table 3.1: Selected Methods for this Research

<table>
<thead>
<tr>
<th>Research Method</th>
<th>Key Features</th>
<th>Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire Survey</td>
<td>- Allow a large population of respondents to be approached.</td>
<td>What are the important issues that should be addressed when managing sustainability knowledge for infrastructure development? (Barriers, enablers, key activities, characteristics of the body of sustainability knowledge, etc.)</td>
</tr>
<tr>
<td></td>
<td>- Allow large numbers of variables to be analyzed quantitatively.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Not restricted in the physical locations of the respondents.</td>
<td></td>
</tr>
<tr>
<td>Interview</td>
<td>- Allow the researcher to directly discuss with participants to collect insights.</td>
<td>Why are these issues important?</td>
</tr>
<tr>
<td></td>
<td>- Allow discussion on complex issues</td>
<td>How to address these issues?</td>
</tr>
<tr>
<td></td>
<td>- Allow the participants to describe “how to...”</td>
<td>(Strategies, tools, existing practices, etc.)</td>
</tr>
<tr>
<td></td>
<td>- Allow the researcher to seek the reasons of the identified results from questionnaire surveys.</td>
<td></td>
</tr>
<tr>
<td>Case Study</td>
<td>- Allow the research to gain detailed information on project.</td>
<td>How to address these issues in the project scenario? (process, key actions, facilitating tools and strategies, etc.)</td>
</tr>
<tr>
<td></td>
<td>- Show the full set of procedures, actions and activates that address the management of sustainability knowledge on project.</td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Research Plan

Based on the above discussion, a plan for this research project is developed as shown in Figure 3.4. As illustrated in the research plan, the research can be separated into 4 stages. In the first stage, KM framework prototype is produced through the review of broad scope of literature. According to this prototype, a questionnaire survey is designed and conducted to investigate the linkage of KM with sustainability knowledge in the infrastructure sector and the prior issues. Main elements of the desired KM framework are identified. The interviews are conducted to investigate the identified issues in depth and detail to gain more
understandings and insights. Afterwards, case studies are conducted to validate the previous finding in real project scenario and gain best practices at project level. At the end, based on the findings of the three data collection methods, final KM framework and according guidelines are formulated.
Figure 3.4: Research Design
3.4 Research Development

3.4.1 Literature Review

According to Cooper (1998), a literature review can be seen as “a body of text that aims to review the critical points of current knowledge on a particular topic”. The main aim of conducting the literature review in academic research is to allow the researchers to uptake the up to date knowledge on a topic in order to understand the underpinning theories, justify the research problems and make their original contribution to existing body of knowledge in the future (Welman and Kruger, 2002).

In this research, an exhaustive literature review is carried out by using books, journals, conference proceedings, industry publications and a collection of unpublished previous research work in the form of dissertations and research reports. The review of the academic, industry and web-based literature is conducted continuously to maintain awareness of current development.

The scope of literature for this research lies on the aim of the research which is to provide a specific KM framework for the Australian infrastructure sector to manage related knowledge in order to promote sustainability. In the simplest sentence, KM can be defined as a discipline focuses on “how to deliver the right information to the right people at the right time”. The relationship between each elements of the question and its relevant literature is illustrated in Figure 3.5.
Figure 3.5: Scope of the Literature Review

Reviewing the literature is shown in three locations of this dissertation.

Firstly, the literature is used to frame the research problem in the introduction to the study.

Secondly, the literature is presented in a separate section as a review of the literature. The main objectives of this literature review are (1) to establish a deep understanding of the scenario of infrastructure development in Australia and its sustainability status, especially from a knowledge perspective; (2) to thoroughly review the KM theory, concepts, strategies, tools, and existing KM frameworks which set the theory foundation for the study; and (3) to develop a KM framework prototype for further development.

Thirdly, the literature is presented after each phase of data analysis as well as at the discussion chapter. Findings from this study will be compared with existing theories and previous research which is an essential approach to contribute to the research community.
3.4.2 Data Sources

According to Fellows and Liu (2008), restrictions for data collection include: confidentiality, ease of collection or provision, cost, time, etc. Especially for obscure and complex processes, and sensitive/historical subjects, finding sources of data/respondents may be difficult. Thus it is suggested that it is easier to collect data from the sources where the researcher have good contacts.

Due to the nature of this research, main data resources are based in the industry practitioner community. Their current behaviors, motives, opinions and suggestion are to be collected during the research. Accessing to data is the main challenge for data collection, however, as suggested by many literature that once an initial source has been found, it may be possible to find others (successively/progressively) by information from that initial source has been found.

In this research, two strategies of approaching data resources are used.

The first strategy is the “snowball approach”. The “snowball” approach concerns the discovery and investigation of different sources for a particular event whilst the tracer approach moves between sources relating to the development/operation of a process (Fellows and Liu, 2008). The main reason for adopting this strategy is that it allows the researcher to access the hidden potential participants. As both sustainability application and KM practices are still at infant stage in the target industry, most qualified potential participant, those who have rich experience and insights in regards with dealing sustainability knowledge and relevant issues, are hidden in the wider industry practitioner community. It is not possible for the researcher to efficiently identify them though random sampling. However, if the approached potential participant can direct the researcher to the other appropriate participants, then the number and the representativeness of selected participants as well as the quality of data obtained will be greatly improved.
The second main strategy is **purposive sampling** by which the researcher chooses the participants based on who they think would be appropriate for the study. The adoption of this approach in selecting interviewees is mainly because sustainability practice in the infrastructure sector is still at the infant stage and there are only limited numbers of industry practitioners that are knowledgeable and resourceful on this research topic. Therefore, participants of the questionnaire survey who have demonstrated good understandings and interests on the research topic will be invited to interviews.

Furthermore, during the interview phase, the researcher will ask the interviewees to recommend relevant best practice in real project context. The pool of potential projects for case study is therefore built for selection.

The relationship of data resources for each research method is shown in Figure 3.6

![Figure 3.6: Access to Data Resource](image)

### 3.4.3 Questionnaire Survey

A questionnaire is a survey instrument that consists of a cluster of pre-formulated written set of questions that designed to gather information and data from respondents (Sekaran, 2003). It is usually seen as a quantitative instrument and particularly useful for collecting information about “what”, “where”, “when”, “how many”, “how frequently” etc. Thus, it is an appropriate method when the researcher clearly knows what is required and how it can be measured.
Czaja and Blair (2005) suggest five steps in the development and completion of a questionnaire survey, including (1) survey design and preliminary designing, (2) pretesting, (3) final survey design and planning, (4) disseminating and (5) data analysis and final report. Figure 3.7 shows the overall inputs, outputs, conduction process and instrumentation of the questionnaire survey in this research.

![Diagram](image)

### Data to be collected

The main objective of the questionnaire survey in this research is (1) to gauge the necessity and readiness of using KM in the construction industry; (2) to identify the prior issues of managing knowledge for sustainability in infrastructure works; and (3) to identify the main elements that should be considered in a holistic KM framework.
In the lights of these objectives, the quantitative data to be collected from the survey are:

- Attributes – e.g. “What is your professional role?”, “How long have you worked in the infrastructure sector?”, etc.

- Facts/Behavior – e.g. “What are the current KM initiatives in your organization?”, “Where do you usually go to get sustainability knowledge?” etc.

- Attitudes/Opinions – “Do you think managing related knowledge can improve infrastructure sustainability?” “Which stakeholder is more active in pursuing sustainability knowledge?”, etc.

**Questionnaire Design**

After reviewing of the literature, a KM framework prototype is developed to show the main unit of analysis for this study and to guide the formulation of the questionnaire. Then pilot survey is conducted to gather feedbacks in terms of the survey design, including wording errors, explanations of main terms, forms of questions, etc.

Single choice questions, multi-choice questions and five-likert scaled questions with open-listed items are adopted in the questionnaire design.

**Instrumentation**

Questionnaire surveys can be carried out in a variety of ways, commonly including: postal questionnaires, personally administered questionnaires, telephone and web-based questionnaires (Brace, 2008). In the light of modern technology, web-based questionnaire survey is becoming increasingly popular for its various advantages (Powell, 1998; Wright, 2005), such as:

- Low cost – It usually cost nothing for the respondents to participate the survey as long as they have access to the internet. The cost for the
researcher can also be relatively low, depending on the type of account, the advancement of service, the size of sampling of the survey.

- Efficient – Disseminating questionnaires through online tools is much quicker than other approaches. Many online survey tools also can facilitate the researcher with questionnaire design. Thus the survey can be conducted swiftly.

- Large capacity – Compared with the traditional paper questionnaire, questions can be more detailed in the web format.

A web-based survey tool, SurveyMonkey (https://www.surveymonkey.com), is employed in this survey to present the final questionnaire and collect and sort the data. It allows the researcher to conduct the survey with a low budget and tight schedule, and overcome the geographical boundaries to connect with the industry practitioners across the nation.

A computerized database of main industry players in Australia will be compiled from various sources during the preparation of the literature review. Survey invitations with a weblink to the online survey page are sent to the construction industry participants via email and professional association newsletters. Identified industry practitioners are from the main stakeholders in the Australian infrastructure sector, namely general contractors, sub-contractors, specialized contractors, suppliers, designing firms, clients, government agencies, consulting firms, academic institutions, etc., who are the key players in the infrastructure sector and have direct involvement in any given infrastructure project; either as decision-maker or implementer.

**Data Analysis**

Gathered data is then put into SPSS for analysis purpose. Mean, standard deviation and frequency are mainly used in quantitative analysis process. Results are discussed in detail as well as compared with the existing literature and previous related research. Finally, a preliminary KM framework is developed based on the results.
Survey Invitation Letter and a sample of collected response are attached to the end of the dissertation (See Appendix I and Appendix II) and the detailed execution of this survey will be discussed in Chapter 4.

3.4.4 Interview

Interview remains a popular method of data gathering by those researching in the built environment disciplines for its potential to generate insights and concepts, and expanding understanding. Furthermore, research results from other methods can be validated with interview (Haigh, 2008).

In general, there are three types of interview, namely, unstructured, semi-structured and structured.

Unstructured interviews are those conducted in order to bring some preliminary issues to the surface so that the researcher can determine what variables need further in-depth investigation.

Semi-structured interviews are designed to have only a number of pre-determined questions which are relatively open, while the subsequent interview questions are raised during the interview conduction (Wengraf, 2001). The order of the pre-determined questions in the semi-structured interviews can be modified during the interview and question wording can be changed, omitted or added based upon the interviewer’s perception of what seems most appropriate (Robson, 2002).

Structured interviews are those operated with all interview questions are pre-formulated when the researcher knows clearly what information is needed. Thus the data gathered by structured interview tends to be quantitative in nature. In general, the more structured or standardized interview questions are, the more a research is able to get qualitative data (Haigh, 2008).

The main objective of the interview is (1) to investigate the reasons and relationships of issues that were identified in the precious questionnaire survey; (2)
to obtain deeper understandings and insights of the topic being researched; and (3) to identify the possible practical solutions for the infrastructure sector to successfully manage sustainability knowledge.

In this research, the researcher has gained understandings on the research topic through the questionnaire survey. A framework that highlights the important issues that need to be further explored is also developed to guide the subsequent qualitative studies. Semi-structured interview, lying in the middle of the structured and un-structure interview, allows the researcher to ask questions according to this pre-developed framework, but also give space to the interviewees to answer questions in depth and detail. Moreover, the flexibility in semi-structured interviews enables the researcher to improve questions in order to guide, and focus on, the sub-topics that the interviewee is most knowledgeable about. Therefore, semi-structured interview is more appropriate for this research and is selected to gather qualitative data. The inputs, outputs, process and instrumentation of the interview execution are illustrated in Figure 3.8.
**Interview Design**

The interview is guided by the results of the questionnaire survey. An interview framework is developed at first hand and then exemplar questions are formulated to guide the interview. However, during the course of the interview, questions that are asked in each interview vary according to the circumstance of the interviewee.

**Interviewees**

Questionnaire survey respondents who have demonstrated their enthusiasm and strong relevant experience and expertise are invited for interview. Meanwhile, interviewees also recommended the most knowledgeable and experienced potential interviewees to the researcher during the interview course. This strategy ensures the researcher has the opportunity to access the “best brain” in the field.
**Instrumentation**

Interviews can be conducted in different manners, mainly face-to-face or through telephone/computer. The employment of a certain method can be affected by the level of complexity of the issues involved, the likely duration of the interview, the convenience of both parties, the geographical area to be covered by the study and the research budget, etc.

Face-to-face discussion can be the best choice for conducting this interview. However, as the interview participants are located across the nations, together with the financial constraints and stressful schedule of the research, most of the interviewees outside Queensland are interviewed through telephone.

Before the interview, a copy of Interview Information Sheet, QUT Research Ethical Consent Form, and a list of questions are provided to the interviewee. The full conversation during the interview is recorded by a digital recorder with the permission of the interviewee.

**Data Analysis**

Literature indicates that planning and preparing for qualitative research interview, and later gathering and analyzing qualitative interview data, are all highly time consuming activities for the researcher and respondents (Haigh, 2008). Regardless how responses were recorded, the transcription and analysis phases often pose the greatest challenge for researchers. Bogdan and Biklen (2006) emphasize that “qualitative data analysis is the process of systematically searching and arranging the interview transcripts, field notes, and other materials that accumulate to increase own understanding of them, and to enable to present what have been discovered to others”. It consists of a range of important actions, such as coding, labeling, breaking down into manageable units, categorizing, synthesizing, identifying patterns, discovering theory and reporting the results.
During this process, many labor intensive actions can be facilitated by specific tools. King argues that (2008) the field of qualitative research is currently undertaking a mini-technological revolution fuelled heavily by the proliferation of computer assisted qualitative data analysis software. Currently various packages are available and are increasingly being used in academia owing to their ability to store, organize and manage the fracture and analytic reassembly of large amount of data, whilst offering high level of transparency.

Such software packages usually have facilitating features including memos, multimedia, hypertexting, mixed methods, editing, coding, storage, search and retrieve, data linking, memoing, content analysis, data display, theory building, graphic mapping etc. Examples of existing qualitative analyzing programs including Atlas.ti (http://www.atlasti.com), QSR NVivo (http://www.qsrinternational.com), HyperRESEARCH (http://www.researchware.com) and MAXqda (http://www.maxqda.com) etc.

Whereas manual analysis is associated with a focus on the research product itself, in the form of a thesis or other outputs, software brings with it an increased ability to assess the entire research process (King, 2008). Thus, such analytical software is worth considering as a modern tool because it allows researchers to deal with more data in an interactive secure systematic and efficient fashion.

In this research, conversations are then been transcribed into text documents and then imported into NVivo, which is a popular software package designed to facilitate qualitative study with data analysis. It offers a range of tools for recording, coding, categorizing, searching and exploring the patterns and theories of data and ideas that gained from a variety of media (e.g. observation, interviews, literature review, case study).

A copy of Interview Participant Information Sheet and Participant Consent Form are attached at the end of the dissertation as Appendix III and Appendix IV. Detailed explanation of the interview execution process and findings of the interviews are discussed in Chapter 5.
3.4.5 Case Study

The case study is an important method of conducting social science research (Yin, 2003) which appears to be highly relevant to an industry that is project driven and made up of many different types of organizations and businesses (Proverbs and Gameson, 2008). It is one of the research methods that can provide an intensive examination of a single entity of a phenomenon of interest. In such process, the researcher can explore in depth a program, an event, a behavior, an activity, a process, or one or more individuals to examine a research problem in the exploratory stages (Walker, 1997; Creswell, 2003). It is becoming a popular research method in the field of management research, employing a variety of means over a sustained period of time to gather information, including interview, retrieving available documents, observation, participation, or even intervention in the actual process (Welman and Kruger, 2002).

As research questions can be defined as different types such as asking “who”, “what”, “how”, “where”, “why”, Yin (2003) indicates that case study method is appropriate to the situation where the researcher is trying to answer a “what” or “how” question. It is also suited to the situations where the phenomena and the context in which they exist are difficult to separate.

Literature suggests that the design of case study investigations should incorporate different kinds of evidence which may come from the following six sources: documents, archival records, interview, detached or direct observation, participant observation and physical artifacts (Yin, 2008; Proverbs and Gameson, 2008).

**Case Study Execution**

The main objective of the case studies is (1) to investigate sustainability management issues by identifying the best practices in the real-case projects and (2) to validate the findings of previous questionnaire survey and interviews in real project scenario. Two infrastructure projects are selected and the inputs, outputs,
process and instrumentation of the case studies’ execution are illustrated in Figure 3.9.

![Diagram of Case Study Execution]

**Data to be collected**

Unit of analysis in case studies is identified as the initiatives that addressing sustainability issues by trying to bridge the knowledge gap. The evidence of such initiatives can exist in the following sources listed in Table 3.2.
Case Selection

During the previous interview, participants were asked to recommend good exemplar infrastructure projects that have striking performance in regards to project sustainability. Thus a pool of potential cases was established. Then two projects are selected according to the following requirement:

- The case project should be a successful infrastructure project with recognized achievements by the industry.
- Have a strong sustainability focus or agenda in its overall project goals
- Must be a recently completed project – finished in 2009 or 2010, and
- The main stakeholders of the project should be Australian organizations and accessible to research (e.g. good contact, confidentiality).

Detailed case study execution process and its findings are presented in Chapter 6.

3.5 Summary

This chapter has highlighted the research methods and design that is employed in conducting this research. Pragmatic paradigm and mixed-methods research strategy have set the philosophical foundation for this study. Triangulation of questionnaire survey, interview and case study are adopted to collect data for
quantitative and qualitative analysis. Explanation of each method, including its input and output, execution process and relevant instrumentations are also provided. More detailed explanation for conducting each data collection methods will be presented in Chapter 4, Chapter 5 and Chapter 6 respectively.
4.1 Introduction

The purpose of the questionnaire survey is (1) to gauge the necessity and readiness for using KM in the construction industry; (2) to identify the prior issues of managing knowledge for sustainability in infrastructure works; and (3) to identify the main elements that should be considered in a holistic KM framework for this industry to better manage sustainability knowledge, integrate various stakeholders, facilitate actions and deliver tangible benefits in real projects.

According to the research plan, a questionnaire survey - as the first data collection phase - is conducted among industry practitioners and a preliminary KM framework is developed according to the survey results. This chapter starts with developing a KM framework prototype. Then the content of the questionnaire is introduced, which is designed according to the structure of the KM framework prototype. The survey conduction process and instruments are then introduced. Furthermore, survey results are discussed in detail, including the profile of the respondents, the analysis of data and the development of the preliminary KM framework.

4.2 Theoretical Framework of the Survey

Past research has emphasized three major elements of managing knowledge: processes, enablers and organizational performance (Lee and Choi, 2003). The relationship between the elements can be seen from Figure 4.1.
Knowledge process refers to a combination of knowledge management activities, which is also frequently called the “KM cycle” in much of the literature. It can be considered as a structured coordination of activities to effectively manage knowledge. Typically the process includes activities such as creating, identifying, obtaining, sharing, storing and maintaining, which are used as the basic operations of knowledge management. Various KM tools and strategies facilitate the completion of these KM activities (Dalkir, 2005; CEN, 2004).

Knowledge management enablers (also called success factors or influencing factors in some literature) are mechanisms for fostering knowledge and facilitating the implementation of KM strategies and, instruments to increase the efficiency of knowledge processes. In KM literature, many KM enablers have been recommended and discussed, including leadership, organizational culture, measurement, IT/ICT technology, and some personal capabilities such as communication skill and ambition (Lee and Choi, 2003; CEN, 2004; Ho, 2009).

Organizational performance may be defined as the degree to which companies achieve their business and other objectives, which is to say, their actual outputs compared with the intended outputs. It may be measured in terms of organizational profitability, organizational learning, competitiveness etc. It is widely argued that the KM initiative should center on the business focus and value-adding processes of an organization (Lee and Choi, 2003; CEN, 2004).

Usually, the nature of knowledge (e.g. tacit vs. explicit knowledge) and the nature of business process have a big impact on the selection of appropriate strategies and tools. As this research need to probe the prevailing opinion and practices of Australian infrastructure sector in managing sustainability knowledge, the
characteristics of sustainability knowledge, the project-oriented business mode and culture of the industry should be considered when developing the KM framework. The following KM framework prototype (Figure 4.2) is developed to direct the formulation of the questionnaire.

![Figure 4.2: A KM Framework Prototype for Sustainable Infrastructure Development](image)

There are eight elements presented in the proposed KM framework prototype. Brief explanations of each element are provided below:

- **KM Process**

  Briefly speaking, all activities that improve the value of knowledge assets can be considered KM activities. They vary in different contexts. Key activities in managing sustainability knowledge for the requirements of infrastructure development need to be identified.

- **KM Strategy**

  KM encompasses a systematic approach to managing the basic knowledge activities and to providing a continuous flow of knowledge so as to enable the efficient and effective decision-making by key decision makers. Realization of the
KM activities is usually facilitated by various strategies. In the infrastructure sector, due to its project-based business mode, the KM strategy should target both project level and organizational level objectives.

- **Stakeholder Integration**

  Stakeholders often have great influence on the uptake and application of sustainability knowledge. Quality decisions can only be made if main stakeholders are kept up to date with the most recent concepts and technology in regards to sustainability. Interactions between stakeholders on project sustainability issues are particularly important.

- **Project Development Process**

  Formulating project sustainability conceptions and their applications are closely intertwined with project development processes. Thus, knowledge managing activities should also be linked with PM processes.

- **Knowledge Architecture**

  Knowledge architecture refers to the body of sustainability knowledge, its classification, characteristics, etc., which need to be considered while choosing the appropriate KM strategy and approaches.

- **KM Enablers**

  Many factors can influence the success of knowledge management initiatives within an organization and project team. For many existing KM frameworks, enablers are usually categorized into two groups, organizational and personal. However, construction organizations are highly project-originated and have a high staff turnover within the industry. Capabilities within the organization as well as the project team are important aspect in the framework.

- **Project Outcomes**
The infrastructure sector is a project-based industry where sustainability can only be achieved project-by-project. Furthermore, it is very common that relevant knowledge is transferred directly from project to project. Thus, managing related knowledge at project level and delivering tangible outcomes is the way for the industry to move toward sustainability.

- **Organizational Performance**

KM initiatives need to link to the organization’s business goal. The outcomes of managing sustainability knowledge and improvement of organizational performance through knowledge management are key issues.

To identify ways of applying knowledge management to increase sustainability consideration and uptake in infrastructure development, a questionnaire survey has been conducted to gauge the status and opinions of Australian infrastructure professionals on how they interpret the KM concept and its various aspects in order to test and further identify the key elements of this KM framework, as well as the relationship amongst these elements. The survey design is introduced in the following section.

4.3 **Questionnaire Design**

Research questions, research objectives, research methodology and the literature review guided the formulation of the questions. Based on the KM framework prototype, as shown in Figure 4.2, 40 questions are categorized into ten sections. Eight sections reflect the eight elements in the KM framework prototype, while the other two are set to collect respondents’ information. The ten sections are:

- Respondents’ information;
- The body of sustainability knowledge;
- KM strategy: linking KM with sustainability knowledge and infrastructure development;
• Stakeholder integration;
• KM process;
• KM in the project development process;
• KM enablers;
• Outcomes of managing sustainability knowledge;
• Organizational Performance;
• Further contact information.

Table 4.1 summarizes the content of the questionnaire. Most of the questions are framed on a five-point Likert Scale in combination with a list of open-ended items in order to identify the missing important items. The Likert scale is composed of an escalating scale from “Strongly disagree” to “Strongly agree”, with “Neutral” as the midpoint.

<table>
<thead>
<tr>
<th>Section</th>
<th>Category</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Respondent Information (Q1-Q7)</td>
<td>This section collects basic information to classify respondents, e.g. professional role in infrastructure, length of professional experience, type of organization, etc.</td>
</tr>
<tr>
<td>2</td>
<td>The Body of Sustainability Knowledge (Q7-Q10)</td>
<td>This section collects professional opinion on current sustainability knowledge according to their experience and expertise; for example, the main knowledge categories, knowledge quality, main knowledge carriers, main knowledge characteristics, etc.</td>
</tr>
<tr>
<td>3</td>
<td>KM Strategy (Q11-Q19)</td>
<td>This section collects information to identify the appropriate KM strategy for the sustainability knowledge management; for example, the current means to manage sustainability knowledge, width and depth of current knowledge application, main impetus and main barriers of such activities, etc.</td>
</tr>
<tr>
<td>4</td>
<td>Stakeholder</td>
<td>In this section, information is collected concerning the</td>
</tr>
</tbody>
</table>
**Integration**
(Q20-Q21)

Interaction between stakeholders (contractor, subcontractor, project manager, designer, quantity surveyor, engineer, local community, consultant, research institution, government agency, etc.) and project sustainability issues; e.g. who are the important stakeholders and what is their willingness to promote project sustainability, etc.

---

**Project Development Process**
(Q22-Q23)

In this section, the stages of a typical life cycle of an infrastructure project are delineated. Information is collected on how project sustainability related activities link with these processes and what the key sustainability related actions/deliverables are.

---

**KM Process**
(Q24-Q30)

Information is collected to identify those processes specific to manage sustainability knowledge for infrastructure development among the typical KM processes. Current status of knowledge management activities inside the organization is also been researched.

---

**KM Enablers**
(Q30-Q34)

This section collects information to identify those factors which help to formulate a positive environment for knowledge management success. Enablers are labeled separately as industrial characteristics, organizational capabilities, project team characteristics and personal capabilities according to their incidence.

---

**Outcomes of Managing Sustainability Knowledge**
(Q35)

This section researches what outcomes could be obtained by managing sustainability knowledge, e.g. judgment, reusable content created, value delivery, presence of subject matter expertise, organizational creativity, employee loyalty, etc.

---

**Organizational Performance**
(Q36)

This section researches what aspect of organizational performance will be improved by managing sustainability knowledge; e.g. profit, market share, organizational reputation, customer recognition, intellectual assets, etc.

---

**Further Information**
(37-40)

This section invites respondents to provide further comments in regards to the research topic and their contact information if they are willing to participate in the subsequent interviews.
4.4 Survey Instrumentation

The survey was conducted through an online survey tool named “Survey Monkey” that can be accessed at [http://www.surveymonkey.com/](http://www.surveymonkey.com/). It is a popular and powerful web-based tool to create and publish customized surveys, collect responses through filters, and then view the results. Wright (2005) acknowledged that there has been an increasing amount of usage of online survey tools in academic research for its various advantages compared with traditional survey methods. For this research, benefits gained from the employment of the online survey tool include (but are not restricted to):

- As many of the potential respondents are located across the country, this survey tool allowed the researcher to access potential survey respondents in distant locations in a cheaper and faster way.

- Once the survey was published online, a unique URL was generated for the questionnaire. Respondents were asked to help the researcher to disseminate the questionnaire to potential respondents, and they can do this by simply forward the URL link through email.

- If a respondent partially finished the survey due to his time schedule, data can be stored online and retrieved later. The researcher can also note the unfinished questionnaire and kindly remind the respondent to arrange a time to finish it.

- Customized filters can be used for data collection; this saved the researcher much effort and time in sorting data. Results can also be viewed in diverse graphic formats.

Figure 4.3 shows the questionnaire design interface of the online survey tool.
Respondents were selected from the main stakeholders involved in large infrastructure projects in Australia, in both public and private sectors, e.g., general contractors, subcontractors, suppliers, government agencies, consulting firms, clients.

Three distribution approaches were used for disseminating the questionnaires.

- The first distribution approach was through email. Initially, 120 potential respondents were selected from the leading organizations across Australia. They were each given a login name and password to the online survey by email. Responses were monitored and non-respondents were kindly reminded during the course of the survey.

- The second distribution approach was via professional associations. Australian Institution of Project Management (AIPM) and Engineers Australia (EA) offered their help by including the survey information in their
regular newsletters. AIPM also posted the survey invitation on their website. A specific online collector was set to collect these responses.

- The third distribution approach was via a professional association as well, but in a different manner from the second approach. The Australian Green Infrastructure Council (AGIC) is an industry body with a strong focus on infrastructure sustainability and is currently developing a national level sustainability rating tool for infrastructure projects. The researcher attended one of their board meetings and disseminated the printed questionnaire to eight attendees. Five valid responses were later received.

4.5 Survey Response Rate and Validity

A sample of a valid respond to the questionnaire survey is attached at the end of the thesis as Appendix I. The main standards for valid responses to this questionnaire survey are listed below:

- Survey questions are fully answered.
- There are no obvious irrational answers (e.g. giving the same score for all items).
- Background of the respondent is appropriate (e.g. not from IT project management area).

Survey responses of the three questionnaire disseminating approaches are discussed below and summarized in Table 4.2.

- **Via email:** In the end, out of the 120 questionnaires mailed to the potential respondents, 18 invitations were returned undelivered and 39 were responded to. Thirty one out of the 39 responses were fully finished and considered valid for data analysis. This gives an effective response rate of 30% (31/102) for this medium.
• **Via industry associations:** 23 responses were collected during the course of the survey, out of which 13 are valid. However, it is challenging for the researcher to tell how many potential respondents were approached through this method as only a small number of AIPM and EA members may satisfy the specific requirements of this survey. For example, some members of EA may be specializing in the building sector, and some AIPM members may be project managers from the IT industry. Furthermore, as AIPM posted the survey invitation on its website, it is hard to know how many potential respondents had been approached via this approach.

• **Via AGIC meeting:** 5 responses were received out of the 8 disseminated. They are all valid. The 62.5% response rate via the AGIC meeting is satisfactory. The reason for this high response rate is that all attendees of that meeting are sustainability ‘champions’ with rich practical experience in infrastructure; thus, they are naturally interested and supportive of this survey.

Table 4.2: Questionnaire Survey Response Rate

<table>
<thead>
<tr>
<th>Disseminating Approach</th>
<th>Give out</th>
<th>Received</th>
<th>Valid</th>
<th>Response Rate (Valid/Give Out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Via email</td>
<td>112</td>
<td>39</td>
<td>31</td>
<td>30%</td>
</tr>
<tr>
<td>Via industry association</td>
<td>unknown</td>
<td>23</td>
<td>13</td>
<td>unknown</td>
</tr>
<tr>
<td>Via AGIC meeting</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>62.5%</td>
</tr>
<tr>
<td>Total</td>
<td>unknown</td>
<td>67</td>
<td>49</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Owen and Jones (1994) suggested that “on average, a response rate of 20 percent of questionnaire returned without reminders is considered satisfactory, while 40 percent is exceptionally good”. Manfreda et al. (2008) found that, on average, web surveys yielded 11% lower response rates than other modes. They further suggested that this difference can be reduced to 5% if the invitations are delivered by email. Based on the above views, the response rate of this questionnaire survey via email invitation is well above acceptable level.
4.6 Survey Result and Analysis

4.6.1 Respondents’ Profile

Respondents are from various types of organizations, both public and private (as shown in Figure 4.4) and have a good coverage of the main stakeholders in the infrastructure sector. Up to 42.9% of the respondents are from general contractors. Others are from engineering firms, consulting firms and governments agency (18.4%, 16.3% and 12.2%, respectively). Labels for the organizations listed in Figure 4.4 are based on the self-descriptions from survey respondents; thus there is a slight overlap between engineering firms and consulting firms, as some of the consulting firms provide engineering specialized services. Only 6% of survey respondents considered themselves as infrastructure clients. The main reason is that, in Australia, many infrastructures are state owned or temporarily owned by the private sector (e.g. BOOT/PPP projects); thus, some of the clients are hidden within the contractor and government agency category.

![Figure 4.4: Organization’s Major Role in Infrastructure Development](image)

As illustrated in Figure 4.5, it is clear that around 70% of the respondents have more than 10 years’ professional experience in the infrastructure sector and one-third of them have worked in this industry for over 20 years. Descriptions of their current positions include: CEO, general manager/director, state manager, senior consultant, project engineer, technical leader, environment manager, project...
This ensured that the survey had a good coverage of industry stakeholders from diverse disciplines and different hierarchies, and could yield highly credible, quality results.

![Figure 4.5: Length of Professional Experience in Infrastructure Sector](image)

The respondents play diverse professional roles in infrastructure development, as shown in Figure 4.6. Many of them have an engineering (38.8%) or management (project manager 24.5%, contractor 22.4%) professional background and are directly involved in infrastructure projects.

![Figure 4.6: Professional Role of Respondents](image)

All types of infrastructure projects are covered by the respondents’ experience; however, transport infrastructure is the most represented (85.7% of the respondents), as shown in Figure 4.7. This result is consistent with the recent drive to upgrade the road and railway systems by all levels of government in
Australia, which involves unprecedented investment by a Commonwealth Government in land transport (Department of Infrastructure and Transport (2010)).

Although the physical locations of the respondents cover five states across Australia, more than 60% of them are currently located in QLD (Figure 4.8). This is because QLD is more actively engaged in infrastructure works. High staff turnover is one of the major characteristics of the construction industry and a majority of the respondents have worked interstate. Therefore, the opinions reflected in this survey can represent the great majority in the Australia infrastructure sector.
4.6.2 The Body of Sustainability Knowledge

Table 4.3 investigates the current quality of the body of sustainability knowledge. Respondents agree that sustainability knowledge is very subjective (4.12/0.63) and challenging to acquire (3.73/0.95). As suggested by the literature, sustainability can only be achieved through a multi-disciplinary approach, which is especially important for infrastructure development as the knowledge is fragmentary and evolving constantly (Wallace, 2005).

Table 4.3: Characteristics of Sustainability Knowledge for Infrastructure Development
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Srongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It is subjective, means different things to different people.</td>
<td>4.12</td>
<td>0.63</td>
</tr>
<tr>
<td>2</td>
<td>It is challenging to acquire.</td>
<td>3.73</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>It is dynamic and evolving constantly.</td>
<td>3.61</td>
<td>0.95</td>
</tr>
<tr>
<td>4</td>
<td>It is fragmentary.</td>
<td>3.59</td>
<td>0.86</td>
</tr>
<tr>
<td>5</td>
<td>It is challenging to articulate and comprehend.</td>
<td>3.59</td>
<td>0.81</td>
</tr>
<tr>
<td>6</td>
<td>It is embedded in the personal mind, hard to codify and transfer.</td>
<td>3.33</td>
<td>0.88</td>
</tr>
<tr>
<td>7</td>
<td>It is challenging to adjust for use in other projects.</td>
<td>3.22</td>
<td>0.94</td>
</tr>
<tr>
<td>8</td>
<td>It is still too immature for implemented.</td>
<td>3.14</td>
<td>0.91</td>
</tr>
<tr>
<td>9</td>
<td>It is contextually/culturally sensitive.</td>
<td>2.94</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 4.4 lists the main resources for industry practitioners to obtain sustainability knowledge. People tend to find help within the organization as colleagues and internal experts are ranked the highest (4.2/0.84, 3.92/0.84, respectively). It is clear that organizational boundary is a barrier for people to obtain knowledge for psychological and convenience reasons.
Table 4.4: Primary Sources of Sustainability Knowledge  
(Level of Importance: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Knowledge Resource</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Colleagues</td>
<td>4.2</td>
<td>0.84</td>
</tr>
<tr>
<td>2</td>
<td>Internal expert</td>
<td>3.92</td>
<td>0.82</td>
</tr>
<tr>
<td>3</td>
<td>Industry best practice</td>
<td>3.59</td>
<td>1.10</td>
</tr>
<tr>
<td>4</td>
<td>Deliverables from previous stages</td>
<td>3.49</td>
<td>0.84</td>
</tr>
<tr>
<td>5</td>
<td>External consultant</td>
<td>3.31</td>
<td>1.16</td>
</tr>
<tr>
<td>6</td>
<td>The construction project team</td>
<td>3.31</td>
<td>0.99</td>
</tr>
<tr>
<td>7</td>
<td>Internal training/workshop/seminar</td>
<td>3.29</td>
<td>1.08</td>
</tr>
<tr>
<td>8</td>
<td>Government agency</td>
<td>3.00</td>
<td>1.10</td>
</tr>
<tr>
<td>9</td>
<td>Quality Assurance Process</td>
<td>2.90</td>
<td>1.14</td>
</tr>
<tr>
<td>10</td>
<td>Research institution</td>
<td>2.86</td>
<td>0.96</td>
</tr>
<tr>
<td>11</td>
<td>Internal database</td>
<td>2.90</td>
<td>1.03</td>
</tr>
<tr>
<td>12</td>
<td>Industry association</td>
<td>2.73</td>
<td>1.25</td>
</tr>
<tr>
<td>13</td>
<td>Other industry</td>
<td>2.55</td>
<td>1.08</td>
</tr>
<tr>
<td>14</td>
<td>Other organization</td>
<td>2.45</td>
<td>1.26</td>
</tr>
<tr>
<td>15</td>
<td>Local communities</td>
<td>2.49</td>
<td>1.06</td>
</tr>
</tbody>
</table>

It is common in the industry nowadays that organizations have internal database for information storage and other purposes. They are encouraged to heavily invest in IT infrastructures such as ICT tools and databases. However, respondents of this survey do not currently see internal databases as a highly valued knowledge resource. It might be because the current databases are not well structured and maintained in regards to sustainability knowledge and thus are of little benefit to users. Thus, a better structured catalogue and more user friendly system interface can be helpful. Furthermore, an index of experts and knowledge maps can be an efficient and applicable tool for locating sustainability knowledge.
It is also noticeable that sustainability knowledge is highly based on people and projects. Thus a “subject” KM approach should be developed which mainly focuses on approaches and activities to encourage and promote the process of knowing, rather than on seeing knowledge as an “object” which can be captured and distributed. Knowledge, in this case, is closely tied to the person who owns it and can be shared mainly though communication. Networking of subject-matter experts is important. IT tools can be helpful in this process, especially the Information and Communication Technology (ICT) tools which can facilitate people’s communication of knowledge.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Knowledge Resource</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lessons learned from internal projects</td>
<td>4.24</td>
<td>0.85</td>
</tr>
<tr>
<td>2</td>
<td>Staff personal capabilities/skills/experience</td>
<td>4.06</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>Industrial best practice</td>
<td>4.00</td>
<td>0.89</td>
</tr>
<tr>
<td>4</td>
<td>Internal best practice</td>
<td>3.94</td>
<td>0.92</td>
</tr>
<tr>
<td>5</td>
<td>Knowledge about industry</td>
<td>3.90</td>
<td>0.92</td>
</tr>
<tr>
<td>6</td>
<td>Staff innovation</td>
<td>3.78</td>
<td>0.92</td>
</tr>
<tr>
<td>7</td>
<td>Knowledge about customer</td>
<td>3.76</td>
<td>1.09</td>
</tr>
<tr>
<td>8</td>
<td>Government guidelines/rules</td>
<td>3.67</td>
<td>1.11</td>
</tr>
<tr>
<td>9</td>
<td>Internal research and design</td>
<td>3.67</td>
<td>0.97</td>
</tr>
<tr>
<td>10</td>
<td>Knowledge about community/society focus</td>
<td>3.65</td>
<td>0.93</td>
</tr>
<tr>
<td>11</td>
<td>Internal standards/processes</td>
<td>3.45</td>
<td>0.98</td>
</tr>
<tr>
<td>12</td>
<td>Knowledge about partners</td>
<td>3.45</td>
<td>1.00</td>
</tr>
<tr>
<td>13</td>
<td>Professional association publications/guidelines</td>
<td>3.22</td>
<td>1.14</td>
</tr>
<tr>
<td>14</td>
<td>Organizational administrative system</td>
<td>3.12</td>
<td>1.11</td>
</tr>
<tr>
<td>15</td>
<td>Knowledge about competitors</td>
<td>3.02</td>
<td>1.22</td>
</tr>
<tr>
<td>16</td>
<td>Academic research outcomes</td>
<td>3.02</td>
<td>1.13</td>
</tr>
<tr>
<td>17</td>
<td>Internal patents, methods</td>
<td>2.92</td>
<td>1.27</td>
</tr>
<tr>
<td>18</td>
<td>External patents, methods</td>
<td>2.63</td>
<td>1.12</td>
</tr>
</tbody>
</table>
The researchers using this survey also attempted to categorize sustainability knowledge; however, taxonomy could not be built from the results. As shown in Table 4.5, the top three ranked items are: lessons learned from internal projects (4.24/0.85), staff personal capabilities/ skills/ experience (4.06/1.05) and industry best practice (4.00/0.89). These results echo the conclusion that the main carriers of sustainability knowledge are exemplary projects and experienced and knowledgeable industry professionals.

Various types of sustainability knowledge can be identified and obtained by the organizations by either internal KM strategies, such as reviewing internal project performance and asking staff to record their lessons learned, or by actively learning from industry best practices. Industry associations and governments should also develop initiatives to promote the advanced knowledge and up-to-date knowledge to these organizations and projects. However, the results indicate that professional associations, government and research institutions currently are not performing well in regards to providing valuable and applicable sustainability knowledge to the industry.

4.6.3 Infrastructure Sustainability & KM

KM encompasses a systematic approach to managing the use of information in order to provide a continuous flow of knowledge to enable the efficient and effective decision-making by key decision makers, and is underpinned by a KM strategy that enables an aim and focus for KM activities (Dalkir, 2005).

According to the results in Table 4.6, the logical link and necessity of adopting knowledge management to promote sustainability application in infrastructure development has again been confirmed. It is widely accepted that sustainability considerations are very important (4.47/0.58), and managing related knowledge can be greatly helpful (4.22/0.65). Organizations also believe that achievements in sustainability contribute to organizational performance.
Table 4.6: Linkage between Infrastructure, Sustainability and KM
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Statements</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability issues need to be considered when developing infrastructure projects.</td>
<td>4.47</td>
<td>0.58</td>
</tr>
<tr>
<td>Consideration of sustainability issues can help my organization’s performance.</td>
<td>4.08</td>
<td>0.95</td>
</tr>
<tr>
<td>Managing related knowledge will help in promoting the sustainability of infrastructure projects.</td>
<td>4.22</td>
<td>0.65</td>
</tr>
<tr>
<td>My organization currently has a KM strategy or is willing to have a KM strategy.</td>
<td>3.47</td>
<td>0.92</td>
</tr>
<tr>
<td>In my organization, there are specific KM criteria to manage sustainability knowledge.</td>
<td>3.14</td>
<td>0.89</td>
</tr>
</tbody>
</table>

It has been reported that some construction organizations have started using KM to maintain and gain advantages (Kamara et al., 2002; Kazi, 2005; Tan, 2010). However, according to this survey, most of the infrastructure practitioners have reservations about the current usage of KM. According to their experience, KM is still a new concept to the construction industry and there is no process or framework to follow.

