BUILDING A SUSTAINABILITY ASSESSMENT MODEL FOR HIGHWAY INFRASTRUCTURE PROJECTS IN YUNNAN, CHINA

JUNJIE ZHANG

A thesis submitted in partial fulfilment of the requirements of the University of Greenwich for the Degree of Doctor of Philosophy

June 2018

DECLARATION

I certify that the work contained in this thesis, or any part of it, has not been accepted in substance for any previous degree awarded to me, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations, except where otherwise identified by references and that the contents are not the outcome of any form of research misconduct.

Signature:…………

Date:………22-06-2018………

ACKNOWLEDGEMENT

I would like to extend thanks to the many people from both China and the UK, who so generously contributed to the work presented in this thesis.

Special mention goes to my enthusiastic supervisors: Dr. Shaun Lundy, Prof. David Isaac for their advice, discussion, supervision and support during in past years. I would like to thank Dr. Stuart Allan for all hard work on correcting and proofreading. I would also like to thank other colleagues at the University of Greenwich for their help.

Without the support of many staff members and friends in the Yunnan Highway Development Investment Co., Ltd. and other organisations, the research would not be completed. I would like to thank my colleagues at Yunnan University of Finance and Economics for their supports.

Finally, but by no means least, thanks go to my family for almost selfless supports and encouragements to finish the thesis. I would also like to thank all my friends who supported to strive towards my goal. At the end, I would like express appreciation to Tao, who was always supported in the difficult moment.

ABSTRACT

Highway infrastructure development in Yunnan Province remains a top priority for the Chinese Government, the aim is to improve access to neighbouring countries and support economic growth and social development in the province. While the social and economic benefits of highway infrastructure projects are indisputable, sustainable performance still leaves room for improvement in Yunnan. In an effort to promote a more sustainable approach to decisions relating to highway infrastructure projects, this research develops a model to assess sustainability in highway infrastructure projects in Yunnan Province.

The research results indicate that although China has made great progress in sustainable development, and studies have suggested various frameworks for evaluating sustainability in highway infrastructure projects, an effective assessment model is not available for the local context of Yunnan. Therefore, this research builds an indicator-based assessment model for highway infrastructure project sustainability by addressing local conditions. The data used for analysis in this research is collected from questionnaires and interviews of three groups of experts in Yunnan, including government officers, academic professionals, and construction engineers in the construction industry. Data collected by questionnaires is used to determine the indictors, and the Analysis Hierarchy Process (AHP) method is used to assign indicators weightings. The opinions from the experts' interviews are used to refine the model, and the content analysis is used to analyse interview data. This research identifies a highway project in Yunnan as a case study to test the applicability of the developed model, and the results indicated that the sustainability assessment model for highway infrastructure projects in Yunnan is reasonable.

However, in practice, it faces extensive challenges in assessing sustainability in highway infrastructure projects in Yunnan. This study demonstrates the importance of sustainability assessment and strives to build a comprehensive indicator system with consideration of all influential factors, as a positive step towards dealing with these challenges.

CONTENTS

DECLARATION ········ I

ACKNOWLEDGEMENT ········ II

ABSTRACT ········ III

LIST OF ABBREVIATION ········ XIII

CHAPTER 1 - INTRODUCTION ········ 1

1.1 Background of the study ········ 1

1.2 Problem statement ········ 4

1.3 Research aims and objectives ········ 6

1.4 Research questions ········ 6

1.5 Research methodology ········ 8

1.6 Contributions and limitations ········ 9

1.7 Structure of the thesis ········ 10

CHAPTER 2 - OVERVIEW OF SUSTAINABILITY ········ 12

2.1 Introduction ········ 12

2.2 Concept of sustainable development ········ 12

2.2.1 Emergence of sustainability ········ 12

2.2.2 Definition of sustainability ········ 17

2.3 Dimensions of sustainable development ········ 20

2.4 Principles of sustainable development ········ 21

2.5 Conclusion ········ 25

CHAPTER 3 - SUSTAINABILITY IN CONSTRUCTION AND THE CHALLENGES IN HIGHWAY INFRASTRUCTURE PROJECTS ········ 26

3.1 Introduction ········ 26

3.2 Review of sustainable construction concept ········ 26

3.2.1 Emergence of sustainable construction concept ········ 26

3.2.2 Definitions of sustainable construction ········ 29

3.3 Principles of sustainable construction ········ 35

3.4 Effects of highway infrastructure construction ········ 41

3.5 Sustainability in highway construction projects ········ 42

3.6 Conclusion ···· 44

CHAPTER 4 - REVIEW OF SUSTAINABILITY ASSESSMENT OF HIGHWAY INFRASTRUCTURE ···· 45

4.1 Introduction ···· 45
4.2 Review of sustainability assessment of highway infrastructure projects ···· 45
4.2.1 Purposes of sustainability assessment ···· 46
4.2.2 Practice principles of sustainability assessment ···· 47
4.2.3 Sustainability assessment indicators ···· 48
4.3 Existing sustainability assessment methods and tools ···· 50
4.3.1 Types of sustainability assessment methods ···· 50
4.3.2 Standards and guidelines for sustainable highway ···· 53
4.3.3 Best practices methods for assessing sustainability in highway ···· 54
4.3.4 Comparative analysis of exiting methods ···· 66
4.4 Conclusion ···· 67

CHAPTER 5 - SUSTAINABILITY ASSESSMENT OF HIGHWAY INFRASTRUCTURE PROJECT IN YUNNAN ···· 68

5.1 Introduction ···· 68
5.2 Background of Yunnan ···· 68
5.3 Overview of sustainable highway infrastructure development in Yunnan ···· 70
5.3.1 Highway construction in Yunnan ···· 70
5.3.2 Challenges of building highway infrastructure projects ···· 72
5.4 Sustainable highway assessment in Yunnan ···· 78
5.4.1 Regulatory system of highway infrastructure ···· 79
5.4.2 Sustainable highway infrastructure policies ···· 81
5.4.3 Supporting standards ···· 83
5.4.4 Feasibility study ···· 86
5.4.5 Current studies of sustainability assessment of highway infrastructure projects in Yunnan ···· 89
5.5 Conclusion ···· 90

CHAPTER 6 - RESEARCH METHODOLOGY ···· 92

6.1 Introduction ···· 92

6.2 Research aim and scope 92
6.3 Research theories and design 93
6.3.1 Research philosophy 94
6.3.2 Research approaches 97
6.4 Research framework 100
6.4.1 Phase 1 - Literature review 101
6.4.2 Phase 2 - Qualitative and quantitative research 102
6.4.3 Phase 3 - Interviews 104
6.4.4 Sample design 105
6.4.5 Pilot study 107
6.5 Data analysis 108
6.5.1 Quantitative data analysis 108
6.5.2 Qualitative data analysis 111
6.5.3 Reliability and validity 112
6.6 Ethical consideration 113
6.7 Conclusion 114

CHAPTER 7 - DEVELOPMENT OF SUSTAINABILITY ASSESSMENT MODEL FOR HIGHWAY INFRASTRUCTURE PROJECT 116

7.1 Introduction 116
7.2 Sustainability assessment model building process 116
7.3 Assessment goal and objectives 118
7.4 Indicator system of sustainability assessment model 119
7.4.1 Purpose of the indicators 119
7.4.2 Indicator selection principles 120
7.5 Indicators formulation process 121
7.5.1 Indicator resources 122
7.5.2 Collecting indicators 128
7.5.3 Types of indicator 133
7.5.4 Indicators validation by questionnaire 135
7.5.5 Indicator weighting 144
7.6 Assessing sustainability based on the AHP weight 155
7.7 Other consideration 155

7.8 Conclusion ········ 156

CHAPTER 8 APPLICATION OF THE SUSTAINABILITY ASSESSMENT MODEL ········ 158

8.1 Introduction ········ 158
8.2 Refining the assessment model by interview method ········ 158
8.3 Results of the interviews ········ 160
8.3.1 Perception of highway infrastructure project development in Yunnan ········ 160
8.3.2 Understanding sustainability assessment in highway infrastructure projects 164
8.3.3 Suggestions of refining the developed model ········ 176
8.3.4 Sustainability assessment in highway infrastructure projects ········ 180
8.4 Improving the sustainability assessment model ········ 181
8.4.1 Public participation test ········ 181
8.4.2 Improving indicator system ········ 186
8.5 Application of the sustainability assessment model – A case study ········ 188
8.5.1 Background of the KQ No.4 highway ········ 188
8.5.2 Impacts of KQ No.4 ········ 190
8.5.3 Sustainability assessment of the KQ No.4 highway ········ 191
8.6 More recommendations ········ 198
8.7 Conclusion ········ 199

CHAPTER 9 - CONCLUSIONS ········ 202

9.1 Introduction ········ 202
9.2 Research process ········ 202
9.3 Conclusion of the study ········ 203
9.3.1 Concept of sustainability in highway infrastructure projects ········ 203
9.3.2 Conditions of sustainability assessment of highway infrastructure projects · 205
9.3.3 Current sustainability assessment system ········ 205
9.4 Contribution of this research ········ 207
9.5 Recommendation for the sustainability assessment model ········ 207
9.6 Recommendation for the further study ········ 208