Table 4.7 shows the major impetuses ranked by the respondents in promoting sustainability pursuits and application in their organization. The biggest drivers in this regard are clients’ awareness and requirements, business benefit, government regulation/legislation and social responsibility. Clients’ awareness and requirements are the most important impetus (highest mean, lowest standard deviation); this is also frequently suggested by the literature. In the real project, if the client is not particularly interested in sustainability, the contractors usually tend to act in minimum compliance with the regulations. It is common that the whole development is driven by a client’s documentation. To truly progress sustainability, clients need to be adamant about their requirements in the project proposal.
Table 4.7: Main Impetus for Promoting Sustainability Pursuits and Application
(Level of Importance: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Impetus</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Client's awareness and requirements</td>
<td>4.45</td>
<td>0.77</td>
</tr>
<tr>
<td>2</td>
<td>Business benefits</td>
<td>4.10</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>Government regulations and legislation</td>
<td>4.04</td>
<td>0.96</td>
</tr>
<tr>
<td>4</td>
<td>Organizational reputation</td>
<td>3.88</td>
<td>0.88</td>
</tr>
<tr>
<td>5</td>
<td>Social responsibility</td>
<td>3.63</td>
<td>1.23</td>
</tr>
<tr>
<td>6</td>
<td>Community awareness</td>
<td>3.50</td>
<td>0.96</td>
</tr>
<tr>
<td>7</td>
<td>Improved competitiveness through labels such as “Green Firm”</td>
<td>3.39</td>
<td>1.24</td>
</tr>
<tr>
<td>8</td>
<td>Threat of climate change and/or other global crisis</td>
<td>3.33</td>
<td>1.30</td>
</tr>
<tr>
<td>9</td>
<td>Problem solving</td>
<td>3.24</td>
<td>1.22</td>
</tr>
<tr>
<td>10</td>
<td>Use of new procurement method in which the developer is responsible for maintaining the project for a period (e.g. PPP, BOOT)</td>
<td>3.10</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Table 4.8 highlights the main barriers to applying sustainability knowledge. Business benefits is ranked second in Table 4.7, showing that sustainability will be greatly promoted if the organizations can see tangible results from its application. However, as shown in Table 4.8, the biggest barrier in this regard is the difficulty of measuring the investment returns in regards to sustainability. As sustainability application in infrastructure is still at the infant stage, industry best practices are rare. The body of knowledge provides limited underpinning for the industry to tangibly measure the input and output of sustainability considerations. Easy-to-follow frameworks and examples should be put at the top of the development agenda.

The limited understanding of sustainability concepts and the lack of consensus among stakeholders are the second hurdle that may strongly limit people’s ability to understand and choose more sustainable designs and activities. The literature suggested that the lack of general and professional education is one of the reasons.
Better decisions can only be made if all the stakeholders had abundant and up-to-date knowledge and care for sustainability. For example, it is common in the industry that people see sustainability as another expression of “environmental protection”; this narrows the scope of their responsibility as well as the opportunities to perform beyond compliance.

Table 4.8: Key Barriers to Pursue and Manage Sustainability Knowledge
(Level of influence: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Barrie</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Difficult to measure the return on investment</td>
<td>4.04</td>
<td>1.02</td>
</tr>
<tr>
<td>2</td>
<td>Lack of co-ordination and consensus among stakeholders</td>
<td>3.73</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>Sustainability concepts are not well understood</td>
<td>3.73</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>Hard to connect sustainability target with organizational business strategy</td>
<td>3.61</td>
<td>0.81</td>
</tr>
<tr>
<td>5</td>
<td>Highly fragmentary nature of the industry</td>
<td>3.55</td>
<td>1.04</td>
</tr>
<tr>
<td>6</td>
<td>Will increase project budget/cost</td>
<td>3.47</td>
<td>1.26</td>
</tr>
<tr>
<td>7</td>
<td>No standardization of key processes to follow</td>
<td>3.43</td>
<td>1.15</td>
</tr>
<tr>
<td>8</td>
<td>Project-oriented nature of the business development type</td>
<td>3.35</td>
<td>1.28</td>
</tr>
<tr>
<td>9</td>
<td>Labor-intensive nature of the infrastructure construction industry</td>
<td>3.16</td>
<td>1.39</td>
</tr>
<tr>
<td>10</td>
<td>Lack of top management’s commitment</td>
<td>3.12</td>
<td>1.03</td>
</tr>
<tr>
<td>11</td>
<td>Complex nature of infrastructure project development</td>
<td>2.98</td>
<td>1.15</td>
</tr>
<tr>
<td>12</td>
<td>Poor financial resources</td>
<td>2.90</td>
<td>1.19</td>
</tr>
<tr>
<td>13</td>
<td>Poor non-financial resources</td>
<td>2.82</td>
<td>0.97</td>
</tr>
<tr>
<td>14</td>
<td>Long duration of infrastructure project development</td>
<td>2.74</td>
<td>1.22</td>
</tr>
<tr>
<td>15</td>
<td>Will extend project completion period</td>
<td>2.73</td>
<td>1.22</td>
</tr>
<tr>
<td>16</td>
<td>Will generate higher risk</td>
<td>2.67</td>
<td>1.39</td>
</tr>
<tr>
<td>17</td>
<td>High staff turnover</td>
<td>2.56</td>
<td>1.15</td>
</tr>
<tr>
<td>18</td>
<td>Intellectual Property protection issues</td>
<td>2.51</td>
<td>1.24</td>
</tr>
</tbody>
</table>
4.6.4 Infrastructure Stakeholders

Various stakeholders in the infrastructure sector are under pressure to respond to the global call for sustainable development. However, due to their different levels of influence and their different priorities, the implementation of sustainability in a certain project always highly relies on the stances of the key stakeholders. Table 4.9 lists the ranking of the influence of the main stakeholders in regard to the pursuit and management of sustainability knowledge, while Table 4.10 lists the current status of willingness of different stakeholders in this regard.

Table 4.9: Influence of Main Stakeholders to Pursue and Manage Sustainability Knowledge
(Level of influence: 1 Low ——> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Stakeholder</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Client</td>
<td>4.49</td>
<td>0.82</td>
</tr>
<tr>
<td>2</td>
<td>Designer</td>
<td>4.02</td>
<td>0.72</td>
</tr>
<tr>
<td>3</td>
<td>Project manager</td>
<td>3.67</td>
<td>0.99</td>
</tr>
<tr>
<td>4</td>
<td>Consultant</td>
<td>3.57</td>
<td>0.76</td>
</tr>
<tr>
<td>5</td>
<td>Government agency</td>
<td>3.53</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>Engineer</td>
<td>3.49</td>
<td>1.02</td>
</tr>
<tr>
<td>7</td>
<td>Contractor</td>
<td>3.12</td>
<td>1.07</td>
</tr>
<tr>
<td>8</td>
<td>Local community</td>
<td>2.73</td>
<td>1.2</td>
</tr>
<tr>
<td>9</td>
<td>Research institution</td>
<td>2.27</td>
<td>0.97</td>
</tr>
<tr>
<td>10</td>
<td>Sub-contractor</td>
<td>2.18</td>
<td>0.95</td>
</tr>
<tr>
<td>11</td>
<td>Quantity surveyor</td>
<td>2.12</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Table 4.10: Willingness of Main Stakeholders to Pursue and Manage Sustainability Knowledge
(Low of influence: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Stakeholder</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Consultant</td>
<td>3.65</td>
<td>0.67</td>
</tr>
<tr>
<td>2</td>
<td>Designer</td>
<td>3.59</td>
<td>0.76</td>
</tr>
<tr>
<td>3</td>
<td>Project Manager</td>
<td>3.43</td>
<td>0.68</td>
</tr>
<tr>
<td>4</td>
<td>Client</td>
<td>3.41</td>
<td>0.91</td>
</tr>
<tr>
<td>5</td>
<td>Engineer</td>
<td>3.41</td>
<td>0.64</td>
</tr>
<tr>
<td>6</td>
<td>Government Agency</td>
<td>3.31</td>
<td>0.89</td>
</tr>
<tr>
<td>7</td>
<td>Research Institution</td>
<td>3.29</td>
<td>0.96</td>
</tr>
<tr>
<td>8</td>
<td>Contractor</td>
<td>3.16</td>
<td>0.80</td>
</tr>
<tr>
<td>9</td>
<td>Local Community</td>
<td>3.08</td>
<td>1.00</td>
</tr>
<tr>
<td>10</td>
<td>Quantity Surveyor</td>
<td>2.37</td>
<td>0.88</td>
</tr>
<tr>
<td>11</td>
<td>Sub-contractor</td>
<td>2.20</td>
<td>0.84</td>
</tr>
</tbody>
</table>

The client is the most powerful stakeholder (4.49/0.82); this also echoes the findings in Table 4.7 that a client’s requirement is the most important driver. Project sustainability needs to be driven from the very beginning (from the project proposal) and involve the end-user. Designers are the key people to embed sustainability concepts and principles into the project design, while the project manager is the key person to transfer the design into the actual project by managing resources and time and providing funding. As the main stakeholders for the project, they may resource a sustainability consultant if they need extra support. The consultant is ranked as comparatively the most enthusiastic stakeholder in sustainability knowledge pursuit and application, which is their core competitive advantage. However, the attendance and influence of the consultant in the project still depends on the endorsement of the key stakeholders, especially the client.
4.6.5 Project Development Process

The integration of sustainability considerations and the project development process has also been investigated in the survey.

Items listed in Figure 4.9 outline a typical process of infrastructure development. It is clear that sustainability considerations should be integrated into the project as early as possible. Mission statements can be important if they are taken seriously and endorsed by clients. Then, at project implementation level, a trail of documentation for sustainability can be helpful to secure its application, as shown in Figure 4.10. Furthermore, respondents also pointed out that a sustainability action plan should be communicated to the project team and specific incentives should be set to promote the plan. Moreover, responsibilities should be delegated to each stakeholder and team member clearly, especially to the contractors.

![Figure 4.9: Important Project Phases for Sustainability Considerations](image-url)
4.6.6 KM for Sustainable Infrastructure Development

Table 4.11 shows the main stages of managing sustainability knowledge in a typical KM cycle, while Table 4.12 indicates the relatively difficulty of these KM stages. Knowledge application is seen as the most important phase (4.65/0.60); this is, however, the most challenging task ranked by the respondents (3.86/1.00). To promote infrastructure sustainability and deliver tangible results, knowledge application in the actual project level is the critical stage and links talks to actions; other stages may happen at the organizational level.
Table 4.11: Main KM Process for Infrastructure Sustainability
(Level of Importance: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Stage</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apply knowledge</td>
<td>4.65</td>
<td>0.60</td>
</tr>
<tr>
<td>2</td>
<td>Share knowledge</td>
<td>4.39</td>
<td>0.79</td>
</tr>
<tr>
<td>3</td>
<td>Maintain knowledge</td>
<td>4.00</td>
<td>0.71</td>
</tr>
<tr>
<td>4</td>
<td>Obtain knowledge</td>
<td>3.92</td>
<td>0.98</td>
</tr>
<tr>
<td>5</td>
<td>Identify knowledge</td>
<td>3.86</td>
<td>0.96</td>
</tr>
<tr>
<td>6</td>
<td>Contextualize knowledge</td>
<td>3.65</td>
<td>1.20</td>
</tr>
<tr>
<td>7</td>
<td>Measure knowledge</td>
<td>3.57</td>
<td>0.98</td>
</tr>
<tr>
<td>8</td>
<td>Search knowledge</td>
<td>3.57</td>
<td>1.04</td>
</tr>
<tr>
<td>9</td>
<td>Store knowledge</td>
<td>3.55</td>
<td>1.06</td>
</tr>
<tr>
<td>10</td>
<td>Create knowledge</td>
<td>3.55</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 4.12: Challenging KM Stages
(Level of Difficulty: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Stage</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Apply knowledge</td>
<td>3.86</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Create knowledge</td>
<td>3.54</td>
<td>1.11</td>
</tr>
<tr>
<td>3</td>
<td>Measure knowledge</td>
<td>3.51</td>
<td>0.96</td>
</tr>
<tr>
<td>4</td>
<td>Contextualize knowledge</td>
<td>3.41</td>
<td>1.22</td>
</tr>
<tr>
<td>5</td>
<td>Share knowledge</td>
<td>3.37</td>
<td>0.81</td>
</tr>
<tr>
<td>6</td>
<td>Maintain knowledge</td>
<td>3.22</td>
<td>0.87</td>
</tr>
<tr>
<td>7</td>
<td>Identify knowledge</td>
<td>3.19</td>
<td>1.08</td>
</tr>
<tr>
<td>8</td>
<td>Obtain knowledge</td>
<td>3.08</td>
<td>0.96</td>
</tr>
<tr>
<td>9</td>
<td>Search knowledge</td>
<td>2.71</td>
<td>1.08</td>
</tr>
<tr>
<td>10</td>
<td>Store knowledge</td>
<td>2.63</td>
<td>1.05</td>
</tr>
</tbody>
</table>
According to the rating, ten tested KM stages can be put into the following four categories: (relatively) important and challenging, (relatively) important but not challenging, (relatively) not important but challenging, and (relatively) not important nor challenging (Table 4.13). In the preliminary KM frameworks, identify knowledge, obtain knowledge, share knowledge, apply knowledge and maintain knowledge will be considered in the KM cycle. Of these, apply knowledge and share knowledge will be given extra focus in the later research stages.

Table 4.13: Relatively Importance and Difficulty of Tested KM Stages

<table>
<thead>
<tr>
<th>Important (&gt;3.8)</th>
<th>Challenging (&gt;3.3)</th>
<th>Not Challenging (&lt;3.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Apply knowledge (4.65/3.86)</td>
<td>• Maintain knowledge (4.00/3.22)</td>
</tr>
<tr>
<td></td>
<td>• Share knowledge (4.39/3.37)</td>
<td>• Obtain knowledge (3.92/3.22)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Identify knowledge (3.86/3.19)</td>
</tr>
<tr>
<td>Not Important (&lt;3.8)</td>
<td>• Contextualize knowledge (3.65/3.41)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Measure knowledge (3.57/3.51)</td>
<td>• Search knowledge (3.57/2.71)</td>
</tr>
<tr>
<td></td>
<td>• Create knowledge (3.55/3.54)</td>
<td>• Store knowledge (3.55/2.63)</td>
</tr>
</tbody>
</table>

Furthermore, it is interesting to see that knowledge creation is seen as the second challenging task (3.54/1.11); however, it is ranked the lowest in regards to its importance to the respondents (3.55/0.94). According to the findings of a 2002 survey initiated by Australian Construction Industry Forum (ACIF), the Australian building and construction industry in general is very slow to innovate and it is well and truly lagging behind (PricewaterhouseCoopers, 2002). Seven years later, in regards to sustainability, the industry still hasn’t changed much as most of the respondents did not recognize the importance of knowledge creation or, at least, it was not high on their agenda. From the survey, a brief KM cycle for sustainability knowledge management can be proposed which integrates identify knowledge, obtain knowledge, share knowledge, maintain knowledge and apply
knowledge. Meanwhile, knowledge application in the actual projects should be especially emphasized. In fact, the literature study shows that knowledge application (also called ‘knowledge using’ and ‘utilization’) is also considered by practitioners and researchers around the globe as the most critical KM activity.

Questions are also asked in order to gauge the current practices of managing sustainability knowledge in the infrastructure sector. Issues related to sustainability knowledge acquisition, creation, storage, sharing and application are investigated and listed in Table 4.14 - 4.18. It can be found that, currently there is no common practice in regards to better manage sustainability knowledge within the infrastructure sector. Some popular approaches such as post project review (PPR), lessons learned and knowledge index are not well utilized in this field.

Table 4.14: Current Status of Sustainability Knowledge Acquisition
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific staff members are responsible for obtaining sustainability knowledge from external resources.</td>
<td>3.84</td>
<td>0.77</td>
</tr>
<tr>
<td>2</td>
<td>Staff members are encouraged to participate in sustainability related conferences/seminars/exhibitions, etc. to get new knowledge.</td>
<td>3.69</td>
<td>1.02</td>
</tr>
<tr>
<td>3</td>
<td>We actively gather emerging sustainability knowledge from external sources.</td>
<td>3.63</td>
<td>0.97</td>
</tr>
<tr>
<td>4</td>
<td>We are informed of sustainability knowledge from external organizations (e.g. professional associations, research institutions, etc.).</td>
<td>3.52</td>
<td>0.97</td>
</tr>
<tr>
<td>5</td>
<td>Senior staff members are assigned to deal with knowledge needs.</td>
<td>3.47</td>
<td>0.89</td>
</tr>
<tr>
<td>6</td>
<td>Staff with experience of sustainability issues is recruited externally.</td>
<td>3.43</td>
<td>0.87</td>
</tr>
<tr>
<td>7</td>
<td>We actively acquire the latest sustainability related technology and follow the best practice.</td>
<td>3.39</td>
<td>1.13</td>
</tr>
<tr>
<td>8</td>
<td>Sustainability related lessons learned are gathered during project closure.</td>
<td>3.24</td>
<td>1.03</td>
</tr>
<tr>
<td>9</td>
<td>Experienced staff and staff about to leave the organization are asked to record their sustainability knowledge and experience.</td>
<td>2.45</td>
<td>1.16</td>
</tr>
</tbody>
</table>
Table 4.15: Current Status of Sustainability Knowledge Creation
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sustainability-related suggestions are encouraged.</td>
<td>3.76</td>
<td>0.90</td>
</tr>
<tr>
<td>2</td>
<td>Staff members are encouraged to find alternative solutions to promote project sustainability for existing assignments.</td>
<td>3.67</td>
<td>0.83</td>
</tr>
<tr>
<td>3</td>
<td>We usually create new knowledge to solve specific sustainability problems during project development.</td>
<td>3.38</td>
<td>0.87</td>
</tr>
<tr>
<td>4</td>
<td>Staff members are encouraged to analyze success factors in order to enrich sustainability knowledge.</td>
<td>3.33</td>
<td>0.83</td>
</tr>
<tr>
<td>5</td>
<td>Staff members are encouraged to analyze mistakes to enrich sustainability knowledge.</td>
<td>3.29</td>
<td>0.91</td>
</tr>
<tr>
<td>6</td>
<td>We do research on sustainability issues internally.</td>
<td>3.22</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 4.16: Current Status of Sustainability Knowledge Storage
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Staff members who possess knowledge in project sustainability are easily identified.</td>
<td>3.37</td>
<td>1.03</td>
</tr>
<tr>
<td>2</td>
<td>Data and information are selected and organized before being stored.</td>
<td>3.08</td>
<td>1.04</td>
</tr>
<tr>
<td>3</td>
<td>We have a specific location for storing sustainability knowledge.</td>
<td>2.88</td>
<td>1.07</td>
</tr>
<tr>
<td>4</td>
<td>Sustainability knowledge is well indexed and staff knows where to find it when they require it.</td>
<td>2.57</td>
<td>1.04</td>
</tr>
<tr>
<td>5</td>
<td>Sustainability knowledge is kept confidential and has restricted access.</td>
<td>2.35</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Table 4.17: Current Status of Sustainability Knowledge Sharing  
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Experienced staff members are encouraged to mentor new or less experienced staff.</td>
<td>3.96</td>
<td>0.89</td>
</tr>
<tr>
<td>2</td>
<td>Knowledge gained from different projects is made accessible to all.</td>
<td>3.51</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>Remote access to the organization’s database is provided.</td>
<td>3.39</td>
<td>0.86</td>
</tr>
<tr>
<td>4</td>
<td>Recurrent training is conducted to distribute sustainability knowledge.</td>
<td>3.14</td>
<td>1.06</td>
</tr>
<tr>
<td>5</td>
<td>Specific staff members are responsible for regularly updating the knowledge in the database library.</td>
<td>3.00</td>
<td>1.06</td>
</tr>
<tr>
<td>6</td>
<td>Knowledge sharing is a measure of an employee’s performance.</td>
<td>2.80</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Table 4.18: Current Status of Sustainability Knowledge Application  
(1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Staff are encouraged to apply sustainability knowledge learned from previous project(s) to subsequent project(s)</td>
<td>3.98</td>
<td>0.72</td>
</tr>
<tr>
<td>2</td>
<td>We actively use sustainability knowledge in our current projects.</td>
<td>3.53</td>
<td>0.82</td>
</tr>
<tr>
<td>3</td>
<td>It requires great effort to adapt the current sustainability knowledge before applying it in real projects.</td>
<td>3.33</td>
<td>0.90</td>
</tr>
<tr>
<td>4</td>
<td>We do pilot projects (or experiments) in order to test sustainability knowledge before its application</td>
<td>2.63</td>
<td>1.05</td>
</tr>
</tbody>
</table>

4.6.7 KM Enablers

Many factors may affect the success of KM initiatives within a project team and organization by helping to formulate a positive environment for KM success. Enablers for sustainability knowledge management were investigated and are shown in Table 4.19 in the order of importance. Out of the 43 listed enablers, 35
are scored over 3.5 and 13 over 4.0. Leadership, communication skill and organization culture are the top three enablers for sustainability knowledge management.

It is confirmed by the survey results that, “soft” enablers are much more important than the “hard” facilities. Managing sustainability knowledge should be driven by leadership, establishing a supportive culture and promoting personal capability, rather than by focusing on IT and systems.

Table 4.19: Main KM Enablers
(Level of Importance: 1 Low —> 5 High)

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Enabler</th>
<th>Category</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leadership</td>
<td>Project/Organizational</td>
<td>4.71</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>Communication skill</td>
<td>Personal</td>
<td>4.43</td>
<td>0.58</td>
</tr>
<tr>
<td>3</td>
<td>Organizational culture</td>
<td>Organizational</td>
<td>4.41</td>
<td>0.76</td>
</tr>
<tr>
<td>4</td>
<td>Project target</td>
<td>Project</td>
<td>4.22</td>
<td>0.55</td>
</tr>
<tr>
<td>5</td>
<td>Team work</td>
<td>Project</td>
<td>4.16</td>
<td>0.80</td>
</tr>
<tr>
<td>6</td>
<td>Organizational mission, vision and strategy</td>
<td>Organizational</td>
<td>4.13</td>
<td>0.82</td>
</tr>
<tr>
<td>7</td>
<td>Technical expertise</td>
<td>Personal</td>
<td>4.12</td>
<td>0.67</td>
</tr>
<tr>
<td>8</td>
<td>Training and education</td>
<td>Organizational</td>
<td>4.08</td>
<td>0.67</td>
</tr>
<tr>
<td>9</td>
<td>Multi-disciplinary integration</td>
<td>Project</td>
<td>4.04</td>
<td>0.99</td>
</tr>
<tr>
<td>10</td>
<td>Sense of social responsibility (personal)</td>
<td>Personal</td>
<td>4.04</td>
<td>0.96</td>
</tr>
<tr>
<td>11</td>
<td>T-shape skill (having knowledge and skills that are both deep and broad; multi-disciplinary)</td>
<td>Personal</td>
<td>4.04</td>
<td>0.84</td>
</tr>
<tr>
<td>12</td>
<td>Capability to codify thoughts, conceptions and experiences, etc. into written document</td>
<td>Personal</td>
<td>4.00</td>
<td>0.58</td>
</tr>
<tr>
<td>13</td>
<td>Stakeholder integration</td>
<td>Project</td>
<td>4.00</td>
<td>0.87</td>
</tr>
<tr>
<td>14</td>
<td>Financial support</td>
<td>Project</td>
<td>3.98</td>
<td>0.88</td>
</tr>
<tr>
<td>15</td>
<td>Sense of social responsibility (organization)</td>
<td>Organizational</td>
<td>3.98</td>
<td>0.97</td>
</tr>
<tr>
<td>16</td>
<td>Project budget</td>
<td>Project</td>
<td>3.90</td>
<td>1.01</td>
</tr>
<tr>
<td>17</td>
<td>Creativity</td>
<td>Personal</td>
<td>3.88</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>Enabler</td>
<td>Category</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>18</td>
<td>Innovation capability</td>
<td>Industry</td>
<td>3.88</td>
<td>0.78</td>
</tr>
<tr>
<td>19</td>
<td>Trust (project)</td>
<td>Project</td>
<td>3.82</td>
<td>0.91</td>
</tr>
<tr>
<td>20</td>
<td>Trust between colleagues</td>
<td>Organizational</td>
<td>3.78</td>
<td>0.85</td>
</tr>
<tr>
<td>21</td>
<td>Networks of subject matter expertise</td>
<td>Industry</td>
<td>3.78</td>
<td>0.80</td>
</tr>
<tr>
<td>22</td>
<td>Financial support</td>
<td>Organizational</td>
<td>3.73</td>
<td>0.86</td>
</tr>
<tr>
<td>23</td>
<td>Project risk management</td>
<td>Project</td>
<td>3.71</td>
<td>0.87</td>
</tr>
<tr>
<td>24</td>
<td>Government administration</td>
<td>Industry</td>
<td>3.71</td>
<td>1.35</td>
</tr>
<tr>
<td>25</td>
<td>Professional education</td>
<td>Industry</td>
<td>3.69</td>
<td>0.82</td>
</tr>
<tr>
<td>26</td>
<td>Research and design</td>
<td>Organizational</td>
<td>3.67</td>
<td>0.90</td>
</tr>
<tr>
<td>27</td>
<td>Change management</td>
<td>Organizational</td>
<td>3.67</td>
<td>0.83</td>
</tr>
<tr>
<td>28</td>
<td>Process and organizational structure</td>
<td>Organizational</td>
<td>3.67</td>
<td>0.69</td>
</tr>
<tr>
<td>29</td>
<td>Time frame</td>
<td>Project</td>
<td>3.55</td>
<td>0.96</td>
</tr>
<tr>
<td>30</td>
<td>Industry codes of conduct</td>
<td>Industry</td>
<td>3.55</td>
<td>0.91</td>
</tr>
<tr>
<td>31</td>
<td>Collaboration of academics and industry practice</td>
<td>Industry</td>
<td>3.49</td>
<td>0.79</td>
</tr>
<tr>
<td>32</td>
<td>Professional association action</td>
<td>Industry</td>
<td>3.35</td>
<td>1.18</td>
</tr>
<tr>
<td>33</td>
<td>Team structure</td>
<td>Project</td>
<td>3.31</td>
<td>0.85</td>
</tr>
<tr>
<td>34</td>
<td>Document management</td>
<td>Project</td>
<td>3.17</td>
<td>0.84</td>
</tr>
<tr>
<td>35</td>
<td>Time management</td>
<td>Personal</td>
<td>3.16</td>
<td>0.75</td>
</tr>
<tr>
<td>36</td>
<td>Administrative support</td>
<td>Organizational</td>
<td>3.14</td>
<td>0.96</td>
</tr>
<tr>
<td>37</td>
<td>IT infrastructure</td>
<td>Organizational</td>
<td>3.14</td>
<td>0.91</td>
</tr>
<tr>
<td>38</td>
<td>Staff incentive schemes</td>
<td>Organizational</td>
<td>3.04</td>
<td>0.96</td>
</tr>
<tr>
<td>39</td>
<td>Technology and IT support</td>
<td>Organizational</td>
<td>3.00</td>
<td>0.84</td>
</tr>
<tr>
<td>40</td>
<td>Increasing average profit rate</td>
<td>Industry</td>
<td>2.94</td>
<td>1.23</td>
</tr>
<tr>
<td>41</td>
<td>Ambition</td>
<td>Personal</td>
<td>2.86</td>
<td>1.35</td>
</tr>
<tr>
<td>42</td>
<td>Human resource turnover</td>
<td>Industry</td>
<td>2.86</td>
<td>1.04</td>
</tr>
<tr>
<td>43</td>
<td>Loyalty to the organization</td>
<td>Personal</td>
<td>2.69</td>
<td>1.12</td>
</tr>
</tbody>
</table>

These listed enablers can be divided into four categories: external environment, organizational environment, project environment and personal capability. In the KM framework provided by the European Committee for Standardization (CEN,
twelve important KM enablers for successful KM implementation were proposed and categorized into two folders: personal knowledge capabilities and organizational knowledge capabilities. Personal knowledge capabilities include: 1) Ambition; 2) Skills; 3) Behavior; 4) Methods, Tools and Techniques; 5) Time Management; and 6) Personal Knowledge. Organizational knowledge capabilities include: 7) Mission, Vision & Strategy; 8) Culture; 9) Process & Organization; 10) Measurement; 11) Technology & Infrastructure; and 12) Knowledge Assets.

Although enablers suggested by CEN (2004) were tested in the survey, none of them are overlapped with the 6 personal capabilities that are ranked within the top 25, as listed in Table 4.20. Sense of social responsibility is highlighted both in personal level and organizational level. This suggests that sustainability can be seen as an attitude of both care and responsibility. Respondents also specifically pointed out that while the knowledge from each discipline is available, having people that can integrate this knowledge is very important; for example, integrating an understanding of transport, energy and power, and water.

Table 4.20: Personal Knowledge Capabilities for Managing Sustainability Knowledge

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Enabler</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Communication skill</td>
<td>4.43</td>
<td>0.58</td>
</tr>
<tr>
<td>7</td>
<td>Technical expertise</td>
<td>4.12</td>
<td>0.67</td>
</tr>
<tr>
<td>10</td>
<td>Sense of social responsibility</td>
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<td>0.96</td>
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<td>11</td>
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<td>0.84</td>
</tr>
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<td>12</td>
<td>Capability to codify thoughts, conceptions and experiences, etc. into written documentation</td>
<td>4.00</td>
<td>0.58</td>
</tr>
<tr>
<td>17</td>
<td>Creativity</td>
<td>3.88</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Seven organizational enablers ranked within the top 25 are listed in Table 4.21. Organization culture and its missions, vision and strategy are important, as suggested by CEN. Training and education, trust and financial support are also
frequently suggested in the literature. The role of leadership is further investigated in the later stage of the research.

Table 4.21: Organizational Enablers for Managing Sustainability Knowledge

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Enabler</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leadership</td>
<td>4.71</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>Organizational culture</td>
<td>4.41</td>
<td>0.76</td>
</tr>
<tr>
<td>6</td>
<td>Organizational mission, vision and strategy</td>
<td>4.13</td>
<td>0.82</td>
</tr>
<tr>
<td>8</td>
<td>Training and education</td>
<td>4.08</td>
<td>0.67</td>
</tr>
<tr>
<td>15</td>
<td>Sense of social responsibility (organization)</td>
<td>3.98</td>
<td>0.97</td>
</tr>
<tr>
<td>20</td>
<td>Trust between colleagues</td>
<td>3.78</td>
<td>0.85</td>
</tr>
<tr>
<td>22</td>
<td>Financial support</td>
<td>3.73</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Important industrial enablers include: (1) Innovation capability (3.88/0.78), (2) Networks of subject matter expertise (3.78/0.80); and (3) Government administration (3.71/1.35). Government administration is the most debatable enabler (highest standard deviation); its role will be further investigated in the later stage.

Table 4.22: Project Level Enablers for Managing Sustainability Knowledge

<table>
<thead>
<tr>
<th>Rank</th>
<th>KM Enabler</th>
<th>Category</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leadership</td>
<td>Project/Organizational</td>
<td>4.71</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>Project target</td>
<td>Project</td>
<td>4.22</td>
<td>0.55</td>
</tr>
<tr>
<td>5</td>
<td>Team work</td>
<td>Project</td>
<td>4.16</td>
<td>0.80</td>
</tr>
<tr>
<td>9</td>
<td>Multi-disciplinary integration</td>
<td>Project</td>
<td>4.04</td>
<td>0.99</td>
</tr>
<tr>
<td>13</td>
<td>Stakeholder integration</td>
<td>Project</td>
<td>4.00</td>
<td>0.87</td>
</tr>
<tr>
<td>14</td>
<td>Financial support</td>
<td>Project</td>
<td>3.98</td>
<td>0.88</td>
</tr>
<tr>
<td>16</td>
<td>Project budget</td>
<td>Project</td>
<td>3.90</td>
<td>1.01</td>
</tr>
<tr>
<td>19</td>
<td>Trust (project)</td>
<td>Project</td>
<td>3.82</td>
<td>0.91</td>
</tr>
<tr>
<td>23</td>
<td>Project risk management</td>
<td>Project</td>
<td>3.71</td>
<td>0.87</td>
</tr>
</tbody>
</table>
Enablers at project level will most affect the application of knowledge. Important ones are listed in Table 4.22. Due to the project-based nature of the infrastructure sector and the unique nature of the sustainability requirement, integration of various stakeholders, different disciplines and project members should be highlighted at project level.

In brief, in order to make the infrastructure sector more knowledgeable and active in sustainability, organizations should establish an appropriate culture, integrate sustainability into their organizational mission and strategy, and provide relevant training. Furthermore, in the project team, leadership formulation, target setting, and discipline and stakeholder integration are indispensible. Industry practitioners should demonstrate communication skills, improve technical expertise, improve the ability to cooperate with other disciplines, and waken their sense of social responsibility. Last but not least, the industry as a whole should improve its innovation ability and promote the liaison of relevant experts.

4.6.8 Outcomes of Managing Sustainability Knowledge

As the infrastructure sector is highly project-oriented, outcomes are divided into two parts: intermediate outcome (that is, mainly at the project level) and organizational performance. Multi-choices questions were asked to identify what outcomes could be improved by managing sustainability knowledge.

Project reputation is the top project outcome (75.3%) that can be improved by managing sustainability knowledge, followed by employees’ sense of responsibility, value delivery, organization’s ability to exploit market opportunity, and customer satisfaction (which was chosen by more than half of the respondents). The top selected area in organizational performance is corporate reputation (83.3%), while customer recognition, intellectual asset and profit come next.

Many businesses have public relations departments dedicated to managing their reputation. The findings explained why some leading construction firms publish
regular Sustainability Reports for marketing or consultancy purposes. Although the direct link between promoting sustainability and profit has not been clearly established, half of the respondents believe that profit can be increased through better usage of sustainability knowledge.

Table 4.23: Outcomes of Managing Sustainability Knowledge

<table>
<thead>
<tr>
<th>Rank</th>
<th>Intermediate Outcomes</th>
<th>%</th>
<th>Performance</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project’s reputation</td>
<td>73.5%</td>
<td>Corporate reputation</td>
<td>83.3%</td>
</tr>
<tr>
<td>2</td>
<td>Employee’s sense of social responsibility</td>
<td>69.4%</td>
<td>Customer recognition</td>
<td>68.8%</td>
</tr>
<tr>
<td>3</td>
<td>Value delivery</td>
<td>65.3%</td>
<td>Intellectual asset</td>
<td>60.4%</td>
</tr>
<tr>
<td>4</td>
<td>Organization’s ability to exploit market opportunity</td>
<td>59.2%</td>
<td>Profit</td>
<td>50.0%</td>
</tr>
<tr>
<td>5</td>
<td>Customer satisfaction</td>
<td>53.1%</td>
<td>Market share</td>
<td>47.9%</td>
</tr>
<tr>
<td>6</td>
<td>Knowledge leadership</td>
<td>46.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Organizational adaptability</td>
<td>42.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Organizational creativity</td>
<td>40.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Reusable content created</td>
<td>36.7%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.7 Main Findings of the Questionnaire Survey

The survey results highlight the following issues with regards to managing sustainability knowledge in the infrastructure sector:

- The top 25 out of 43 enablers were selected and divided into four categories. Internal enablers are more important than external enablers, especially at the project level. Many of the enablers are different from the cluster of enablers provided by the previous KM framework.

- Enablers are mainly soft in nature. IT tools are not considered very important.
• The first important driver of sustainability knowledge pursuit and application is the awareness and requirement of clients. However, they are not very active in pursuing sustainability knowledge. Thus, related knowledge should be specifically provided to clients/funding providers.

• The monitoring process for sustainability application should be entwined with project management processes throughout the project and should involve the client.

• Sustainability knowledge is highly people centered. Indexing expert and best practice index can be applicable. A “subjective” KM approach should be adopted which focuses on communication and networking among industry practitioners and subject-matter experts.

• Promoting industry best practice should be at the top of the action plan for the industry.

• Sustainability knowledge application is the most important phase of the whole KM cycle; however, it is also the most challenging phase.

• The role of knowledge creation is worth discussing as the respondents ranked the importance of knowledge creation the lowest. It is also highly challenging, as revealed by the survey.

• According to the characteristics of sustainability knowledge, seeking consensus among stakeholders is the task of first priority.

• It is not often possible to increase business profit through managing knowledge for sustainability, as it is not often possible to increase profit through increasing project sustainability itself. However, other important aspects of organizational performance could be improved by managing sustainability knowledge and increasing profit in an indirect way.

• Governments can impact project sustainability KM in the following ways:
- Enabling KM through administering the industry (Mean 3.71, SD 1.35, ranked 25th of 25 important enablers) (However, this is the most debatable enabler)

- Being a knowledge provider (Mean 3.00, SD 1.1, ranked 8th of primary knowledge sources)

- Being an influential project stakeholder (Mean 3.53, SD 1.12)

- Promoting sustainability considerations through regulations and legislation (Mean 4.04, SD 0.96, ranked 3rd of the main impetuses)

- Being the most influential stakeholder and the most important driver of sustainability applications (as the client of the infrastructure projects).

Table 4.24 extracts and highlights the main findings of the questionnaire survey.
Table 4.24: Main Findings of the Questionnaire Survey

<table>
<thead>
<tr>
<th>Topics Investigated</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1. The Body of Sustainability Knowledge in Infrastructure Sector | The body of sustainability knowledge for infrastructure development is usually considered:  
- subjective  
- dynamic and evolving  
- challenging to acquire  
- highly related to infrastructure development |
| 2. KM Enabler – External Environment                      | - Government policy & legislations  
- Industry innovation capability  
- Networks of subject matter expertise |
| 3. KM Enabler – Organizational Environment                | - Leadership  
- Organizational culture  
- Organizational mission, vision and strategy  
- Training and education  
- Sense of social responsibility (organization)  
- Trust between colleagues  
- Financial support |
| 4. KM Enabler – Project Environment                       | - Client’s awareness and requirements are the most important impetus  
- Other project level enablers include:  
- Leadership  
- Project target  
- Team work  
- Multi-disciplinary integration  
- Stakeholder integration  
- Financial support  
- Project budget  
- Trust (project)  
- Project risk management |
| 5. KM Enabler – Personal Capabilities                     | - Communication skill  
- Technical expertise  
- Sense of social responsibility  
- T-shape skill  
- Capability to codify  
- Creativity |
| 6. KM Strategies                                          | - Managing relevant knowledge is critical to promote the adoption of sustainability knowledge in infrastructure projects.  
- “Soft” issues (e.g. attitude, culture) are more important and usually harder to tackle than “hard” |
| 7. Identify Sustainability Knowledge | - Identifying sustainability knowledge is important, but not very challenging.  
- Rank of main stakeholders’ willingness on managing sustainability knowledge: consultant > designer > project manager > client > engineer > government agency > contractor.  
- Organizations and projects should actively identify internal lessons learned and external industry best practice.  
- External bodies (government agencies, industry associations, etc.) should also promote sustainability concepts to the organizations. |
| 8. Obtain Sustainability Knowledge | - Obtain sustainability knowledge is very important, but not very challenging.  
- Rank of main stakeholder influence on managing sustainability knowledge: client > designer > project manager > consultant > government agency > contractor.  
- To obtain sustainability knowledge, industry practitioners usually go to colleagues and internal experts, as well as referring to the industry best practice.  
- Knowledgeable practitioners and industry good practices should be highlighted for obtaining sustainability knowledge. |
| 9. Share Sustainability Knowledge | - Sustainability knowledge sharing is both very important and challenging.  
- Sharing of knowledge can be facilitated through IT tools and other traditional approaches.  
- Sharing of knowledge should be across various disciplines and stakeholders. |
Maintain Sustainability Knowledge

- Maintain sustainability knowledge is very important, but not very challenging.
- Maintaining sustainability knowledge is more than simply storing the knowledge in the database. Project information and index of subject–matter experts are important.

Apply Sustainability Knowledge (Project Level Implementation)

- Sustainability knowledge application is the most important and challenging phase.
- Sustainability knowledge application needs to be integrated into the whole process of project management.
- Main stakeholders must be integrated for sustainability tasks, especially the client, designer and project manager.

12. Project Performance

The following areas of project performance can be improved through managing sustainability knowledge:
- Project’s reputation
- Employee’s sense of social responsibility
- Organization’s ability to exploit market opportunity
- Customer satisfaction

13. Organization Performance

The following areas of organizational performance can be improved through managing sustainability knowledge:
- Corporate reputation
- Customer recognition
- Intellectual asset
- Profit

### 4.8 Preliminary KM Framework

Based on the findings discussed in Table 4.24 and the KM framework prototype shown in Figure 4.2, a preliminary KM framework for managing sustainability knowledge in the infrastructure sector is developed, as shown in Figure 4.13. This preliminary KM framework highlights the main activities and priority issues of managing sustainability knowledge in the Australian infrastructure sector including: (1) the main activities that constitute the KM process for managing sustainability knowledge (identify knowledge, obtain knowledge, share knowledge, maintain knowledge and apply knowledge); (2) important issues that need to be addressed by the KM strategies to facilitate the KM activities (e.g. communication of knowledgeable practitioners, industry good practice recording.
and transferring, stakeholder integration, etc.); (3) KM enablers that shape a positive environment for managing sustainability knowledge (including enablers in industry, organization, project and personal levels); and (4) the possible outcomes that can be delivered through managing sustainability knowledge.

The elements in this preliminary framework will be further explored and verified through the semi-structured interviews during the second data collection phase of this research. Furthermore, effective KM strategies and instruments for addressing the identified issues will be probed in the interviews to improve this preliminary framework.
Figure 4.11: A Preliminary KM Framework for Managing Sustainability Knowledge in the Infrastructure Sector
4.9 **Summary**

This chapter outlined the process and results of a questionnaire survey among Australian infrastructure sector practitioners in order to identify the prior issues and main elements that should be considered in a holistic KM framework for managing sustainability knowledge in the infrastructure sector.

Through a web-based survey tool, 49 valid responses were collected for analysis. The body of sustainability knowledge, various stakeholders, and integration with the PM process, KM enablers, project performance and organizational outcomes were discussed. A table was developed to highlight the main findings of the questionnaire survey. Based on the findings, a preliminary KM framework has been developed according to the survey results that will guide the interviews in a later stage of the research.
CHAPTER 5
INTERVIEW

5.1 Introduction

The questionnaire results reported in Chapter 4 confirmed the necessity and potential of adopting KM within the Australian infrastructure sector to manage sustainability knowledge more effectively. Furthermore, it uncovered the main issues and essential processes to address those concerns. According to the research plan (Refer to Chapter 3 and Figure 3.4), 24 semi-structured interviews were conducted with selected industry practitioners with robust knowledge and experience in terms of infrastructure sustainability, in order to explore the highlighted issues at length in order to gain in-depth understandings, insights and suggestions.

This chapter reports on the findings of the interviews. It first introduces the selection process of the interviewees and their backgrounds. The following sections represent the instruments, structure and format of the interview survey. Questions asked revolved around the organizational and project context for the management of sustainability knowledge, the current practices of knowledge transfer across organizations, projects and practitioners, and the challenges and opportunities for the management of sustainability knowledge. Aggregated findings, analysis and discussions from the interviews are then presented. The interview results are summarized at the end of this chapter.
5.2 Participants’ Selection and their Background

5.2.1 Selection of Interviewees

As discussed in Section 3.4, the snowball approach and a purposive sampling strategy were employed to select interviewees.

At the end of the questionnaire survey, participants were asked to state their willingness to participate in the subsequent interview survey to discuss the research topic at length. 36 out of the 49 questionnaire survey respondents (73%) said “yes” to the interview invitation. Selection of interviewees was based on their current positions, professional background, relevant experience, and availability during the arranged interview period. Finally, 16 were interviewed, most of whom possess executive level positions and have long years of experience in the Australian infrastructure sector. However, as the survey progressed, more potential participants were recommended by the interviewees, as they knew who was more knowledgeable and resourceful within the industry in regards to infrastructure sustainability, especially at project level. Most of these recommended participants are people who are keen sustainability practitioners or champions. Many of them possess sustainability related positions (e.g. sustainability manager, environmental manager, sustainability consultant) and are dealing with project sustainability issues in a practical sense as part of their job responsibility. This is how eight sustainability managers/consultants were added to this interview survey sample. In the end, 24 industry practitioners with a wealth of knowledge and practical experience in infrastructure sustainability were interviewed from late October to late December 2009.

5.2.2 Interviewee Background

Table 5.1 lists a full profile of the interviewees.
<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
<th>Position</th>
<th>Stakeholder Type/Role</th>
<th>Infrastructure Experience</th>
<th>Years of Experience</th>
<th>Interview Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>QLD</td>
<td>Chair / Adjunct Professor</td>
<td>Engineering Consulting/Professional Association / Research Institution</td>
<td>Transport, Energy</td>
<td>&gt;20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R2</td>
<td>QLD</td>
<td>General Manager</td>
<td>Corporate Services</td>
<td>General Contractor</td>
<td>Transport, Energy, Mining</td>
<td>&gt;20</td>
</tr>
<tr>
<td>R3</td>
<td>QLD</td>
<td>Principal Consultant/Adjunct Professor</td>
<td>PM Consulting / Research Institution</td>
<td>Energy</td>
<td>&gt;20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R4</td>
<td>QLD</td>
<td>Deliver Manager</td>
<td>General Contractor</td>
<td>Transport, Mining</td>
<td>10~15</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R5</td>
<td>QLD</td>
<td>Deputy Project Director</td>
<td>Training Specialist</td>
<td>Transport, Water</td>
<td>5~10</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R6</td>
<td>QLD</td>
<td>Project Engineer</td>
<td>Government Agency / Client</td>
<td>Transport</td>
<td>5~10</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R7</td>
<td>QLD</td>
<td>Managing Director</td>
<td>Supplier</td>
<td>Telecommunication, Water</td>
<td>15~20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R8</td>
<td>QLD</td>
<td>Director</td>
<td>Government Agency / Client</td>
<td>Transport</td>
<td>10~15</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R9</td>
<td>QLD</td>
<td>Chief Operating Officer</td>
<td>General Contractor</td>
<td>Transport, Telecommunication, Energy, Water, Mining, Marine, residential, recreational</td>
<td>&gt;20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R10</td>
<td>QLD</td>
<td>Construction Supervisor</td>
<td>Engineering Consulting</td>
<td>Transport, Mining</td>
<td>10~15</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R11</td>
<td>QLD</td>
<td>Manager Sustainability / Manager Support</td>
<td>Engineering Consulting</td>
<td>Transport</td>
<td>5~10</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R12</td>
<td>QLD</td>
<td>Sector Leader</td>
<td>General Contractor</td>
<td>Transport, Water, Mining</td>
<td>10~15</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R13</td>
<td>WA</td>
<td>Sustainability Consultant</td>
<td>Engineering Consulting</td>
<td>Transport</td>
<td>5~10</td>
<td>Phone</td>
</tr>
<tr>
<td>R14</td>
<td>VIC</td>
<td>Director/Executive General Manager Overseas</td>
<td>General Contractor</td>
<td>Transport, Water, Mining</td>
<td>&gt;20</td>
<td>Phone</td>
</tr>
<tr>
<td>R15</td>
<td>NSW</td>
<td>Sustainability Manager</td>
<td>Government Agency / Client</td>
<td>Transport, Telecommunication, Energy, Water</td>
<td>15~20</td>
<td>Phone</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>R16</td>
<td>QLD</td>
<td>Director</td>
<td>Environment Consulting</td>
<td>Transport, Energy, Water, Mining</td>
<td>&gt;20</td>
<td>Phone</td>
</tr>
<tr>
<td>R17</td>
<td>VIC</td>
<td>Sustainability Leader</td>
<td>Engineering Consulting</td>
<td>Transport</td>
<td>10~15</td>
<td>Phone</td>
</tr>
<tr>
<td>R18</td>
<td>NSW</td>
<td>Manager – Sustainability &amp; Climate Change</td>
<td>Engineering Consulting</td>
<td>Transport, Energy, Water</td>
<td>5~10</td>
<td>Phone</td>
</tr>
<tr>
<td>R19</td>
<td>NSW</td>
<td>Group Sustainability Manager</td>
<td>General Contractor</td>
<td>Transport, Telecommunication, Energy, Water</td>
<td>&gt;20</td>
<td>Phone</td>
</tr>
<tr>
<td>R20</td>
<td>QLD</td>
<td>Technical Director - Sustainability &amp; Climate Change</td>
<td>General Contractor</td>
<td>Transport, Energy, Water</td>
<td>15~20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R21</td>
<td>NSW</td>
<td>CEO</td>
<td>Engineering Consulting</td>
<td>Transport, Telecommunication, Energy, Water, Mining, Marine</td>
<td>&gt;20</td>
<td>Phone</td>
</tr>
<tr>
<td>R22</td>
<td>QLD</td>
<td>Senior Consultant</td>
<td>Strategic Consulting</td>
<td>n/a</td>
<td>15~20</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R23</td>
<td>QLD</td>
<td>Technical Leader</td>
<td>Engineering Consulting</td>
<td>Water</td>
<td>10~15</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>R24</td>
<td>VIC</td>
<td>Executive General Manager</td>
<td>Specialist Businesses</td>
<td>General Contractor</td>
<td>Transport, Water</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

As shown in Figure 5.2, 16 (67%) of the interviewees are currently working in Queensland, three (13%) are from Victoria, four (17%) are from New South Wales and one (4%) is from Western Australia. The infrastructure sector is a highly project-oriented industry sector, and has a high rate of staff turnover. Many big organizations within the industry sector commonly undertake projects across the country, even overseas. Thus, although more than half of the interviewees are currently based in Queensland, most of them had project experience in other Australian states. Thus, the information and insights provided by the interviewees can effectively represent the nationwide context and status of the Australian infrastructure sector.
Professional roles of the interviewees are diverse. Eight of them are from general contracting companies who are the builders of the projects, ten are from consulting firms who are the project designers or project executives, and three are from government agencies (who are typically the clients as well as the regulators of the infrastructure projects in the Australian context), and one interviewee is from a specialist supplier. They represent the major stakeholders of the Australian infrastructure sector. In particular, there is an interviewee (R22) from a strategic management consulting company who is specializing in information and knowledge management systems, and had experience in helping construction firms to design KM system. Furthermore, another interviewee (R5) from an education institution was interviewed as well as she is currently working on a sustainability training program for the construction industry.

As discussed above, backgrounds of the interviewees covered different professions and stakeholders, from both private and public sectors. They possess various positions in the industry sector (from CEO to project engineers) and have practical experience in both project delivering and high-level management areas. Furthermore, many of them have rich experience in the area of infrastructure sustainability (such as the sustainably managers). Thus, information, insights and recommendations provided by the interviewees are highly valuable to this research.
5.3 Interview Instruments

Before the interview, each interviewee was given the following information electronically through email:

- Interview Participant Information Sheet (Appendix III),
- Consent Form for QUT Research Project (Appendix IX), and
- Interview Question Sheet.

The interview survey was carried out through a combination of face-to-face and telephone interviews. Interviewees from Queensland were interviewed in the face-to-face manner, while people outside Queensland were mainly interviewed by phone due to the tight research schedule, financial constraints and the complexity of arranging suitable time for each interviewee across the nation. On average, each of the interviewees was exclusively interviewed for about one hour. Telephone interviews are generally a bit shorter than face-to-face interviews.

Each interview began with the author explaining to the interviewee the specific objectives of the interview, and the overall research objective. To ensure that they understood the intended meanings of the questions, relevant background information (for example, questionnaire survey findings, definition of specific terms, etc.) were provided and any queries from the interviewees were clarified. Then the interviewees were required to read through and sign the “Consent Form for QUT Research Project”. Interview conversations were fully recorded with a digital recorder with the permission of the interviewees.

5.4 Interview Format and Structure

The semi-structured interview was formulated on top of the previous questionnaire survey. Questions are qualitative in nature which can increases the potential of collecting insights and concepts, and expanding understanding. Questions are mainly about how to address the issues highlighted in the
preliminary KM framework and the current best practices in regard to managing sustainability knowledge within the organization and projects.

Questions are generally categorized into five folders which are the main stages of the KM process for managing sustainability knowledge in the infrastructure sector (Refer to Section 4.6.6 and Section 4.7), namely: identify knowledge, obtain knowledge, share knowledge, apply knowledge and maintain knowledge. Important KM enablers are included into these folders as well according to their relevance.

Warm-up questions were asked to get general information about the interviewees and their general impression of infrastructure sustainability. Table 5.2 outlines the main questions of a typical interview. As the interview was semi-structured, interview questions were usually changing. For instance, if the interviewee possessed a high executive management position, questions were more strategic from a high management level perspective. On the other hand, if the interviewee was a project manager, the interviewer probed more into the practical issues at project level.

Table 5.2: Interview Questions

<table>
<thead>
<tr>
<th>Category</th>
<th>Questions</th>
</tr>
</thead>
</table>
| Apply Knowledge     | • As identified through my previous survey, people think it is relatively difficult to apply sustainability knowledge into real infrastructure projects. What can be the reasons?  
• Leadership has been identified as the most important knowledge management enabler to promote sustainability at the project level. Who should take the leadership? (Design team? Client? Project manager?)  
• Could you please give me an example of how sustainability knowledge has been applied in a real project? What was the process? (Where is the knowledge from? Who proposed sustainability? Who agreed with the plan? How to secure its application in the later project processes?)  
• How can the process of applying sustainability be entwined with the project management process? What are the key actions along the PM process?  
• If we resource a sustainability manager in each project team, will
<table>
<thead>
<tr>
<th>Identify Knowledge</th>
<th>Background information: The main locations of sustainability knowledge are identified as: lessons learned from internal projects, industrial best practice and internal or external experts.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• How can we increase the industry practitioners' awareness of sustainability knowledge?</td>
</tr>
<tr>
<td></td>
<td>• How can sustainability related industry best practice be noted by practitioners in infrastructure projects?</td>
</tr>
<tr>
<td></td>
<td>• How can internal/external experts be easily identified? (Knowledge map? expert index?)</td>
</tr>
<tr>
<td></td>
<td>• How can new knowledge generated in internal projects be noticed and shared?</td>
</tr>
<tr>
<td>Obtain Knowledge</td>
<td>• Many people feel that sustainability knowledge is not always available or easy to get when they need it. What can be the reasons for that?</td>
</tr>
<tr>
<td></td>
<td>• What are the common forms of industry best practice? How can it be obtained by practitioners across organizational boundaries? (Detailed plan? Technical instructions? Case study publications? etc.)</td>
</tr>
<tr>
<td></td>
<td>• Who should be in charge of obtaining sustainability knowledge? (Organization based position? Project based position?)</td>
</tr>
<tr>
<td>Share Knowledge</td>
<td>Background information: Colleagues and internal experts are the most popular resources for people to get sustainability knowledge.</td>
</tr>
<tr>
<td></td>
<td>• What are useful methods to share sustainability knowledge inside the organization and inter-project? (IT tools? Non-IT methods?)</td>
</tr>
<tr>
<td></td>
<td>• How about the use of databases and ICT (information communication technology)?</td>
</tr>
<tr>
<td></td>
<td>• From the previous survey, people think sustainability knowledge is usually not easy to articulate or comprehend. How can we improve this situation?</td>
</tr>
<tr>
<td>Maintain Knowledge</td>
<td>• How can the sustainability knowledge be maintained in the organizations? (Set up a database? Retain the experts?)</td>
</tr>
</tbody>
</table>
5.5 Data Interpretation and Analysis

Interview data has been processed in the following steps:

**Step 1:** Interview records were fully transcribed into a text document. A one-hour interview took around six hours of work on average to be fully transcribed.

**Step 2:** The compiled narratives were imported into NVivo, which is a high quality qualitative data analysis software package (as discussed in section 3.4.4).

**Step 3:** Labels were designed and data were coded according to the labels through NVivo. The initial labels are from the highlighted elements and issues extracted from questionnaire survey findings. Then, during the coding processes, unimportant labels were deleted while new codes emerged. Activities involved in this inductive coding processes included: examining, comparing, and breaking down. Figure 5.2 shows how data was labeled via NVivo.

![Figure 5.2: NVivo Software Interface](image-url)
Step 4: Conceptualizing and categorizing of the coded data were involved in this stage. The code development process was time-consuming. During the process, related codes were linked and overlapping contents were associated. Then a categorization scheme started to appear. As the main aim of the interview study was to identify the effective KM strategies and tools that facilitate the management activities for sustainability knowledge in the infrastructure sector, current KM practices were highlighted in the categorization structure.

5.6 Interview Results and Discussion

5.6.1 The Body of Sustainability Knowledge

In the Australian construction industry, people tend to have different opinions on describing the body of sustainability knowledge. On the one hand, most interviewees agree that sustainability is still a vague concept, especially for the infrastructure sector, as there is neither solid systematic supporting scientific knowledge, nor demonstrative projects that have delivered real outcomes in terms of sustainability. The lack of a widely accepted definition and indicator system make it difficult for industry practitioners to apply the knowledge in actual projects.

On the other hand, many interviewees believe that, in general, sustainability knowledge is no different from any other knowledge domains. There is a lot of knowledge recorded in books, articles, online forums and other mediums. Well-designed training resources are also available. People just need to be motivated to start the knowledge cycle: learning knowledge, sharing knowledge, processing knowledge and creating new knowledge through its application and innovation in real projects. Some interviewees even argued that the industry is using the claim that sustainability knowledge is immature or too hard to get as an excuse. There is plenty of knowledge in terms of technology; however, there are more attitudinal reasons and institutional barriers that are stopping practitioners utilizing the technology to improve infrastructure sustainability. Nevertheless, consensus has been reached on the fact that properly managing the body of knowledge in order
to maximize, share and maintain it, and to provide it with an innovative base is an urgent requirement because of the serious issues we are facing right now.

5.6.2 Key Barriers to Embracing Sustainability

Sustainability knowledge faced many barriers on the way to being identified, shared and actually applied by the industry to real projects. As management of sustainability knowledge is the focus of this study, barriers having relevance to sustainability knowledge and its management (creating, sharing, learning, application, maintenance, etc.) were foregrounded in the interviews. These barriers are discussed below.

**Barrier No. 1: Lack of awareness**

Construction corporations, mainly the large and leading organizations, are reacting to a set of trends and market forces and changing the way they compete and deliver projects. However, infrastructure projects are still mainly driven by economic benefits. Sustainability is still a new pattern of doing business that, at this moment, is not highlighted in the infrastructure sector, as it should be. None of the interviewees think there is yet total awareness of the seriousness of the sustainability crisis and the urgent need for the infrastructure sector to act in this regard.

The infrastructure sector is starting to make changes to incorporate a more sustainable approach. However, at the early stages of the changeover, support from industry practitioners is usually not forthcoming, at least not unless the client of a certain project has a strong sustainability focus. Thus, the current situation allows little room and motivation for practitioners to seek sustainability knowledge. There are a few sustainability champions in the industry sector who are really making some changes. However, overall in this infrastructure sector there is still a long way before sustainability principles and knowledge can penetrate the whole industry. This will not happen until there is awareness of the
need and all stakeholders want to achieve the competitive edge of being able to deliver projects that are more sustainable.

**Barrier No. 2: Deficiency of current sustainability education**

According to the interviewees, current education for sustainability is not effective in helping the industry practitioners establish their knowledge, skill, attitude and confidence in delivering sustainability in practice. This affects both the young graduates and the senior practitioners. Practitioners do not have the confidence and knowledge that they need for implementing sustainability across real projects, as sustainability knowledge that is currently understood by industry practitioners is limited.

They also mentioned that new graduates generally have better knowledge than existing practitioners. Existing practitioners need to be trained through continuing professional development, through programs run by organizations and industry associations as well as by the universities, TAFE colleges and so on. Although there are currently some sustainability related training courses, these courses are not delivering enough and effective education to the industry practitioners. This is supported by the questionnaire survey results. The rating for the statement “recurrent training is conducted to distribute sustainability knowledge” is only 3.14 (Maximum 5; refer to Section 4.6.6). Furthermore, the effectiveness of current training courses has failed to satisfy the infrastructure sector. Interviewees, especially sustainability managers who have experiences of running sustainability training sessions, mentioned that understanding sustainability is a very personal journey. If it is not something people believe in and really care about, then it is very difficult for people to move from talk to action.

**Barrier No. 3: Lack of guidelines and examples for industry practitioners to move from talk to action**

In regards to sustainability, industry practitioners are facing extensive challenges to move from talk to actions. It is a common issue that practitioners do not know where to start, as definitions of sustainability are sometimes vague and conceptual;
thus numerous efforts need be made to interpret the meaning of sustainability in individual contexts. Infrastructure sustainability frameworks and indicator systems are used to address this challenge, which will be discussed in the following sections. However, existing sustainability criteria are not presented in a way that project managers can readily identify with and deliver projects accordingly.

Some other constraints were also proposed in the interview survey, such as: information explosion, sustainability legislation, requirements raised by clients, and time constraints. Main opinions include:

- Sustainability is not legislated, and this is being used as an excuse by many organizations and practitioners for not including sustainability in their decision-making process and selection methodology. Many interviewees have mentioned the legislation of “construction safety” in comparison with of “sustainability”. In the Australia construction industry, “safety” was heavily pushed by the government at first until it became common practice.

- Some main stakeholders are not interested in sustainability and do not embrace sustainability principles in their decision-making process, especially clients and project managers. Moreover, they are hard to educate and persuade in terms of project sustainability, unless they can see actual outcomes.

- The massive volume of information is one of the issues that people have struggled with in their daily work. Information on sustainability has been imposed on people (such as through emails, newsletters) and is buried in other information. Face-to-face communication is still the most effective way of sharing sustainability knowledge.
5.6.3 Important Enablers for Successful Sustainability Knowledge Management

Several important enablers are necessary for the success of KM initiatives in sustainability in project teams and organizations by helping to formulate a positive and motivating environment for KM success. Referring back to the discussion of questionnaire survey results in Section 4.6.7, important enablers for managing sustainability knowledge were identified and were further discussed in the interview surveys, and the following issues were highlighted.

**Enabler No.1: Knowledgeable and committed project client**

As endorsed by all the interviewees, a client’s commitment and support for sustainability is the most effective driver for a project to be successful in sustainability. Usually, if the clients do not want sustainability (in order to keep the budget low or minimize the construction time) then the whole project team will not be motivated to act beyond compliance. This situation will inevitably limit the space for sustainability knowledge sharing and application and block the possibility of any innovation.

**Enabler No. 2: Leadership**

Leadership can be broadly described as the processes of influencing the choices and actions of others (Politis, 2001) Nowadays, it is a term which is usually used in the context of change management. Sustainability is not a destination but a process which requires the industry section to progressively change its current business mode to address not only economic benefits but also social and environmental outcomes. It also requires a change in people’s judgment and knowledge settings. This explains why, in the previous questionnaire survey, leadership is ranked as the most important enabler for sustainability KM success. This result is also echoed by the interviewees; however, they did nominate different stakeholders to take the leadership role.

Main suggestions from the interviewees include:
• Government should take the leadership by advocating sustainability, regulating standards, publishing guidelines, awarding good practices, punishing bad practices and promoting knowledge sharing and communication.

• The real leaders of the project (such as the client, project manager and design director) should take the leadership role by embracing sustainability principles in their decision-making process.

• Everyone who really believes and reasonably understands infrastructure sustainability and the related technology knowledge can take the leadership role by continuously talking to people about it, and always trying to act beyond compliance.

The term “sustainability champions” is usually used in the industry sector to refer to the industry practitioners who are constantly trying to challenge the industry status quo, and are influencing people around them, trying to imbed sustainability into jobs. They are people who are actually leading the change. In many cases, they are serving as knowledge kernels at different community levels. Some sustainability champions are given a formal title in relation to sustainability, such as “sustainability manager”, “sustainability consultant”. This is becoming a common practice in the Australian construction industry, which will be discussed in depth in later sections.

Anyone in the organization can be a sustainability champion. It is particularly helpful if the sustainability champion is in the executive level as she/he then has more persuasive power and impact in the organization. However, in practice, it is not always the case. In the organization, sustainability champions may possess junior management positions, and thus will need support from executive level in order to reinforce the organization’s commitment to sustainability and management of knowledge assets.

*Enabler No. 3: Project Target*
It is essential that the project client and the project team work together to set project sustainability goals and objectives in order to achieve levels of performance that are beyond minimum compliance and comparable to industry good practices. These goals and objectives need to be high but achievable and need to consider the performance of good practices in the industry sector, and the performance of the requisite processes, systems, and technologies. Target setting is largely based on the interpretation of sustainability in the project context. Furthermore, it will allow the project team to identify the knowledge gap and to efficiently obtain the knowledge as needed. However, in practice, all the interviewees agreed that project target setting is highly dependent on a client’s endorsement and active involvement. Thus, clients should be educated and motivated on sustainability in order to raise the bar on project sustainability targets.

**Enabler No. 4: Policy and Legislation**

As discussed in Section 5.6.2, the fact that sustainability is not legislated is an important barrier to implementing sustainability in the infrastructure sector. Most interviewees agreed that legislating sustainability will push the industry sector to raise the bar on project sustainability performance and push the organizations and projects to compliance with higher standard requirements. This will inevitably trigger the sharing, obtaining, maintenance and application of relevant knowledge.

**Enabler No 5: Practitioners with Multi-disciplinary Knowledge**

Sustainability is an area that requires system thinking and integration of people from different disciplines. Many interviewees (especially the sustainability managers) confirmed that having multi-disciplinary knowledge is critical for industry practitioners to communicate with team members from other disciplines and integrate the knowledge into practice.

**Enabler No.6: Industry Sustainability Awareness**
Interview results show that lack of industry sustainability awareness is the biggest issue that constrains the flow of sustainability knowledge and the uptake of sustainability consideration in real projects (See Section 5.6.2). Industry’s good understanding and a culture of care for sustainability would be a powerful interior incentive for the industry to look for innovative solutions to respond to the sustainability crisis.

**Enabler No 7: Network of Subject-matter Experts**

Almost all the interviewees agreed that there are not many people who can claim to be an expert in the area of infrastructure sustainability. However, there are experienced practitioners – sustainability champions, or more formally entitled sustainability managers, for example – who are more knowledgeable and experienced on sustainability. Their contribution to the management of sustainability knowledge will be discussed in later sections. Frequent communication and collaboration among those people will greatly facilitate the transferring of industry good practice.

**5.6.4 Roles and Perspectives of Stakeholders**

Project stakeholders are people who are actually managing sustainability knowledge. The initiatives for managing sustainability are conducted for these stakeholders as well. Thus, attitudes and roles of important stakeholders have also been discussed in the interviews. These stakeholders include clients, project manager, designers, contractors and government.

- **Client**

As discussed earlier, a client’s endorsement of sustainability is the most important driver for sustainability application in real projects. A knowledgeable and committed project client is one of the prerequisites for project sustainability success and related management of knowledge. Furthermore, with up-to-data knowledge, the project client may raise the bar on requirements in one or more areas of sustainability. However, in practice, clients are usually driven by cost and
time, giving much less attention to sustainability. Compared with clients from the public sector, private clients are even less knowledgeable on sustainability.

- Designer

Compared with other stakeholders, engineering consulting firms are more active in pursuing and sharing sustainability knowledge. Some leading consulting firms have resourced sustainability manager positions and business units to provide sustainability related services. Moreover, designers do educate clients during the bidding process if the clients have not included sustainability requirement, by providing alternative solutions and nominating more sustainability elements.

- Project manager

The project manager is the leader of the project; however, project management is a profession that has not yet fully embraced sustainability principles into its scope of work. Project managers tend to say that project management is about delivering the project on time and on budget and sustainability is someone else’s responsibility. However, the majority of the interviewees agreed that sustainability should be entwined with the process of project management, which should be the vehicle that drives sustainability.

- Contractors

At the present time, compared with other stakeholders (e.g. designers and government agencies), contractors are less enlightened on sustainability. If not pushed by the clients, they tend to act in minimum compliance with relevant policies and regulations, rather than actively seek opportunities to embrace sustainability. According to the experience of several interviewees, engineers are especially hard to be convinced. Therefore, special attention, education and motivation should be given to contractors to motivate them to act on sustainability.

- Government
In regards to infrastructure sustainability, different levels of governments are playing the following roles:

- In the Australian infrastructure sector, government is commonly the client of big infrastructures. Thus they are playing an essential role in promoting sustainability and relevant knowledge sharing and application through requiring sustainability focus in the tendering process.

- Many interviewees have suggested that the government should heavily push sustainability in the industry sector through properly regulating, setting standards and publishing guidelines to raise the bar on sustainability in general.

- Certain departments of the government may play the role of “knowledge gatekeeper” to collect industry good practices and relevant information and to disseminate these though diverse forms of reports and guidelines.

### 5.6.5 Current Practice in Managing Sustainability Knowledge

The other aim of the interviews was to investigate the current practices of KM within the Australian infrastructure sector in managing sustainability knowledge. Although KM is still a new concept for the relatively traditional construction industry, evidence and past research have shown that industry practices are being conducted with an aim to facilitate the flow and application of sustainability knowledge for infrastructure development. These practices may not be given a formal KM title, but they reflect the thinking and management of the body of knowledge, albeit with differences in emphasis and extent of implementation.

Through the interviews, several KM tools that currently exist in the infrastructure sector for managing sustainability knowledge were identified; however, most of these are not treating sustainability knowledge significantly differently from other knowledge domains, nor are they being used with full awareness. The following findings from the interviews outline the current practice of KM within the sector in regards to infrastructure sustainability.
5.6.5.1 Post Project Reviews (PPRs)

Post Project Reviews (PPRs) can be seen as “debrieing sessions” that are commonly used in project-oriented industries to highlight and capture the lessons learned during the course of a project. Usually PPR can be conducted formally or informally, in the form of ongoing reviews or post project evaluations (Robinson et al., 2010; Tan et al., 2010).

In the construction industry, PPR is a common practice to facilitate the capture of important project knowledge and lessons learned, and the creation of shared understandings among stakeholders. It is usually conducted at the end of a project to obtain the whole story of a project, and considerations of sustainability issues are part of its concern. It is a valuable tool for whole project teams and organizations to capture and store the achievement of project sustainability.

The following issues undermine the current practice of using PPR to capture sustainability knowledge:

- **Lack of format for representing sustainability knowledge:** Lessons learned on project sustainability, if they exist, are usually fragmented and submerged by the massive volume of information. Some parts of the information will be hidden in technical documents, and some are just too general to be useful in the future.

- **Time constraints:** Teams are dissolved during or right after the project completion; this may cause valuable information to be lost before the PPR session. Furthermore, PPR sometimes is seen as a burden to the project team and is rushed through if not enough time is allocated to such activity, in which case sustainability issues have no chance of being considered.

“Yes we do post project reviews sometimes; however, we didn’t have any session particular for sustainability issues.”

Remark by an interviewee
5.6.5.2 Education and Training

Personal training and education are usually seen as the most important as well as frequently used KM instrument for knowledge acquisition and sharing (Tan et al., 2010). According to remarks from the interviewees, university education yet is not doing enough for their graduates to have the confidence of practice in sustainability. Furthermore, as sustainability is a new discipline especially for construction practice, many experienced practitioners even understand less than the new graduates as they have had no sustainability education or relevant experience themselves. Thus, on-job training is extremely important to facilitate the penetration of a sustainability focus in the industry. Sustainability training programs are organized by organizations, professional associations, or within the project teams, to raise employees’ awareness, to enhance understandings and to provide assistance, especially in linking sustainability principles to their professional domains.

“...I think the education is still evolving as there is no certain definition to sustainability, but there is certainly a place for internal training, but not many organizations are doing it. There are a lot of little things are around, seminar etc. but for deep understanding, very little. They might do small pieces of it, such as energy efficiency and water, but nothings in a holistic view about sustainability principles, environmental designs etc. Universities are doing, but more on researches, the education part is really lacking....”

Remark by an interviewee
Importance of education and training for addressing sustainability issues include:

- Raise sustainability awareness,
- Build absorptive capacity,
- Facilitate individual and organizational learning, and
- Create a solid base for sustainability knowledge application and innovation.

KM is more than formal education and training which concentrates mainly on explicit knowledge. In the infrastructure sector, tacit knowledge is more valuable for the practitioners to solve real problems and deliver higher value projects. However, the main barriers to the industry promoting sustainability are still highly rooted in the reality that there are still not many practitioners who understand and care enough about sustainability. Education and training will help the industry to enhance its absorptive ability and then to use the knowledge creatively. That is how real change can be boosted in the industry.

“... I think sustainability is a very personal journey that people go on... If it's not something that they care about, it’s very difficult for people to start. As soon as people have started that journey, it’s easy to get them on board... 

Remark by an interviewee

Training can be mainly conducted in two ways, through conventional training or training aided by computer. The former is instructor-led and mainly involves face-to-face interaction, while the latter is usually delivered via downloads from the internet, intranet or email (Tan et al., 2010).

Computer aided training is more efficient in a modern learning environment; however, all the interviewees agree that face-to-face interactions are more effective in facilitating sustainability learning. At the very beginning, people need
to develop the feeling of responsibility, care and interest for learning. A passionate and knowledgeable champion in their field will be of great value to influence people, especially in helping them to build the link between the big sustainability picture and their own professional domains.

For the industry practitioners, during the process of learning and moving from talk to actions, many barriers exist. Sustainability education should be delivered in a structured way and provide a sequence of programmed instruction to help the industry practitioner to overcome these barriers.

### Sustainability Education

- Sustainability education is critical for the infrastructure sector to raise the industry practitioners’ awareness and build the absorptive capacity for sustainability knowledge.
- Sustainability education can be provided in project teams, in organizations and at industry level.
- Face-to-face communication is still the most effective way to deliver sustainability education, and allows open discussion.
- Sustainability education should be delivered in a systematic and structured way.

#### 5.6.5.3 Sustainability Reporting

History of corporate sustainability reporting can be traced back to late 1980s initiated by the chemical industry. At the end of the 1990s, increasing companies started to encompass social issues into their environmental reports, inspired and driven by the Global Reporting Initiative (Wallace, 2008).

In the Australian construction industry, some leading organizations have started to publish corporate sustainability reports on a regular basis. Furthermore, some
critical infrastructure projects, especially big projects under an alliance contract, also produce sustainability reports during their development or at the closure phase to summarize and review their sustainability initiatives and the processes being conducted. The intention of this reporting, especially at organizational level, is to relieve some of the pressures being applied by the environmental and public advocacy groups by presenting in a positive way their actions toward improving their environmental performance and social responsibility. Thus, to some extent, it is seen as a marketing instrument to improve an organization’s reputation and its public image. Nevertheless, the reporting initiatives have made organization performance information more transparent to public and other organizations.

Reporting on project sustainability achievements, in particular, sometimes serves as a PPR document, in which sustainability wins and mistakes, important initiatives, tools and reference are coded and able to be retrieved for future projects. It naturally can be seen as a sustainability case study and is a very important vehicle for sustainability knowledge storage and dissemination within the industry sector.

“…In that project, we also did sustainability reports regularly while the project went on… The sustainability reports from the project helped to document the project gains and experiences and share these with stakeholders and industry groups...

Remark by an interviewee

Current issues of using sustainability reporting in the infrastructure sector:

- **Objectivity**: The objectivity of findings and opinions of a sustainability report are questionable in some cases when they serve as a marketing instrument. Achievements may be exaggerated and negative issues might be concealed, such as lack of high-level commitment, etc.
Protection of key technology and techniques: Although the majority of the interviewees stated that sustainability knowledge is not kept confidential in their organization and they are willing to share the knowledge with the whole industry, some of the interviewees, especially those from engineering consulting firms, see cutting-edge sustainability knowledge and techniques as part of their knowledge asset and business advantage; thus, they will not reveal the key information outside their organization.

Sustainability Reporting

- Current practices of sustainability reporting are organization-based or project-based.
- A project sustainability report is similar to PPR on sustainability. It is a very effective way of identifying, recording and sharing sustainability information on projects.
- A sustainability report should provide a certain extent of technique and decision-making information and be objective.

5.6.5.4 Sustainability Staffing

Recruitment is a process of finding new people to join a company and is usually an effective means of bringing new knowledge into an organization (Tan et al., 2010). It adds new knowledge to the organization’s knowledge base, and allows other members to learn from the new member. In regards to sustainability, recruitment is a relatively easier way to import sustainability knowledge, especially when the organization had no previous experience in this area. However, a lack of experts in the infrastructure sustainability domain is a big challenge for the whole industry sector.

Many companies in the Australian construction industry now have resourced sustainability managers (or sustainability consultants) to facilitate sustainability considerations and implementation in projects, especially in big engineering
consulting companies and contracting companies. They work at project or organizational level, providing services in sustainability education, organizational change and project facilitation, with a view to implementing project processes or decision making frameworks in which sustainability considerations are embedded.

Basically, sustainability managers can be categorized into 2 types: organization based and project based. An organization based sustainability manager is usually resourced to develop and implement organizational sustainability goals. They work as an operational position at organizational level to provide support to different projects. They can influence a project to some extent but will not be directly resourced into project teams. In some organizations, organizational based sustainability managers are not even working full time on this position. They might be technical leaders from some department but also sustainability champions who are knowledgeable and passionate about sustainability.

Typically, their main responsibilities are to:

- develop and implement strategies that embed sustainability for the organization;
- write sustainability reports and provide sustainability organizational information to clients;
- build processes and systems to support sustainability implementation;
- work on strengthening a culture of sustainability within the organization;
- provide sustainability education to staff;
- set sustainability frameworks for management and performance measurement;
- develop and maintain sustainability frameworks and toolkits to facilitate various projects.

Another type of sustainability manager is usually called a “sustainability consultant”. In the organization, the sustainability group works as a functional
department that is project oriented and will actually bid for work. Currently, their work is generally related to climate change, such as greenhouse gas inventory assessment, policy change on carbon emission, innovative energy and resource efficiency solutions. They work in project teams and usually report to an environmental manager or project manager.

Existing sustainability managers have very diverse backgrounds. Ideally, sustainability managers have to be generalists, as many disciplines need to contribute to sustainability achievements. An engineering background is not a must, but some extent of technical knowledge can be very helpful, as sustainability managers need to talk the same language as the engineers. Furthermore, they need to know the industry very well, and reasonably know the system the organization is using to manage projects and make decisions, and the culture of the company. Of course, they need to understand the whole picture of the principles and concepts of sustainability and do need to know the infrastructure sustainability knowledge that can be implemented in the projects.

Generally speaking, while conducting their work, sustainability managers need a technical focus, system focus and behavior focus to:

- Understand engineering from a technical point of view,
- Understand the industry, organization, and how to respond to the project management process,
- Communicate with, connect with and influence people on what they do at their personal influential level.

More importantly, they have to be good at communication, passionate, and able to engage with people who have the detailed technical knowledge.

The following issues undermine current practice of resourcing sustainability managers at project or organization level:
• **Limited Power of Influence:** Although sustainability managers are resourced in many consulting and contracting companies in the Australian construction industry, their influence is still limited. Other people in the company tend to say that sustainability is not their responsibility, only the responsibility of the sustainability manager. Or, only if the chief executive says so, will they engage in sustainability considerations. Therefore, the sustainability manager tends to face a constant challenge in getting sustainability into projects.

• **Limited Impact on Projects:** Understanding, interpretation and implementation of sustainability in infrastructure projects are still at the infant stage. It will be most helpful if all staff is trained and all take responsibility. Thus, most sustainability managers in companies are actually working on training, awareness raising and education rather than driving initiatives in projects.

• **Risk of Taking All the Responsibility:** One of the main risks of resourcing a sustainability manager in a project or organization is that people will shirk the responsibility and shift the blame onto the sustainability managers. However, sustainability should be contributed by all disciplines and everyone in the project, and eventually be part of everything we do. During the transition to this ideal state, the position of sustainability manager should be a temporary one, and its role should be to remind people of what is possible.

> “I think it’s good to have some champions. But one of my concerns of having “sustainability people” is what will happen is that this “sustainability person” is responsible for sustainability and no one else in the team takes on the ship. My view is it’s great to have champions who constantly try to challenge the status and the way we always done it. But they shouldn’t be taking responsibility for trying to be the person that imbeds sustainability into the job. Every single designer on the project needs to be involved.”

**Remark by an interviewee**
Community of Practice (CoP)

A Community of Practice (CoP) can be defined as a cluster of people who share a common interest, an area of knowledge, a set of problems or a passion about a topic. They are organized around a common shared interest and share experience and practice on an ongoing basis to deepen their knowledge and expertise (Wenger et al., 2002). CoPs can be various: informal or formal, natural or supported, structured or unstructured. They capture, organize, share and maintain the body of knowledge by providing a platform for the practitioners in the area to interact around problems, solutions, insights and best practices. Thus, CoPs are seen as an important KM technique and have an essential role in knowledge sharing and, in turn, can develop a more knowledge-productive culture of learning in organizations (Wenger et al, 2002; APQC, 2001).

Usually, new CoPs can form as new issues emerge, and old ones close when their area of interest becomes common knowledge. As sustainability is still a fresh and subjective issue without agreed definition and standard solution, the emergence of
relevant CoPs is natural. Wallace (2005) suggests that “whatever the case, the important first step of any organization intending to market and deliver sustainable development service is to set up a CoP in sustainable development that crosses all the business lines of the company.” Furthermore, to achieve sustainability goals, a systematic view should be adopted and all disciplines involved in infrastructure development should all contribute. As CoPs exist outside the formal organizational structure, they have the advantage of sharing knowledge and triggering collaboration across functional boundaries.

It has been identified from the interviews that CoP is a common KM technique that is being adopted by the sustainability practitioners within the industry to spread sustainability knowledge; however, most of these CoP-like groups are not recognized as CoPs at all. Infrastructure sustainability CoPs lie in different levels: industry, organization, project and inter-project. Sustainability managers and sustainability champions are playing important roles within sustainability CoPs.

Existence of a sustainability CoP within an organization depends largely on the firm’s perceived market for infrastructure sustainability and the level of corporate commitment. Usually the CoP is supported by the top administrative level and initiated by a coordinator or coordinating team. The coordinator/coordinating team members are the sustainably champions within the firm who are knowledgeable, experienced and very enthusiastic sustainability. They act as housekeepers to collect knowledge, coordinate discussions, maintain the sustainability knowledge database, and disseminate best practices. More importantly, as a CoP cuts across department and discipline boundaries and is open to everyone, the sustainability focus can be expanded beyond the scope of “greenies” (people with an environmental background are called “greenies” in the industry). Furthermore, the coordinators also act as quasi-mentors for others and become guardians of professional expertise and important originators of knowledge assets. They initiate training and workshops, trying to encourage more and more people to talk about sustainability, and consider every possible opportunity to embed sustainability into actual projects.
Similarly, CoPs also exist at project level if the project has a strong sustainability focus and has a high level of commitment from main stakeholders, especially from the clients. Sustainability managers are resourced to drive sustainability training and implementation. They bring previous best practices from their mother organizations and, in return, collect the lessons learned from the projects they work on to enrich a mother organization’s sustainability knowledge assets. Although project-based CoPs are short-term and temporary, they are an important approach to raise sustainability awareness among the existing industry practitioners by providing them real project sustainability experience. Although only a small portion of potential members can become active participants, they will accumulate sustainability knowledge and may be more active in future projects.