REFERENCE ········ 210

APPENDIX I ········ 243

APPENDIX II ········ **247**

APPENDIX III ········ **250**

TABLES

Table 1.1 Research matrix 7
Table 2.1 Sustainable development process 16
Table 3.1 Definitions of sustainable construction 30
Table 3.2 Principles of sustainable construction from Kibert (2008) 36
Table 3.3 Principles of sustainable construction from Hill and Bowen (1997) 37
Table 4.1 Purpose of highway sustainability assessment 46
Table 4.2 Assessing sustainability: principles in practice 47
Table 4.3 A checklist of sustainability indicators 49
Table 4.4 Four categories of sustainability assessment methods 51
Table 4.5 International green building rating systems 61
Table 4.6 Assessment criteria of the four rating systems 63
Table 4.7 Four highway infrastructure projects rating systems 65
Table 5.1 Highway mileage in Yunnan (Year 2011-2015) 70
Table 5.2 Freight by railway, highway and waterway 71
Table 5.3 Construction environment characteristics of highway in Yunnan 73
Table 5.4 Factors of Specification for Environmental Impacts Assessments 85
Table 6.1 Differences between positivism and interpretivism 96
Table 6.2 Quantitative, qualitative and mixed methods approach 97
Table 6.3 Strengths and limitations of two approaches 98
Table 7.1 Main sustainable construction standards in China 123
Table 7.2 Assessment indicators categories 125
Table 7.3 Relevant studies of the sustainability assessment indicators 127
Table 7.4 Indicator resources 129
Table 7.5 Preliminary list of indicators 131
Table 7.6 Mean of the indicators 140
Table 7.7 Experts' group score of indicators 141
Table 7.8 Cronbach's Alpha coefficient result 143
Table 7.9 Scale of relative importance (Saaty, 1980) 146
Table 7.10 Example of pairwise comparison matrix *A* 147
Table 7.11 Example of computing AHP weight 148
Table 7.12 Overall weight of AHP 148
Table 7.13 Random consistency index (RI) 149

Table 7.14 Level 1 judgment matrix 151
Table 7.15 Economic judgment matrix 152
Table 7.16 Social judgment matrix 152
Table 7.17 Environmental judgment matrix 153
Table 7.18 Technological judgment matrix 153
Table 7.19 Governance judgment matrix 153
Table 7.20 Indicators weighting by AHP method 154
Table 8.1 Summary of the interviewees 159
Table 8.2 Factors of sustainable highway infrastructure project 168
Table 8.3 Comments on the individual indicators 177
Table 8.4 Updating indicator system 187
Table 8.5 Assessment result 194
Table 8.6 Land-use situation of Malong County (hundred meter2, %) 197
Table 8.7 Land-use situation of Huize County (hundred meter2, %) 197
Table 8.8 Land-use situation of Dongchuan County (hundred meter2, %) 197

FIGURES

Figure 2.1 Three elements of sustainability ... 20
Figure 2.2 Sustainability principles ... 22
Figure 2.3 Six principles of sustainability ... 23
Figure 3.1 Elements of sustainable construction ... 28
Figure 3.2 Conventional project measure and sustainable project measure ... 32
Figure 3.3 Sustainable construction lifecycle ... 33
Figure 3.4 Framework of sustainable construction system ... 34
Figure 3.5 Sustainable construction criteria from Zabihi and Habib (2012) ... 38
Figure 3.6 Infrastructure project performance requirements ... 43
Figure 4.1 Sustainable highway project lifecycle ... 59
Figure 5.1 Location of Yunnan Province ... 69
Figure 5.2 Highway infrastructure project related departments ... 79
Figure 5.3 Highway infrastructure project development process ... 87
Figure 6.1 Research design process ... 93
Figure 6.2 Research process ... 101
Figure 6.3 Building hierarchical structure ... 109
Figure 6.4 Judgement matrix generation and comparison data input ... 110
Figure 6.5 Weight calculation ... 111
Figure 6.6 Research diagram ... 115
Figure 7.1 Sustainability assessment model building steps ... 117
Figure 7.2 Indicators formulation steps ... 122
Figure 7.3 Key assessment factors from industry standards ... 124
Figure 7.4 The result chain of indicators ... 134
Figure 7.5 Backgrounds of the experts ... 137
Figure 7.6 View of comments about indicators ... 138
Figure 7.7 Sustainability in highway infrastructure project’s hierarchy ... 151
Figure 8.1 Problems of highway infrastructure project development in Yunnan ... 161
Figure 8.2 Keywords of sustainable highway ... 164
Figure 8.3 Communicability of the model ... 178
Figure 8.4 Participants’ backgrounds ... 182
Figure 8.5 Public understanding of highway infrastructure influence on economy and environment ... 183

Figure 8.6 Factors of highway development 184
Figure 8.7 Location of the industrial cluster... 189
Figure 8.8 Location of Kunming –Qujing highway 189
Figure 8.9 Role of experts and stakeholders during model development process .. 201

LIST OF ABBREVIATION

AHP	Analysis Hierarchy Process
APSIQ	General Administration of Quality Supervision, Inspection and Quarantine, China
BREEAM	Building Research Establishment Environmental Assessment Method
CBA	Cost-Benefit Analysis
CPG	Central People's Government of China
ESSP	Earth System Science Partnership
EIA	Environmental Impact Assessment
ERTRAC	European Road Transport Research Advisory Council
ESGB	Evaluation Standard for Green Building of China
EU	European Union
FIDIC	International Federation of Consulting Engineers
GDP	Gross Domestic Product
GNP	Gross National Product
IAIA	International Association for Impact Assessment
IPMA	International Project Management Association
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature
LCA	Lifecycle Analysis
LEED	Leadership in Energy and Environmental Design
MCDA	Multi-Criteria Decision Analysis
MDGs	Millennium Development Goals
MHUD	Ministry of Housing and Urban-Rural Development
MOEP	Ministry of Environmental Protection
MOT	Ministry of Transport of China
NBS	National Bureau of Statistics of China
NDRC	National Development and Reform Commission
NPC	The National People's Congress of the People's Republic of China
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development