Contributions from the organization are important. They encourage the emergence of the CoPs, support them with facilities such as meeting rooms, database and virtual discussing forums, and sometimes provide a modest time budget for the coordinator. Currently in the industry, many sustainability managers that have been resourced in projects and organizations are actually playing the role of sustainability CoP “housekeeper”. As discussed in the previous section, these sustainability managers are sometimes part-time or even full-time CoP coordinators. Furthermore, they participate in the industry level sustainability CoPs, communicate and network with other sustainability managers and champions, and then bring back state-of-the art concepts and solutions to their own company and projects. Sustainability CoPs at industry level exist principally to provide a supportive professional network for their members. This is how sustainability knowledge is shared across organizational boundaries.

At industry level, professional institutions, which are essentially CoPs that have become big and formal, are playing an important role. In the Australian construction industry, active sustainability focused associations include the Australian Green Infrastructure Council (AGIC) and the Sustainability Group within Engineers Australia. Other associations such as the Queensland Major Contractor Association (QMCA) and the Civil Contractors Federation of Australia
(CCF) are also promoting some aspects of construction sustainability. These professional associations collect, organize and store sustainability knowledge, identify and reward industry good practices, facilitate industry education and training, provide relevant tools, hold relevant conferences and workshops, and more importantly, provide a platform for the sustainability practitioners to share ideas.

Although professional associations and conferences continue to contribute to sustainably knowledge sharing, the proportion of people able to take advantage of them is typically small. Moreover, they fail to influence people at a deep and personal level, especially beginners. Usually, contact with peers within people’s immediate environment is more comfortable and effective. Thus, different levels of CoPs should be integrated for knowledge sharing.

...I think the role of professional associations is very important... I think it is the only way how industry best practices can be shared.... They got a role in terms of facilitating knowledge share, hosting conferences sessions on what have happened, internet chat session etc.... But the problem is that sometimes people are so busy with their day-to-day work.

Remark by an interviewee

**Sustainability CoP**

- Existing sustainability CoPs lay in project teams, organizations, within projects and at the industry level (industry sustainability associations).
- Sustainability CoPs should not be limited by business departments, disciplines and position hierarchies.
- Sustainability champions are active participants of sustainability CoPs.
- Sustainability CoPs accumulate sustainability knowledge, and foster sustainability activists, thus are effective KM technique that promotes sustainability knowledge sharing and culture cultivating.
5.6.5.6 Sustainability Measurement

According to the Association of Chartered Certified Accountants (2008), “Sustainability measurement is a term that denotes the measurements used as the quantitative basis for the informed management of sustainability”. It usually covers environmental, social and economic domains and is still evolving. Frameworks, criteria, indicators, KPA/KPIs, as well as assessment, appraisal tools and other systems are currently used for sustainability measurement in various levels and domains, including the construction industry. Especially in the building sector, sustainability rating tools (e.g. Green Star, LEED, BREAM, etc.) are widely adopted, as discussed in Section 2.3.3.

Such a measurement system is also essential for sustainability implementation in infrastructure projects. As sustainability is still a subjective term without a well-accepted and practical definition within the infrastructure sector, project teams need to interpret what sustainability means to their project – firstly, with regard to the stakeholders’ expectations and the unique nature of their projects. Sustainability frameworks and indicators thus have the potential to translate the generic concept of sustainability into practical guidelines for its application.

Wallace (2005) also suggests that in order to promote tangible achievement at the project level, it is critical to develop a sustainability framework, set project sustainability goals and adopt a process to measure the progress. Such practice can facilitate the project owner, designers and construction team with setting practical project goals and striking a balance between the stakeholders’ aspirations and the issues of cost, risk, time, profit and achievability.
From a knowledge perspective, a framework and compliance indicators are also indispensable for their ability to provide a scope and catalogue to index what the required knowledge is in order to achieve the project’s sustainability goals successfully. Furthermore, they can be seen as the “tables of content” of all the sustainability initiatives that the project adopted, and can easily be retrieved for future projects. Thus a comprehensive set of project-suitable frameworks and indicators are important tools for measuring achievement, demonstrating tangible outcomes to stakeholders, building a knowledge base for practitioners, and indexing sustainability concerns and implementations for future projects.

This belief is echoed by the questionnaire survey findings discussed in previous sections (see Section 4.6.7): that the project target is seen as one of the most important KM enablers to promote sustainability knowledge management at project level. Many interviewees acknowledged that, if there were serious sustainability foci and considerations in a project, a framework to define sustainability is indispensable. Roughly designed criteria are also used to support communication and decision-making. These criteria can either come from the clients in the bidding document as the basis of decision-making, or be suggested by designers in later stages as important options. However, development and usage of elaborate indicators is still rare in current practices.

*Remark by an engineering consultant*
The biggest driver for the existence of such frameworks and indicators is the client. At the same time, the client is also the main challenge.

### Sustainability Measurement

- Frameworks, indicators, assessment tools, etc. are indispensable to the success of project sustainability.
- From a knowledge perspective, sustainability measurement provides a direction for the project sustainability practice, thus setting the scope of what knowledge is needed to achieve the goals.

#### 5.6.5.7 IT Tools: Intranet, Database and Others

KM practice can be heavily facilitated by the use of various KM tools to perform the KM processes (e.g. obtain knowledge, share knowledge, maintain knowledge and apply knowledge). The KM techniques discussed in previous sections are mainly soft and not IT tools; there are, however, various IT tools that are used for the management of sustainability knowledge, such as the Internet, Intranet, Databases and ICT tools. Although none of these IT tools are described as KM-specific, they contribute towards the enhancement of communication, networking efficiency and other issues relevant to sustainability knowledge. Effectiveness of such IT tools depends largely on the extent to which they are used to process sustainability knowledge.

An Intranet is an information communication technology (ICT) system based upon Internet technology, which is now widely used in organizations to distribute information (Boersma and Kingma, 2005). It can be seen as a company-wide Internet through which all staff in the company can browse uploaded information and retrieve documents stored in the linked database from a remote office, a project site or home. Company procedures, templates, standard statements, previous project information and other explicit knowledge can be stored in an
intranet to accumulate organization’s knowledge asset. Furthermore, a well-developed intranet will also allow people to communicate with other colleagues via its ICT tools to transfer tacit knowledge. Thus, it is seen as a valuable KM tool which can improve communication and enable better collaboration among various functional departments and different projects (Tan et al., 2010). It has the potential to facilitate knowledge identification, knowledge storage and knowledge sharing if the tool is well developed and used.

In the Australian construction industry, many big companies have built up Intranets. They facilitate the management of sustainability knowledge in the following ways.

**A. Storing Sustainability Knowledge**

Usually specific storing space is given to each knowledge domain, including sustainability knowledge if there is sustainability consideration in the organization. Relevant resources to be stored in the database usually include: 1) Information of internal projects which have a strong sustainability focus; 2) Technical papers, news articles, conference papers, discussion papers and reports on sustainability and infrastructure themes; 3) Examples of sustainability-relevant tools, frameworks, indicators and checklists that can be used by projects to plan, design, deliver and operate infrastructure projects; 4) Training and education information; 5) Index of external resources, e.g. references, websites, links to national and international organizations.

**B. Representing Knowledge**

On the Intranet, it is common for a knowledge domain to have a homepage. Sustainability related resources being stored in the database are presented here to facilitate people’s search for, and retrieval of, information.

Sustainability knowledge is usually indexed by three means: theme, people and project. Firstly, sustainability knowledge can be categorized according to
differently themes, such as GHG (Greenhouse Gas) emission assessment, energy saving, sustainable material, sustainability appraisal and assessment tools, carbon management and climate change and sustainability policy. This indexing approach makes it easy for people to browse by content, and is especially effective for knowledge obtaining and storing for companies which have established sustainability business units and are actually delivering sustainability services. Furthermore, explicit knowledge can be effectively indexed in this way, and is thus more suitable for referencing of training and education materials.

Secondly, sustainability knowledge is linked to projects for the reason that the infrastructure sector is a highly project-based industry sector and sustainability can only be achieved project-by-project. One of the essential functions of organizational databases is to store previous project information for later usage to prevent re-inventing the wheel. This information includes project bidding documents, design drafts, post-project reviews, and project sustainability reports. Sustainability initiatives, such as sustainability appraisal tools, improvements in certain sustainability themes, mistakes and lessons learned, can be retrieved later and reused in similar projects, and form the basis of organizational knowledge assets.

Indexing through people is highly praised by many interviewees. It is a fact that much valuable knowledge is hidden in people’s mind and it takes enormous time to be articulated and written down. It is also questionable sometimes, depending on whether it is peer reviewed, corrected etc. On the other hand, conversations with experienced people can happen very quickly. It is also supported by the questionnaire survey results (See Section 4.6.2) that industry practitioners usually go to their colleagues (ranked 1st, mean 4.2) and internal experts (ranked 2nd, mean 3.92) for sustainability knowledge rather than to the database, which is ranked 11th (mean 2.90). Thus, practically, some organizations will have “people pages” on their Intranet. Staff members are asked to indicate and regularly update their professional experience and knowledge, as well as useful reference documents. Knowledge domains and projects are linked to people in the
organization. This is how people with the knowledge can be easily identified and approached by other staff.

### Representing Sustainability Knowledge

- Sustainability knowledge can be indexed in three ways: by themes, by people, and by project.
- Knowledge themes, relevant experts and practitioners, and projects should be cross-indexed to facilitate future reuse.

### C. Supporting Communication

The Intranet can also have the function to facilitate communication on sustainability knowledge. Wiki-style forums help people to discuss and get feedback on certain sustainability issues and broader infrastructure development to solve their problems at hand.

*Remark by a sustainability manager*

> I’m trying to do is that I created a list of projects with either generated sustainable outcomes. I would also include things like the nature of the project could be considered sustainable. I put the list on the webpage and intend people to either email me or others to contribute to that list. We got a little bit of track of record of what the project is about, why it was sustainable (we got a category such as good community outcomes, green house gas assessments etc), so try to track that information, we got 50% projects on that website in the moment, I will expect it will grow.

*Remark by a sustainability manager*
5.6.5.8 Case-based Reasoning

Broadly construed, case-based reasoning (CBR) can be seen as a problem-solving method, relying on previous similar cases to find solutions to current problems. According to Kolodner (1993), a case is a “contextualized piece of knowledge representing an experience that teaches a lesson fundamental to achieving the goals of the reasoner”. A typical process for CBR consists of four steps, namely retrieve, reuse, revise, and retain. It has been formalized for purposes of computer reasoning; however, in fact it is a pervasive behavior in everyday human problem solving.

In the construction industry, which is a highly project-based industry, CBR, as a method, is playing an important role in transferring knowledge through projects. Industry practitioners are doing their jobs based on past cases personal experience. Furthermore, much domain knowledge is shared in the form of project information and case studies. The power of exemplar projects is undeniable.

Sustainability initiatives and lessons learned from actual projects are valuable knowledge asset for the project stakeholders, involved organizations and the whole industry. Team members will bring the sustainability knowledge gained from these projects to future projects and reuse them to solve new problems. Interviewees indicate that industry practitioners who had sustainability related experience in previous projects are more likely to be active in pursuing sustainability knowledge and apply it wherever possible. Organizations accumulate sustainability knowledge from internal projects and this contributes to future projects. An interviewee, an organizational-based sustainability manager in an engineering consulting firm, described the process of tracking previous project information for the usage of new projects as follows:

At industry level, industry best practice is seen by most of the interviewees as the best format for transferring sustainability knowledge. It is also supported by the previous questionnaire survey results where industry best practice is ranked as the third most important source of people’s sustainability knowledge (after colleagues
and internal experts; see Section 4.6.2). However, interviewees are feeling nervous about using the term “best practice” as sustainability is an area where best practice is still uncertain. They prefer to use “good practice” and “better practice” instead because there are not many really good projects in the infrastructure sector where sustainability has really driven the outcome.

Case studies of such “good practices” are highly praised by industry practitioners as a vehicle for sustainability knowledge dissemination. Small case studies of individual sustainability issues are often more useful than case studies of the whole project which are sometimes too general to give helpful information. Professional associations are supposed to take the role of publishing good quality case studies on infrastructure sustainability. However, the current main challenge is still the lack of existing exemplary projects.

Finding it first is challenging in terms of what is best practice. This is fairly a new area and there is no enough information around. It does take a lot of time to get that. It will be good if we have more time to do the research, establish where the best practice were and set the benchmark for the project.

Remark by a sustainability manager

Case-based Reasoning

- The infrastructure sector uses CBR on sustainability through: reuse of previous project experience, learning from similar projects, and learning from industry best practice.

- Industry best practice contained in project case study format is the most effective vehicle to transfer sustainability knowledge for infrastructure development.
### 5.7 Main Findings of the Interviews

Table 5.3 extracts and highlights the main findings of the questionnaire survey.

**Table 5.3: Main Findings of the Interview Study**

<table>
<thead>
<tr>
<th>Topics investigated</th>
<th>Remarks</th>
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</table>
| 1. The Body of Sustainability Knowledge in Infrastructure Sector | - Subjective, not well defined in the industry; thus every project needs to define sustainability according to the project’s characteristics.  
- Rare “good practice” exemplar projects  
- Sustainability knowledge has similarity to other knowledge domains, but bad attitudes stop the KM cycle. |
| 2. Main Barriers                                          | - Lack of awareness  
- Deficiency of current sustainability education  
- Lack of guidelines and examples for industry practitioners to move from talk to action |
| 3. KM Enablers                                            | - Knowledgeable and committed project client  
- Leadership  
- Project target  
- Policy and legislation  
- Practitioners with multidisciplinary knowledge  
- Industry sustainability awareness  
- Network of subject-matter experts |
| 4. Existing Strategies on Managing Sustainability Knowledge | **Post Project Review (PPR)**  
- Conducting PPR is important to identify and capture the generated knowledge and lessons learnt on sustainability for future reuse.  
- PPR is a popular technique in the infrastructure sector, but not yet fully explored to review sustainability initiatives.  
- Project report is by nature a PPR report on sustainability. |
|                                                          | **Sustainability Reporting**  
- Current practices of sustainability reporting are organization-based or project-based. |
- Project sustainability report is similar to a PPR on sustainability. It is a very effective way of identifying, recording and sharing sustainability information on projects.
- Sustainability reports should provide techniques and decision-making information and be objective.

### Education and Training
- Sustainability education is critical for the infrastructure sector to raise the industry practitioners’ awareness and to build the absorptive capacity for sustainability knowledge.
- Sustainability education can be provided in project teams, in organizations and at an industrial level.
- Face-to-face communication is still the most effective way to deliver sustainability education as it allows open discussion.
- Sustainability education should be delivered in a systematic and structured way.
- Getting people on board is a challenge.

### Sustainability Staffing
- There are sustainability managers (formal positions) and sustainability champions in the infrastructure sector.
- They are knowledgeable and passionate about sustainability, and are valuable knowledge assets for organizations and project teams.
- Sustainability champions are taking the leadership role in the infrastructure sector to promote sustainability applications.
- They contribute greatly to the management of sustainability knowledge in the industry sector.
- Important capabilities of these sustainability people are: passion for sustainability, communication skill and knowledge of different disciplines.

### Community of Practice (CoP)
- Existing sustainability CoPs lay in project teams, organizations, within projects and at the industry level (industry sustainability associations).
- Sustainability CoPs should not be limited by business departments, disciplines and position hierarchies.
- Sustainability champions are active participants of
sustainability CoPs.
- Sustainability CoPs accumulate sustainability knowledge, and foster sustainability activists; thus, they are an effective KM technique that promotes sustainability knowledge sharing and culture cultivation.

**Sustainability Measurement**
- Frameworks, indicators, assessment tools, etc. are indispensible to the success of project sustainability.
- From a knowledge perspective, sustainability measurement provides a direction for the project sustainability practice, and thus sets the scope of what knowledge is needed to achieve the goals.

**IT Tools – Intranet, Database and others**
- IT tools facilitate the storage, representing and sharing of sustainability knowledge.
- Sustainability knowledge can be indexed in three ways: by themes, by people, and by project.
- Knowledge themes, relevant experts and practitioners, and projects should be cross-indexed to facilitate future reuse.

**Case-based Reasoning**
- The infrastructure sector uses CBR on sustainability through: reuse of previous project experience, learning from similar projects, and learning from industry best practice.
- Industry best practice contained in project case study format is the most effective vehicle to transfer sustainability knowledge for infrastructure development.

5.8 **Summary**

The semi-structured interview findings presented in this chapter have been used to outline the current status of the management of sustainability knowledge in the Australian infrastructure sector. The body of sustainability knowledge, key constraints for its application, the main enablers for successfully knowledge management, and the roles of diverse stakeholders were analyzed.
Currently in the industry, general awareness of sustainability and relevant education is still far from satisfactory. These are the main obstacles which are inhibiting the platform for the KM activities of managing sustainability knowledge. Moreover, infrastructure sustainability is still an area where best practice is uncertain. The lack of practical guidelines and exemplar projects are the urgent issues for the industry.

Prerequisites to enable successful sustainability related KM initiatives are also discussed. A knowledgeable and committed project client can provide the most powerful driver for project sustainably achievement, thus motivating the project team members to actively obtain, share and apply sustainability. A strong leadership is essential to organizations and teams to alter their conventional business mode to embed more sustainability elements. Furthermore, high but achievable project targets are indispensable for interpreting sustainability in project contexts; these also set the scope for knowledge activities. Last but not least, the culture of sharing knowledge is critical to any KM initiatives.

Despite KM still being a new concept to the construction industry, there is evidence to suggest that there are aspects of current practice that broadly reflect current thinking and efforts in this area, albeit with differences in emphasis. KM tools that are currently used by the industry to manage sustainability are identified and discussed. Although these initiatives may not be given a formal KM title, they are actually addressing the issue that the industry is facing massive challenges to fill the knowledge gap in linking sustainability concepts to actions. These initiatives include: post-project review (PPR), education and training, sustainability reporting, sustainability staffing, community of practice (CoP), sustainability measurement, case-based reasoning and diverse IT tools.

However, the absence of a proactive strategy for the management of the sustainability knowledge means that the potential benefits of KM will not be fully realized. It will also make it difficult to measure the impact of any initiatives that are geared towards the management of knowledge.
CHAPTER 6
CASE STUDY

6.1 Introduction

Through the semi-structured interviews, the holistic environment, general approaches, relevant enablers and other important issues of managing sustainability knowledge in the Australian infrastructure sector were studied and reported in the previous chapter. To further investigate these issues especially at project level, two case studies were conducted.

The purpose of the two case studies is (1) to investigate how sustainability knowledge is applied in project and how KM support sustainability application in the project scenario; (2) to verify the findings (e.g. KM enablers, KM activities, KM strategies, etc.) of the previous questionnaire survey and interviews; and (3) to provide real project examples that demonstrate how those KM elements within the proposed KM framework may influence and facilitate the management of sustainability knowledge during infrastructure development.

This chapter presents and analyzes the data gained from the two case projects. It first clarifies the selection of these two case projects and the data collection methods used to conduct the case studies. Then it discusses the characteristics of Case Project A and Case Project B. General information of the projects were provided firstly, followed by the processes, methods, tools and other issues that the project teams used to embrace sustainability knowledge and implement them in the real projects.

6.2 Selection of Case Study Projects

As introduced in Chapter 3, during the semi-structured interviews, industry practitioners were asked to recommend recent infrastructure projects that not only
had strong sustainability focus, but also took KM strategies and initiatives to identify, and obtained the knowledge they need, passed that knowledge to the whole project team, actually implemented the knowledge on the project, stored and transferred their experience and innovation to the industry.

However, sustainability in the Australian infrastructure sector is currently an area where good practices are rare. Not many projects had shown strong sustainability commitment beyond compliance at project level yet. Not to mention that, as KM is still an emerging concept for the construction industry, even less projects had systematically embraced KM methods on managing sustainability relevant knowledge.

Considering the above-mentioned circumstances, it was a challenging job to find projects that firstly had a strong sustainability focus, secondly, had proactive and systematic KM initiatives at project level. Thus only two case projects recommended by interviewees were selected to study, the Northern Gateway Alliance (NGA) project near Auckland in New Zealand and the SAFElcink Alliance project near Brisbane in Australia.

Although NGA project is located in New Zealand, the general contractor of the project is an Australian construction company. Furthermore, the construction industry in New Zealand and Australian share similar culture and technique, in particular, the NGA project was in compliance with both New Zealand and Australian relevant standards. Thus NGA project was considered eligible to be selected as a case project for this research.

However, the two case projects reflected different emphasis on how the project team managed sustainability knowledge relevant to the project, due to the different conditions and how sustainability focus emerged on the project. Eventually, the two case projects provided mutually complementary data to this research.
In Case Project A, sustainability requirement was high on the agenda from the initiating phase of the project mainly due to the new legislative environment. With a strong commitment from the client and Alliance senior level, sustainability consideration were integrated in the project from the design phase and systematically measured and monitored in the later stages. Thus the researcher is able to investigate how relevant knowledge was transferred across project phases.

Case Project B gives a different story. Extensive sustainability considerations were not embraced into the project during the project initiating stage. After the project team was formed, a sustainability champion for the Alliance Leadership Team (ALT) raised the relevant issues up and then the project team started to incorporated into the project performance measurement system. Extensive education and other communication initiatives have been a strong emphasis in the Alliance team. As a result, the construction team and some very senior managers and engineers are enthused and carried the learning to future projects.

6.3 Case Study Data Collection

The two case studies were conducted from January to May in 2010. Multiple data collection methods were employed to collect extensive data from various sources, including interviews, documents, archival records and observation.

6.3.1 Interviews

Interviews via different approaches were conducted to the key sustainability persons on the two case projects, including Sustainability Coordinator/Champions, Design Managers, Construction Manager and Executive staff form mother companies etc.

Case project A is located in New Zealand and was completed a year before this case study was conducted. As the Alliance staffs were already dismissed from the project and working on others around Australia and New Zealand, phone and
email interviews were adopt. Case project B is located in Brisbane, thus all interviews were conducted face-to-face.

Table 6.1 shows the list of 9 interviewees who participated in the case studies.

<table>
<thead>
<tr>
<th>Interviewee’s Position in the Project Team</th>
<th>Mother Company</th>
<th>Interview Approach</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability Champion</td>
<td>Engineering Consulting</td>
<td>Phone &amp; Email</td>
<td>2 times, 3 hours in total</td>
</tr>
<tr>
<td>Project Alliance Board (PAB) Member</td>
<td>General Contractor</td>
<td>Phone &amp; Email</td>
<td>1.5 hour</td>
</tr>
<tr>
<td>Design Manager</td>
<td>Engineering Consulting</td>
<td>Phone</td>
<td>0.5 hour</td>
</tr>
<tr>
<td>Construction Manager</td>
<td>General Contractor</td>
<td>Phone</td>
<td>0.5 hour</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interviewee’s Position in the Project Team</th>
<th>Mother Company</th>
<th>Interview Approach</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability Coordinator</td>
<td>Engineering Consulting</td>
<td>Face-to-face</td>
<td>2 times, 4 hours in total</td>
</tr>
<tr>
<td>Sustainability Representative</td>
<td>Engineering Consulting</td>
<td>Face-to-face</td>
<td>0.5 hour</td>
</tr>
<tr>
<td>Project Director</td>
<td>Client</td>
<td>Face-to-face</td>
<td>1 hour</td>
</tr>
<tr>
<td>Alliance Leadership Team (ALT) Member</td>
<td>General Contractor</td>
<td>Face-to-face</td>
<td>1.5 hour</td>
</tr>
<tr>
<td>Onsite Engineer</td>
<td>General Contractor</td>
<td>Face-to-face</td>
<td>0.5 hour</td>
</tr>
</tbody>
</table>

6.3.2 Archival Records and Documents

Diverse archival records and documents from the case projects were collected and used to extract data for research purpose, including:

- Corresponding letters with project team members,
- Sustainability reports,
- Project monthly/annually reports,
- Other project documents involves project information on sustainability, and
- Project related case studies and publications.

As discussed in Chapter 5 (see Section 5.6.5.3 for reference), sustainability reporting on projects is becoming an important approach for storing and passing sustainability knowledge. The two case projects both have developed regular monitoring reports as well as reviewing reports on project sustainability considerations, initiatives and implementations for team members, wilder stakeholders and the whole industry and public. Moreover, as the two projects have been complemented, case studies on certain subjects have been published around these two projects. These documents provided extensive information for this research in regards to project facts.

### 6.3.3 Observation

While this case study was conducted, Case project B was at its closure phase and some knowledge & experience exchanging programs were going on. The researcher attended one of the inter-project meetings which was held by the client and attended by many Sustainability Managers and sustainability champions from other projects to share sustainability experience and gains on their projects. This informal observation was used to discover the forms, process, culture and communications of such knowledge transferring activities.

### 6.4 Case Project A

The following sub-sections introduce the key information about the Case Project A – Northern Gateway Alliance (ALPURT B2) Project. To fulfill the aims of this research, sustainability considerations on the project, how they were embraced
into the project, and how the project team managed relevant sustainability knowledge were introduced in following subsections.

6.4.1 Project Overview

At a total cost of $360 million New Zealand dollars (around 248 million Australian dollars), the 7.5km Northern Motorway Extension of State Highway 1 between Orewa and Puhoi (also known as the ALPURT B2) was the largest ever capital single engineering project in New Zealand in 2004. It was also one of the largest engineering projects ever undertaken in New Zealand (Boffa Miskell. (2010).

This project was of regional and local significance. The previous State Highway 1 route between Orewa and Puhoi contained winding, narrow sections of road and was not designed to carry heavy traffic volumes. The new motorway, which is mostly four-lane, features clearer sight lines, smoother turns and reduced road gradients, making for a safer drive. It was an important project to demonstrate the vision of the Auckland Regional Land Transport Strategy. Since completed, the motorway improved transport infrastructure and support the economic and social well being of Northland, Rodney District and the wider Auckland region. It was also the first toll road on the State Highway Network in New Zealand and the construction is partially funded from debt finance repaid from the toll revenue (Australian National Construction Review, 2009).

This project was one of the nation’s most challenging road projects to build because of the engineering and environmental complexities. The new motorway passes through a diverse landscape and areas, many of which are environmentally sensitive areas that are home to endangered and protected flora and fauna. Constructing works of the project consists of a 7.5 km of 4-lane motorway, 3.3 million cubic meters of soil and rock to excavate, move and compact, 6 bridges, a twin road tunnel, 200,000 m² pavements, drainage, retaining walls and barriers and tolling infrastructure. Therefore, environmental and social measures and
performance were considered to be critical to the success of the project. Table 6.2 summarizes the key information of Case Project A.

Table 6.2: Key Information of Case Project A

<table>
<thead>
<tr>
<th>Location</th>
<th>State Highway 1 between Orewa and Puhoi, north of Auckland, New Zealand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>The New Zealand Transport Agency (Formerly Transit NZ)</td>
</tr>
</tbody>
</table>
| Form of Contract | Alliance – special contract  
Subcontractors engaged under Master Builder subcontractor agreement (3% of the work) |
| Total Cost | AU $248 million (Transit New Zealand funded)  |
| Project Construction Timescale | December 2004 - January 2009 |
| Some Project Statistics | 7.5 km of 4 lane motorway  
380-meter twin tunnels, state of the art  
over 4 million m$^3$ earthwork, cut/fill balance  
6 structures  
200,000 m$^2$ pavements |
| Benefits | To ease traffic congestion through Orewa, enhance opportunities for economic growth in the Rodney District and create a safer and easier route between Auckland and Northland. |

Despite the complexity and engineering challenges, the project was delivered ahead of time and to budget. Moreover, it had a full integration of social and environmental measures and, in process, promoted sustainability consideration and innovative practices. Table 6.3 shows a list of state and national awards and high commendations received by the project for its Environment and Sustainability achievements.
Table 6.3: List of Sustainability Related Awards Received by Case Project A

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2009, <strong>Concrete³ Sustainability Award</strong>, Cement and Concrete Association of New Zealand.</td>
</tr>
<tr>
<td>2</td>
<td>2009, <strong>Arthur Mead Award for the Environment and Sustainability</strong>, Institute of Professional Engineers New Zealand (IPENZ).</td>
</tr>
<tr>
<td>3</td>
<td>2008, <strong>Sustainability Award for Excellence</strong>, New Zealand Institute of Landscape Architects (NZILA), Pride of Place Landscape Awards.</td>
</tr>
<tr>
<td>4</td>
<td>2008, <strong>Silver Award in Landscape Design</strong> in the Commercial / Industrial / Institutional category, New Zealand Institute of Landscape Architects (NZILA), Pride of Place Landscape Awards.</td>
</tr>
<tr>
<td>5</td>
<td>2008, <strong>Best Practice (Environmental Sustainability) Award</strong>, Roading New Zealand Excellence Awards.</td>
</tr>
<tr>
<td>6</td>
<td>2008, Auckland Branch of NZ Contractors Federation’s <strong>Overall Safety Award</strong> for All Categories.</td>
</tr>
<tr>
<td>7</td>
<td>2007, <strong>Supreme Environmental Award</strong> for projects over $10 million in value, New Zealand Contractors Federation awards.</td>
</tr>
<tr>
<td>8</td>
<td>2006, the Public Relations Institute of New Zealand’s (PRINZ) award for <strong>Best Sustained Public Relations Program</strong> at the 2006 annual PRINZ awards.</td>
</tr>
</tbody>
</table>

### 6.4.2 Project Stakeholders and Project Team

Due to the high risks and complex engineering challenges of the project, the project client - NZ Transport Agency – selected the Alliance model to design, project management and construct the project, for its advantages over traditional contracting models on addressing non-financial issues (Northern Gateway Alliance, 2007). As the New Zealand’s state highway manager, NZ Transport Agency considered that alliance is particular suited to complex projects and where the interests of the community, environment, business and Government must all be considered. Under such circumstance, Northern Gateway Alliance (NGA) was formed to design, project management and construct this project. Table 6.4 summarizes the participant organizations of the Alliance.
Table 6.4: Participants of Case Project A

<table>
<thead>
<tr>
<th>The Alliance</th>
<th>Northern Gateway Alliance (NGA)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client</strong></td>
<td>The New Zealand Transport Agency (Formerly Transit NZ)</td>
</tr>
<tr>
<td><strong>Contractor</strong></td>
<td><strong>Contractor A</strong>: one of Australia's largest project development and contracting group.</td>
</tr>
<tr>
<td></td>
<td><strong>Contractor B</strong>: a large infrastructure construction, roadworks and aggregate supplier company in New Zealand, which is also active in wider Australia.</td>
</tr>
<tr>
<td><strong>Designers &amp; Consultants</strong></td>
<td><strong>Designer A</strong>: An international engineering consulting firm from Australia, with 40 offices and approx. 46,500 employees around the world.</td>
</tr>
<tr>
<td></td>
<td><strong>Designer B</strong>: An environmental and engineering consultancy based in New Zealand.</td>
</tr>
<tr>
<td></td>
<td><strong>Designer C</strong>: A leading New Zealand environmental planning and design consultancy.</td>
</tr>
</tbody>
</table>

The NGA operates as a “virtual organization” and is governed by the Project Alliance Board (PAB), which was formed by representatives from every Alliance participant’s senior management teams. The PAB met monthly at the Project Office, guided the NGA’s management direction, monitored performance against the project KRAs and KPIs, and provided the ultimate decision-making for the Alliance.

Day-to-day management of the Alliance was the responsibility of the Alliance Management Team (AMT), led by Project Director, who reported to the PAB. Under the Project Director, there were separated groups led by assigned managers including Design & Engineering Manager, Construction Manager (Road & Earthworks), Construction Manager (Structures), Construction Manager (Tunnels), Environment Manager, Project Services Manager, and Commercial Manager etc. Figure 6.1 shows the structure of the Alliance.
6.4.3 Emergence and Execution of Sustainability on the Project

New legislative environment had been an important driver that triggered the project team to embed extensive sustainability considerations into this significant infrastructure project.

In 2002, the New Zealand Transport Strategy (NZTS) was published by the New Zealand Government to direct the transport sector to effectively respond to the sustainability requirements and to support the nation becoming more sustainable (New Zealand Ministry of Transport, 2002). Later in 2003, the principles and objectives of the NZTS were legislated into the Land Transport Management Act (LTMA) (New Zealand Ministry of Transport, 2003) and came into effect.

As the first environment-sensitive project that operated under the new act, ALPURT B2 project was required to integrate sustainability considerations that surpass the past similar infrastructure projects. As a result of these requirements, more opportunities for sustainability have been discovered and integrated into project design, as well as the decision-makings throughout the project (Griffiths, 2007). Specific requirements stipulated by the LTMA include:
To ensure the affected communities are adequately involved,

- To assist economic development,

- To assist safety and personal security,

- To improve access and mobility,

- To protect and promote public health,

- To ensure environmental sustainability,

In order to respond to the requirements of the LTMA and NZTS, the Alliance has taken specific actions to incorporate the principles of sustainability into a wide variety project facets, including the overall project objectives and performance measurements, design-decisions process, project management plans, HRM, stakeholder relationship strategies and construction methodologies (Griffith, 2007).

First of all, project vision was stated to show the commitment of the Alliance. Then project objectives were clarified to show the specific sustainability definitions to the very project. Sustainability criteria were developed and incorporated into decision-making processes during design and selecting options, furthermore, reviewing and verifying designs during later phases. Moreover, sustainability criteria were incorporated into and reflected in Project Management Plans. Together with the established KRA/KPIs and other initiatives, sustainability considerations were monitored and reinforced during construction phase.

6.4.4 Project Sustainability Interpretation

At the time this project was initiated in 2004, there was limited understanding on integrating sustainability on infrastructure projects. This was problematic in some ways as it was not clear to the project exactly what the team needed to do to achieve best practice sustainability performance as there was no guideline or
examples to follow, but it was positive in other ways as the project team was able to drive their own agenda.

As mentioned before, this NGA project traversed complex terrain through a highly sensitive and valued environment. Thus, compared with the other two pillars of sustainability (social and economic), environmental consideration was listed at the top of the project’s sustainability agenda.

Vision of the project was stated as:

**PROJECT VISION**
Create a visual showcase of environmental and engineering excellence.

In order to deliver the project vision, the following project objectives were developed:

**PROJECT OBJECTIVES**
- Safety first,
- Enhanced community relations,
- Team empowerment and recognition,
- Engineering excellence,
- Deliver a fully operational tollway under the LTMA, at the optimum whole-of-life cost,
- Net environmental benefit (enhancement),
- Achieve new behavioral benchmarks,
- A visual showcase.

Furthermore, the project team has developed an Environmental and Sustainability Policy to facilitate the Alliance with guidelines by which the project vision and sustainability objectives can be delivered.
Main resources guided this project sustainability framework include:

- Triple Bottom Line,
- Relevant LTMA criteria,
- Global Reporting Initiative (GRI) – Sustainability Reporting Guidelines,
- The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL),
- Project Sustainability Management Guideline– International Federation of Consulting Engineers (FIDIC).

### 6.4.5 Sustainability Implementation

In order to implement sustainability knowledge and make sustainability principles tangible and practical for the project, multi-criteria analysis tools, Project Management Plans and KRA & KPI framework were used to integrate sustainability into the project.
6.4.5.1 Multi-Criteria Sustainability Assessment

During the early stage of the project, multi-criteria were developed to integrate sustainability considerations into design options and were also considered for the designing of individual elements of the project. In the later phases, designs were reviewed and enhanced in progress when opportunities for enhancement were identified. Corresponding rating sheets were also developed for assessing individual elements of the design. These sustainability criteria and corresponding rating sheets had served as a checklist and a useful framework for decision-making, particularly when trade-offs were required during the project lifecycle. Table 6.5 summarizes the factors considered by the Alliance when assessing design elements in terms of sustainability.

Table 6.5: Decision Making Criteria for Sustainable Design
(Source: Griffith, 2007)

<table>
<thead>
<tr>
<th>Key Design Objectives</th>
<th>The “must meet” criteria for the specific design element.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consent Criteria</td>
<td>Both project generic and location specific consent requirements.</td>
</tr>
<tr>
<td>Design Standards</td>
<td>The relevant New Zealand and Australian Standards relating to the particular design element.</td>
</tr>
<tr>
<td>Design Issues Related to Sustainability Criteria</td>
<td>Relevant criteria that identified for each design element. These criteria were fed into the Sustainability Assessment Rating Sheet.</td>
</tr>
</tbody>
</table>

One of the examples of showing how sustainability criteria affected the project design option is the significant enhancement to the Specimen Design. In order to provide a preliminary assessment of the Specimen Design options, a review was carried out against the developed sustainability criteria by a multi-disciplinary team from the Alliance, including ecological, environmental, sustainability and engineering expertise. Table 6.6 is the rating sheet for this assessment that illustrates the relevant principles, criteria and weight for each criterion.
### Table 6.6: Sustainability Assessment Rating Sheet for Specimen Design
(Source: Griffith, 2007)

<table>
<thead>
<tr>
<th>LTMA Principles</th>
<th>Related Criteria</th>
<th>Specimen Design</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>W</td>
<td>S</td>
<td>WxS</td>
</tr>
<tr>
<td>Assist safety and personal security</td>
<td>Safety</td>
<td>40</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Weighted Total Safety and Personal Security</td>
<td>40</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>Improve Access and Mobility</td>
<td>Severance</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Public Transport</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Walking and Cycling</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Weighted Total Access and Mobility</td>
<td>5</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Ensures Environmental Sustainability</td>
<td>Landscape</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Wildlife</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Habitats</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Landtake</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Cultural / Heritage</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Earthworks Balance</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Drainage / Water Quality</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Air Pollution</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Noise &amp; Other Disturbances</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Weighted Total Environmental Sustainability</td>
<td>40</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>Community Impacts</td>
<td>Network Implications</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Disruption to community (due to construction)</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Weighted Total Community Impacts</td>
<td>5</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Life Cycle Impacts</td>
<td>Material Demand</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Disposal and Demolition</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Weighted Total Life Cycle Impacts</td>
<td>10</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td><strong>WEIGHTED TOTAL</strong></td>
<td><strong>100</strong></td>
<td><strong>300</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

W – Weight, S - Score
Rating on scale of 1 to 5; relative scores using the specimen design as the point of comparison

Weightings Used for Overall Total: 40% - Safety; 5% - Access & Mobility; 40% - Environmental Sustainability; 5% Community Impacts; 10% - Life Cycle
As per the Alliance, the Sustainability Assessment process ensured that “sustainability considerations were presented in all concepts, preliminary and final design reports by the designers and peer review by the sustainability advisors” (Griffith, 2007).

### 6.4.5.2 Project Management Plan

In order to ensure sustainability implementation on this project, sustainability principles were reflected in the Project Management Plans which incorporated sustainability criteria as appropriate to each area. Furthermore, the Environmental Management Plan (EMP) specifically detailed the Alliance commitment and action regarding to sustainability. Other than the Environmental & Sustainability Policy described in Section 6.4.4, there were some other sustainability activities governed by the EMP including:

- Sustainable Procurement Practices
- Sustainable Office Practices
- Waste and Energy Management Strategy

### 6.4.5.3 KRA & KPI Framework

The Key Result Area (KRA) and Key Performance Indicator (KPI) Framework for this project provides financial incentives and disincentives based on the cost and non-cost outcomes of the project. However, the primary aim of the KRA / KPI Framework is to drive the right behaviors, i.e. to promote innovative thinking towards achieving outstanding results.

Key Result Area means an area of the project in which the performance is of significant interest to the Alliance participants and other stakeholders. To measure the performance, three KRAs have been adopted according to the TBL (triple bottom line) framework - economic, social and environment. The Economic KRA
has a 20% weighting; Social and Environment have equal weightings of 40% and all KRAs will combine to the overall score of the project performance.

Key Performance Indicator (KPI) means the indicator that demonstrates the level of achievement in a KRA, which is used to assess project performance. Each KPI has a measure that describes how it will be assessed as well as the frequency of reporting, which varies from monthly assessments to one-off assessments at the end of the project.

A Performance Spectrum has been developed for each KPI that describes the range of performance from “failure” to “breakthrough” with scores from -100 to 100. Interim points are defined along a spectra ranging from “inferior” through to “as expected” and “superior.” These labels are described as following:

- “Failure” – not achieving industry standards.
- “Inferior” – Industry BAU
- “As Expected” – Industry Best Practice
- “Superior” – Conceivable believable and setting a new industry benchmark
- “Breakthrough” – Conceivable but no known way of achieving. Requires methods and techniques that have not been used before or attitudinal shift and management focus that is unprecedented.
Table 6.7: Spectrum of KRAs and KPIs of Case Project A  
(Source: Northern Gateway Alliance. 2007)

<table>
<thead>
<tr>
<th>ECONOMIC KRA</th>
<th>Description</th>
<th>% within KRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Time – Practical Completion</td>
<td>20</td>
</tr>
<tr>
<td>C2.1</td>
<td>Engineering / Construction Excellence – Quality/Rework</td>
<td>60</td>
</tr>
<tr>
<td>C2.2</td>
<td>Engineering / Construction Excellence – Finishing Standards</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Operational Tollway</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SOCIAL KRA</th>
<th>Description</th>
<th>% within KRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1.1</td>
<td>Safety – TIFR</td>
<td></td>
</tr>
<tr>
<td>S1.2</td>
<td>Safety – Health &amp; Safety Audit</td>
<td>40</td>
</tr>
<tr>
<td>S1.3</td>
<td>Safety – Site Inspections</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Legacy – Skill Development</td>
<td>15</td>
</tr>
<tr>
<td>S3.1</td>
<td>Legacy – External Recognition</td>
<td></td>
</tr>
<tr>
<td>S3.2</td>
<td>Legacy – External Recognition (Conference Presentations &amp; Published Articles)</td>
<td>15</td>
</tr>
<tr>
<td>S4.1</td>
<td>Wider Community – Level of Engagement</td>
<td></td>
</tr>
<tr>
<td>S4.2</td>
<td>Wider Community – Local Media Coverage</td>
<td>15</td>
</tr>
<tr>
<td>S5.1</td>
<td>Key Stakeholders – Follow-up time</td>
<td></td>
</tr>
<tr>
<td>S5.2</td>
<td>Key Stakeholders – Annual Survey</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENVIRONMENT KRA</th>
<th>Description</th>
<th>% within KRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>EMP (Environmental Management Plan) Implementation</td>
<td>30</td>
</tr>
<tr>
<td>E2</td>
<td>Compliance with Legislation</td>
<td>30</td>
</tr>
<tr>
<td>E3</td>
<td>Net Environmental Benefit (NEB) Outcomes</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 6.7 shows the KRA/KPI framework of the NGA project. According to the developed KPIs, everyone on the project team was encouraged to find ways to deliver on the KPIs, look for and respond to the relevant opportunities when they arose. Relevant industry best practices were identified and utilized by the project through this approach. More importantly, the focus of environmental and social indicators encouraged had resulted in a number of innovations on the project. Specially, within the social KPIs, S3.2 Legacy – External Recognition (Conference Presentations & Published Articles) was specifically designed to encourage transferring project knowledge to the industry.
6.4.6 Approaches of Managing Sustainability Knowledge in the Project

6.4.6.1 Sustainability Staffing

The NGA Alliance did not resource a full time Sustainability Manager position. However, there was a keen sustainability champion from the consulting company who worked as an untitled Sustainability Manager on the project.

In the early stages of the project, the sustainability champion worked with the design and construction teams and reported to the Environment Manager. At this stage, the sustainability champion endeavored to make sustainability concepts tangible and practical for the project management and wider project team, and integrate the concepts into project design through setting project objectives and developing multi-criteria assessment tools.

During the construction phase of the project, she was also the KRA & KPI Manager reported to the Project Services Manager and helped to drive the Alliance performance across all the dimensions of triple bottom line as described in the previous subsection (see the KRA & KPI framework for reference). Furthermore, she had good access to the Project Director and also worked with various members of the AMT. As sustainability is a strong focus and an important part of the project vision, the sustainability champion had good opportunities to exert her influence and convince the right people to help make things happen.

Briefly speaking, on one hand, the sustainability champion worked mainly on developing customized framework for the project and supports the designers and the construction team to identify opportunities, to take appropriate actions and to monitor progress.

On the other hand, given the fact that incorporating sustainability focus in big infrastructure project was a very new field at that time, the sustainability champion had led an important role on sustainability awareness building on the
project team, and document the gains and pains of the project and transfer the knowledge to the industry.

6.4.6.2 Sustainability Reporting

Throughout the project life, according to the KRA & KPI framework, the Alliance’s and project’s performance of the three areas of sustainability – social, environmental and economic – were regularly reported to the AMT, the PAB and the wider project team through monthly reports, project briefings and newsletters as well as various team meeting and events. Furthermore, during the project construction phase, Annual Sustainability Report was published and shared with internal and external stakeholders.

Through the conduction of such project sustainability reporting activities, the Alliance aimed at keeping the project board members and the wide team members informed, updated, motivated and engaged in the project sustainability initiatives and performance (Griffith, 2007). As a result, through sustainability reporting, sustainability considerations and initiatives had been systematically documented, clarified, stored and shared with stakeholders and wider industry colleagues.

6.4.6.3 Sustainability Education and Sustainability Awareness Building

With the aim to reinforce the message derived from the project objectives and KRA/KPIs, the Alliance has conducted prestart workshops and two box meetings to spread the NGA agreed sustainability achievements and targets. Managers in the Alliance were trained to actively seek opportunities to address sustainability considerations and to improve the environmental and social performance of the Alliance.

Furthermore, with the understanding that raising awareness and developing mindset of the industry practitioners is as critical as the physical design and the development of measurement systems for project sustainability, the Alliance has
put a strong emphasis on imbedding sustainability into the culture of the project team. Specific programs and training sessions were delivered to project team members to help them to understand both the high-level sustainability principles and the project-level practical means (Northern Gateway Alliance. 2007). Examples of these initiatives include:

- Lifetime Program that consists of the sustainability principles - “Be Green, Stay Safe and Live Well “.
- Alliance induction process.
- Individual Performance Management connected to the three KRAs.
- Staff survey questions directly related to environmental excellence, community needs, long term focus as well as overall staff satisfaction.
- Sustainable office practices – paper use and recycling, energy use, transport, etc.
- A number of sessions focused on particular aspects relevant to the project as well as on broader sustainability topics. Examples included: a sustainability champion from Shell New Zealand present on their approaches to sustainability especially around bio-fuels; the Environmental Manager from Fulton Hogan presented on a project on 100% recycled road, and an expert on Sustainability in the Residential Built Environment talked about sustainability opportunities at home.

### 6.4.7 Innovation on the Project

As introduced before, the design and construction of this project was driven by environmental and social measures. KRA & KPI framework was designed to emphasis relevant environmental and social issues. Guided by such instructions, many aspects of sustainability considerations have been carried out in a manner and to a level that people within the project had not previously experienced. However, the Alliance appointed: “the most surprising result of adopting social
and environmental measure has been the internal impacts on the people working on the project. A pyramid of innovations has resulted, as people felt listened to and valued. This is evidenced in every aspect of the team’s practice.” (Constructing Excellence in New Zealand, 2009)

Table 6.8 lists some examples of sustainability related innovation on the project.

<table>
<thead>
<tr>
<th>Table 6.8: Innovations in Case Project A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapted from (Boffa Miskell, 2010; Construction Clients’ Group, 2009)</td>
<td></td>
</tr>
<tr>
<td><strong>Increased Lifecycle</strong></td>
<td>The NGA increased the value of the road pavement from the initial specification to deep lift asphalt. This decision added $2.5 million cost. However, as this pavement had a lower maintenance period than the previous design, thus provided significant cost savings over the whole life-cycle of the project.</td>
</tr>
<tr>
<td><strong>Encourage Biodiversity</strong></td>
<td>The design of the fish baffles through the culverts went beyond consent conditions and the team came up with ways of not only providing passage but establishing fish habitat with rock pools within the large culvert.</td>
</tr>
<tr>
<td><strong>Reducing the Footprint of the Road</strong></td>
<td>Stepping up the batters meant less bush clearing, reducing the impact on a sensitive environment. In this project, the slops were cut using GPS guided excavators and all cleared areas have been re-vegetated.</td>
</tr>
<tr>
<td><strong>Game Breaking Performance</strong></td>
<td>The Alliance seen the regular environmental monitoring as part of the consent process and had a strong focus on continuous improvement. This stimulated healthy competition to find ways to improve erosion settlement control which is measured weekly.</td>
</tr>
<tr>
<td><strong>Design Improvements</strong></td>
<td>The project team challenged some standards within the NZTA by investigating alternatives such as roadside barriers.</td>
</tr>
<tr>
<td><strong>Leaving a Legacy</strong></td>
<td>The Alliance financially contributed to environmental programs in locals schools.</td>
</tr>
</tbody>
</table>
6.4.8 Knowledge Engagement beyond the Project Scope

One of the important features of managing relevant knowledge on NGA project was that the Alliance set a specific KPI (S3.2: Legacy – Conference Presentations & Published Articles) to emphasis their focus on sharing knowledge to the industry, as shown in Table 6.7 (Subsection 6.4.5.3). This is not a typical objective for most previous infrastructure projects, but it has led to one of the most important sustainability gains for the project.

According to the description of this indicator, this KPI measures the number of conference presentations and published articles completed by NGA staff over the life of the project. These did not include journalist’s articles written as a result of the Alliance or other participants’ media releases or news stories related to the project activity.

Presentations and articles covered majority of the project disciplines, including:

- Project Management / Business Management;
- Engineering (Design and Construction);
- Landscape Concepts, Design;
- Construction Related – Methodologies, Work Practices;
- Environmental;
- Planning;
- Sustainability;
- Communication / Consultation / Community Involvement;
- Safety – Road Safety / Workplace Safety.

As a result of this specific KPI and the according knowledge sharing initiatives, the Alliance acknowledged that, in many ways, the most gains of the project were
from a marked increase in people's awareness and knowledge that has then transferred to other projects.

6.4.9 Case Project A Discussion

As discussed in the previous sections, drove by a new legislative environment and the strong commitment from the client and other key stakeholders, the NGA project has embraced opportunities to develop and execute a wide range of practices to integrate sustainability considerations into the project. Relevant knowledge was systematically identified and transferred through different project stages, and shared with various stakeholders and wider industry practitioners. This case project provides a real life example of how sustainability knowledge was managed in the project scenario, and outlined the process of how the knowledge can be applied into real practices.

Although sustainability knowledge application usually happens at project level, other KM activities – identify knowledge, obtain knowledge, share knowledge, and maintain knowledge – were also carried out to form a KM process within the project scope. Various KM enablers that promoted the embracement and enhancement of sustainability considerations were witnessed in this case project. Various initiatives to facilitate the flowing of relevant knowledge and to raise the awareness of sustainability within the project team have also been executed. These KM enablers, activities and strategies echoed the main elements that were identified through the previous questionnaire survey and interviews.

**KM Enablers**

- **Policy & Legislation** – As discussed in section 6.4.3, the LTMA has set a new legislation environment for this project. Its requirement was the most important trigger for the Alliance to seek opportunities to embed sustainability considerations into the project.
- **Committed client** – The NZ transport agency have set intense requirements in regards to sustainability and encouraged the Alliance to actualize the vision and objectives of LTMA.

- **Organizational culture and vision** – The main stakeholders of this project have a good understanding, attitude and capacity to engage in sustainability embracement. It enabled them to respond to the requirements and to actively trying to find better solutions to raise the bar of project sustainability.

- **Project target** - The Alliance set the project sustainability target through developing sustainability framework, multi-criteria for design option and KRA/KPI system to make sustainability objectives tangible and practical. It set the basis for relevant knowledge identification.

- **Leadership** – The sustainability champion, the client, and other committed stakeholders and practitioners on the project had shown their leadership on encouraging the team to seek opportunities to embrace sustainability considerations, and addressed the relevant activities for awareness and capacity building, such as education sessions, reporting on sustainability, etc.

- **Support from the management level** - During the project, the Alliance Management Team have been supportive to the activities related to managing sustainability knowledge (e.g. education sessions, presentation opportunities, etc.) by providing resources, allocating time and encourage the team to look for and respond to opportunities when they arose.

- **Sense of care and responsibility for sustainability** - Interviewees from the project confirmed that imbedding sustainability into the culture of project team is crucial for sustainability education and the management of relevant knowledge. It is the most important interior impetus that encourages the practitioners to actively participate in the KM cycle.

- **Communication skill** – Transferring of knowledge in the multi-disciplinary project team environment requires good communication skill of individuals, especially for the subjective topics like sustainability.
**KM Strategies**

The following KM strategies were found in case project A that employed by the Alliance to facilitate the identification, obtaining, sharing, maintenance and application of sustainability knowledge. These measures are reported in Section 6.4.6 in detail.

- **KM staffing** – The Alliance resourced a sustainability champion from one of the designers of the project. This sustainability champion was encouraged and supported by the AMT and addressed a wide range of activities to facilitate the project’s embracement of sustainability. She contributed to the project sustainability and the management of relevant knowledge in many areas, including: designing sustainability framework, criteria and KRA/KPI system, monitoring project performance on sustainability, addressing sustainability education, documenting relevant gains and experience and share with stakeholders, and delivering presentations on the project to wider industry, etc.

- **Sustainability reporting** - The project sustainability reports were published on an annual base. The Alliance utilized sustainability reporting as the main way of documenting sustainability initiatives, experiences, innovative solutions and project sustainability performance. It was also an important approach for the Alliance to share the information to all stakeholders.

- **Sustainability education** – The Alliance confirmed that building a culture of care and raising the capacity of the workforce to respond to sustainability is as important as to deliver tangible project outcomes. Some education sessions and inviting presentations were held on project. Special activities were also conducted to

- **Transfer of better practice** – As discussed in Section 6.4.7, this project has embraced sustainability considerations in a manner and to a level that exceeded previous similar projects. A number of innovations have resulted and became the better practices that aspires future projects. The Alliance documented the innovations and other lessons learnt into real project case studies and looked for opportunities to share the knowledge with the wider
industry. A specific KPI (refer to Table 6.7 and subsection 6.4.8) was designed to address the team performance on knowledge sharing. Publications and presentation on a wide range of sustainability related topics were delivered by the Alliance to transfer project experience to other projects.

- **Sustainability Measurement** – The Alliance designed multi-criteria for selecting more sustainable design options and to further refine the design. It set the specific objectives which is the basis for identify relevant knowledge. Furthermore, specific PKI were used to monitor project sustainability performance and the implementation and progress of the knowledge sharing initiatives.

**KM Outcomes**

Through the management of sustainability knowledge, following outcomes were achieved:

- **Expanded Infrastructure Sustainability Knowledge Asset** – Section 6.4.7 shows the sustainability related innovations resulted from the project. Other than these innovations, the process, tools, strategies that used by the Alliance to address sustainability issues, and the according case studies and publications enriched the body of sustainability knowledge that can be used by other projects.

- **Sustainability enlightened and knowledgeable stakeholders** – Through the sustainability knowledge sharing initiatives and education sessions, stakeholders’ sustainability awareness have been raised, and their mindset and knowledge structure were changed as well. They experienced a high standard project and learned the knowledge ready to be taken to further projects.

- **A benchmark for future projects** – This project has been recognized as an outstanding project which encompasses rich sustainability considerations. It is an exemplar project that inspires future projects.

**Applying the Sustainability Knowledge in Project Scenario**
Applying sustainability knowledge is seen as the most important but the most challenging KM activity in the Australian infrastructure sector. As discussed in Section 6.4.5, a range of tools and actions were utilized by the Alliance to help the project to cascade high level sustainability principles and statement to the whole project team across different project phases. These tools and actions facilitated the completion of each KM activities in a project scenario, and especially ensured the knowledge to be used in the project.

Before reaching the construction phase of the project, the Alliance outlined a serious of policies to address sustainability issues, including Sustainability Vision, Project Sustainability Objectives, Environmental and Sustainability Policy, Design & Select Criteria, KRAs & KPIs, and Project Management Plan that integrated with sustainability integration. Multi-disciplines were involved in this process to ensure these policies are comprehensive and practical. This is also a process of seeking consensus among the different stakeholders. Specifically, the Alliance had designed specific KPI to address the sustainability knowledge sharing activities throughout the project life.

During the construction phase, the Alliance focused on (1) seeking opportunities to refine and enhance the design in regards to sustainability; (2) raising sustainability awareness and building capacity within the team, especially to the construction people; (3) continuously monitoring the project and team performance, identifying and recording sustainability activities and innovations; and (4) communicating with and sharing relevant knowledge to all stakeholders. A sustainability champion was authorized to address these issues.

When the project was about to be closed, the Alliance have reviewed the sustainability achievements and mistakes on the project. Sustainability related case studies and publications were delivered on the whole project and on individual topics. These valuable project experiences were widely shared with mother companies and other projects and industry practitioners.
Table 6.9 summarizes the main actions, processes and activities in this project for applying sustainability knowledge.

**Table 6.9: Managing Sustainability Knowledge in Case Project A**

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Main Actions</th>
<th>KM Methods/Tools</th>
</tr>
</thead>
</table>
| **Before Construction** | - Project Vision  
- Project Objectives  
- Environmental and Sustainability Policy  
- Design & Select Criteria  
- KRAs & KPIs  
- Project Management Plan | Designing these project policies and tools based on:  
- Consensus among various stakeholders;  
- Sustainability Principles,  
- Policy & Regulation  
- Industry best practice,  
- Industry guideline,  
- Available rating tools and criteria, etc. |
| **During Construction** | - Seek opportunities to refine the design to be more sustainable  
- Indentify and record sustainability related activities and innovations  
- Develop workforce awareness and build sustainability capacity  
- Share sustainability knowledge to all stakeholders | Actions can be facilitated by the following methods/tools:  
- Identify and authorize sustainability champion  
- Induction  
- Newsletters and Posters  
- Sustainability Education  
- Specific Initiatives  
- Recognition Schemes  
- Regular review project on sustainability  
- Publish regular sustainability reports |
| **During Closure** | - Thoroughly review project sustainability experience  
- Compile case studies to document project good practices  
- Widely share the knowledge with mother organizations and the whole industry sector. | - Publish case studies and deliver presentations  
- Store project information and sustainability experience in mother organizations’ database |
## 6.4.10 Case Project A Summary

Table 6.10 extracts the main findings from case project A and these findings are categorized according to the structure of the preliminary KM framework shown in Figure 4.11 in order to make the results be easily compared with the results from other studies.

<table>
<thead>
<tr>
<th>Topics investigated</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Body of Sustainability Knowledge</td>
<td>These types of knowledge directed the project’s consideration and implementation of project sustainability:</td>
</tr>
<tr>
<td></td>
<td>- TBL</td>
</tr>
<tr>
<td></td>
<td>- Policy &amp; Legislation</td>
</tr>
<tr>
<td></td>
<td>- Industry guidelines</td>
</tr>
<tr>
<td></td>
<td>- Industry good practices</td>
</tr>
<tr>
<td>2. KM Enabler – External Environment</td>
<td>- Policy &amp; Legislation</td>
</tr>
<tr>
<td>3. KM Enabler – Organizational Environment</td>
<td>- Organizational culture and vision</td>
</tr>
<tr>
<td>4. KM Enabler – Project Environment</td>
<td>- Committed client</td>
</tr>
<tr>
<td></td>
<td>- Support from the management level</td>
</tr>
<tr>
<td></td>
<td>- Project target</td>
</tr>
<tr>
<td></td>
<td>- Leadership</td>
</tr>
<tr>
<td>5. KM Enabler – Personal Capabilities</td>
<td>- Communication skill</td>
</tr>
<tr>
<td></td>
<td>- Sense of care and responsibility about sustainability</td>
</tr>
<tr>
<td>6. KM Strategies</td>
<td>- Sustainability Staffing (Sustainability champion)</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Reporting</td>
</tr>
<tr>
<td></td>
<td>- Transfer of Best practice</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Education</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Measurement</td>
</tr>
<tr>
<td>7. Identify Sustainability Knowledge</td>
<td>- Search according to the project’s specific objectives</td>
</tr>
<tr>
<td>8. Obtain Sustainability</td>
<td>- Network of subject matter expertise</td>
</tr>
<tr>
<td>Knowledge</td>
<td>9. Share Sustainability Knowledge</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>- Sustainability staffing</td>
<td>- Setting specific KRA &amp; KPI on knowledge sharing</td>
</tr>
<tr>
<td>- Transfer of good practice</td>
<td>- Sustainability Reporting</td>
</tr>
<tr>
<td></td>
<td>- Education and Training</td>
</tr>
<tr>
<td></td>
<td>- Sharing knowledge through presentations to mother companies / industry colleagues</td>
</tr>
<tr>
<td></td>
<td>- Sustainability staffing</td>
</tr>
<tr>
<td></td>
<td>- Post Project Review</td>
</tr>
<tr>
<td></td>
<td>- Publication</td>
</tr>
<tr>
<td>10. Maintain Sustainability Knowledge</td>
<td>- Sustainability reporting</td>
</tr>
<tr>
<td></td>
<td>- Post project review</td>
</tr>
<tr>
<td></td>
<td>- Case study publication</td>
</tr>
<tr>
<td></td>
<td>- Keep knowledge in mother companies’ database</td>
</tr>
<tr>
<td></td>
<td>- Publication</td>
</tr>
<tr>
<td>11. Apply Sustainability Knowledge (Project Level Implementation)</td>
<td>- Project Vision / Project Objectives /</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Policy</td>
</tr>
<tr>
<td></td>
<td>- Multi-criteria sustainability assessment</td>
</tr>
<tr>
<td></td>
<td>- Sustainability integrated into Project Management Plan</td>
</tr>
<tr>
<td></td>
<td>- KRA &amp; KPI system to monitor performance</td>
</tr>
<tr>
<td>12. Outcomes</td>
<td>- Expanded Infrastructure Sustainability Asset</td>
</tr>
<tr>
<td></td>
<td>- Sustainability enlightened and knowledgeable stakeholders</td>
</tr>
<tr>
<td></td>
<td>- A benchmark for future projects</td>
</tr>
</tbody>
</table>

### 6.5 Case Project B

The following sub-sections introduce the key information about the Case Project B – Ipswich Motorway Upgrade: Wacol to Darra. Similar to Case Project A, the following subsections introduce the sustainability considerations on the project, how they were embraced into the project, and how the project team managed relevant sustainability knowledge.
6.5.1 Project Overview

The Ipswich Motorway provides the principal connection between the cities of Brisbane and Ipswich in Queensland, Australia. It has been recognized as a significant freight route, with approximately 80,000 vehicles per day travelling through the Wacol to Darra section alone. With traffic volumes increasing, a planning study of the motorway identified the need for an upgrade. Ipswich Motor Way Upgrade from Wacol to Darra is a major upgrade of the Centenary Highway Interchange and widening of a nine-kilometer section of the Ipswich Motorway from four to six lanes, with the provision for eight lanes in the future. It aims to relieve traffic congestion and improve safety and reliability on this important road.

The previous interchange between the Centenary Highway and the Ipswich Motorway was a signalized roundabout. A major feature of the project was the replacement of this interchange to a free flowing, multi-level interchange with capacity to accommodate future traffic volumes for a minimum of 20 years.

The upgrade project involved:

- Widened the Ipswich Motorway from four to six lanes with provision for eight lanes in the future
- Transformation of the Centenary Highway Interchange to a free-flowing multi level system interchange
- New pedestrian and cyclist paths
- Earthworks and bridgeworks for a new rail line from Darra to Springfield passing through the new Centenary Highway Interchange
- New bridges over Bullockhead and Sandy Creeks and the Ipswich rail line
- Removal of motorway access and exit points at Campbell Avenue at Wacol, Bakery Road and Kelliher Road at Darra and Bullockhead Street at Sumner to improve safety and traffic flow.

The project was completed in March 2010, on budget and well ahead of its targeted December 2010 completion date. But more importantly, has surpassed
benchmarked safety targets. A number of factors, including budget and schedule, made this project a success, including innovatively integrating sustainability education and initiatives into the project. These achievements were recognized by the Client when the project received the Director- General’s award for Innovation at the Department of Transport and Main Roads Excellence Awards 2010. Table 6.11 summarizes the key information of Case Project B.

<table>
<thead>
<tr>
<th>Location</th>
<th>Ipswich Motorway between Wacol and Darra, Brisbane, Queensland, Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Queensland Department of Main Roads</td>
</tr>
<tr>
<td>Form of Contract</td>
<td>Alliance</td>
</tr>
<tr>
<td>Total Cost</td>
<td>AU $824 million (Australian Government funded)</td>
</tr>
<tr>
<td>Project Construction Timescale</td>
<td>March 2007 – April 2010</td>
</tr>
<tr>
<td>Some Project Statistics</td>
<td></td>
</tr>
<tr>
<td>23 structures</td>
<td></td>
</tr>
<tr>
<td>618 piles</td>
<td></td>
</tr>
<tr>
<td>1.4 million m$^3$ of earthworks</td>
<td></td>
</tr>
<tr>
<td>420.000 tones of asphalt</td>
<td></td>
</tr>
<tr>
<td>Benefits</td>
<td>To improve safety, reduce congestion, improve traffic flow, increase reliability and reduce travel times.</td>
</tr>
</tbody>
</table>

### 6.5.2 Project Stakeholders and Project Team

The Ipswich Motorway Upgrade between Wacol and Darra is fully funded by the Queensland Government. The Department of Transport and Main Roads, responsible for the delivery of the upgrade, determined that an integrated alliance project team was needed to deliver the project and meet the objectives for the upgrade. SAFElink Alliance was established in late 2006 as a fully functioning, independent business, with its own unique branding and co-located offices separate from parent companies. It consists of six partners including Queensland Department of Transport and Main Roads as the client of the project, two
contractor organizations and two engineering consulting firms. Table 6.12 summarizes the participant organizations of SAFElink Alliance.

Table 6.12: Participants of Case Project B

<table>
<thead>
<tr>
<th>The Alliance</th>
<th>SAFElink Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Queensland Department of Transport and Main Roads</td>
</tr>
</tbody>
</table>
| Contractor       | Contractor A: One of Australia's largest project development and contracting group, with more than 10000 employees.  
                 | Contractor B: An Australia based privately owned construction and consulting organizations with around 1200 employees. |
| Consultants      | Designer: A global professional services firms providing services for all aspects of the built environment, with over 10,000 employees.  
                 | Project Management: A global provider of professional engineering technical and management support services, with around 52,000 employees around the world |

The alliance team is governed by the “Alliance Leadership Team” (ALT), which was essentially the business board of directors, and included a representation from each organization. The day-to-day operation is managed by the “Alliance Management Team” (AMT) which includes key managers on the project.

Under the ALT, project team members was structured into 7 functional groups, which are: design group, construction group, system and control group, procurement group, environment group, training & human resources group, and community relations group. Figure 6.2 outlines the structure of SAFElink Alliance.
6.5.3 Emergence and Execution of Sustainability on the Project

When the project started in early 2007, infrastructure sustainability was a new concept in the Australian infrastructure sector. Requirement of sustainability achievement was not propounded in the project initial phase. However, an experienced ALT member advocated sustainability as part of his core values and vision for the construction industry. Since then, sustainability was put on agenda for this project.

6.5.4 Project Sustainability Interpretation

The alliance acknowledged that sustainability is a term that is broadly defined, therefore, it is important to decide how to interpret sustainability on a major road upgrade project.

The ALT and AMT agreed to define sustainability as: “Going beyond compliance in the areas of environment (conservation), natural resources (consumption), economy and society.” This definition guided the framework for implementing sustainability during the project.

Other resources also guided the project sustainability framework include:
• South East Queensland Regional Plan (2005-2006)

• Global Reporting Initiative (GRI) – Sustainability Reporting Guidelines

• The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL)

• Project Sustainability Management Guideline – International Federation of Consulting Engineers (FIDIC)

• Infrastructure Sustainability Rating Scheme - Australian Green Infrastructure Council (AGIC)

6.5.5 Sustainability Implementation

As sustainability consideration was not integrated in the project from early stages, thus design analysis criteria and project management plan did not include specific sustainability clause. However, once the sustainability principles were brought forward, relevant performance objectives were set and monitored though incorporating relevant criteria into KRA & KPI system, which also affect the decision-making for ongoing design analysis and amendments.

6.5.5.1 KRA & KPI Framework

KRAs and KPIs were used to by the alliance to drive the team behaviour necessary to meet the project objectives.

In this project, KRA refers to overall areas identified to drive desired behaviours, and reflects areas of significant interest to the alliance partners. Each KRA was measured with a suite of KPIs, using a performance spectrum of fail, minimum condition of satisfaction, stretch and outstanding.

Specific KRAs were provided by the client. These KRAs are linked to financial incentives and attracted a pain/gain regime based on performance against agreed KPIs. In addition to those cost related KPAs, three additional KRAs were
considered and measured on a monthly KPI basis. According to the team members, the KPIs reinforced the need for continual team consultation and external knowledge sharing in order to drive the implementation of project initiatives.

Sustainability was one of these three non-financial KRAs. And there are three overarching KPIs as part of the sustainability KRA. They are:

- KPI 1 – Consult with SAFElink team and other key stakeholders - engaging with the team,
- KPI 2 – Implement initiatives – ideas in action,
- KPI 3 – Knowledge sharing – industry capacity building.

In 2007 when the project commenced, there was limited emphasis on sustainability within the civil contracting sector. As consultation built understanding and acceptance within the team, engaging with the team was set as a first KPI for sustainability KRA that weighted 20%. Furthermore, consultation educated the team on technical aspects of sustainability, and provided a framework of sustainability based on quadrants of environment, natural resources, society and economy. As there was a two-way flow of information, it allowed the team to consider what they could do within their scope of influence, and encouraged the team to consider sustainability in day-to-day decision making, beyond implementing a set “list” of initiatives. On the other hand, as there was a risk that the team would be sceptical about the benefits of sustainability, consultation allowed the team to ask questions.

The second KPI involved implementing initiatives. The purpose of this KPI was to provide tangible actions toward sustainability, to set targets for performance, and to maintain a system to allocate points and measure progress. As KPI 2 was valued at 60% of the sustainability KRA, a further detailed measuring regime was developed. A performance spectrum of fail, minimum condition of satisfaction, stretch and outstanding was set for each initiative along with allocated points. This performance spectrum mirrored the way that the overall KRAs were
measured. Each initiative was allocated a high, medium, or low priority based on its long-term cost/benefit and education/awareness value. Points were allocated to match the priority level. The collective performance contributed to KPI 2.

The third KPI involved documenting and communicating the results to share knowledge and build industry capacity. In this project, the knowledge sharing took place throughout the project, rather than only at the end. This KPI on sharing knowledge was dependent on implementing initiatives in KPI 2. This initiative prompted the project team to consolidate their learning and communicate with industry and government, in the interest of seeing tangible changes in sustainability in major infrastructure projects.

A summary of the three KPIs for sustainability KRA measurements is shown in Table 6.13.
### Table 6.13: Sustainability KRA Measurement
(Source: Boyd, 2009)

<table>
<thead>
<tr>
<th>KPI 1: Team involvement and education in developing initiatives and promoting a culture of sustainability</th>
<th>Overall weight</th>
<th>Overall purpose of KRA</th>
<th>Tracking method</th>
<th>Frequency of measurement</th>
<th>Type of measurement</th>
<th>Evidence provided</th>
</tr>
</thead>
</table>
| 20% | - Educate the team on technical aspects of sustainability.  
- Solicit sustainability ideas from team members to make KRA meaningful to team.  
- Encourage team to consider sustainability in day-to-day decision-making, beyond implementing a set “list” of initiatives. | Checklist of team members – in Sustainability database. | Monthly | Cumulative | Checklists Sustainability Champion’s Group notes  
Inter-alliance sustainability group notes |

| KPI 2: Implementing initiatives | 60% | - Provide a tangible list of actions toward sustainability.  
- Set targets for performance.  
- Maintain a system to allocate points and an objective measuring system. | Each team has a suite of initiatives to deliver. Each initiative has a performance spectrum (fail, minimum condition of satisfaction, stretch, outstanding). These performance spectrums are collated monthly to develop a package for reporting on the KRA. | Monthly – each initiative is assessed on the “trigger date”. The trigger dates are listed on the monthly reporting spreadsheet. | Cumulative | Each individual responsible for delivering an initiative is to provide relevant evidence: e.g. drawings, memos, photos, notes, etc. |

| KPI 3: Industry capacity building – knowledge sharing | 20% | - In the spirit of the Alliance, share learning with parent companies.  
- Build understanding of sustainability in construction locally.  
- Promote successes of SAFElink Alliance.  
- Seek recognition | Checklist of parent companies and external bodies – in Sustainability database. | Monthly | Cumulative | Presentations to: Inter-alliance sustainability group, parent companies, government departments etc. Newsletter articles, sustainability bulletin board. |
6.5.5.2 Implemented Sustainability Initiatives

In order to respond to the requirements of KPI 1, the Alliance designed various strategies for team engagement, including: delivering sustainability educations and trainings, holding sustainability related events and campaigns. Stakeholders from all disciplines were included in these initiatives. Table 6.14 lists these strategies in detail. The main focus of the team engagement strategies was to share the general sustainability principles and practical sustainability knowledge for infrastructure development to project team members in order to raise the sustainability awareness and to build their sustainability capacity. Sustainability education on project will be discussed in later sections.

<table>
<thead>
<tr>
<th>Team Engagement Strategies</th>
<th>Included All/ Select Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability Education Workshops</td>
<td>All</td>
</tr>
<tr>
<td>Sustainability Champions Group</td>
<td>Select</td>
</tr>
<tr>
<td>Events – Clean up Australia/ Ride to Work/ World Environment Day</td>
<td>All</td>
</tr>
<tr>
<td>Posters – e.g. carbon footprint, cycling</td>
<td>All</td>
</tr>
<tr>
<td>Campaigns – waste, anti-idling, cycling, sustainable shopping</td>
<td>All</td>
</tr>
<tr>
<td>Carbon 101 Training</td>
<td>All</td>
</tr>
<tr>
<td>Sustainability bulletin board and library</td>
<td>All</td>
</tr>
<tr>
<td>Environmental Toolbox talks</td>
<td>All</td>
</tr>
</tbody>
</table>

In order to respond to the requirements of KPI 2, during the project construction phase, the Alliance conducted a wide range of sustainability initiatives to embed sustainability considerations into various aspects of the project, including: project design (focus on refining project design), construction (e.g. material reuse, etc.), system and controls (e.g. accessible contact for guidance, KM register, etc.), procurement (e.g. include sustainability statement in contract tender invitations, etc.), environment (environmental competitions, tracking waste and recycling, etc.), training and human resources (e.g. employment development program, etc.).
community relations (e.g. community events, donating materials to local community, etc), and site office (e.g. green power, green fleet, etc).

In order to respond to the requirements of KPI 3, the Alliance actively looked for opportunities to share the project sustainability experience with mother companies, other projects and the wider industry that beyond the project scope. These knowledge sharing activities will be further discussed in Section 6.5.6.5.

6.5.6 Approaches of Managing Sustainability Knowledge in the Project

6.5.6.1 Sustainability Staffing

In the project team, two sustainability positions were resourced: a Sustainability Coordinator and a Sustainability Representative. The roles were critical in keeping sustainability within the day to day project focus.

The Sustainability Coordinator was resourced from the design environment group. This full time position was located separately to a specific “group” on the organisational chart. This was done deliberately to avoid the perception that sustainability was only relevant to the environmental group. The Sustainability Coordinator role involved the following key responsibilities:

- develop and communicate the sustainability strategy across the team,
- develop and maintain a sustainability management process,
- promote awareness of sustainability issues and solutions throughout the team,
- consult with team to identify practical initiatives,
- provide advice, research, coaching and encouragement to team members responsible for implementing initiatives,
- identify and action opportunities throughout the life of the project,
- document progress and report monthly on sustainability,
• coordinate and deliver external promotion of the project and sustainability, and

• manage the role of the Sustainability Representative.

In addition to the Sustainability Coordinator, the Sustainability Representative role was set up to deliver tangible sustainability initiatives and promotes the initiatives undertaken by the groups. It was a part-time position and the resourcing was shared with the alliance’s environment group. As the environment role involved going on site to ensure compliance, the Sustainability Representative was in an influential position to cascade sustainability thinking to the work force. The on-site role allowed relationships to be formed with the labour force, and increase understanding of sustainability.

6.5.6.2 **Sustainability Reporting**

A sustainability report was developed monthly for the Alliance Leadership Team (ALT) and Alliance Management Team (AMT). The report provided a score for the three key performance indicators: consultation with team, implementing initiatives, knowledge sharing. In addition, the report provided anecdotal notes on general progress.

Sustainability reporting was facilitated by software specifically developed for the sustainability KRA. A Sustainability Action Manager provided an Access database interface for entering initiatives and associated actions. The program generated a summary report which enabled a way of monitoring and communicating progress.

During the closure phase of the project, the sustainability coordinator developed a final sustainability report. The sustainability report described the cultural and technical sustainability wins across the Alliance team in detail, and made suggestions for future projects.
6.5.6.3 **Sustainability Champion Group**

On this case project, a Sustainability Champions Group was developed in mid 2007. The Sustainability Coordinator was the coordinator of this groups that consisted of other 16 members representing the different groups across the project, including a representative from the Alliance Leadership Team (ALT). Members were selected by their managers based on individual interest in sustainability.

In total, eight meetings were held. The objectives of the SCG included the following:

- Review progress on sustainability KRA initiatives across project
- Exchange ideas and information on sustainability
- Promote general learning on sustainability issues
- Cascade sustainability progress to the Wider Project Team.

Topics discussed included project sustainability initiatives, as well as the progress being made in their parent companies through corporate sustainability initiatives. During each meeting, members were encouraged to discuss evolving sustainability initiatives being undertaken by their group through day-to-day problem solving. After the meetings, members reviewed the outcomes with their group, so that the information would cascade through the project.

6.5.6.4 **Sustainability Education and Sustainability Awareness Building**

It was indicated by the sustainability coordinator that, although sustainability is delivered through technical initiatives on a civil engineering project, awareness and cultural change drive the initiatives.
When the project commenced in 2007, there was little emphasis on sustainability within the infrastructure sector. In this case, it was critical to build understanding and acceptance on sustainability within the team through a number of measures as discussed below.

**Sustainability posters**

To start with, a sustainability poster was designed to reinforce the message of sustainability across the project team, which featured a circle with segments labelled with each group of the project team.

Furthermore, themed sustainability posters were designed and displayed in the site office, e.g. carbon awareness poster, carbon footprint versus ecological footprint poster, site office initiatives posters.

**On-going Sustainability Education Workshops**

Secondly, on-going Sustainability Education Workshops were held throughout the project construction phase. The workshops concentrated on the nexus between sustainability as a concept, and practical implementation of what could be done on this project. They were a critical part of team engagement. A diverse array of team members was involved in the Sustainability Education Workshops: design, construction, project managers, engineers and foremen, community relations, human resources/training, procurement, and commercial.

The Sustainability Coordinator facilitated the on-site workshops. Usually there were only a small number of people per workshop, which helped to involve participants and provided a chance for their input during the workshop. The workshop forums allowed valid and valuable conversations to take place, and to investigate how to make a meaningful difference on the project.

To introduce sustainability, the Sustainability Coordinator provided a framework derived from mother company’s well established sustainability framework, which
comprises four categories: Environment (conservation), Natural Resources (consumption), Society (healthy community), and Economy (supporting local economy, healthy construction team).

Next, the Sustainability Coordinator presented global case studies of road projects that encompassed sustainability initiatives. Stemming from the case studies, participants were encouraged to provide stories from their own experience.

**Sustainability workshops for target group**

In addition to regular sustainability education workshops, two extra workshops were held to target engineers. The main reason of having such workshops was that engineers tend to be practical, and they usually see sustainability lacks scientific rigour. Their existing mindset, education background, knowledge structure and project experience have also limited their understanding on infrastructure sustainability. As sustainability is still a new area in infrastructure development in the Australian construction industry, most of the engineers do not have ample experience on applying sustainability within their professional scope in precious projects. Thus during the second engineer workshop, a sustainability consultant with expertise in energy/carbon strategies was invited to communicate with the engineers on project. During the workshops, sustainability ideas that are involved in an engineer’s role were discussed and developed into tangible initiatives that could be applied across the project. Action list was development and circulated.

**Sustainability events and campaigns**

Sustainability events and campaigns were held to raise sustainability awareness, including Clean Up Australia Day Event, World Environment Day Event, National Ride to Work Day, Waste hierarchy campaign, Anti-idling campaign, Cycling campaign, and Sustainable shopping.

**Sustainability bulletin board and library**
A large bulletin board was put up in the main tea room of site office to promote sustainability. In addition, a magazine rack held the “sustainability library”, which comprised magazines and books on sustainability.

6.5.6.5 **Knowledge Engagement beyond the Project Scope**

In this project, the third KPI reinforced the importance of documenting and communicating the project gains and mistakes in order to consolidate team learning and share knowledge with the industry, in the interest of see tangible changes in sustainability in infrastructure projects.

Numbers of presentations were developed and delivered to parent companies, other groups and in relevant conferences and industry forums. The Sustainability Coordinator led the role of documenting and transferring sustainability knowledge gains and project experience with external groups via workshops, presentations, industry conferences, etc. Table 6.15 lists the knowledge sharing opportunities utilized by the alliance during the project life cycle, noting the general content, and a summary of the feedbacks and comments received from the audiences. In fact, every team member involved in the sustainability initiatives was encouraged to find opportunities to promote the project wins and reuse the knowledge in future projects.

**Table 6.15: Summary of Sustainability Knowledge Sharing Initiatives**

<table>
<thead>
<tr>
<th>Type of the Organizations</th>
<th>Main Method and Content</th>
</tr>
</thead>
</table>
| Mother Companies          | • Usually presented by the Sustainability Coordinator.  
                            | • Review sustainability strategies, initiatives, progress and lessons learned.  
                            | • Contribute to the sustainability knowledge asset of mother companies. |
| Potential clients for Future Infrastructure Projects | • Discuss the design of project sustainability KPIs and project performance monitoring issues. |
| Research Institutions     | • Provide project information and experience to researchers on sustainability related topics. |
| Industry Associations     | • Provide lessons learned and good practices from the project.  
                            | • Store the project case study in the industry association’s database.  
                            | • Seek resonation from the industry. |
**Inter-Project Sustainability Groups**

The Case Project B - Ipswich Motorway Upgrade project is one of the Western Corridor Transport Program which consists of 6 projects with over 4 billion Australian dollar state and federal funding. The Department of Transport and Main Roads is delivering this program in conjunction with other government agencies and private sector partners.

Supported by the Department of Transport and Main Roads, Sustainability Managers and sustainability champions from Western Corridor Transport Program teams met frequently to share their understanding on infrastructure sustainability and according project experience. This sustainability group provided a platform for these sustainability practitioners to share, as well as to gain highly relevant sustainability knowledge and practical implementation advices from other project teams with similar culture and conditions.

**Connecting with Industry Associations**

During the project development process, the Alliance worked in close partnership with the AGIC, which was formed by the like-minded construction industry professional whose mission is to promote sustainability in infrastructure through a rating tool and sharing industry knowledge. The Sustainability Coordinator on SAFElink actively took part in AGIC strategy sessions as a volunteer. AGIC rating tool have helped the project to define its own sustainability framework and according indicators. Meanwhile, the Sustainability Coordinator also identified events to promote AGIC and its infrastructure sustainability rating scheme within and outside the project team.