ROI	Return on Investment
SEA	Strategic Environmental Assessment
SIA	Social Impacts Assessment
UN	United Nations
UNCRD	United Nations Centre for Regional Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNECD	United Nations Conference on Environment and Development
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
WCED	World Commission on Environment and Development
WCS	World Conservation Strategy

CHAPTER 1 - INTRODUCTION

1.1 Background of the study

Highway infrastructure projects play a vital role in contributing to economic growth, raising the quality of life and reducing poverty (Stevens *et al*., 2006). China has the world's largest highway network, and the government is continually investing in highway infrastructure (Djankov and Miner, 2016). In China's 13th Five Year Plan (2016-2020), the specific targets in relation to highway infrastructure include building or upgrading 20,000 kilometres of rural roads and constructing 30,000 kilometres of new highways, the investment is expected to reach $0.26 trillion (National Development and Reform Commission [NDRC], 2016). The Central People's Government of China (CPG) has made great strides in developing highway infrastructure over the past decades, the growth of highway infrastructure projects is at an average of 20 percent per year, and is considered a development driver for the economic and social development in China (Ministry of Transport of China [MOT], 2016)

Yunnan is a province located in southwest China. It shares international borders with Myanmar (Burma), Laos and Vietnam, and domestic border with Tibet, Sichuan, Guizhou and Guanxi. The Province has great advantages in geographic locations and rich nature resource, but it also has various constraints in the current development. It has a low economic base and still one of the economically lagging provinces in China. Transportation continues to be a bottleneck constraining development. The province is dominated by the plateau, with mountainous terrain and plateaus accounting for 94% of the total. For many years, the topographic conditions acted as a geographic barrier, hampering transportation and economic development in the province (He, 2014). Being an inland province, subject to the geographical constraints on plateaus, the costs for railways and waterway infrastructure construction are higher than highway. Highway has been a major transport model in Yunnan for a long history, according the National Statistics (2016) the volume of road freight represents 94.7% of Yunnan's total freight in 2015.

In 1999, the CPG started to build infrastructure to decrease the development gap between eastern coastal areas and the western land-locked regions in China. With an increase in trade and investment between China and south and southeast Asian nations, the CPG regarded

Yunnan as the most convenient land passage connecting China with the Southeast and South Asia. In 2009, the CPG strategically positioned Yunnan province as the bridge to Southeast and South Asia. The aim is to promote balanced development among the regions, accelerate poverty eradication and modernise rural areas by building major international land routes. At the same time, the construction of highway infrastructure has become the priority to move towards the 'Bridgehead Strategy' of Yunnan (MOE, 2016).

The government plans to achieve the goals of development of industry, tourism, education, technology, and other industries in Yunnan through investment in transportation infrastructure. By the end of the 12th five-year plan (2010-2015), the investment in highway infrastructure in Yunnan reached $47.49 billion, the highway network was gradually improved (MOT, 2016). The Provincial 13th Five Year Plan (2016-2020) set $58.51 billion highway infrastructure investment target over the following 5 years (Government of Yunnan Province, 2016). The development plans are designed to support economic and social development, and enhance the close economic relations with neighbouring countries. (MOT, 2016).

This rapid highway infrastructure development which has enabled the expansion of cities and powered economic growth, has also brought development to remote areas and increased access to health and community services and improved mobility of labour (Sun and Li, 2013). Highway infrastructure also comes with environmental degradation (Cheng and Wang, 2007). In recent years, an increasing volume of research revealed that the rapid development of highway infrastructure can result in a range of environmental problems such as resource consumption, natural and anthropogenic landscape destruction, environmental pollution, construction quality, and coordination between transportation modes and so on (Yan *et al*., 2016). Some studies criticise that in China, the expectation is that investment in highway infrastructure projects are focused on economic benefits, with little consideration of the wider social and environmental issues (Cheng and Wang, 2007). The International Energy Agency (2015) revealed that China has become the largest energy consumer and the second-largest building energy user in the world accounting for nearly 16% of total global building energy use. According to Yunnan Provincial Bureau of Statistics (2016), energy consumption in construction industry occupies one third of the total in Yunnan. Besides the environmental problems, the country's development pattern has raised social tension and other economic problems (Sun, 2010). The value of the investment on transportation projects has been questioned due to poor overall planning and implementation (Shen *et al*., 2010). Many transportation projects such as highways and railways have not been effectively implemented and are often underutilised due to over-forecasting the investment benefits (Ansar *et al*., 2016). Some of the road construction projects with large investment have been abandoned completely due to insufficient maintenance (Sun, 2010). Moreover, Yunnan is a multi-ethnic province with diversified cultures, and the unique lifestyles and cultural traditions of ethnic minority groups have been damaged due to road construction (World Bank, 1997).

With the recognition of the relationship between development and the environment, highway construction needs to face the challenge of sustainability, and the provision of appropriate highway infrastructure projects is an urgent and ongoing requirement in China. As the World Commission on Environment and Development (WCED) stated, development cannot subsist upon a deteriorating environmental resource base, and the Brundtland Report defined the term ‘sustainable development’ as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ (WCED, 1987). In the past decades, many organisations and scholars have undertaken research into sustainable development in China, but mainly focused on the macro-fields (e.g. society), and ignored the micro-fields (e.g. project) (Sun and Li, 2013). Although the concept of sustainability is now better understood in certain contexts, it is still far from being clearly defined. However, the concept of sustainability has become increasingly prevalent with an interaction of various factors including ecological, social, economic, cultural, and political with the purpose to maintain economic growth and social progress while protecting the environment.

The concept of sustainable highway infrastructure projects has emerged since the WCED developed the idea of sustainability. It has been defined in many ways, and involves many factors. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) (2006) defined that a project will maintain sustainability in the economy and environment by designing and maintaining roads, and ensure resource conservation over the project lifecycle.

In an attempt to integrate sustainability in the development process of highway infrastructure projects, a number of tools and methods have been developed for assessing sustainability in highway projects, but effective approaches are still lacking (Wang *et al.*, 2005). Yunnan is a multi-ethnic region with a diversified culture, located in the south-eastern border of China having distinctive regional characteristics. It not only has the common development problems of China, but also specific and unique circumstance which require more varied approaches and initiatives to sustainability assessment (Gao, 2009). There is a growing need for a standard integrated model to assess the sustainability of highway infrastructure projects in the province.

1.2 Problem statement

In this research, the term 'sustainable highway infrastructure project' is regarded as an individual construction project, referring to a fixed asset with a certain amount of investment in the early stage of planning, design, construction and with a series of phases (Yang *et al*., 2010). The development of infrastructure projects are highly capital intensive, resource utilisation, once invested, cannot be changed and it has long-lasting impacts on society and environment (Zhou and Liu, 2015). Thus, it should satisfy lifecycle functional requirements of social development and economic growth while demonstrating concerns for the natural environment (Dong and Zhou, 2012).

In China, the rapid growth of infrastructure construction brings a series of problems, such as low operating efficiency, low construction quality, high assets depreciation rate, heavy losses, resources wastage and environment pollution (Zhou and Liu, 2015). China has made some progress in tackling the issues associated with sustainability in construction projects by acknowledging the current problems, for example, the CPG released the Regulations on the Administration of Construction Project Environmental Protection, and established a set of corresponding environmental regulations and standards to promote sustainability in highway infrastructure project (Chinese Academy of Engineering and Ministry of Environmental Protection of China, 2011). The MOE planned to build six low-carbon, energy-saving highways in 2013. One was in Yunnan, 105.7 kilometres in length which was completed in 2015 (MOE, 2016). Although with this acknowledgment by the government, unbalanced development transportation network, poor coordination, and unsustainable problems of infrastructure projects are still prominent in China (UN, 2012). Many studies highlight that China is facing numerous challenges in the development of sustainable highway infrastructure, and there is a call for sustainability assessment of highway infrastructure projects to support the making of sustainability decisions (Gibson, 2006).

Since the early 1990s, the development of assessment tools for the construction sector has been active and achieved some success based on previous experiences (Haapio and Viitaniemi, 2008a). There are some conventional assessment methods of construction projects which were focused on three factors: cost, schedule, and quality, the overall social and environmental impacts were not considered (Lee *et al*., 2013). There are also many methods for evaluating the environmental, social and economic sustainability of construction projects across the world, but not all of them can identify with the actual conditions in China. According to Wang *et al*. (2014b), currently there are approximately 600 tools for evaluating sustainability, including Cost-Benefit Analysis (CBA), Multi-Criteria Analysis (MCA) and other project appraisal techniques that are essential for economic appraisal purpose; green building rating systems for building sustainability assessment are available, such as Evaluation Standard for Green Building of China (ESGB), but they mainly focus on assessing environmental performance of a building project during design, operation, maintenance, and management (Tsai and Chang, 2012), and fail to consider the social aspects of sustainable development (Pan *et al*., 2016). Besides, most of existing assessments methods/tools are designed for general building/construction, and several methods have been suggested and developed for general and specific types of infrastructure projects (Shen *et al*., 2010), such as road projects and railway projects, but the very different characteristics of highway infrastructure are not included (Peng, 2011). However, those methods/tools are valuable for measuring the sustainability of these types of projects, but some practical issues remain unresolved, and the assessment methods are still ineffective and lack standardisation to evaluate a highway infrastructure project's sustainability (Bueno *et al*., 2013; Pan *et al*., 2016).

Yunnan is regarded as a remote province in China, highway infrastructure serves strategically to promote development, but there is a question to be asked about how fast highway infrastructure development aligns with the principles of sustainable development. The studies on sustainability evaluation of highway infrastructure projects in Yunnan show that it is yet to influence practice. The government standards and guidance for construction are mainly used for sustainability assessment in highway infrastructure projects, there is no standardised and commonly accepted method for evaluating sustainability in highway infrastructure projects over their lifecycle (Yang *et al*., 2017). Therefore, it is necessary to develop a comprehensive and effective sustainable development assessment model for the design and implementation of individual projects to ensure they actually meet the needs of people who should benefit from them.