**6.5.7 Barriers to Implement Sustainability Initiatives**

In this project, on-going sustainability education was a critical part of team engagement and sustainability knowledge sharing within project scope. It is also the main focus of sustainability knowledge management approach on this case
project. The sustainability education was delivered to all the stakeholders of the project not only through the structured courses, trainings, but also the wide range of sustainability initiatives.

The success of implemented sustainability initiatives were based on the understanding and cooperation of project team members. During the construction phase of this project, there were still many initiatives researched but not implemented. Reasons for the unimplemented initiatives beyond compliance were deeply related to whether the relevant sustainability knowledge were understood or accepted by project members.

The Sustainability Coordinator summarized the following barriers faced by the SAFElink Alliance when implement initiatives that were beyond compliance as shown in Table 6.16.

Table 6.16: Barriers to Implement Sustainability Initiatives
(Source: Boyd, 2009)

<table>
<thead>
<tr>
<th>Status of the Practitioners</th>
<th>Key categories of barriers</th>
<th>Key characteristics observed on site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninformed</td>
<td>Uninformed - No prior training or experience/exposure to sustainability on previous projects</td>
<td>Decisions made without considering sustainability opportunities.</td>
</tr>
<tr>
<td>Apathy</td>
<td>I can’t make a difference. Someone else can do it.</td>
<td></td>
</tr>
<tr>
<td>Sceptical</td>
<td>How do we really know about our impacts? Shouldn’t we focus on profit?</td>
<td></td>
</tr>
<tr>
<td>Ingrained habit</td>
<td>I always use this supplier.</td>
<td></td>
</tr>
<tr>
<td>Lack of incentive</td>
<td>What is in it for me? We are only rewarded for time and budget. What value will it add?</td>
<td></td>
</tr>
<tr>
<td>Technical gap</td>
<td>We want to but we don’t know how. There is not enough physical space.</td>
<td></td>
</tr>
<tr>
<td>Other Competing priorities</td>
<td>It is not safe to do.</td>
<td></td>
</tr>
<tr>
<td>External factors</td>
<td>We follow given specifications. We can only use available products.</td>
<td></td>
</tr>
</tbody>
</table>
According to the Sustainability Coordinator, there were two overarching stages of sustainability knowledge identified: the first one is uninformed, which refers to someone on the team who had not previously encountered the concept of sustainability; the second stage of knowledge is encompassed by the term “informed”, which means that a basic framework and understanding of sustainability had been acquired. Key categories of barriers are gleaned from observations recorded by the Sustainability Coordinator over the life of the project, and are from practical experience.

The barriers are ordered to show progressive characteristics leading from “uninformed” to “informed”. For example, once someone on the team was informed, they may have still displayed apathy. Once they become more convinced that they should get involved, they may then be sceptical of the values of sustainability. In the early days of the project, more experienced team members noted that sustainability was fundamentally incongruent to sustainability, particularly the ecological aspects. Through open discussions and examining case studies, most team members were later on board to explore what sustainability could mean to their scope of influence. However, even as scepticism was overcome, there were ingrained habits that people fell into, for example, ordering materials and suppliers based on previous projects.

Once the team members were concerned, convinced and ready to move past habitual responses, the barrier faced was often lack of incentive. The Project had demanding program milestones, and emphasis on cost savings. Change might have seemed like a good idea in a workshop, but often lacked criticality on the project at hand. Although sometimes a sustainability idea was rewarded and promoted by the project management level, it may still be abandoned due to the lack of technical support by the project team. Competing priorities such as the perception of safety risk provided another barrier. Finally, once the previous barriers were crossed, specifications could prevent the option for a sustainability change.
Observation and identification of the barriers are important because the process of share sustainability knowledge is not simply as deliver the knowledge to the person. More efforts are required to help the industry practitioners to accept the concepts and actually make a change.

### 6.5.8 Case Project B Discussion

Case Project B project defined sustainability as going beyond compliance in the areas of environment (conservation), natural resources (consumption), economy and society. Although the Alliance did not systematically integrate sustainability considerations into the project design during the initiating phases, sustainability focus was later raised up by a sustainability champion and embraced into the project though developing KRAs and KPIs, and implementing initiatives according to these KPIs. Many initiatives were designed to facilitate the communication of sustainability knowledge within and beyond the project team with the aim to raise sustainability awareness and build industry capacity. The successful implementation of these initiatives and the management of sustainability knowledge were enabled by various factors, and resulted in tangible outcomes.

**KM Enablers**

- **Leadership** – As discussed in previous sections, the keen sustainability champion from the ALT led the project beginning to embrace sustainability principles into refining project designs and monitoring project and the Alliance performance. The later resourced Sustainability Coordinator and the Sustainability Representative took the role of addressing sustainability education, communication and relevant initiatives.

- **Support from the management level** – Support from the management level secured the implementation of project sustainability initiatives (e.g. establishment of Sustainability Champion Group) by providing resources, time and incentives.
Organizational culture and vision – Some main stakeholders of the project have sustainability embedded in their organizational vision and culture, and a good collection of sustainability related experience and good practices. Thus when sustainability was put on agenda of the project, they responded quickly and actively, looked for opportunities and proposed possible solutions to embed sustainability into the project.

Network of subject matter expertise – The Sustainability Coordinator had closely networked with sustainability champions from other projects and industry associations. This enabled the smooth flowing of industry good practice across the project boundary.

Sense of care and responsibility about sustainability – Project team members who actively participated in the sustainability groups are all care about and interested in sustainability.

Communication skill – Communication skill ensures the project members from different backgrounds to learn and discuss sustainability knowledge and its application on job which requires multi-disciplinary integration.

KM Strategies

The following KM strategies were found in case project B that employed by the Alliance to facilitate the identification, obtaining, sharing, maintenance and application of sustainability knowledge. These measures are reported in Section 6.5.6 in detail.

KM Staffing – A Sustainability Coordinator and a Sustainability Representatives were resourced to address the sustainability initiatives. They also worked as knowledge “gatekeeper” who worked at identifying industry good practices and seeking opportunities to apply the knowledge on project, as well as identifying and recording the innovations from the project and sharing it with the wider industry.
• **Sustainability Reporting** – Monthly reports and a comprehensive final report on sustainability were produced by the Alliance to monitor progress, review initiatives, document innovations and lessons learned, and facilitate the knowledge sharing within and beyond the Alliance.

• **Sustainability Education** – Sustainability Education was put at the top of the project agenda in order to raise sustainability awareness and to build team capacity. Various barriers were identified during the initiative conduction and learning process.

• **Sustainability CoP** – Sustainability groups similar to CoPs were found in this case project, including: (1) the Sustainability Champion Group which can be seen as a primary-form sustainability CoP that consisted sustainability champions from diverse disciplines and organized by the Sustainability Coordinator; (2) the Inter-project Sustainability Group is a small cross project sustainability CoP consisted of sustainability champion/managers from several similar infrastructure projects; (3) industry association which is in nature an industry-based sustainability CoP. The Sustainability Coordinator’s participations in these CoPs built a bridge of transferring sustainability knowledge across project boundaries.

• **Sustainability Measurement** – The Alliance designed specific KPIs to address sustainability knowledge sharing, sustainability education and other sustainability initiatives. Project performance was monitored according to the KPIs to secure the effectiveness of the management of sustainability knowledge on project.

**KM Outcomes**

Through the management of sustainability knowledge, following outcomes were achieved:

• **Sustainability enlightened and knowledgeable stakeholders** – The structured sustainability education through the training courses and the
relevant indicatives have greatly improved the team members’ understanding and capacity on sustainability, especially for the construction team.

- **Expanded Infrastructure Sustainability Knowledge Asset** – Experiences and lessoned learned from the project and the according reports, publications and case studies have left a knowledge legacy for future projects.

**Applying the Sustainability Knowledge in Project Scenario**

Table 6.17 summarizes the main actions, processes and activities in this project for applying sustainability knowledge.

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Main Actions</th>
<th>KM Methods/Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Construction</td>
<td>- Defining sustainability for the project</td>
<td>Designing these project policies and tools based on:</td>
</tr>
<tr>
<td></td>
<td>- KRA &amp; KPIs (with specific KPI to address the management of sustainability knowledge)</td>
<td>- Consensus among various stakeholders;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Sustainability Principles,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Industry best practice,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Industry guideline,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Available rating tools and criteria, etc.</td>
</tr>
<tr>
<td>During Construction</td>
<td>- Seek opportunities to refine the design to be more sustainable</td>
<td>Actions can be facilitated by the following methods/tools:</td>
</tr>
<tr>
<td></td>
<td>- Indentify and record sustainability related activities and innovations</td>
<td>- Resource a Sustainability Coordinator and a Sustainability Reprehensive</td>
</tr>
<tr>
<td></td>
<td>- Raise workforce awareness and build sustainability capacity</td>
<td>- Newsletters and Posters</td>
</tr>
<tr>
<td></td>
<td>- Share sustainability knowledge to all stakeholders and other projects</td>
<td>- Sustainability Education</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Specific Initiatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Regular review and report on sustainability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Establish Sustainability Champion Group</td>
</tr>
<tr>
<td>During Closure</td>
<td>- Thoroughly review project sustainability experience</td>
<td>- Publish case studies and deliver presentations</td>
</tr>
<tr>
<td></td>
<td>- Compile case studies to document project good practices</td>
<td>- Store project information and sustainability experience in mother organizations’ database</td>
</tr>
<tr>
<td></td>
<td>- Widely share the knowledge with mother organizations and the wider industry sector.</td>
<td>- Network with industry association</td>
</tr>
</tbody>
</table>
### Case Project B Summary

Table 6.18 extracts the main findings from case project B (next page).

<table>
<thead>
<tr>
<th>Topics investigated</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. The Body of Sustainability Knowledge</strong></td>
<td>These types of knowledge directed the project’s consideration and implementation of project sustainability:</td>
</tr>
<tr>
<td></td>
<td>- TBL</td>
</tr>
<tr>
<td></td>
<td>- Policy &amp; Legislation</td>
</tr>
<tr>
<td></td>
<td>- Industry guidelines</td>
</tr>
<tr>
<td></td>
<td>- Industry good practice</td>
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<tr>
<td></td>
<td>- Mother company good practice</td>
</tr>
<tr>
<td><strong>2. KM Enabler – External Environment</strong></td>
<td>- Network of subject matter expertise</td>
</tr>
<tr>
<td><strong>3. KM Enabler – Organizational Environment</strong></td>
<td>- Organizational culture and vision</td>
</tr>
<tr>
<td><strong>4. KM Enabler – Project Environment</strong></td>
<td>- Leadership</td>
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<tr>
<td></td>
<td>- Support from the project management level</td>
</tr>
<tr>
<td><strong>5. KM Enabler – Personal Capabilities</strong></td>
<td>- Communication skill</td>
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<tr>
<td></td>
<td>- Sense of care and responsibility about sustainability</td>
</tr>
<tr>
<td><strong>6. KM Strategies</strong></td>
<td>- Sustainability Education</td>
</tr>
<tr>
<td></td>
<td>- Cultivate Sustainability CoP in project</td>
</tr>
<tr>
<td></td>
<td>- Involved in other level Sustainability CoPs</td>
</tr>
<tr>
<td></td>
<td>- Resource Sustainability Coordinator</td>
</tr>
<tr>
<td></td>
<td>- Reviewing and Reporting on Sustainability</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Measurement</td>
</tr>
<tr>
<td><strong>7. Identify Sustainability Knowledge</strong></td>
<td>- Recommended by mother companies</td>
</tr>
<tr>
<td></td>
<td>- Delivered industry good practices</td>
</tr>
<tr>
<td><strong>8. Obtain Sustainability Knowledge</strong></td>
<td>- Network of subject matter expertise</td>
</tr>
<tr>
<td></td>
<td>- Sustainability staffing</td>
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<tr>
<td><strong>9. Share Sustainability Knowledge</strong></td>
<td>- Setting specific KRA &amp; KPI on knowledge sharing</td>
</tr>
<tr>
<td></td>
<td>- Sustainability reporting</td>
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<tr>
<td></td>
<td>- Post Project Review</td>
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<tr>
<td></td>
<td>- Education and Training</td>
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<tr>
<td></td>
<td>- Sustainability CoP (project / organizational / industry)</td>
</tr>
<tr>
<td></td>
<td>- Sustainability staffing</td>
</tr>
<tr>
<td><strong>10. Maintain Sustainability Knowledge</strong></td>
<td>- Sustainability reporting</td>
</tr>
<tr>
<td></td>
<td>- Post project review</td>
</tr>
<tr>
<td></td>
<td>- Case study publication</td>
</tr>
<tr>
<td></td>
<td>- Store knowledge in mother companies’ database</td>
</tr>
<tr>
<td><strong>11. Apply Sustainability Knowledge (Project Level Implementation)</strong></td>
<td>- Defining sustainability for the project</td>
</tr>
<tr>
<td></td>
<td>- KRA &amp; KPIs (with specific KPI to address the management of sustainability)</td>
</tr>
<tr>
<td><strong>12. Outcomes</strong></td>
<td>- Expanded Infrastructure Sustainability Knowledge Asset</td>
</tr>
<tr>
<td></td>
<td>- Sustainability enlightened and knowledgeable stakeholders</td>
</tr>
</tbody>
</table>
6.6 Summary

This chapter outlined how sustainability concepts have been interpreted and implemented in two case projects and how the project teams managed the relevant knowledge among team members, key stakeholders and beyond the project scope. The rich project information, their approaches, process, performance measurement methods and other initiatives implemented in the real high standard projects were described in detail. Main KM enablers, process and strategies used in these two projects were discussed and put into tables to highlight the main findings from the case studies.

These findings, together with the results gained from the previous questionnaire survey and semi-structured interviews, will be synthesized and further discussed in the next chapter in order to cross check with and supplement each other, and to formulate the final KM framework for managing sustainability knowledge in the Australian infrastructure sector and according guidelines.
CHAPTER 7

KNOWLEDGE MANAGEMENT FRAMEWORK AND GUIDELINES

7.1 Introduction

The research reported in this thesis investigated the issues related to the management of sustainability knowledge in the Australian infrastructure sector. It was carried out with the objectives specified in Chapter 1 and followed the research plan specified in Chapter 3. Following an extensive literature review (presented in Chapter 2) a triangulation of three data collection instruments – questionnaire survey, semi-structured interview and case study – were employed to gain rich data for achieving the objectives of the research. Analyses of the results of these research instruments were reported respectively in Chapter 4, Chapter 5 and Chapter 6.

In this chapter, for the formulation of final research findings and recommendations, the data analysis results from the earlier studies will be integrated with findings from the literature study, and be further explained. A KM framework for managing sustainability knowledge in the infrastructure sector will be formulated to give a holistic view of balanced activities. Furthermore, a guideline for applying sustainability knowledge and implementing KM at project level is provided.
7.2 Synthesis of the Questionnaire Survey, Interview and Case Study Results

As specified in Chapter 3, three research methods, which are questionnaire survey, semi-structured interviews and case studies, were employed in this research for data collection. These three studies were conducted in turn after an extensive literature review. Results and findings from these three studies all contribute to the investigation of research questions and the achievement of research objectives.

According to the research plan, in the first phase, a questionnaire survey among industry practitioners in the Australian infrastructure sector was conducted to quantitatively test relevant hypothesis and concepts gained from the reviewing of literature. It mainly focused on the “what” part of the KM framework; for example: “What are the main enablers for managing sustainability knowledge?”, “What are the main KM stages of managing sustainability knowledge?”, “Who are the important stakeholders?” The structure of the questionnaire followed a KM framework prototype that was developed by the researcher based on existing KM frameworks and concepts. As reported in Chapter 4, the necessity of adopting KM to promote the capture and implementation of sustainability knowledge in the Australian infrastructure sector was confirmed. It has also been confirmed that the process of managing and implementing sustainability knowledge needs to be integrated into the project management process in this project-oriented industry sector.

Five essential stages of the KM cycle were identified: identify sustainability knowledge, obtain sustainability knowledge, share sustainability knowledge, apply sustainability knowledge and maintain knowledge. Furthermore, 25 KM enablers were identified through the survey and were classified into four categories: external environment, organizational environment, project environment and personal capabilities. The role of stakeholders has also been investigated, with the client, design team and project manager being identified as the most important stakeholders involved in the KM cycle. In addition, areas such
as project performance and organization performance that can benefit from managing sustainability knowledge were also identified.

Based on the results of the questionnaire survey, semi-structured interviews and two real project case studies were conducted to qualitatively investigate “how” the industry currently manages sustainability knowledge and “how” to improve the management process. The semi-structured interviews covered a wide range of issues from industry level, organization level, project level, to personal level.

In the KM cycle for managing sustainability knowledge in the infrastructure sector, knowledge implementation is seen as the most important as well as the most challenging stage. The reason is that the infrastructure sector is a highly project-oriented industry sector, where sustainability goals can only be achieved project-by-project. In order to understand the KM cycle for sustainability knowledge, especially to understand its actual implementation in the real project scenario, two case studies were conducted to complement the interview results. Furthermore, as the questionnaire survey identified the five main KM stages for managing sustainability knowledge, the interviews and case studies could focus on how the cycle is facilitated and realized in the industry. Important strategies and processes were identified.

The results derived from the three studies are discussed and presented in Chapters 4, 5 and 6 respectively and the main findings are outlined in Table 4.24, Table 5.3, Table 6.10 and Table 6.18. These three studies have different focuses; thus these findings are mutually complementary. During the later study stages, the researcher also utilized every opportunity to justify the results gained from the earlier stages.

Table 7.1 is a combination of Table 4.24, Table 5.3, Table 6.10 and Table 6.18 and lists the main findings from the studies so that they can be easily reviewed and compared. These findings are categorized into 12 themes, including: (1) the body of Sustainability Knowledge in the infrastructure sector, (2) KM Enablers at industry level, (3) KM Enablers at organizational level, (4) KM Enablers at project level, (5) KM Enablers at the personal level, (6) KM Strategy, (7) identify
Sustainability Knowledge, (8) obtain Sustainability Knowledge, (9) share Sustainability Knowledge, (10) maintain Sustainability Knowledge, (11) apply Sustainability Knowledge and (12) outcomes of managing sustainability knowledge.
### Table 7.1: Results from Questionnaire Survey, Interviews and Case Studies

<table>
<thead>
<tr>
<th>1. The Body of Sustainability Knowledge in the Infrastructure Sector</th>
<th>Questionnaire Survey</th>
<th>Interview</th>
<th>Case Study A</th>
<th>Case Study B</th>
</tr>
</thead>
<tbody>
<tr>
<td>The body of sustainability knowledge for infrastructure development is usually considered:</td>
<td>- Subjective, not well defined in the industry, thus every project need to define sustainability according to the project’s characteristics. - Rare “good practice” exemplar projects - Sustainability knowledge has similarity to other knowledge domain, but bad attitudes stops the KM cycle.</td>
<td>- TBL - Policy &amp; Legislation - Industry guidelines - Industry good practices</td>
<td>- TBL - Policy &amp; Legislation - Industry guidelines - Industry good practice</td>
<td></td>
</tr>
</tbody>
</table>


| 3. KM Enabler – Organizational Environment | - Leadership - Organizational culture - Organizational mission, vision and strategy - Training and education - Sense of social responsibility (organization) - Trust between colleagues - Financial support | - Organizational culture and vision | - Organizational culture and vision |
### 4. KM Enabler – Project Environment

- Client’s awareness and requirement is the most important impetus;
- Other project level enablers include:
  - Leadership
  - Project target
  - Team work
  - Multi-discipline integration
  - Stakeholder integration
  - Financial support
  - Project budget
  - Trust (project)
  - Project risk management

- Knowledgeable and committed project client
- Leadership
- Project Target

- Committed client
- Support from the management level
- Project target
- Leadership

- Leadership
- Support from the project management level

### 5. KM Enabler – Personal Capabilities

- Communication skill
- Technical expertise
- Sense of social responsibility
- T-shape skill
- Capability to codify
- Creativity

- Multi-discipline Knowledge

- Communication skill
- Sense of care and responsibility about sustainability

- Communication skill
- Sense of care and responsibility about sustainability

### 6. KM Strategies

- Managing relevant knowledge is critical to promote the adoption of sustainability knowledge in infrastructure projects.
- “Soft” issues (e.g. attitude, culture) are more important and usually harder to tackle than “hard” issues (e.g. IT systems, technology advancement).
- A “subject” KM approach should be adopted for managing sustainability knowledge.
- Currently, KM activities for managing sustainability knowledge are conducted randomly and unsystematically.
- KM strategies should address the important issues

- Post Project Review (PPR)
- Sustainability Reporting
- Education and Training
- Sustainability Staffing
- Community of Practice (CoP)
- Sustainability Measurement
- IT Tools – Intranet, Database and others
- Case-based Reasoning

- Sustainability Staffing
- Sustainability champion
- Sustainability Reporting
- Transfer of Best practice
- Sustainability Education
- Sustainability Measurement

- Sustainability Education
- Cultivate Sustainability CoP in project
- Involved in other level Sustainability CoPs
- Resource Sustainability Coordinator
- Reviewing and
such as: transferring of industry best practice, communication of knowledgeable practitioners, industry sustainability awareness, integration of different stakeholders and disciplines, etc.

<table>
<thead>
<tr>
<th>7. Identify Sustainability Knowledge</th>
<th>Reporting on Sustainability Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Identifying sustainability knowledge is important, but not very challenging.</td>
<td>- Search according to the project’s specific objectives</td>
</tr>
<tr>
<td>- Rank of main stakeholders’ willingness on managing sustainability knowledge: consultant &gt; designer &gt; project manager &gt; client &gt; engineer &gt; government agency &gt; contractor.</td>
<td>- Recommended by mother companies</td>
</tr>
<tr>
<td>- Organizations and projects should actively identify internal lessons learned and external industry best practice.</td>
<td>- Delivered industry good practices</td>
</tr>
<tr>
<td>- External bodies (government agencies, industry associations, etc.) should also promote sustainability concepts to the organizations.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Obtain Sustainability Knowledge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Obtain sustainability knowledge is very important, but not very challenging.</td>
<td>- Network of subject matter expertise</td>
</tr>
<tr>
<td>- Rank of main stakeholder influence on managing sustainability knowledge: client &gt; designer &gt; project manager &gt; consultant &gt; government agency &gt; contractor.</td>
<td>- Sustainability staffing</td>
</tr>
<tr>
<td>- To obtain sustainability knowledge, industry practitioners usually go to colleagues and internal experts, as well as referring to the industry best practice.</td>
<td>- Transfer of good practice</td>
</tr>
<tr>
<td>- Knowledgeable practitioners and industry good practices should be highlighted for obtaining sustainability knowledge.</td>
<td>- Network of subject matter expertise</td>
</tr>
<tr>
<td></td>
<td>- Sustainability staffing</td>
</tr>
<tr>
<td>9. Share Sustainability Knowledge</td>
<td>10. Maintain Sustainability Knowledge</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------------------</td>
</tr>
</tbody>
</table>
| - Sustainability knowledge sharing is both very important and challenging.  
  - Sharing of knowledge can be facilitated through IT tools and other traditional approaches.  
  - Sharing of knowledge should be across various disciplines and stakeholders. | - Maintain sustainability knowledge is very important, but not very challenging.  
  - Maintaining sustainability knowledge is more than simply storing the knowledge in the database. Project information and index of subject-matter experts are important. |
| - Setting specific KRA & KPI on knowledge sharing  
  - Sustainability Reporting  
  - Education and Training  
  - Sharing knowledge through presentations to mother companies / industry colleagues  
  - Sustainability staffing  
  - Post Project Review  
  - Publication | - Sustainability reporting  
  - Post project review  
  - Case study publication  
  - Keep knowledge in mother companies’ database  
  - Publication | - Setting specific KRA & KPI on knowledge sharing  
  - Sustainability reporting  
  - Post Project Review  
  - Education and Training  
  - Sustainability CoP (project / organizational / industry)  
  - Sustainability staffing  
  - Publication  
  - Store knowledge in mother companies’ database |
11. Apply Sustainability Knowledge (Project Level Implementation)

- Sustainability knowledge application is the most important and challenging phase.
- Sustainability knowledge application needs to be integrated into the whole process of project management.
- Main stakeholders must be integrated for sustainability tasks, especially the client, designer and project manager.

| Project performance: |
| - Project’s reputation |
| - Employee’s sense of social responsibility |
| - Organization’s ability to exploit market opportunity |
| - Customer satisfaction |

| Organization performance: |
| - Corporate reputation |
| - Customer recognition |
| - Intellectual asset |
| - Profit |

| Project Vision / Project Objectives / Sustainability Policy |
| - Multi-criteria sustainability assessment |
| - Sustainability integrated into Project Management Plan |
| - KRA & KPI system to monitor performance |

| Defining sustainability for the project |
| - KRA & KPIs (with specific KPI to address the management of sustainability |

12. Outcomes

| Project performance: |
| - Expanded Infrastructure Sustainability Asset |
| - Sustainability enlightened and knowledgeable stakeholders |
| - A benchmark for future projects |

| Organization performance: |
| - Expanded Infrastructure Sustainability Knowledge Asset |
| - Sustainability enlightened and knowledgeable stakeholders |
Table 7.2: Key Elements of the Final KM Framework for Managing Sustainability Knowledge in the Australian Infrastructure Sector

<table>
<thead>
<tr>
<th>Main Sections of the KM Framework</th>
<th>Main Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KM Enabler</strong></td>
<td><strong>Main Contents</strong></td>
</tr>
<tr>
<td></td>
<td><strong>External Environment</strong></td>
</tr>
<tr>
<td></td>
<td>- Sustainability Awareness</td>
</tr>
<tr>
<td></td>
<td>- Policy &amp; Legislation</td>
</tr>
<tr>
<td></td>
<td>- Network of Subject-matter Experts</td>
</tr>
<tr>
<td></td>
<td><strong>Organizational Environment</strong></td>
</tr>
<tr>
<td></td>
<td>- Organizational Vision and Culture</td>
</tr>
<tr>
<td></td>
<td><strong>Project Environment</strong></td>
</tr>
<tr>
<td></td>
<td>- Leadership</td>
</tr>
<tr>
<td></td>
<td>- Project Target</td>
</tr>
<tr>
<td></td>
<td>- Knowledgeable and Committed Client</td>
</tr>
<tr>
<td></td>
<td>- Support from the Project Management Level</td>
</tr>
<tr>
<td></td>
<td><strong>Personal Capabilities</strong></td>
</tr>
<tr>
<td></td>
<td>- Sense of Care and Responsibility about Sustainability</td>
</tr>
<tr>
<td></td>
<td>- Communication Skill</td>
</tr>
<tr>
<td></td>
<td>- Multi-disciplinary Knowledge</td>
</tr>
<tr>
<td></td>
<td><strong>KM Strategies</strong></td>
</tr>
<tr>
<td></td>
<td>- Sustainability Education</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Staffing</td>
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<tr>
<td></td>
<td>- Sustainability CoP</td>
</tr>
<tr>
<td></td>
<td>- Knowledge and Expert Mapping</td>
</tr>
<tr>
<td></td>
<td>- Best Practice Transfer</td>
</tr>
<tr>
<td></td>
<td>- Sustainability Measurement</td>
</tr>
<tr>
<td></td>
<td><strong>KM Activities</strong></td>
</tr>
<tr>
<td></td>
<td>- Identify sustainability knowledge</td>
</tr>
<tr>
<td></td>
<td>- Obtain sustainability knowledge</td>
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<tr>
<td></td>
<td>- Share sustainability knowledge</td>
</tr>
<tr>
<td></td>
<td>- Maintain sustainability knowledge</td>
</tr>
<tr>
<td></td>
<td>- Apply sustainability knowledge (Sustainability Implementation in Project)</td>
</tr>
<tr>
<td><strong>KM Outcomes</strong></td>
<td><strong>Main Contents</strong></td>
</tr>
<tr>
<td></td>
<td>- Sustainability Knowledgeable and Committed Stakeholders</td>
</tr>
<tr>
<td></td>
<td>- More Sustainability-sound Infrastructure Projects</td>
</tr>
<tr>
<td></td>
<td>- Expanded Infrastructure Sustainability Knowledge Asset</td>
</tr>
</tbody>
</table>
Synthesizing the results listed in Table 7.1 led to the identification of the most important issues that should be addressed to effectively manage sustainability knowledge in the Australian infrastructure sector; these are: KM enablers, KM strategies, KM activities and KM outcomes. They will also be the main elements of the final KM framework. Detailed discussions on these issues listed will be presented in the following sections.

### 7.3 The Body of Sustainability Knowledge

Through the studies conducted for this research, it is confirmed by the industry sector that sustainability issues need to be considered when developing infrastructure projects. And managing relevant knowledge is crucial to the organizations, project teams and industry practitioners for their achievements of infrastructure sustainability goals.

In this research context, “sustainability knowledge” is seen as the type of knowledge that improves the sustainability of an infrastructure project during a project’s life cycle. In the infrastructure sector, a well-accepted definition for “infrastructure sustainability” is still nonexistent. Relevant knowledge is usually considered subjective, fragmentary, dynamic and constantly evolving. Although there is no structured taxonomy of sustainability knowledge, the body of sustainability knowledge contains various forms that can be listed, including high-level sustainability principles, legislation and policy, industry guidelines, assessment tools and indicators, industry good practices and lessons learned from previous projects.

Table 7.3 illustrates some important forms of sustainability knowledge and remarks on their characteristics and current status.
Table 7.3: Examples of Existing Sustainability Knowledge for Infrastructure Development

<table>
<thead>
<tr>
<th>Form</th>
<th>Examples</th>
<th>Characteristics/Status</th>
</tr>
</thead>
</table>
| High level sustainability principles      | Triple Bottom Line (TBL), Sustainable Construction principles etc.        | - Explicit  
- Too general to direct sustainability application at project level                                                                            |
| Legislation & Policy                     | Regional Plans, Acts and Policies etc. that comprise sustainability relevant requirements | - Explicit  
- Support in a general level  
- Inadequate                                                                                                                                 |
| Assessment tool and indicators           | Such as: The Civil Engineering Environmental Quality and Assessment Scheme (CEEQUAL), AGIC rating scheme, ARUP SPeAR sustainability framework etc. | - Explicit  
- Mainly adapted from the assessment tools of building sector,  
- Has a great potential to support infrastructure sustainability in a project level  
- Still under development.  
- Not widely used in the industry |
| Industry guidelines                      | Project Sustainability Management Guideline—International Federation of Consulting Engineers (FIDIC), Global Reporting Initiative (GRI) – Sustainability Reporting Guidelines | - Explicit  
- General  
- Not mainstream  
- Not widely used by the industry                                                                                                                                 |
| Project management process               | Project Sustainability Management process, sustainability related KRA/KPI system etc. | - Explicit  
- Very helpful for sustainably application at the project level  
- Varies greatly from project to project                                                                                                                                 |
| Industry best practice                   | Case study publications, Lessons learned from projects                   | - Tacit and/or explicit  
- Very helpful carrier of sustainability knowledge,  
- Good practices are rare  
- Hard to define good practice  
- Good practices are not well acknowledged, analyzed, and compiled into case studies publications  
- Often lost after project closure                                                                                                                                 |
| Individual knowledge and experience      | Project experience and memory, expert insight, professional expertise | - Tacit  
- Fragmentary  
- Hard to articulate and transfer  
- Often lost when staff leave the project team and/or organization                                                                                                                                 |
| Academic research outcome                | Green materials, energy saving technologies, advance design methodology, etc. | - Explicit  
- Gap between theory and practice  
- Poor collaboration between academia and industry                                                                                                                                 |
High-level sustainability principles such as TBL (Triple Bottom Line) and other sustainable construction guidelines, relevant legislation and policies, and industry guidelines are playing an essential role in guiding industry practitioners to implement sustainability in their professional domains. However, these principles are usually too general to direct sustainability application at project level. As there is no well-accepted definition of sustainability in this industry sector, diverse stakeholders tend to have different interpretations based on their own stance. Existing definitions are usually concerned with “sustainability” at industry and organizational levels, and are thus deemed to be impractical for industry practitioners to relate to the project level.

In this project-oriented industry sector, sustainability can only be achieved project-by-project. In practice, each project has to interpret “sustainability” in the first place, due to the project’s unique characteristics, as illustrated in the two case studies. In both cases, the project teams personalized the definition of sustainability based on some well-known high level sustainability principles, for example: Triple Bottom Line, relevant policy and legislations and industry guidelines such as CEEQUAL (The Civil Engineering Environmental Quality and Assessment Scheme), Project Sustainability Management Guidelines by FIDIC and Sustainability Reporting Guidelines.

Under such circumstances, industry exemplary projects and relevant case studies showing the evaluation, decision-making and implementation process can be very helpful to inspire future projects. Thus, industry good practices are seen as the most important and efficient carrier for collecting and transferring practical sustainability knowledge. However, currently, good practices on infrastructure sustainability are rare and not yet fully identified, recorded and shared. The lack of relevant case studies and publications explains why many industry practitioners feel that sustainability knowledge is hard to find and acquire.

Assessment tools and indicator systems are important and practical tools for project teams to de-mystify sustainability in an infrastructure context and help them achieve sustainable outcomes. As per the literature review, project
sustainability assessment tools and indicator systems have started to appear in a number of places to transfer general, global sustainability principles into local, project level objectives (Refer to Section 2.3.3). In the construction industry, relevant assessment tools are mostly for construction in the building sector, such as residential buildings and office complexes (such as Green Star). In the Australia infrastructure sector, a rating scheme is being developed by the Australian Green Infrastructure Council, which aims to provide a project-based sustainability assessment checklist for large infrastructure projects. Before an industry accepted assessment tool is developed, in practice, project teams usually develop simple sustainability matrices, or a KPI/KPR system, to monitor project sustainability performance, as described in the two case study projects.

Individual knowledge and experience in infrastructure sustainability is also a very important resource. In fact, according to the questionnaire survey results, industry practitioners tend to firstly go to their colleagues and internal experts for help when they need sustainability knowledge in their work. Even when people are looking for previous project information, they usually feel that first finding the relevant person is the most efficient approach. These people can be sustainability practitioners who have rich relevant project experience, or sustainability champions who have the enthusiasm and interest to extend infrastructure sustainability, or they may even be officially appointed sustainability officers, coordinators or managers. They are valuable knowledge assets within an organization and the industry sector.

Some industry practitioners and experts argue that the body of knowledge on infrastructure sustainability is no different to other knowledge domains. The main obstacles that stop its transfer and application in the industry stem from people’s attitudes to change and from commitment at all levels.
7.4 Status of KM Adoption for Managing Sustainability Knowledge

KM is a new concept for the Australian construction industry, but it does not mean that the industry sector is not actively managing important knowledge. Communication of expertise, transfer of information, professional training and learning is happening extensively everyday across the industry. The literature suggests that, in this highly project-oriented industry sector, KM facilitates continuous improvement through project learning and innovation (Robinson et al., 2010). KM initiatives and learning were found at different levels; for example: inter projects (knowledge sharing between projects), intra-project (transferring knowledge during the project lifecycle) and cross-sector (supporting learning outside the project sector environment).

In the infrastructure sector, industry level associations are working on promoting sustainability practices through conducting training courses, facilitating networks, rewarding good practices, developing relevant tools, building accessible knowledge databases and setting rating standards. They are trying to push organizations and industry practitioners to absorb more sustainability knowledge and integrate it into practice. Some leading organizations have also started to design KM systems, using advanced IT tools to facilitate knowledge storage and knowledge sharing, and ICT tools to assist communications.

In addition, sustainability champions are found throughout the industry and organization hierarchies. They have a passion for sustainability and are trying hard to influence their colleagues and projects they are involved with. Supported by superiors or not, sustainability champions are devoting themselves to building networks and platforms in order to share and apply sustainability knowledge and to raise the awareness of sustainability across the industry sector.

As discussed in the interview and case study chapters, there are considerable initiatives on managing relevant sustainability knowledge in the industry sector, and there are also some KM tools adopted; for example: PPR (Post Project...
Another issue is that there is still a heated dispute in the field of KM on the importance of soft issues versus hard issues and how to place IT tools in KM programs. As discussed in the literature, majority of the existing efforts and practice of KM implementation have usually employed a “technology-push” approach, investing greatly on IT systems and tools. The same trend exists in the infrastructure sector, as evidenced by some KM systems that are currently under development in some organizations. However, the majority of industry practitioners involved in this research agree that, in order to promote sustainability knowledge application, KM should prioritize attention on soft issues – including attitude and cultural aspects, leadership and change management, new and improved project management processes, communication and collaboration – rather than setting up expensive IT systems, as IT is but one of the tools that can assist the whole process.

7.5 **Enablers for Successful Infrastructure Sustainability KM**

As discussed in pervious chapters, there are various barriers in the way of embracing sustainability knowledge for industry practitioners, project teams and organizations (Refer to Section 4.6.3 and Section 5.6.2). The main barriers are listed below in Table 7.4.
Table 7.4: Key Barriers to the Management of Sustainability Knowledge

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of awareness across the industry sector</td>
<td>Sustainability is still a new concept that is not highlighted enough in the infrastructure sector. There is not yet complete awareness of the seriousness of the sustainability crisis and the urgent need for the infrastructure sector to address it. Such a situation allows little room and motivation for practitioners to actively seek sustainability knowledge.</td>
</tr>
<tr>
<td>Deficiency of current sustainability education</td>
<td>Many industry practitioners are not enlightened on infrastructure sustainability at a professional and practical level. Education courses and training sessions are not delivered systematically and efficiently and a fundamental industry education capacity has not been built.</td>
</tr>
<tr>
<td>Lack of guidelines and examples for industry practitioners to move from talk to action</td>
<td>There is no well-accepted definition for infrastructure sustainability in the industry sector. Common practice is that every project has to initially define sustainability. Inspirational good practices and exemplary projects are rare. Industry practitioners need more guidelines to practically apply sustainability knowledge.</td>
</tr>
<tr>
<td>Lack of regulation</td>
<td>Project sustainability is not yet regulated. Some projects even try to avoid the word “sustainability” in project documents and use the term “environmental concerns” instead. If not driven by the client, mainstream practices will stay firmly in compliance rather than venture beyond compliance.</td>
</tr>
<tr>
<td>Not required and/or supported by client</td>
<td>During a project life cycle, time, budget and resources are limited. Management of knowledge is time consuming and requires extra funding and resources to support. If sustainability consideration is not required and/or supported by clients, then it is hard for KM for sustainability knowledge to progress.</td>
</tr>
<tr>
<td>Lack of consensus and collaboration among stakeholders</td>
<td>Sustainability progress can only be achieved through the collaboration of all stakeholders involved in the project. The same is true of the management of relevant knowledge. The main stakeholders in the industry currently have different degrees of willingness and initiative to work on sustainability. Ideal consensus and collaboration is hard to build.</td>
</tr>
</tbody>
</table>

Therefore, one of the most important questions for the industry sector and its organizations that are interested inefficiently promoting the management of
sustainability knowledge and its application in practice is: What are the key enablers that may help in overcoming these barriers? As discussed in previous chapters, enablers can be categorized into four levels according to the scope of their influence – External Environment (industry level), Organizational Environment (organizational level), Project Environment (project level) and Personal Capabilities (individual level) (Refer to Section 4.2).

The questionnaire survey, interview and case studies, yielded important enablers for successfully managing sustainability knowledge, as listed in Table 7.5.
<table>
<thead>
<tr>
<th>Enablers</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External Environment (Industry Level)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sustainability Awareness</strong></td>
<td>Raising awareness of sustainability among industry practitioners is crucial to the management of sustainability knowledge. A better understanding of the practical significance of sustainability for the industry sector will promote sustainability’s embodiment in mainstream business practices and thus drive the sharing, maintaining and application of relevant knowledge.</td>
</tr>
<tr>
<td><strong>Policy &amp; Legislation</strong></td>
<td>As of now, organizations and projects tend to stay firmly in compliance with environmental and social requirements. Thus, Policy and Legislation changes could raise the bar of industry practice towards sustainability.</td>
</tr>
<tr>
<td><strong>Network of Subject-matter Experts</strong></td>
<td>A subject-matter expert is a person who is an expert in a particular area. Many people agree that, currently in the infrastructure sector, there is almost no real expertise in the domain of infrastructure sustainability, as industry practice on sustainability is still new and in an exploratory stage. However, there are still practitioners with relatively more knowledge and experience than others, such as Sustainably Coordinators/Officers or Sustainability Champions from any related disciplines. Frequent and flowing communication and collaboration among them could accelerate the dissemination of industry good practice and accelerate the progress of state-of-the-art technology.</td>
</tr>
<tr>
<td><strong>Organizational Environment (organizational level)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Organizational Vision and Culture</strong></td>
<td>To embed sustainability effectively into an organization, it is important that the organization has an ethos that recognizes and promotes the importance of sustainability. With such recognition stated in the organization’s statement of mission, vision and business strategy, management of sustainability knowledge will have closer linkage with an organization’s business process and focus.</td>
</tr>
<tr>
<td><strong>Project Environment (project level)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Leadership</strong></td>
<td>To some extent, the sustainability challenge is a leadership challenge. Success with sustainability requires leadership within the industry sector, at the organizational level, and within a project team, to identify sustainability opportunities and innovative solutions, and to inspire people to build their capacity to address sustainability issues in their work. Sustainability leadership is not the role of any single stakeholder. All stakeholders can take a role in leading change.</td>
</tr>
</tbody>
</table>
Leadership is a role, not a position. Sustainability champions that can be found in any hierarchy of a project team or organization should take the leadership role. While they may hold junior or middle management position and lack the authority to make a change, they can still influence and convince others to make things happen.

| Project Target | Project sustainability targets describe what sustainability objectives the project wants to achieve, and how these will be achieved. Without knowing these, it would be very difficult to link the general sustainability knowledge to the project context. The first step of the knowledge cycle – identify knowledge – in particular, would have no basis. |
| Knowledgeable and Committed Client | In the construction industry, a client’s endorsement of sustainability is the most important driver for sustainability application in real projects. With support and commitment from clients, more opportunities to embed sustainability can be identified, thus providing more space and higher priorities for the management of relevant knowledge. |
| Support from the Project Management Level | Although many knowledge processes and KM activities are on a more or less voluntary basis, they can be time and resource consuming. Especially in regards to sustainability at its emerging stage in this industry, empowerment and support from the management level will have much impact on success in accepting, sharing, maintaining and applying knowledge. |

**Personal Capabilities (individual level)**

| Sense of Care and Responsibility for Sustainability | A sense of caring for sustainability characterized all of the sustainability champions in the industry. People are likely to actively seek, share and apply sustainability knowledge at work when they feel a personal responsibility and regard for sustainability. |
| Communication Skill | Achievements in infrastructure sustainability require integration of multiple disciplines and collaboration of all stakeholders. During the knowledge cycle – its identification, obtaining, sharing, maintenance and, especially, its application – communication skill is central to the process that enables industry practitioners to effectively communicate and collaborate with diverse stakeholders. |
| Multi-disciplinary Knowledge | Sustainability is a field that requires system thinking and contributions from diverse disciplines. Communicating with practitioners from other disciplines and integrating knowledge and practices from various domains is required to implement sustainability in projects. |
7.6 KM Strategy

KM strategies are methods, instruments and approaches that industry practitioners adopt to facilitate the key knowledge activities (e.g. identification, obtaining, sharing, maintaining, and applying knowledge). From the studies reported here, several effective KM strategies and instruments that facilitate these knowledge activities are shown to include:

- Sustainability Education
- Sustainability Staffing
- Sustainability CoP
- Transfer of Best Practice through Project Case Studies
- Sustainability Measurement
- Reporting on Sustainability.