1.3 Research aims and objectives

The aim of this research is to develop a standard model to assess the sustainability of highway infrastructure projects in Yunnan Province. To achieve the overall aim, the following objectives are proposed:

1) Critically evaluate the sustainability issues relating to highway infrastructure projects based on the principles of sustainable development theories and practices.

2) Determine the status of any existing sustainability assessment frameworks/ models and compare it with existing sustainability initiatives in Yunnan.

3) Develop a suitable sustainability assessment model that can be used by construction professionals involved in highway infrastructure projects.

4) Test the applicability of the model in practice and identify areas of improvement.

1.4 Research questions

The research questions provide guidance for conducting the study, as Maxwell (1998) stated the research questions are at the heart of research design. Based on the aims and objectives of this research, the research questions are defined in Table1.1.

Table 1.1 Research matrix

Objective	Questions
1. Critically evaluate the sustainability issues relating to highway infrastructure projects based on the principles of sustainable development theories and practices.	1. What is 'sustainability'? What are the principles of sustainable development?
	2. What are the impacts of construction of highway infrastructure construction? Why is sustainability important in construction sector?
	3. How do the sustainable development principles apply to construction projects, especially in respect of highway infrastructure projects?
2. Determine the status of any existing assessment models and compare with current sustainability initiatives of Yunnan	4. What are the purposes and principles of sustainability assessment?
	5. What is the performance of existing sustainability assessment methods or frameworks?
	6. How much progress have highway infrastructure projects made in sustainability assessment in China?
	7. Are the existing assessment models or methods suitable for the current situation in Yunnan?
	8. What are the problems and requirements for sustainable highway development in Yunnan?
3. Develop a suitable sustainability assessment model that can be used by construction professionals involved in highway infrastructure projects in Yunnan.	9. How can the outcomes of above be absorbed and combined to form a suitable assessment model for highway infrastructure projects?
	10. How do experts from a range of professional areas organise and prioritise the sustainability assessment indicators?
	11.What are the most important sustainability criteria for assessing highway infrastructure projects in Yunnan, and what are their relative weightings?
4. Test the applicability of the model in practice and identify areas of improvement.	12.How do experts view sustainability in highway infrastructure projects in Yunnan?
	13. How suitable is the assessment model for Yunnan's sustainability requirements?

1.5 Research methodology

Having considered the issues associated with sustainable highway infrastructure project in Yunnan, a mixed method approach that combines both qualitative and quantitative techniques has been identified as the most appropriate approach to match the aim of developing and testing a suitable sustainable assessment model in a real-world environment. The main research methods include a literature review, questionnaire, and interview.

Data from existing literature applicable to the research will be used and then will be enhanced by the collection of primary data. Literature reviews of sustainability, sustainable construction, sustainable highway and sustainability assessment frameworks or methods will be used to fulfil objectives 1 and 2.

Sustainability assessment indicators developed by governments and authorities (e.g. Ministry of Transport [MOT]) and existing assessment frameworks/systems will be collected, the data will help to form the list of preliminary indicators for sustainability assessment models by comparing them with the practical situations of highway infrastructure projects. The indicators presented in existing documents reflect experiences gained by governments and researchers which will be useful for reviewing the existing problems and developing a new indicator system to measure sustainability. The contents analysis will be undertaken to define the assessment indicators of the model in objective 3, this method will help to categorise indicators into various dimensions of sustainable highway infrastructure project by addressing indicator themes. To determine assessment indicators, experts from three groups (academic professional, construction engineers, and government officers) will be invited to rank the significance of the preliminary indicators by means of a questionnaire. It is intended through this method to elicit views and suggestions on key issues and criteria for sustainability assessment in highway infrastructure projects. The data from the questionnaires will be analysed using SPSS and EXCEL. In the last step, once the indicators are determined, the Analytic Hierarchical Process (AHP) method, a multi-criteria decision analysis method, will be used to assign the weighting for each indicator, YAAHP 10.0 software will be employed to implement AHP.

In objective 4, the assessment model will be tested and refined using a qualitative approach to collect feedback and experiences from experts. This phase involved the use of open-ended interviews.

As Harris and Brown (2010) stated, questionnaire and interview are often used together in mixed studies. The questionnaire is an effective method for measuring the behaviour, attitudes, preferences, opinions, and intentions of relatively large numbers of subjects cheaply and quickly. The interview can increase the response rate and help to exploit information which might be neglected in a questionnaire survey (Kendall, 2008). The interviews will help to clarify the experts' perceptions regarding the current problems of highway infrastructure projects and the development of a sustainability assessment process for Yunnan, as well as establishing their views of the model developed during this research. Content analysis will be used to analyse the interview data. As a widely used qualitative research technique it is a flexible method for analysing text data (Hsieh and Shannon, 2005).

1.6 Contributions and limitations

The core contribution of this research is to use a mixed method to develop a sustainability assessment tool for highway infrastructure projects in Yunnan Province, China. Moreover, it is anticipated that this study will highlight the importance of sustainability and apply the sustainability principles into highway infrastructure projects, and serve as a reference for further studies in this area. Finally, it will public awareness of sustainability to improve performance of highway infrastructure projects.