7.6.1 Sustainability Education

Sustainability education is playing a foremost role with regards to the management of sustainability knowledge in the infrastructure sector. This is mainly because, at the present stage, full awareness of sustainability for infrastructure development has not been built across the industry sector. Previous studies revealed that, although the industry practitioners might have learned and accepted sustainable development principles and might also have made efforts in their personal life towards sustainability, they might not be able to embed sustainability considerations into work at a practical level. Therefore, sustainability education is essential to raise the awareness of sustainability across the industry, as well as to build the sustainability capacity of the industry sector.

Sustainability Education in Australia

2005 to 2014 has been claimed to be the Decade of Education for Sustainable Development (DESD) by the United Nations General Assembly. The progress of
Education for Sustainable Development (ESD) has been evident in both institutional and program areas at international, regional and national levels (UNESCO, 2009).

In Australia, in order to respond to the DESD, the Government has conducted a series of nation-wide initiatives. The Australian Government’s National Action Plan – “Environmental Education for a Sustainable Future” – outlined the goals to promote sustainability across the nation through education in order to raise sustainability awareness, building relevant capacity of various groups (e.g. general community, governments, and industry practitioners), and ultimately accelerating Australia’s progress towards sustainable development (Department of Sustainability, Environment, Water, Population and Communities, 2010).

**Sustainability Education in the Australian Infrastructure Sector**

In the construction industry, sustainability education usually aims to help industry practitioners to develop the attitude, skills and knowledge to make informed decisions, to act upon these decisions, and to further influence other industry practitioners and projects within their personal and professional scope of influence in ways that can contribute to project sustainability.

In schools and universities, sustainability education has been integrated into curriculum frameworks which include sustainability as a cross-curriculum dimension (The Department of the Environment, Water, Heritage and the Arts, 2010). Many industry practitioners confirmed that new graduates have better knowledge and awareness of sustainable development and, therefore, are more willing to integrate sustainability principles into their day-to-day work. However, existing industry practitioners are less enlightened on sustainability.

Therefore, existing industry sustainability education is focusing on introducing sustainability principles and practices in Sustainable Development from a holistic view and in diverse themes within the engineering and built environment professions. These themes include whole system design, energy saving and
sustainable water solutions. As a part of vocational education, sustainability knowledge is delivered through training courses, seminars, workshops, even lunchtime speeches. As for other domains, sustainability education may happen in many places: at the industrial level (e.g. training courses organized by industry associations), within organizations (e.g. in-house training) or within project teams during the construction phase of a project when people from different disciplines work together (e.g. training sessions and theme workshops, as illustrated in the two case studies).

Although the industry sector is under increasing pressure to engage with and respond to sustainability issues, the questionnaire survey and interview results show that sustainability education in the industry sector is still not being conducted concurrently, systematically and to all industry participants. In fact, sustainability education should persistently and broadly cover all stakeholders in the industry sector. Achievement of sustainability can only be made through the collaboration of multi-disciplinary teams and various stakeholders involved in different phases of the project life cycle. Sustainability education for infrastructure sustainability makes it possible to develop enlightened, active and responsible industry practitioners and infrastructure stakeholders across the industry.

**Deliver Sustainability Education Step by Step**

The process of sustainability education is not as simple as delivering the knowledge to an individual. There are various barriers impeding the learning process and it involves great effort to prompt industry practitioners to make a change and transfer from talk to action. Different types of knowledge should be given to help industry practitioners to overcome these barriers. Figure 7.1 describes the process of how an industry practitioner and/or an organization may accept and finally act beyond compliance on infrastructure sustainability. This process is developed over several phases.

- **Phase I** - In the first phase, industry practitioners are uninformed of infrastructure sustainability; thus, decisions are made without considering any
sustainability opportunities. At this stage, sustainability education should focus on introducing the principles and practices of sustainable development in the engineering and built environment professions.

- **Phase II** - In the second phase, people are informed, but maybe still skeptical or apathetic about infrastructure sustainability due to their limited understandings of the link between sustainability principles and their professional domains. Thus, they do not want to make a change. Interviewees pointed out that project managers and engineers are hardest to convince.

- **Phase III** - Even when practitioners want to make a change, they may still not know what to do and how to do it due to the lack of practical tools, examples and relevant experience. There are also various obstacles stopping industry practitioners from moving from talk to action. It might be because clients do not require sustainability considerations, or because the project team fails to measure the value that can be delivered, or because of the limit budget, tight project schedules, etc. Organizations and project teams tend to stay firmly in compliance with the relevant policies and requirements, rather than actively seek opportunities to promote sustainability applications.

At this stage, education should show the tangible value of sustainability considerations through the example of real industry good practice projects. Once people are convinced, they will be willing to seek and share more knowledge. Furthermore, specific and practical sustainability knowledge and tools should be provided to the industry practitioners at this stage to help them to solve problems at project level.

- **Phase IV** - In the fourth phase, industry practitioners, project teams and organizations will be more active and efficient and try to act beyond compliance by comparing their performance with industry good practices. Before this phase, sustainability education focuses on conveying knowledge to the industry practitioners. At this stage, education should provide a platform for the practitioners, helping them to communicate the latest good practices, solutions, and state-of-the-art technologies. Standardized assessment tools, indicator systems, PM tools, etc. will enable the project
teams to set tangible targets and benchmark themselves with industry good practice.

- **Phase V** - Finally, in the last phase, when the project sustainability considerations are driven by the clients and a culture of care is built, industry practitioners will be able to creatively solve problems and deliver industry best practice.

Education in the first two phases serves the sustainability awareness development process in the industry sector, while in the third and fourth phases it serves industry capacity building. The fifth phase is where innovation occurs and leads to the improvement of sustainability application in projects.
Main Barriers

- Not driven by clients’ needs
- Lack of innovation culture
- Lack of incentive

- Lack of tangible targets, objectives within professional domain
- Lack of framework & tools
- Lack of supportive processes
- Other competing priorities

- Not client need
- Not required by law
- Unable to measure the value that can be delivered
- Unable to see sustainability link with own discipline
- Unable to see own level influence
- Ingrained habit
- Lack of incentive
- Limited budget

- Limited understanding of sustainability and its link to infrastructure

Focus

- Sustainability concepts/principles
- Show tangible value through real case study
- Industry good practice
- Specific sustainability knowledge which is practical at the project level
- Use assessment tools to compare with industry good practice
- Motivation
- Competence

Figure 7.1: Sustainability Education in the Infrastructure Sector
Sustainability Staffing

As discussed in interview findings and illustrated by the two case studies, sustainability staffing is currently playing an important role in facilitating the management of knowledge in the industry sector. There are two types of sustainability roles in the industry sector: (1) official positions entitled Sustainability Manager (or, similarly, Sustainability Coordinator, Sustainability Officer) and (2) sustainability champions.

Sustainability Officers are resourced by organizations that want to make a change towards sustainability or to manage projects that have a strong sustainability focus, mainly in leading contracting firms and engineering consulting firms. On the one hand, some Sustainability Officers are resourced into a business department and actually bid work that is related to some topic of sustainability such as climate change or energy saving. One the other hand, some of them work at an operational

Sustainability Education Highlights

- At present, sustainability education is playing a significant role in the Australia infrastructure sector to address sustainability knowledge, awareness and capacity issues.
- Sustainability education can be conducted in project teams, in organizations and at an industrial level.
- Face-to-face communication is still the most effective way to deliver sustainability education as it allows open discussion.
- Sustainability education should be delivered in a systematic and structured way and should cover all stakeholders in the infrastructure sector.
- Sustainability education should be progressively delivered to the industry practitioners in order to help them to overcome various barriers and to walk through different learning phases (Uninformed, Skeptical and Apathetic, Compliant, Efficient & beyond Compliance, and Creative).

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position at organizational level to provide support to different projects and to facilitate activities to enable a culture change towards a more sustainable business pattern. One of the main roles of these sustainability managers is organizing sustainability in-house trainings, raising employee awareness about sustainability, providing information and help to projects, and collecting sustainability experience from internal projects. They also network with industry bodies, other organizations and other Sustainability Managers, building a knowledge transfer bridge between internal and external organizations.

Sustainability champions are industry practitioners who are passionate about, and willing to work on, sustainability. Usually they are also knowledgeable on sustainability and they aspire to persuade their colleagues, organizations and projects with which they are involved to make a change. Sustainability champions can be found throughout the hierarchy of an organization, a project team, any discipline within the industry scope, and any stakeholder group. They are influencing people around them. Moreover, although most of them hold junior or middle positions in their project teams or organizations and lack the authority to make changes themselves, they are trying to convince the people who can make it happen. For example, designers may try to convince their clients to accept a more sustainable engineering solution by showing them its tangible value and providing them with the essential relevant knowledge. In Case Project A, the sustainability champion on the project made a big contribution by bringing in advanced sustainability management tools and coordinating their application, as well as by seeking opportunities to share her project experience with industry. In Case Project B, sustainability considerations were integrated into the project due to the advocacy of a credible sustainability champion on the project.

Naturally, sustainability managers and industry sustainability champions value sustainability knowledge, and they are the people who are actively seeking opportunities to obtain, share and apply the knowledge at work wherever possible. On the one hand, networking among these sustainability people provides an effective platform for better practice transfer and knowledge sharing. On the other hand, collaboration, education and networking between these sustainability people.
and other industry practitioners enable sustainability knowledge to be transferred widely.

### Sustainability Staffing Highlights

- There are sustainability managers (formal positions) and sustainability champions in the infrastructure sector and they contribute greatly to the management of sustainability knowledge in the industry sector.
- Usually sustainability managers are sustainability champions who are given a formal title within a project or organization.
- Sustainability champions are usually passionate and knowledgeable about sustainability, have good communication skill and multi-disciplinary knowledge. They are valuable knowledge assets for organizations and project teams.
- Sustainability champions are taking the leadership role in the infrastructure sector to promote the embracement of sustainability considerations into real infrastructure projects.
- Identifying, resourcing and cultivating sustainability champions will help the infrastructure sector to expand sustainability knowledge assets and better manage them within the industry.

### 7.6.3 Sustainability CoP

According to Wenger et al. (2002), a CoP is a cluster of people who are organized around a common shared interest and share experience and practice on an ongoing basis to deepen their knowledge and expertise. When industry practitioners get together regularly to share sustainability problems, insights, better practices and innovative solutions – either formally or informally, face-to-face or virtually in an online forum– a Sustainability CoP is built.

A Sustainability Community of Practice (CoP) is an effective approach for industry practitioners to share and learn sustainability knowledge. Wallace (2005)
suggests that setting up a Sustainability CoP that crosses all the business lines of the organizations should be the first step for any organization intending to market and deliver sustainability. In the infrastructure sector in Australia, although none of them is tagged with a “CoP” label, groups like CoPs are found in many places: within project teams, inter-projects, in organizations, and at an industrial level.

Sustainability related industry associations, such as the Australian Green Infrastructure Council (AGIC), are formal Sustainability CoPs in essence. Sustainability Managers and Sustainability Champions are actively involved in the industry level Sustainability CoPs, bringing the CoP insights, cutting-edge technology, insights and best practice case studies. Compared to other level Sustainably CoPs, industry level Sustainability CoPs have more functions and responsibilities than others in regards to the management of relevant knowledge, including the responsibility to:

- to collect, organize and maintain sustainability knowledge and make the knowledge accessible to industry practitioners
- to recognize industry better practice, and
- to develop and promote relevant tools.

Sustainability CoPs are also found within project teams, inter-projects, and in organizations. Usually a Sustainability CoP consists of three main elements: the domain, the community and the practice; these are explained in Table 7.6.
Sustainability CoPs facilitate the management of sustainability knowledge through a variety of activities, such as: requesting information, problem solving, group learning, seeking experience, reusing assets, documenting knowledge, mapping knowledge, developing tools and generating new knowledge.

Project-based and inter-project sustainability CoPs were witnessed in Case Project B; however, these had only a basis structure and organization. Recommendations to successfully establish and organize a Sustainability CoP are provided below.

- **Resource one or several passionate and credible Sustainability Champions:** To start a Sustainability CoP, passionate and credible Sustainability Champions are essential. They should be knowledgeable, good at communication, and have the ability to encourage people to join the community. They should be the core group who participate intensely in the CoP, and take the leadership in guiding the CoP.

- **Make it across all disciplines:** CoPs exist outside the formal organizational structure and, by nature, have the advantage of sharing knowledge and

<table>
<thead>
<tr>
<th>Elements</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The domain</strong></td>
<td>Sustainability (or some specific themes of sustainability) is the domain of interest that is shared by the industry practitioners in this community.</td>
</tr>
<tr>
<td><strong>The community</strong></td>
<td>Usually, members of a Sustainability CoP are sustainability champions. In pursuing their interest, they engage in joint activities and interact and learn from each other. One or several passionate sustainability champions may take a leading role and foster the communication within the community.</td>
</tr>
<tr>
<td><strong>The practice</strong></td>
<td>This community is not merely a group of people who share a common interest. People in this community are practitioners. They develop and maintain their knowledge assets: databases, online forums, case studies, stories, tools, expert maps, etc. These are sustained until the domain becomes common knowledge.</td>
</tr>
</tbody>
</table>
triggering collaboration across functional boundaries. Furthermore, sustainability is an area that needs system-thinking and contributions from various disciplines. Thus, in Sustainability CoPs, ideally, members should cover all disciplines.

- **Support from Administration:** Sustainability is not yet a mainstream conception the infrastructure sector. High-level support is important for a CoP to get started. Such support includes: providing a physical and virtual space for the group, providing funding, allocating a time slot for its members, etc.

- **Welcome and allow different levels of participation:** As discussed in Section 7.6.1, industry practitioners accept the sustainability principles and engage in actions step-by-step. They should be allowed to attend and participate based on their own situation.

- **Create A knowledge base:** Knowledge and practice shared by the community should be documented and sustained in an appropriate form such as an online form, database, and knowledge catalogue or project portfolio.

- **Connect with other CoPs:** Project-based and organization-based CoPs should communicate with each other for knowledge sharing. They also should connect with industry level CoPs to bridge a flowing transfer of good practices across the industry. Figure 7.2 illustrates the knowledge communication among project-level, organization-level and industry-level Sustainability CoPs.
Sustainability CoP Highlights

- Existing sustainability CoPs lay in project teams, organizations, inter-projects and at the industry level (industry sustainability associations).

- Sustainability CoPs accumulate sustainability knowledge and foster sustainability activists, thus are an effective KM technique that promotes sustainability knowledge sharing and culture cultivating.

- Sustainability champions are active participants of sustainability CoPs.

- Recommendations to successfully establish and organize a sustainability CoP include:
  - Resource one or several passionate and credible Sustainability Champions
  - Have the CoP represent all disciplines
  - Seek support from administration
  - Welcome and allow different levels of participation
  - Create a knowledge base
  - Connect with other CoPs.
7.6.4 Transfer of Best Practice through Project Case Studies

In the infrastructure sector, practitioners prefer the term “better practice” than the common term “best practice”, for the reason that projects with extensive sustainability considerations embedded are still rare and immature. Practices of infrastructure sustainability are just starting to evolve, and there is yet no best way of doing it, nor have huge achievements been made. However, transfer of these better practices still can be a powerful way to share cutting-edge sustainability knowledge, and to drive improvements in a project’s sustainability performance. A better practice can be a way of interpreting sustainability, a technique, a method, a process to integrate sustainability, a tool or an initiative. Usually, it is only applicable to a particular condition or circumstance and may have to be modified or adapted for similar projects, as every project has its unique characteristics, and is delivered by a unique project team.

Industry practitioners confirmed that publishing project case studies is the most effective way of transferring sustainability best practice. Project case studies include the context information, decision-making process, and participant information, and thus enable practitioners to have a better understanding of the conditions of the knowledge. Furthermore, one of the barriers for sustainability practice in infrastructure is that many stakeholders fail to see the tangible values that can be delivered. Project case studies containing sustainability best practices can be a showcase of how project performance can be improved by addressing sustainability considerations.

Transfer of Industry Best Practice through Project Case Studies

- Currently, there are very few best practice projects in the infrastructure sector.
- Lack of exemplary projects is a main constraint for the industry practitioners to apply sustainably in real projects.
- Publishing project case studies is the most effective way of transferring sustainability best practice.
7.6.5 Sustainability Measurement

Sustainability measurement and rating is a powerful way of promoting the integration of sustainability into projects. Many scholars suggest that if progress toward sustainability is to be achieved in real projects, it is essential to develop a sustainability framework, to set project sustainability goals and to establish a process to measure progress (AGIC, 2009a; Wallace, 2005; Lim, 2009).

Sustainability measurement usually covers environmental, social and economic domains according to the TBL structure. Indicators, benchmarks, audits, indexes and accounting are usually included in a sustainability measurement system. Ideally, sustainability measurement should be used on a quantitative basis. However, in practice, measurement of sustainability is used in a wide range of depth and extent, and at different stages of a project. Common sustainability measurement practices in the industry sector include:

- setting a sustainability framework or metrics to briefly show which area of sustainability considerations will be integrated in the project
- conducting multi-criteria assessment to select more sustainable designs
- designing a set of indicators (e.g. PRA/KPI) to address the implementation of sustainability initiatives and knowledge sharing initiatives, and to monitor project performance
- establishing an industry level rating scheme to compare project sustainability performance and to discover industry best practice.

Existing sustainability measurement tools that are designed for infrastructure development are listed in Table 7.7
Table 7.7: Existing Sustainability Measurement Tools for Infrastructure Projects

<table>
<thead>
<tr>
<th>Measurement Tool</th>
<th>Region</th>
<th>Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIDIC’s Project Sustainability Management</td>
<td>Global</td>
<td>Development projects</td>
</tr>
<tr>
<td>Arup’s SPeAR©</td>
<td>Global</td>
<td>All projects</td>
</tr>
<tr>
<td>CEEQUAL</td>
<td>UK and some other countries</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>VicRoads/TCI</td>
<td>Australia</td>
<td>Roads</td>
</tr>
<tr>
<td>Enduring Value</td>
<td>Australia</td>
<td>Mining</td>
</tr>
<tr>
<td>AGIC Infrastructure Sustainability Rating Scheme</td>
<td>Australia</td>
<td>Infrastructure projects (under development)</td>
</tr>
</tbody>
</table>

Other than benchmarking project sustainability performance, sustainability measurement also makes a significant contribution to the management of sustainability knowledge. A comprehensive sustainability measurement system includes catalogues, indicators and weightings of the indicators which map the sustainability knowledge structure for a project. It helps the practitioners to identify their knowledge gap, and then to have a definite objective in view when searching for sustainability knowledge.

**Sustainability Measurement Highlights**

- Sustainability measurement and rating is a powerful way of promoting the integration of sustainability into projects and the management of relevant knowledge.

- From a knowledge perspective, sustainability measurement facilitates sustainability knowledge identification by setting the scope of what knowledge is needed to achieve the project sustainability goals.
7.6.6 Reporting on Sustainability

Currently in the industry sector, reporting on sustainability is a common practice for many leading organizations, and project that have some extent of sustainability focus.

Corporate sustainability reports are usually published on an annually base. The intention of these reports is largely for marketing purpose, listing the activities have been conducted, the achievements have been made, sustainability performance of their project, etc., as a showcase of the organizations’ sense of social responsibility, and their ability to compliance with sustainability requirements.

Project sustainability reports are usually developed from large infrastructure projects that have a relatively strong sustainability focus. Reports can be published during the project construction phase or during the project closure phase.

Regularly publishing sustainability reports is a good approach to disseminate sustainability knowledge to various stakeholders and wider communities. Furthermore, in order to generate the report, the project team needs to record and document activities, decision-making process, considerations, mistakes and achievements continuously along the project development process, and consequently reduce the amount of valuable knowledge lost over time.

Final project sustainability report can be seen as a product of PPR (Post Project Review) on sustainability, which usually highlights the effective tools, management process, innovative solutions, advanced techniques, lessons learnt as well as the people information that links to a specific area of practice.

These project-based sustainability report, naturally, are similar to project case studies, contains rich explicit sustainability knowledge and are easy to be shared and reused.
7.7 **KM Cycle**

Through the questionnaire survey, the KM cycle for managing sustainably knowledge was identified; this mainly includes five basic knowledge activities: identify knowledge, obtain knowledge, share knowledge, maintain knowledge and most importantly, apply knowledge in real infrastructure projects. These activities are performed to support a wide range of organizational and project tasks, such as problem solving. Their integration and performance have to be supported by the right KM strategies and tools.

7.7.1 **Identify Knowledge**

Identifying knowledge is a crucial and strategic step. Organizations and project teams should first think about what they want to achieve and what knowledge is required to make it happen. Gap analysis usually needs to be conducted during this process, which means identifying the gap between existing knowledge assets and the knowledge needed to achieve the goals. The gap analysis is especially crucial for project teams. Infrastructure development is project based and task oriented and usually has a very tight timeline. Setting project targets is considered...
as one of the most important sustainably KM enablers at project level. It is mainly because project targets set the basis for identifying knowledge.

Identifying knowledge is also crucial to prevent “reinventing the wheel”. Industry best practices contained in project case studies are valuable as they set a new benchmark for the industry practice. Furthermore, identification of existing knowledge as well as new generated knowledge is also important to the maintaining of knowledge assets and the reuse of knowledge in future projects. Strategies and tools that support this KM activity include: sustainability measurement, reporting on sustainability, brainstorming and consulting with experts.

7.7.2 Obtain Knowledge

Obtaining knowledge is considered relatively easy and straightforward by the industry practitioners. Once certain knowledge is identified, it is usually accessible. The main reason is, sustainability is not yet a mainstream business concern and is not profitable in many cases. Thus, sustainability knowledge is not currently highly protected by organizations and teams. On the contrary, they tend to be willing to share their experience and achievements on sustainability, as it simply “looks good”. Then the problem lies in how to encourage practitioners to actively obtain knowledge. For an organization, sustainability staffing is an effective way of obtaining knowledge. Strategies and tools that support this KM activity include: networking, undertaking training and retrieving databases.

7.7.3 Share Knowledge

Sharing knowledge is essential to the management of sustainability knowledge. On the one hand, at the industry level, knowledge sharing aims to raise the industry awareness on sustainability and the bar of sustainability practice. On the other hand, at the project level, knowledge sharing aims to transfer the knowledge.
Modern ICT tools are developed to facilitate knowledge sharing. However, there is always a misunderstanding in the field of practice, considering the development of fancy and complex IT and/or ICT tools as KM. Furthermore, successful KM mainly depends on soft issues. Strategies and tools that support this KM activity of knowledge sharing include: networking, CoP, best practice transfer, internet/intranet/, sustainability publications and sustainability education.

7.7.4 Maintain Knowledge

Through proper maintenance, sustainability knowledge gained by individuals, project teams and organizations will be accumulated and leveraged, rather than lost over time. In the infrastructure sector, sustainability knowledge is mainly embedded in three places:

- **Knowledge storage** - Explicit knowledge (e.g. sustainability tools, indicators, documented case studies) is codified and stored in the articles, books and online database that can easily be accessed.

- **Sustainability practitioners** - Tacit knowledge (e.g. know-how, insights, project experience) is embedded in the minds of experts, sustainability champions and other industry practitioners and is hard to be articulated and transferred.

- **Infrastructure projects** – project knowledge (project context, lessons learnt, decision-making in certain condition, etc.) is embedded in the process of conducting activities and the completion of specific tasks in real projects. This kind of knowledge is only valid within the circumstances and conditions of the specific project.

Thus, current practice for knowledge maintenance in the industry sector consists of mapping knowledge, indexing experts and practitioners, and indexing projects. Usually, the three activities are also cross-indexed, especially between practitioners and projects.
7.7.5 Apply Knowledge

Applying sustainability knowledge is considered to be the most important but challenging KM activity by the industry practitioners. Knowledge can only add value when it is being used. In this project-oriented industry sector, sustainability knowledge application happens in real projects. As discussed in Section 7.5, various barriers stop industry practitioners moving from talk to action. However, there are tools and processes that exist in the industry that enable practitioners to address knowledge application. In fact, in a project scenario, applying knowledge does not exist in isolation. It has to be integrated with other activities in the KM cycle, such as identifying knowledge, obtaining knowledge and sharing knowledge. To apply sustainability knowledge in real projects, we cannot discuss knowledge application on its own. According to the findings from interviews and case studies, the following actions and KM activities are found helpful.

Before reaching the construction phase of a project, the question of “What is sustainability for this project?” should be firstly defined and scoped, based on general sustainability and sustainable construction principles. Project sustainability targets need to be set and then refined into detailed sustainability assessment criteria. This defining process is crucial for sustainability KM success as it sets the basis for determining “what knowledge is needed” to successfully achieve sustainability goals. Then sustainability knowledge can be identified and obtained through various KM tools and activities (e.g. consulting with experts, case-based reasoning on previous projects from mother organizations, benchmarking with industry best practices), and from a variety of sources (e.g. Policy and Regulation, industry guidelines, and existing project sustainability measurement tools).

During this initial stage, sustainability considerations should also be integrated into Project Management Plans to ensure their realization. Ideally, KM strategies should also be addressed in this plan. Furthermore, setting KPA and KRI is a common practice in projects in order to address expected performance. In this case, specific KPA should be set to address sustainability knowledge sharing and
learning within the project team as well as communication beyond the project scope.

During the construction phase of a project, which is usually relatively long and stable, extensive knowledge sharing and joint learning can happen and should be facilitated. Main KM actions in this stage focus on:

- **Constantly sharing sustainability knowledge with all stakeholders** – Once people gain project experience on sustainability, they are easy to get on board in future projects.

- **Workforce awareness and capacity building on sustainability** – The project team is a good ground for sustainability education. Practitioners from various positions and disciplines have opportunities to discuss sustainability from diverse points of view, to solve problems in a collaborating manner, and to gain detailed and practical knowledge on a project.

- **Seeking opportunities to refine the design to be more sustainable** – In a project context, problems emerge frequently and need new knowledge to be solved. Once new knowledge gaps are observed, a new process of identifying knowledge, obtaining knowledge, sharing knowledge, applying knowledge and maintaining knowledge will start. This is how the KM cycle works.

- **Identifying and recording sustainability related activities and innovations** – Knowledge can be refined spontaneously when it is being applied in projects. Especially in the sustainably field, which is evolving constantly and always needing innovative solutions to achieve certain objective, innovations may emerge. Activities and innovative solutions on sustainability practice should be recorded in certain ways and maintained properly to avoid their loss overtime and on completion of the project.

In addition, during the construction stage, various KM tools and activities can facilitate the above-mentioned actions, including:

- Structured sustainability education
• Support of project level Sustainability CoP
• Posters around workplace
• Regular project review on sustainability
• Development of Project Sustainability Briefing/Induction
• Regularly publication of sustainability report.

Usually, appointing a full-time or part-time sustainability manager can be very helpful to address these sustainability actions and activities. Alternatively, identifying and authorizing sustainability champions can be effective as well.

The closure phase of a project is also crucial to the management of sustainability knowledge. At this stage, a thorough review on project sustainability performance should be conducted and documented. The review should not only cover the achievements the project team made, but also the mistakes and lessons learned from the project. Based on the review, a project sustainability report and case study should also be published to make the knowledge available to the industry sector.

Sustainability champions, technical leaders, designers and project managers on the project should seek opportunities to present the project experience to the whole industry. Face-to-face communication is still the most effective way of transferring sustainability knowledge as it allows open discussion. Project knowledge should also be transferred to mother-organizations in order to expand their knowledge assets and benefit future projects.

### 7.8 Outcomes of Managing Sustainability Knowledge

Individual practitioners, infrastructure projects, and organizations can all benefit from the management of sustainability knowledge. The outcomes may include:

• **Sustainability Knowledgeable and Committed Stakeholders**
At the individual level, through intensive sustainability education conducted in the industry, practitioners’ sustainability awareness would be raised, and their capability would be improved. They would be able to establish the confidence to take actions to implement sustainability in real projects. Therefore, they would be more knowledgeable and committed stakeholders when involved in a project.

- **More Sustainability-sound Infrastructure Projects**

Facilitating knowledge application in real projects is the aim of managing sustainability knowledge. The effect of proper management of relevant knowledge on a project’s sustainability performance has been confirmed by industry practitioners through questionnaire survey, interviews and case studies. The most important action is to actually apply relevant knowledge on projects, as knowledge can only add value when it is being used.

- **Expanded Infrastructure Sustainability Knowledge Assets**

Sustainability knowledge is stored in explicit formats, in projects, and in practitioners’ minds. Increasing numbers of knowledgeable practitioners and projects with a sustainability focus expand the body of knowledge. Furthermore, new knowledge emerges during the knowledge application process. For example, innovative solutions can be found when a new problem emerges. Knowledge can be renewed when being applied in a different circumstance. Ideas can be generated during the communication of experts. KM of sustainability knowledge in itself is a process of cultivating the body of sustainability knowledge.

### 7.9 KM Framework

#### 7.9.1 Proposing the KM Framework

Based on the discussions from Section 7.2 to Section 7.8, the following final KM framework for managing sustainability knowledge in the Australian infrastructure sector is formulated. This framework includes two parts:
• KM Framework Part I that illustrates KM in general to provide a holistic view, as shown in Figure 7.3; and

• KM Framework Part II that provides a guideline of how to implement sustainability KM at project level, as shown in Figure 7.4.
Figure 7.3: KM Framework for Managing Sustainability Knowledge in the Australian Infrastructure Sector (Part I) – A Holistic View
### Pre-construction Phase

<table>
<thead>
<tr>
<th>Key Actions</th>
<th>Knowledge Resources &amp; KM Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define &quot;what is sustainability&quot; for the project</td>
<td>• Sustainability and sustainable constructions principles, etc.</td>
</tr>
<tr>
<td>Setting Project Sustainability targets</td>
<td>• Policy &amp; Regulation</td>
</tr>
<tr>
<td>Refine the Objectives into Design &amp; Selection Multi-criteria System</td>
<td>• Industry Guidelines</td>
</tr>
<tr>
<td>Integrate Sustainability Considerations into Project Management Plan</td>
<td>• Consult with external experts</td>
</tr>
<tr>
<td>Develop KPA&amp;KPI System to monitor performance on sustainability</td>
<td>• Benchmark with industry better practices</td>
</tr>
<tr>
<td>Include sustainability knowledge sharing strategies in the plan</td>
<td>• Case-based reasoning (previous projects from mother organizations)</td>
</tr>
<tr>
<td>Include KPA&amp;KPI for knowledge sharing, maintenance and team capacity building</td>
<td>• Available checklist, rating criteria etc. (e.g. CEEQUL, AGIC rating tool, etc.)</td>
</tr>
</tbody>
</table>

### During Construction Phase

<table>
<thead>
<tr>
<th>Key Actions</th>
<th>Knowledge Resources &amp; KM Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share Sustainability Knowledge to all Stakeholders</td>
<td>• Project Sustainability Briefing/induction</td>
</tr>
<tr>
<td>Develop workforce awareness and build sustainability capacity</td>
<td>• Regularly publish sustainability report</td>
</tr>
<tr>
<td>Seek opportunities to refine the design to be more sustainable</td>
<td>• Deliver structured sustainability education</td>
</tr>
<tr>
<td>Identify and record sustainability related activities, innovations</td>
<td>• Establish and support project level Sustainability CoP</td>
</tr>
<tr>
<td>Resource a sustainability coordinator, or identify and support sustainability champions</td>
<td>• Posters around workplace</td>
</tr>
</tbody>
</table>

### During Closure Phase

<table>
<thead>
<tr>
<th>Key Actions</th>
<th>Knowledge Resources &amp; KM Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoroughly review project sustainability achievements &amp; mistakes</td>
<td>• Post-project Review</td>
</tr>
<tr>
<td>Document the review results and publish case studies on better practices on the whole project or on single topic</td>
<td>• Report from sustainability champions on project</td>
</tr>
<tr>
<td>Share project sustainability experience with mother organizations</td>
<td>• Presentations in relevant conferences, seminars, workshops etc</td>
</tr>
<tr>
<td>Share project sustainability experience with industry sector</td>
<td>• Report to industry associations and other level Sustainability CoPs</td>
</tr>
</tbody>
</table>

![Diagram](image)

Figure 7.4: KM Framework for Managing Sustainability Knowledge in the Australian Infrastructure Sector (Part II) – Managing Knowledge in Projects
7.9.2 Understand the KM Framework

7.9.2.1 Sustainability Knowledge

In order to describe the core knowledge process and activities, definitions of sustainability knowledge and KM are briefly introduced below:

“Knowledge” is the combination and advanced form of data and information. It is a fluid mix of framed experiences, values, contextual information and expert insight. Knowledge can be explicit (which has been articulated in formal languages) and/or tacit (which is embedded in individual experience), individual and/or social (Refer to Section 2.4.1).

In the context of infrastructure sustainability, “Sustainability Knowledge” refers to the type of knowledge that improves the sustainability of an infrastructure project during its life cycle. In the infrastructure sector, as a well-accepted definition does not currently exist, sustainability knowledge is usually considered subjective, fragmentary, dynamic and constantly evolving. Some examples of sustainability knowledge include: high-level sustainability principles, legislations and policy, industry guidelines, assessment tools and indicators, industry good practices, and lessons learned from previous projects.

7.9.2.2 Managing Sustainability Knowledge

According to the highlighted research findings listed in Table 7.2, the proposed KM framework for managing sustainability knowledge in the infrastructure sector consists of four main sections which are most important for sustainability KM: KM enablers, KM strategies, KM activities and KM outcomes. Elements within these four sections are put into different layers of the KM framework.

The first layer points out the aims and outcomes of managing sustainability knowledge.
Though proper management of sustainability knowledge, infrastructure sustainability knowledge assets can be expanded; more sustainability knowledgeable and committed stakeholders will be cultivated, and more sustainably sound projects will emerge in the industry sector (Refer to Section 7.8).

The second layer illustrates the five key activities within the sustainability knowledge cycle.

These five key KM activities include: identify knowledge, obtain knowledge, share knowledge, apply knowledge and maintain knowledge. These activities are usually facilitated by various KM strategies and tools (Refer to Section 7.7).

Among these KM activities, apply knowledge is the most important and challenging activity. However, knowledge can only add value when it is being used, which in the scenario of the infrastructure sector, means being applied in real projects. Thus, a guideline for applying sustainability knowledge and implementing KM at the project level is developed as illustrated in Figure 7.4 (Refer to Section 7.7.5).

The third layer recommends six effective KM strategies to facilitate the sustainability knowledge cycle.

These KM strategies include:

- Sustainability education (Refer to Section 7.6.1)
- Sustainability staffing (Refer to Section 7.6.2)
- Building sustainability CoP (Refer to Section 7.6.3)
- Transfer of best practice through case study (Refer to Section 7.6.4)
• Sustainability measurement (Refer to Section 7.6.5) and
• Reporting on sustainability (Refer to Section 7.6.6).

These enablers are categorized into four types based on their level of influence: individual level, project level, organizational level and industrial level (Refer to Section 7.5).

**7.9.2.3 Uniqueness of the Proposed KM Framework and Guidelines**

Although the visual appearance and the category of the main KM elements delineated in this KM framework - namely KM outcome, KM activities, KM strategies, and KM enablers – appear to be similar to some existing KM frameworks, the individual element within each category can be fundamentally different. The framework’s originality includes but is not limited to the following facets.

**The cluster of KM enablers**

• Some of the enablers are specific to addressing sustainability issues only, such as industry level “sustainability awareness” and individual “sense of care and responsibility for sustainability”.

• Individual level enablers such as “trust”, “ambitious”, “time management capability” are highly recognized in some existing KM frameworks and research (CEN, 2004b; Jafari et al, 2007; etc.). However, in regards to the management of sustainability knowledge, these enablers are much less important.
Enablers at project level are considered to be the leading success factors. This is mainly due to the fact that the infrastructure sector is project-oriented, and delivering tangible sustainability outcomes through project development is the ultimate goals of managing relevant knowledge.

**The suggested KM strategies**

- These KM strategies are tailored for managing sustainability knowledge in the Australian infrastructure sector at present. For example, sustainability education is playing the foremost role at present, as sustainability practice in infrastructure is still at an infant stage. However, its priority will decrease with time as the industry gradually raises its awareness and builds its capacity.

- Some of the strategies, such as measurement, are not even considered as part of KM in other discipline. However, with regard to managing sustainability knowledge, sustainability measurement is irreplaceable as it facilitates knowledge identification by scoping the target for any KM tasks, especially at project level.

- Some of the strategies have been investigated in previous research within the field of infrastructure development to address sustainability issues in general, such as sustainability staffing, sustainability measurement and sustainability reporting. However, this research investigated the roles of these approaches from a knowledge management perspective and gave recommendations accordingly.

**KM activities**

- Due to the project-based nature of the infrastructure sector, this KM framework puts strong emphasis on knowledge application and provides a procedure-oriented guideline to assist knowledge application and KM implementation at project level.
7.9.2.4 **Implications of the Proposed KM Framework and Guidelines**

It is well accepted that sustainability issues need to be considered when developing infrastructure projects. In addition, incorporating sustainability considerations into real projects will optimize project and organization performance. Managing relevant knowledge is essential for this industry sector to build its capacity to implement sustainability and to deliver real achievements.

Anecdotal evidence and past academic research has shown that successful KM implementation can provide the industry, organizations and project teams with multi-disciplinary knowledge sharing, communication and collaboration, which in turn will boost industry knowledge assets and innovation. Although every organization and project teams has their own way of obtaining, sharing and applying knowledge in their day-to-day work and activities, conscious knowledge management makes their practice more effective and efficient. KM is a balancing act that involves various competing practices, priorities, processes and solutions.

This KM framework sets the overall context for managing sustainability knowledge in the Australian infrastructure sector. It will help industry practitioners to prioritize attention on relevant important issues at present. These are mainly soft issues – including sustainability awareness, clients’ commitment, leadership, improved project management processes, education and networking – rather than expensive IT investment or domain technical details. For practical use, this guideline gives step-by-step recommendations on how to apply sustainability knowledge and implement KM at project level.

This framework and guideline also aims to:

- Provide industry practitioners in the Australian infrastructure sector with a practical introduction to understanding KM and using KM to manage sustainability knowledge within the industry sector, organizations or projects;
• Recommend potentially effective practices in the infrastructure sector for managing sustainability knowledge;

• Stimulate interested practitioners and researchers to join an ongoing discussion on the body of sustainability knowledge, effective KM strategies and their implementation processes, which will help the industry to build its capacity to absorb sustainability knowledge and to promote its application in real infrastructure projects.

7.10 Summary

This chapter starts with an integration of the parts of the research conducted and with a synthesis the results of the three studies. The second section discusses the main issues arising from the synthesizing of the results to provide an overall understanding of the knowledge management issues in regards to infrastructure sustainability in the Australian infrastructure sector. This then leads to the formulation of a specific KM framework. The last section of the chapter proposes the KM framework and the related guidelines as part of the end goals of this research project.
8.1 Introduction

This chapter draws conclusions based on the work set forth in this research and highlights the research contribution and limitations. It begins with reviewing the research questions raised in Chapter 1 and the research design and the development process described in Chapter 3. This research contains three studies for data collection. The conduct of the three studies and their results are presented in Chapter 4, Chapter 5 and Chapter 6 respectively. They are then combined and discussed in Chapter 7. This final chapter draws conclusions based on the findings from these chapters. The research contributions to academic knowledge, its implications for the Australian infrastructure sector, and the limitation of the research are summarized. Enlightened by the research findings and limitations, recommendations for future research are given.

8.2 Review of Research Questions and Development Processes

This research is aimed to develop a specific KM approach for the Australian infrastructure sector to facilitate the flow of sustainability knowledge within the industry sector and promote its application in infrastructure projects. Specifically, the research objectives set in Chapter 1 are:

1. To investigate the body of knowledge that is relevant to infrastructure sustainability
2. To investigate the characteristics of the infrastructure sector as the context for managing sustainability knowledge
3. To identify the main issues which affect the management of sustainability knowledge in the infrastructure sector

4. To investigate the appropriate approaches which help the infrastructure sector and its practitioners to manage sustainability knowledge

5. To investigate the approaches that facilitate sustainability knowledge application in real project scenarios

6. To outline the main findings in a holistic KM framework and according guidelines as a major outcome of this research.

Pragmatic paradigm and mixed-methods research strategy have set the philosophical foundation for this research. Triangulation of three data collection methods was adopted to collect data for quantitative and qualitative data analysis. These methods included:

- Questionnaire survey among industry practitioners,
- Semi-structured interviews with experienced industry practitioners, and
- Case studies on real infrastructure projects.

Before the conduct of the questionnaire survey, a KM framework prototype of sustainable infrastructure development was designed based on the research questions, objectives, and an extensive cross-discipline literature review. The questionnaire was designed according to the structure of the KM framework prototype. By analysing the data extracted from the 49 valid responses, the existing issues and main elements that should be considered in a holistic KM framework were identified. These findings contributed to the achievement of Objective 1, 2, and 3. In addition, a preliminary KM framework was designed based on the analysis of the results.

During the second data collection phase, 24 industry practitioners with a wealth of knowledge and experience in infrastructure sustainability were interviewed in a face-to-face manner, or through phone calls. Interviews were semi-open and structured, and based on the results of the questionnaire survey with the main aim to qualitatively investigate the issues highlighted in questionnaire results.
Strategies of existing practices on managing sustainability knowledge in the industry sector are highlighted. These results made **Objective 4** achieved and also consolidated the achievement of **Objective 1, 2 and 3**.

In the last data collection phase, two recently finished infrastructure projects that have a sustainability focus and have conducted KM initiatives were chosen and investigated. The case studies provided rich information, especially on “how sustainability knowledge can be applied in real projects” and “how this process can be facilitated by KM initiatives”. The investigation of case studies also provided the researcher opportunities to communicate with industry practitioners to validate results from previous the questionnaire survey and interviews. By the end of this phase, **Objective 5** has been achieved.

Finally, results extracted from these three studies were synthesized in Chapter 7 and discussed. The final KM framework for managing sustainability knowledge in the infrastructure sector was formulated, as well as the guidelines on how to apply sustainability knowledge and implement KM in projects. These outcomes signified the achievement of **Objective 6**.

### 8.3 Conclusions

#### 8.3.1 Characteristics of the Body of Sustainability Knowledge for Infrastructure Development

Sustainability knowledge can be seen as types of knowledge that improve the sustainability of an infrastructure project during a project’s life cycle. Currently, no classification system is officially designed to categorize sustainability knowledge. Important forms of sustainability knowledge are listed in Table 8.1.
Table 8.1: Examples of Existing Sustainability Knowledge for Infrastructure Development

<table>
<thead>
<tr>
<th>Form</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>High level sustainability principles</td>
<td>Triple Bottom Line (TBL), sustainable construction principles</td>
</tr>
<tr>
<td>Legislation and Policy</td>
<td>Regional plans, acts and policies that comprise sustainability relevant requirements</td>
</tr>
<tr>
<td>Assessment tool and indicators</td>
<td>CEEQUAL, AGIC rating scheme, ARUP SPeAR sustainability framework</td>
</tr>
<tr>
<td>Industry guidelines</td>
<td>FIDIC Project Sustainability Management Guideline, Global Reporting Initiative (GRI) Guidelines</td>
</tr>
<tr>
<td>Project management process</td>
<td>Project Sustainability Management Process, sustainability related KRA/KPI system</td>
</tr>
<tr>
<td>Industry best practice</td>
<td>Case study publications, lessons learned from projects</td>
</tr>
<tr>
<td>Individual knowledge and experience</td>
<td>Project experience and memory, expert insight, professional expertise</td>
</tr>
<tr>
<td>Academic research outcome</td>
<td>Green materials, energy saving technologies, advance design methodology</td>
</tr>
</tbody>
</table>

8.3.2 Essential Issues of Managing Sustainability Knowledge in the Infrastructure Sector

The Australian infrastructure sector is critical in determining the efficiency and productivity of the nation’s economy. However, it is uniquely characterized by its project-based nature, conservative culture, long and complex development processes, enormous financial investment and significant environmental impact. This industry sector is currently under pressure to respond to the sustainability calls to embed sustainability principles into infrastructure development. However, the lack of relevant knowledge is a big challenge faced by the industry practitioners.

Practices related to the management of sustainability knowledge are witnessed across the industry sector. They lie in different levels; for example, inter-project (knowledge sharing between projects), intra-project (transferring knowledge during the project lifecycle) and cross-sector (supporting learning outside the project sector environment). However, these practices are mainly conducted in a random and unsystematic manner, and are not widely performed within.
Main barriers that prevent knowledge transfer and application in the infrastructure sector include:

- Lack of awareness of infrastructure sustainability across the industry sector
- Deficiency of current sustainability education
- Lack of guidelines and examples for industry practitioners to move from talk to action
- Lack of regulation
- Lack of demand or support from client and
- Lack of consensus and collaboration among stakeholders.

Various enablers that drive the identification, obtaining, sharing, maintenance and application of sustainability knowledge are identified in four categories according to their influential scope: external environment, organizational environment, project environment, and personal capabilities. Some enablers are specific to the infrastructure sector’s management of sustainability knowledge and have not been witnessed in other KM literature. These enablers are listed in Table 8.2 and were discussed in detail individually in Section 7.5. Furthermore, these KM enablers are presented in the proposed KM framework in Layer 4, as presented in Figure 7.3.

Table 8.2: Enablers for Managing Sustainability Knowledge in the Australian Infrastructure Sector

| External Environment (Industry Level) | - Sustainability Awareness  
- Policy & Legislation  
- Network of Subject-matter Experts |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Environment (organizational level)</td>
<td>- Organizational Vision and Culture</td>
</tr>
</tbody>
</table>
| Project Environment (project level) | - Leadership  
- Project Target  
- Knowledgeable and Committed Client  
- Support from the Project Management Level |
| Personal Capabilities (individual level) | - Sense of Care and Responsibility for Sustainability  
- Communication Skill  
- Multi-disciplinary Knowledge |
8.3.3 Effectively Managing Sustainability Knowledge in the Infrastructure Sector

This research has investigated the nature of the infrastructure sector, the main activities of managing sustainability knowledge, and existing effective strategies of industry KM practices for sustainability knowledge. The main findings are presented in the proposed KM framework in Layers 1, 2 and 3, as illustrated in Figure 7.3.

Firstly, expected outcomes drive the conduct of KM activities in the industry and should be put in the center of the framework to remind practitioners of the purpose of managing sustainability knowledge. They are: (1) more sustainability knowledgeable and committed stakeholders, (2) expanded infrastructure sustainability knowledge assets, and (3) more sustainability-sound infrastructure projects.

Secondly, main KM activities are identified as: identify knowledge, obtain knowledge, share knowledge, maintain knowledge and apply knowledge. Applying knowledge is seen as the most important and challenging KM activity in this project-oriented industry sector, as sustainability knowledge adds no value if not being applied in real infrastructure projects.

Thirdly, important KM strategies that facilitate the KM cycle are identified. These strategies are proven to be effective for the Australian infrastructure sector as they facilitate the knowledge flow across different functional departments, project phases and disciplines and among various stakeholders, addressing the characteristics of the project-based and fragmented infrastructure sector.

Main findings on these KM strategies are listed in Table 8.3. In the Australian infrastructure sector, organizations and projects can use the highlighted KM strategies to facilitate the sustainability KM cycle – identify, obtain, share, maintain and apply – in order to deliver the outcomes.
<table>
<thead>
<tr>
<th>KM Strategy</th>
<th>Remarks and Recommendations</th>
</tr>
</thead>
</table>
| **Sustainability Education**                    | - Sustainability education is currently playing a foremost role with regards to the management of sustainability knowledge in the infrastructure sector.  
- Education should be delivered structurally, constantly, and broadly cover the range of stakeholders.  
- Industry practitioners usually go through five phases when learning sustainability knowledge: uninformed, sceptical and apathetic, compliant, efficient and beyond compliance, and creative. Different education focus and content should be given in each phase.                                                                                                                   |
| **Resourcing Sustainability Champions and Sustainability Managers** | - Some organizations and projects resource Sustainability Managers to drive the initiatives to embed sustainability into organizational culture and projects. They usually also take a role of managing relevant knowledge.  
- Sustainability champions are currently taking the leadership in driving the sustainability application in the industry sector. They are valuable sustainability knowledge assets for projects and organizations.  
- Resourcing and cultivating sustainability champions is an effective way to obtain sustainability knowledge and stay connected with industry knowledge sources.                                                                                           |
| **Sustainability CoP**                          | - CoP is a very effective approach for industry practitioners to share and learn sustainability knowledge. Sustainability CoPs can be found within a project, within an organization, across projects and at an industry level.  
- One or several passionate and credible Sustainability Champions are essential to start a CoP.  
- Sustainability CoPs should cross all relevant disciplines.  
- Support from administration level is important to cultivate a CoP.  
- Sustainability CoPs should welcome and allow different levels of participation.  
- A shared knowledge base needs to be built.  
- CoPs should connect with each other, especially to industry level CoPs.                                                                                                                                                                                                                                                                  |
| **Transfer of Best Practice through Project Case Studies** | - Case studies that contain best practice in sustainability are important vehicles to store sustainability knowledge.  
- Best practice projects are currently rare in the industry sector. Lack of exemplary projects is a main constraint for industry practitioners to gain practical sustainability knowledge.                                                                                                                                                                                                                                               |
Sustainability Measurement

- A comprehensive sustainability measurement system maps the sustainability knowledge structure for a project. It helps practitioners to identify their knowledge gap, and to have a definite objective in view when researching sustainability knowledge.

Reporting on Sustainability

- Sustainability reporting may be based on organizations or projects.
- Reporting on sustainability requires the project team or organization to constantly identify the emerging knowledge and record and document lessons learnt. It prevents the loss of knowledge over time.
- Reports can easily be shared across the industry sector.

8.3.4 Promote Sustainability Knowledge Application in Real Infrastructure Projects

In order to assist industry practitioners in applying sustainability knowledge in projects, this research investigated the actions involved in embedding sustainability considerations in real project, and identified tools, resources and strategies that can facilitate these actions. The main findings are presented in the proposed guideline, as shown in Figure 7.4.

Before the construction phase of a project, identified key actions to embed sustainability considerations into infrastructure projects include:

- Define “what is sustainability” for the project
- Set project sustainability targets
- Refine the objectives into Design & Selection Multi-criteria System
- Integrate sustainability considerations into Project Management Plan and
- Develop KPA&KPI system to monitor performance on sustainability.

Various forms of sustainability knowledge and KM strategies can help the completion of these actions. The full KM cycle is also involved in the process. Strategies for knowledge sharing can be included in the Project Management Plan.
in order to address knowledge sharing for the project duration. Specific KPA/KPI can also be set to monitor the KM performance.

During the construction phase, the main focus of KM is to facilitate learning, knowledge sharing and knowledge recording on a project. Main actions include:

- Sharing sustainability knowledge with all stakeholders
- Workforce awareness capacity building on sustainability
- Seeking opportunities to refine the design to be more sustainable
- Identifying and recording sustainability related activities and innovations.

The project team may resource a Sustainability Manager to lead the actions. Alternatively, the project can also identify and support the sustainability champions to take the role. However, these actions should be taken cooperatively by all stakeholders.

During this phase, helpful KM strategies and tools include: development of a Project Sustainability Briefing/Induction process, regularly publishing a sustainability report, delivering structured sustainability education, establishing and supporting a project level Sustainability CoP, putting sustainability posters around the workplace and regular project reviews on sustainability.

During the closure phase, the main focus of KM is to identify knowledge on the project, to properly document it and share it with stakeholders and wider industry practitioners. Key actions include:

- Thoroughly reviewing project sustainability achievements and mistakes
- Documenting the review results and publishing case studies on better practices for the whole project or on a single topic
- Sharing project sustainability experiences with mother organizations and
- Sharing project sustainability experiences with the industry sector.

KM strategies involved in these actions include: post-project reviews; presentations at relevant conferences, seminars and workshops; reports to industry
associations and other level Sustainability CoPs; and publication of project case studies in online databases.

8.4 Research Contributions

As an empirical study with intensive participation by industry practitioners, this research contributes to both academic knowledge and to the industry sector.

8.4.1 Contribution to Academic Knowledge

- Very limited studies in the built environment discipline have drawn attention to infrastructure sustainability issues from a knowledge perspective, and made further efforts to investigate operative means of managing knowledge to promote infrastructure sustainability. This research has described how sustainability knowledge is managed in the Australian infrastructure sector and what the main associated issues. The two case studies have also provided examples of how sustainability knowledge is managed and applied in real projects. Thus, this research has contributed a new dimension of knowledge to the disciplines of infrastructure sustainability and project management, by illustrating the main forms of sustainability knowledge, investigating the main knowledge activities and suggesting effective strategies for managing sustainability knowledge.

- Currently in the infrastructure sector, there is no existing KM framework that provides a comprehensive and holistic view of KM for addressing sustainability issues. This research is the first attempt at designing such a framework to illustrate the key aspects, elements and enablers and their relationships with KM in managing sustainability knowledge.

- The cluster of KM enablers, KM activities and KM strategies identified in this research are different from the KM elements that are shown in the other KM frameworks in literature (Refer to Section 7.9.2.3). Thus, the development process and results of this specific KM framework may inspire future researchers and KM adopters.
In the literature, the approaches that facilitate the industry practitioners’ and project teams’ uptake and application of sustainability knowledge are uncertain. This research, however, has identified six potentially effective means (namely KM strategies) to facilitate sustainability knowledge flow and application within the Australian infrastructure sector. Amongst these strategies, sustainability reporting, sustainability measurement and sustainability staffing have been discussed by various previous studies in the field of sustainable construction as effective tools for sustainability implementation. However, in differing from these studies, this research investigated these approaches mainly from a knowledge perspective, and revealed their roles in facilitating the management of sustainability knowledge.

8.4.2 Contribution to the Australian Infrastructure Sector

This research contributes to the Australian infrastructure sector through two aspects: research outcomes and the conduct of the research process.

- The proposed framework points out the existing issues and activities that are involved in managing sustainability knowledge and effective strategies and enablers to secure its success. Guidelines also provide recommendations on how to apply sustainability knowledge and implement KM in infrastructure project scenarios. These tools can help industry practitioners to better understand KM and to design their own KM initiatives.

- This research involved intensive industry participation during the data collection phases. KM is a relatively new area to the construction industry, and many of the participants were found to have limited knowledge of KM. This research provided a chance for the researcher to introduce KM to the industry, by explaining research objectives, answering questions during data collection, and sharing research outcomes after survey and interviews.
8.5 Limitations of the Research

Different types of construction projects have very different mechanisms. The results of this research are specific for infrastructure projects, and may not be also applicable to other types of construction projects, such as buildings.

Furthermore, constrained by the available resources and the tight research timeframe, this research investigated the issues relevant to the management of sustainability knowledge in the Australian infrastructure sector generally at the macro level, without considering the unique characteristics of different types of infrastructure projects, various perceptions of individual stakeholders, or a specific type of sustainability knowledge. Individual organizations and projects may need verification of the findings for their specific circumstances.

In addition, as the research aimed at proposing a holistic KM approach that addresses the management of sustainability knowledge in the Australian infrastructure sector, studies conducted in this research focused on identifying the priority issues, main enablers, key activities and effective strategies. These individual issues were explored and discussed; however, not thoroughly and deeply enough to make very detailed recommendations. For example, sustainability education was introduced as a KM strategy in the infrastructure sector. This research discussed the current status practices, main barriers and phases of delivering sustainability education; however, it did not give step-by-step instructions on how to design and conduct courses for sustainability education.

8.6 Recommendations for Future Research

In the light of the research findings and limitations, some areas are highlighted for future research and are discussed below.

- In order to identify the key KM activities for managing sustainability knowledge, potential activities were rated by industry practitioners during the
questionnaire survey. Their ratings were based on an activity’s perceived importance and on the extent of the challenge to conduct these activities in the workplace. It is interesting to see that, although creating knowledge is considered to be the second most challenging KM activity, it is seen as being of least importance, as illustrated in Table 8.4. This result is greatly different from the main perceptions in much of the literature, which argue that innovation is critical for sustainable development success (Lemelson-MIT Program, 2003; Vollenbroek, 2002; and Newman 2005; etc.). This issue was raised during analysis of the questionnaire survey results but has not been thoroughly explored in detail, as this research focuses on addressing the priority issues at present, as identified by the industry practitioners. However, it will be worthwhile for future researchers to investigate this issue of innovation and knowledge creation and its implications.

<table>
<thead>
<tr>
<th>Table 8.4: KM Activities for Managing Sustainability Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Challenging (&gt;3.3)</strong></td>
</tr>
<tr>
<td><strong>Important (&gt;3.8)</strong></td>
</tr>
<tr>
<td>• Apply knowledge (4.65/3.86)</td>
</tr>
<tr>
<td>• Share knowledge (4.39/3.37)</td>
</tr>
<tr>
<td><strong>Not Important (&lt;3.8)</strong></td>
</tr>
<tr>
<td>• Contextualize knowledge (3.65/3.41)</td>
</tr>
<tr>
<td>• Measure knowledge (3.57/3.51)</td>
</tr>
<tr>
<td>• Create knowledge (3.55/3.54)</td>
</tr>
</tbody>
</table>

- This research identified and investigated the existing KM strategies that currently are used by the industry sectors to facilitate the knowledge cycle. General recommendations on how to implement these strategies are given by this research; however, further investigation and research on these strategies individually may yield valuable outcomes for the industry sector.

- As identified from this research, the fact that sustainability is not yet effectively regulated is one of the key constraints that inhibit the adoption of sustainability within the industry sector. To tend toward compliance with regulation rather than to act innovatively is a culture of this relatively
traditional industry sector. Investigation in the area of public policy for infrastructure sustainability can be useful.

8.7 Closure

The Australian infrastructure sector is under pressure to respond to the calls for sustainable development and is seeking measures to embrace sustainability principles into infrastructure development. However, the lack of knowledge and industry capacity is a challenge faced by industry practitioners. In the light of the existing KM research, practices and tools, the research reported in this thesis has developed a holistic KM framework to outline the important issues and effective strategies in helping the Australian infrastructure sector to better manage sustainability knowledge.

With an understanding of the unique character of the infrastructure sector and the nature of sustainability knowledge, this research employed a combination of literature review, questionnaire survey, semi-structured interview and case studies to formulate, evaluate, and validate the critical elements, key processes and prior issues of KM for the Australian infrastructure sector. In the end, a holistic KM framework for managing sustainability knowledge within the infrastructure sector was presented. Guidelines were also provided for applying sustainability knowledge and implementing KM in projects.

The formulation of the integrated framework and guidelines will provide industry practitioners a starting point in understanding the balancing act of KM and its link to infrastructure sustainability: a checklist by which to examine their own practices in managing knowledge for sustainability, and an approach to facilitate integrated decision-making and to enhance sustainability application in infrastructure development.
REFERENCES


Appendix I

Questionnaire Survey Invitation Letter
An Invitation to Questionnaire Survey
Managing Knowledge to Promote Sustainability of Infrastructure Projects

Dear Sir/Madam,

As a PhD student in the School of Urban Development at QUT, I am currently undertaking a research project entitled “An Integrated Knowledge Management Framework for Sustainable Infrastructure Development”. In response to the significant infrastructure growth in Australia, this research is aimed at establishing a specific knowledge management (KM) approach in order to facilitate the processes of creating, obtaining, storing, sharing and applying sustainability knowledge, and to promote an integrated decision making during infrastructure development.

This survey is designed for the professionals in infrastructure sector. Because of your relevant experience and expertise, you are kindly requested to take and complete this questionnaire at your earliest convenient time. We also would appreciate it very much, if you could forward this request to your colleagues in infrastructure industry, where applicable.

You can also access the questionnaire online at the following address:

Password: 87647

This questionnaire is divided into 12 sections and will take approximate 25 minutes of your time, but you may save and resume the questionnaire and complete it at your convenience.

Your cooperation is completely voluntary and all responses will be kept strictly confidential (see the back of this letter for more details). Should you have any enquiries about this project, please do not hesitate to contact myself or my Principal Supervisor Assoc. Prof. Dr Jay Yang on (07) 3138 1028 or QUT Research Ethics Office on (07) 3138 2340 if you have concerns about the ethical conduct of the project.

Your contribution towards this study is greatly appreciated!

Yours sincerely,

Mei Yuan
PhD Candidate
School of Urban Development, Faculty of Built Environment and Engineering
Queensland University of Technology
Room 504, L Block, QUT GP Campus, 2 George St. Brisbane, QLD 4000 Australia
PARTICIPATION

Thank you for taking time to consider this survey. Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will in no way impact upon your current or future relationship with QUT.

Please note it will not be possible to withdraw, once the questionnaire has been submitted.

RISKS

There are no risks beyond normal day-to-day living associated with your participation in this project.

CONFIDENTIALITY

All comments and responses are anonymous and will be treated confidentially. The project is funded by Queensland University of Technology (QUT). The funding body will not have access to the data obtained during the project.

CONSENT TO PARTICIPATE

The return of the completed questionnaire is accepted as an indication of your consent to participate.

QUESTIONS / FURTHER INFORMATION ABOUT THE PROJECT

Should you have any enquiries about this survey, please do not hesitate to contact Mei YUAN on (07) 3138 7647 or email mei.yuan@student.qut.edu.au

CONCERNS / COMPLAINTS REGARDING THE CONDUCT OF THE PROJECT

QUT is committed to researcher integrity and the ethical conduct of research projects. However, if you do have any concerns or complaints about the ethical conduct of the project you may contact the QUT Research Ethics Officer on (07) 3138 2340 or ethicscontact@qut.edu.au. The Research Ethics Officer is not connected with the research project and can facilitate a resolution to your concern in an impartial manner.
Appendix II

A Sample of Collected Questionnaire Responses
Knowledge to Promote Sustainability of Infrastructure Projects

About This Survey

*Thank you for taking time to consider this survey.

In response to the significant infrastructure growth, the purpose of this research is to establish a specific knowledge management (KM) approach in order to facilitate the processes of creating, obtaining, storing, sharing and applying sustainability knowledge, and to promote an integrated approach for the decision making during infrastructure development.

There are totally 39 questions in this questionnaire, which will take approximate 25 minutes of your time, but you may save and resume the questionnaire and complete it at your convenience.

Should you have any enquiries about this survey, please do not hesitate to contact Mei Yuan through mei.yuan@student.qut.edu.au.

Section 1: General Information

* This section collects basic information to classify the various responses.

- Your main professional role in infrastructure project:
  - Architect
  - Operator
  - Governance (overall)
  - Engineer
  - Contractor
  - Financial
  - Project manager
  - Researcher
  - Legal
Other (please specify)

- How many years of experience do you have working on infrastructure projects?
  - [ ] 0-5 years
  - [ ] 5-10 years
  - [ ] 10-15 years
  - [ ] 15-20 years
  - [ ] over 20 years

- What types of infrastructure projects does your experience relate to?
  - [x] Transport infrastructure (e.g.: roads, railways, bridges, ports etc.)
  - [x] Telecommunication (e.g.: satellites, fibre cabling, networking etc.)
  - [ ] Energy (e.g.: dam, hydro-electric, solar etc.)
  - [ ] Water/Waste water treatment projects
  - [x] Mining (e.g.: coal, oil, gas etc.)

Other (please specify)

- Your title in your organization:
  - Delivery Manager

- Organization’s name:
  - XXXXX

- How would you classify your organization’s major role in infrastructure development?
Section 2: The Body of Sustainability Knowledge

*In this research context, ‘sustainability knowledge’ is defined as the type of knowledge which improves the sustainability of an infrastructure project during a project’s life cycle. Examples include methods of greenhouse gas emission reduction during construction and identification of indicators for measuring the sustainability of infrastructure etc.

In this section, please provide your opinion on sustainability knowledge according to your experience and expertise.

- What are the main categories of sustainability knowledge? (Select and rank the importance of relevant items ONLY. Level of importance: 1 Low ----> 5 High. Mark N/A if you feel an item is not applicable.)

<table>
<thead>
<tr>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff personal capabilities/skills/experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Innovation of staff</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Internal patents, methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Internal best practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Organizational administrative system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Internal standards/processes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Internal research and design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Lessons learned from internal projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Knowledge about industry
Knowledge about customer
Knowledge about partners
Knowledge about competitors
Knowledge about community/society focus
Academic research outcomes
Government guidelines/rules
Industrial best practice
Professional association publications/guidelines
External patents, methods

Other (please specify):

- Please give your opinion on the following statements regarding the quality of sustainability knowledge.

<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is easy to articulate and comprehend.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is always available or easy to get the knowledge when I need it.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is mature enough to be applied into practice.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is contextually/culturally sensitive.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Select and rank the importance of the main carriers of sustainability knowledge. (Level of importance: 1 Low ----> 5 High. Mark N/A if you feel an item is not applicable.)
- Give your opinion on the following statements of the characteristics of sustainability knowledge which may prevent its uptake and implementation in infrastructure projects.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is dynamic and evolving constantly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is challenging to acquire.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is immature to be implemented.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is challenging to articulate and comprehend.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is contextually/culturally sensitive.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is challenging to be adjusted and used in other project.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is embedded in personal mind, hard to be codified and transferred.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is fragmentary.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>It is objective, means different things to different people.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Other (please specify):
Section 3: KM Strategy

*Knowledge management (KM) encompasses a systematic approach to managing the use of information in order to provide a continuous flow of knowledge so as to enable the efficient and effective decision making by key decision makers and is underpinned by a KM strategy which enables an aim and focus for KM activities. This section collects information to identify the appropriate KM strategy for the sustainability management.

Please give your opinion on the following statements from 11 to 15.

- Sustainability issues need to be considered when developing infrastructure projects.
  - [ ] Strongly disagree    [ ] Disagree    [ ] Neutral    [ ] Agree    [ ] Strongly agree

- Consideration of sustainability issues can help my organization’s performance.
  - [ ] Strongly disagree    [ ] Disagree    [ ] Neutral    [ ] Agree    [ ] Strongly agree

- Managing related knowledge will help in promoting the sustainability of infrastructure projects.
  - [ ] Strongly disagree    [ ] Disagree    [ ] Neutral    [ ] Agree    [ ] Strongly agree

- My organization currently has a KM strategy or is willing to have a KM strategy.
  - [ ] Strongly disagree    [ ] Disagree    [ ] Neutral    [ ] Agree    [ ] Strongly agree

- In my organization, there are specific KM criteria to manage sustainability knowledge.
  - [ ] Strongly disagree    [ ] Disagree    [ ] Neutral    [ ] Agree    [ ] Strongly agree
Please select and rank the influence of the main impetus for promoting an organization's pursuit and application of sustainability knowledge in infrastructure projects. (Level of influence: 1 Low ----> 5 High. Mark N/A if you feel an item is not applicable.)

<table>
<thead>
<tr>
<th></th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
<th>N/A (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client's awareness and requirement</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community awareness</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government regulations and legislation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business benefits</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved competitiveness through labels such as 'Green Firm'</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social responsibility</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of new procurement method in which the developer is responsible for maintaining the project for a period (e.g. PPP, BOT)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem solving</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organization reputation</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threat of climate change and/or other global crisis</td>
<td>X</td>
<td></td>
<td></td>
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</tbody>
</table>

*Other (please specify): if the client is not particularly interested, the contractor typically also won't be interested and then push the community/social issues back to the client, or blame the approval process. Very little, if any sustainability management is considered at a day-to-day level. Perhaps conceptually each project has a procedure/policy, but it is not actively pursued.*

Please select and rank the influence of the key barriers for your organization (or staff in your organization) to pursue and manage sustainability knowledge in infrastructure development. (Level of influence: 1 Low ----> 5 High. Mark N/A if you feel an item is not applicable.)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
</table>
Sustainability concepts are not well understood | X
Hard to connect sustainability target with organizational business strategy | X
Lack of top management's commitment | X
Lack of co-ordination and consensus between stakeholders | X
Labour-incentive nature of the infrastructure construction industry | X
Poor financial resources | X
Poor non-financial resources | X
No standardization of key processes to follow | X
Difficult to measure the return on investment | X
Will extend project completion period | X
Will increase project budget/cost | X
Long duration of infrastructure project development | X
Will generate higher risk | X
Highly fragmentary nature of the industry | X
Intellectual Property protection issues | X
High staff turnover | X
Project-oriented nature of the business development type | X
Complex nature of infrastructure project development | X

Others (please specify and rank): typically no evidence of training on sustainability, or focus on it during design development. Perhaps a minimal amount done during tender/bid phase to secure the work. Does not translate into design.

- Select and rank the importance of the primary sources of emerging sustainability knowledge within the construction industry. (Level of
Please select and rank the importance of the primary sources of information for staff in your organization to get sustainability knowledge on their projects. (Level of importance: 1 Low ----> 5 High. Mark N/A if you feel an item is not applicable.)

<table>
<thead>
<tr>
<th>Source of Information</th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
<th>N/A (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry pilot projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Academic research outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Industry-academic R&amp;D (research and design) collaboration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Internal R&amp;D (research and design) outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>New knowledge generated from internal project experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Staff innovation</td>
<td></td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>Other (please specify):</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Please select and rank the importance of the primary sources of information for staff in your organization to get sustainability knowledge on their projects. (Level of importance: 1 Low ----&gt; 5 High. Mark N/A if you feel an item is not applicable.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry association</td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>----------------------------</td>
<td>---</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Industry best practice</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other industry</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government agency</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research institution</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local communities</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify):</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Section 4: Stakeholder Integration

*In the infrastructure development processes, stakeholders often have a great deal of influence on the uptake and application of sustainability knowledge. Quality decisions can be achieved if stakeholders are informed about the most recent concepts and technology. In this section, key stakeholders in infrastructure project are identified. Information is collected concerning the interaction between stakeholders and project sustainability issues.

- Please decide the level of influence the following stakeholders have on decision-making regarding project sustainability issues. (Level of importance: 1 Low ---> 5 High.)

<table>
<thead>
<tr>
<th></th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractor</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-contractor</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project manager</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designer</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity surveyor</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineer</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local community</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Consultant</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Research institution</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Government agency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Other (please specify): needs to be driven from the project proposal and involve the end-user. Contracting industry will typically only do enough to get the project built. To truly progress sustainability, the clients need to be adamant in the project proposal of the requirements.

- What is the willingness of each of the following stakeholders to pursue and manage knowledge in order to promote project sustainability?

<table>
<thead>
<tr>
<th></th>
<th>Very poor</th>
<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Section 5: Project Development Process

*Formulating project sustainability considerations and their applications are closely intertwined with project developing processes.

In this section, the stages of a typical life cycle of an infrastructure project are delineated. Information is collected on how project sustainability related activities link with these processes.

- Please select and rank the following project phases in which sustainability considerations will have strong influence over the end results. (Level of importance: 1 Low ----> 5 High. Mark N/A if it is not applicable.)

<table>
<thead>
<tr>
<th>Phase</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrating and conceptualizing the need</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### What actions/deliverables are important for promoting project sustainability during the infrastructure development process? Select and decide the importance. Level of importance (1 Low ----> 5 High). Mark N/A if it is not applicable.

<table>
<thead>
<tr>
<th>Action</th>
<th>Importance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepare sustainability mission statement for the project</td>
<td></td>
</tr>
<tr>
<td>Scope sustainability issues</td>
<td></td>
</tr>
<tr>
<td>Prepare sustainability plan</td>
<td></td>
</tr>
<tr>
<td>Undertake sustainability assessment of conceptual design</td>
<td></td>
</tr>
<tr>
<td>Monitor production information against sustainability plan</td>
<td></td>
</tr>
<tr>
<td>Monitor construction against sustainability plan</td>
<td></td>
</tr>
<tr>
<td>Compile post-construction review against sustainability targets</td>
<td></td>
</tr>
</tbody>
</table>

**Other (please specify):**
Section 6: KM Process

*A wide variety of practices and processes are used in knowledge management. Some of the more common ones are illustrated in this section.

Information is collected to identify those processes specific to manage sustainability knowledge for infrastructure development.

- What stages should be the essential components for securing the uptake and application of sustainability knowledge in real infrastructure projects? Select and decide the degree of importance (1 Low ----> 5 High). Mark N/A if it is not applicable.

<table>
<thead>
<tr>
<th></th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
<th>N/A (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Store knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contextualize knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apply knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- What stages below may be relatively difficult to implement? Select and decide the degree of difficulty (1 Low ----> 5 High). Mark N/A if it is not applicable.

<table>
<thead>
<tr>
<th></th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
<th>N/A (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify knowledge</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Please give your opinion on how sustainability knowledge can be acquired in your organization.

<table>
<thead>
<tr>
<th>Measure knowledge</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Obtain knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Store knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Share knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Contextualize knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Apply knowledge</td>
<td>X</td>
</tr>
<tr>
<td>Maintain knowledge</td>
<td>X</td>
</tr>
</tbody>
</table>

**Other (please specify):** Its an evolving process with only limited historical information i.e. the major infrastructure projects currently being built have nothing in the past of similar nature which sets the benchmark for sustainability.

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific staff is responsible for obtaining sustainability knowledge from external resources.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experienced staff on sustainability issues is recruited externally.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staffs are encouraged to participate in sustainability related conferences/seminars/exhibitions etc to get new knowledge.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We actively acquire the latest sustainability related technology and follow the best practice.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We actively gather emerging sustainability knowledge from external sources. X

We are informed of sustainability knowledge from external organizations (e.g. professional associations, research institutions etc). X

Experienced staff and staff approaching leaving the organization are asked to record their sustainability knowledge and experience. X

Sustainability related lessons learned are gathered during project closure. X

Senior staff is assigned to deal with knowledge needs. X

- Please give your opinion on sustainability knowledge creation in your organization.

<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staffs are encouraged to find alternative solutions to promote project sustainability for existing assignments.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability-related suggestions are encouraged.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staffs are encouraged to analyse success factors in order to enrich sustainability knowledge.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staffs are encouraged to</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
analyse mistakes to enrich sustainability knowledge.

We do research on sustainability issues internally.

We usually create new knowledge to solve specific sustainability problems during project development.

- Please give your opinion on sustainability knowledge storage in your organization.

<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data and information are selected and organized before being stored.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability knowledge is well indexed and staffs know where to find it when they require it.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staffs that possess knowledge in project sustainability are easily identified.</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability knowledge is kept confidential and has restricted access.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>We have a specific location for storing sustainability knowledge storage.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

- Please give your opinion on sustainability knowledge sharing in your organization.

<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
</table>

Experienced staffs are encouraged to mentor new or less experienced staff. | X |
---|---|
Knowledge gained from different projects is made accessible to all. | X |
Recurrent training is conducted to distribute sustainability knowledge. | X |
Knowledge sharing is a measure of employee’s performance. | X |
Remote access to the organization's database is provided. | X |
Specific staffs are responsible for regularly updating the knowledge in the database library. | X |

- Please give your opinion on sustainability knowledge application in your organization.

<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff are encouraged to apply sustainability knowledge learned from previous project(s) to subsequent project(s)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We actively use sustainability knowledge in our current projects.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It requires great effort to adapt the current sustainability knowledge before applying in real projects.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We do pilot projects (or experiments) in order to test sustainability knowledge before its application.

**Section 7: KM Enablers**

*There are many factors which may affect the success of knowledge management initiatives within a project team or organization. This section collects information to identify those factors which help to formulate a positive environment for knowledge management success.*

*In each question, select from the provided items and decide the importance. Level of importance: 1 Low ----> 5 High. Mark N/A if you feel the item is not applicable."

• Which of the following industrial characteristics are important for managing sustainability knowledge in infrastructure development?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(0)</td>
</tr>
</tbody>
</table>

- Government administration: X
- Innovation capability: X
- Networks of subject matter expertise: X
- Collaboration of academics and industry practice: X
- Professional education: X
- Human resource turnover: X
- Increasing average profit rate: X
- Professional association action: X
- Industry Codes of Conduct: X

*Other (please specify):*

• Which of the following organizational capabilities are important for managing sustainability knowledge in infrastructure development?
| Organizational mission, vision and strategy | X |
| Organizational culture | X |
| Trust between colleagues | X |
| Sense of social responsibility | X |
| Process and organizational structure | X |
| IT technology & infrastructure | X |
| Financial support | X |
| Staff incentive schemes | X |
| Training and education | X |
| Administrative support | X |
| Research and design | X |
| Change management | X |

**Other (please specify):**

- Which of the following project team characteristics are important for managing sustainability knowledge in infrastructure development?

<p>| Team work | X |
| Leadership | X |
| Project budget | X |
| Stakeholder integration | X |
| Technology and IT support | X |
| Team structure | X |
| Trust | X |
| Project risk management | X |</p>
<table>
<thead>
<tr>
<th>Category</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial support</td>
<td>X</td>
</tr>
<tr>
<td>Project target</td>
<td>X</td>
</tr>
<tr>
<td>Time frame</td>
<td>X</td>
</tr>
<tr>
<td>Multi-discipline integration</td>
<td>X</td>
</tr>
<tr>
<td>Document management</td>
<td>X</td>
</tr>
<tr>
<td>Other (please specify):</td>
<td></td>
</tr>
</tbody>
</table>
• Which of the following personal capabilities are important for managing sustainability knowledge in infrastructure development?

<table>
<thead>
<tr>
<th>Capability</th>
<th>1 (1)</th>
<th>2 (2)</th>
<th>3 (3)</th>
<th>4 (4)</th>
<th>5 (5)</th>
<th>N/A (0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-shape skill (having knowledge and skills that are both deep and broad; multi-disciplinary)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Technical expertise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Communication skill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Time management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Sense of social responsibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Ambition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Creativity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Capability to codify thoughts, conceptions and experiences etc into written document</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Loyalty to the organization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Other (please specify):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section 8: Outcomes of Managing Sustainability Knowledge

• Which of the following areas do you think will be improved by managing sustainability knowledge?

☐ Judgment
☐ Reusable content created
☒ Value delivery
☐ Presence of subject matter expertise
☐ Knowledge leadership
☐ State of networking environment
☒ Organizational creativity
☐ State of supply chain management
☒ Customer satisfaction
☒ Organizational adaptability
☒ Organization’s ability to exploit market opportunity
☐ Employee loyalty
☐ Employee’s sense of social responsibility
Which of the following areas of organizational performance do you think will be improved by managing sustainability knowledge?

- Profit
- Organizational reputation
- Intellectual asset
- Market share
- Customer recognition
- Project's reputation
- Other (please specify)

Section 10: Further Information

Thank you for taking time to complete this survey.

Please provide your contact information if you would like to participate in the 2nd round of this survey by which you will be entitled a full copy of this research findings.

All identities provided are for contact purpose only and will be confidential!

- Your comments are also welcome on the management of sustainability knowledge for infrastructure projects.

- Your contact information
Name: XXX

Company: XXXXXXXX

Address 1: XXXXXXXX

City/Town: XXXXXXXX

State/Province: XXXXX

ZIP/Postal Code: XXX

Email Address: XXXXXXXX

Phone Number: XXXXXXXX

- Would you like a copy of the research findings?

  ☐ Yes  ☐ No
Appendix III

Interview Participant Information Sheet
PARTICIPANT INFORMATION for QUT RESEARCH PROJECT

Managing Knowledge to Promote Infrastructure Sustainability

Research Team Contacts

<table>
<thead>
<tr>
<th>Mei Yuan</th>
<th>Prof. Jay Yang</th>
</tr>
</thead>
<tbody>
<tr>
<td>07 3138 7647</td>
<td>07 3138 1028</td>
</tr>
<tr>
<td><a href="mailto:mei.yuan01@gmail.com">mei.yuan01@gmail.com</a></td>
<td><a href="mailto:j.yang@qut.edu.au">j.yang@qut.edu.au</a></td>
</tr>
</tbody>
</table>

Description

It is well accepted by Australian construction industry that sustainability should be put at the top of the agenda during infrastructure development. The industry can make a significant change towards sustainability if the organizations be facilitated the dense and up-to-date knowledge and expertise. However, previous survey has shown us that, sustainability knowledge (the kind of knowledge that can improve the sustainability of infrastructure projects if being applied) is not easy to articulate and comprehend, nor easy to acquire across organizational as well as professional boundaries.

The focus of this research is to investigate an efficient knowledge management approach in order to formulate a framework and guideline which will help the industry practitioners to identify, obtain, share and apply sustainability knowledge in real infrastructure projects. To achieve the goal of this PhD research, we request your assistance by sharing with us your knowledge, insights and suggestions related to best practice for managing sustainability knowledge in infrastructure projects.

Participation

Thank you for taking time to consider this survey. Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will in no way impact upon your current or future relationship with QUT.

Your participation will involve focused interview to investigate matters related to managing knowledge to promote sustainability knowledge for infrastructure projects. Approximate interview time will be around 45 minutes.

Risks
There are no risks beyond normal day-to-day living associated with your participation in this project.

**Confidentiality**

All comments and responses will be treated confidentially. Organization’s name and participants’ names will not be included in all reports and publications. The project is funded by Queensland University of Technology (QUT). The funding body will not have access to the data obtained during the project.

**Consent to Participate**

We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate.

**Questions / further information about the project**

Please contact the researcher team members named above to have any questions answered or if you require further information about the project.

**Concerns / complaints regarding the conduct of the project**

QUT is committed to researcher integrity and the ethical conduct of research projects. However, if you do have any concerns or complaints about the ethical conduct of the project you may contact the QUT Research Ethics Officer on 3138 2340 or ethicscontact@qut.edu.au. The Research Ethics Officer is not connected with the research project and can facilitate a resolution to your concern in an impartial manner.
Appendix IV
Consent Form
CONSENT FORM for QUT RESEARCH PROJECT

Managing Knowledge to Promote Infrastructure Sustainability

Statement of consent

By signing below, you are indicating that you:

• have read and understood the information document regarding this project
• have had any questions answered to your satisfaction
• understand that if you have any additional questions you can contact the research team
• understand that you are free to withdraw at any time, without comment or penalty
• understand that you can contact the Research Ethics Officer on 3138 2340 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
• the interview will include a digital recording
• agree to participate in the project.

Name ____________________________________________
Signature ____________________________________________
Date ___________ / ___________ / ___________