The mixed method can contribute to building an effective assessment model. Initially, this research will evaluate the relationship between traditional construction project development and a sustainable development approach and propose the baseline and contents for sustainability in highway infrastructure projects. Secondly, it will review the existing assessment frameworks and methods from various countries to identify the gaps between theories and practice in Yunnan Province. Finally, with the experience and knowledge of experts, apply the model to a highway infrastructure project in Yunnan to further refine it. This will ensure that the model is suitable for planning and development of new highway infrastructure projects, and provide criteria for evaluating and reconstructing existing highways.

Because of the low level of interest in sustainability issues in Yunnan, there is a paucity of literature and data on this area which has influenced this research. The primary limitation of this research is t the lack of statistical data has resulted in assessment model testing being based on experts' interviews, the determination of the elements and the assessment indicators are based on personal experiences and awareness, therefore, individual subjectivity significantly influences the results. The accuracy and objectivity of the assessment model will need to be further analysed.

Additionally, there are some significant regional variations within Yunnan, the requirements and meaning of sustainability will be shifted in the context of the local situation, therefore, the views of other experts' groups within different construction projects, and stakeholder perspectives to validate the assessment model will be useful for future research.

1.7 Structure of the thesis

This thesis consists of 9 chapters, the contents of each chapter are in follow:

Chapter 2 - provides an overview of the general meaning of sustainable development, define the concepts of 'sustainability', examines the influencing factors of sustainability, and defines the principles of 'sustainable development' based on the previous studies on sustainability.

Chapter 3 - evaluates the significance of the construction and highway infrastructure, and addresses their impacts on the environment since construction is a significant consumer of natural resources, and causes pollution of the environment. Defines the term of 'sustainable construction'. This chapter fulfils objective 1 of this research.

Chapter 4 - explains the main issues of sustainability assessment process, evaluates and compares the existing assessment models of sustainability in highway infrastructure.

Establishes if the current sustainability assessment frameworks can address the sustainable priorities in Yunnan.

Chapter 5 - provides the background of Yunnan, reviews highway development in Yunnan and lists the distinct conditions in this region for building a suitable model for relevant projects in Yunnan. Explains to what extent sustainable highway and sustainability assessment are being practiced in Yunnan. Chapters 4 and 5 addresses objectives 2 of this research.

Chapter 6 - outlines the research methodology used to achieve the research aim through each of the objective areas. The details of the methods for collecting and analysing the data are explained.

Chapter 7 - develops a sustainability assessment model for highway infrastructure projects in Yunnan based on previous knowledge in earlier chapters. The regulations, codes and standards of the industry are adopted as guidance, and current sustainability frameworks, systems and tools are used as references. This Chapter also quantitatively explores the extent to which success criteria influence the sustainable highway infrastructure project. Objective 3 of this research is addressed in this chapter.

Chapter 8 - the model developed in chapter 7 will be introduced to a group of professional experts in academia, industry and government. Objective 4 is fulfilled in this chapter. The developed sustainability assessment is applied to a case study to test its applicability in real life.

Chapter 9 - summarises the major research findings incorporating the conclusions of the study, and discusses the recommendations and future research.

A reference list will include all the sources cited in the text of this thesis. Important documents supporting the content of the text are appended to the thesis as appendices, including questionnaire and interviews of experts.

CHAPTER 2 - OVERVIEW OF SUSTAINABILITY

2.1 Introduction

The purpose of this chapter is to identify the critical issues associated with sustainability and prepare the ground for subsequent chapters. First, it will review the development and progress of sustainability, and discuss the various definitions of sustainability and sustainable development through the examination of previous research and various other publications. Secondly, several elements will be examined to establish the principles for sustainable development. Finally, six principles will be recommended covering economic, social and environmental development, long-term and short-term development goals, technology and good governance.

2.2 Concept of sustainable development

Since the idea of 'sustainability' first appeared in the second half of the twentieth century, it has grown in importance. From the first awareness of its practice, sustainability has undergone significant refinement and development to become the future direction of human progress. Many international organisations, research institutions and scholars have produced and published extensively on sustainable development theory and the outcome of this research will now be examined in detail.

2.2.1 Emergence of sustainability

The concepts of sustainability and sustainable development have evolved over the past few decades. The initial wave of concern for the environment occurred in the 1960s and 1970s, after the Second World War several developed countries achieved rapid economic growth through developing large-scale economies and accelerating the industrialisation process. People began to express concern over development patterns with their resultant pressure of economic growth, urban expansion, increasing population, overuse of natural resources, environmental pollution and other problems (Niu, 2012a). In 1962, the American biologist Rachel Carson described pesticide pollution in her book 'Silent Spring' and triggered a worldwide debate on human impacts on the natural environment (Wang *et al.*, 2000). In 1972, the Club of Rome published the book 'The Limits to Growth' to analyse the relationship between economic growth and natural resources through computer modelling. The book reveals that the nature resource would not be sufficient for the needs of human beings if the current development patterns continued (Meadows *et al.*, 1972). The authors believe that the planet's resources are limited, a view shared today by many people (Wu, 2013). Since then, the concern expressed by the early researchers about the environment and development patterns has led to an almost universal recognition of the concept of sustainability.

The concept of sustainable development emerged from international efforts between 1972 and 1992. During this period, a series of international conferences and events took place to discuss a range of global environmental problems. The 1972 United Nations (UN) Conference on the Human Environment was held in Stockholm, its main purpose was to examine the impact of humans on the ecological environment, and it achieved a universal consensus on how to preserve the environment around the world (UN, 2011b). One of the most important outcomes of the conference was the Stockholm Declaration which enhanced global awareness of environmental issues and aided in setting international environmental policy for the future (Handl, 2012). This was a significant step towards the establishment of the concept of sustainable development based upon the relationship between environment and growth (UN, 2011b). In 1980, the term 'sustainable development' was referred to by the International Union for Conservation of Nature and Natural Resource (IUCN) in the World Conservation Strategy (WCS). The Strategy emphasised that future development should focus on maintaining and sustainably using the ecological system (IUCN *et al.*, 1980). Many countries have formulated national conservation strategies since the WCS was developed. The initial concept of sustainable development was introduced by the various conferences discussed previously, consequently, the public started to demonstrate concern about the environment.

In 1983, the UN established the World Commission on Environment and Development (WCED) and formulated 'A Global Agenda for Change' to address concerns of environmental issues and human development in the world (UN, 2011a). Sustainability is clearly associated with environmental protection but also extends to include the quality life.

In 1987, the report of the WCED ‘Our Common Future’, also known as the Brundtland Commission Report, provided the first clear definition of ‘sustainable development’ and laid the foundation for its future (WCED, 1987). The report made a clear statement that the balance of the ecological environment must be taken into consideration during the development process, extending it to include social concerns (reduction of poverty and realisation of equality) as well as habitat conservation (Zhu *et al.*, 2011). WCED encouraged international attention to focus on a development approach based on three considerations: economic growth, natural resource consumption and social satisfaction, and it illustrated the contribution made by the environment to social and economic growth, and demonstrated that social development cannot be improved by destroying the environment.

The WCED has brought sustainability into public discourse with international discussions held focussing on human development problems. The most significant milestone in the evolution of sustainability was the UN Conference on Environment and Development (UNCED) in Rio de Janeiro, 1992, also referred to as the Rio Summit and Earth Summit, the largest international conference for discussing solutions to global problems. Several important agreements were achieved in the conferences, the key outcomes being the Rio Declaration on Environment and Development and Agenda 21. The Rio Declaration proposed 27 principles for setting sustainable development policies, and Agenda 21 provided an action plan for sustainable development to deal with problems of human development and ecosystems. These documents offered ‘policies and programmes to achieve a sustainable balance between consumption, population and Earth’s life-supporting capacity’ (UNCED, 1992). Agenda 21 has been considered as a comprehensive blueprint for sustainable development on global, national and local levels, attempting to balance environmental protection with social and economic concerns (Butler, 2003; Niu, 2012a).

The UN held the Rio+5 conference in 1997 and Rio+10 in 2002 to conduct the five-year and 10-year review of the Rio Decisions. In Rio+5, no new achievements had been made, with little of implementation of Agenda 21 (Niu, 2012a). Rio+10 was held in 2002 in Johannesburg. The Johannesburg Declaration on Sustainable Development achieved agreements on environment problems (UN, 2012). The assembly described the attitude of some state governments to sustainable development as ‘more talk than action’, failing to recognise that all states and individuals in society have a responsibility for sustainable development.

In 2010, the Millennium Summit of the UN established eight international development goals - The Millennium Development Goals (MDGs) which covered poverty, hunger, disease, unmet schooling, gender inequality and environmental degradation (UN, 2012). The aim through these goals is to build a broad development vision for global action, and are the requirements for whole sustainability. In 2012, heads of state and high-level representatives held a conference in Rio de Janeiro, also known as 'Rio+20' – twenty years after the milestone 1992 Earth Summit in Rio. This conference summarised the advances made over the previous two decades, but more importantly set the guidelines for next 10 to 20 years. The outcomes of 'The Future We Want' resulted in guidelines for achieving a sustainable future, drawing a common vision to ensure the promotion of an economic, social and environmental sustainability, and reaffirming the commitment by each state to ensure full implementation of the past plans such as the Rio Declaration on Environment and Development and Agenda 21 (UN, 2012).

Through years' of development, the term of sustainability has become an interdisciplinary science including ecology, economics, sociology, ethics, politics, etc.(Niu, 2012a). With the concept of sustainability gaining widespread recognition, the term 'green' has become fashionable, e.g. 'Green Economy', 'Green Growth', 'Green Industry' and so on (Allen and Clouth, 2012). The emergence of the 'green' concept is regarded as providing strategies and roadmaps for sustainable development in many countries (United Nations Industrial Development Organization, 2011). Its development is based on theories and practice of sustainable development, and aims to increase lasting well-being.

Established through the long-term practice and experience of many people, the idea of sustainable development has transitioned from being an interesting concept to an important international development direction. A timeline of how the concept of sustainability has developed is given in Table 2.1.

Table 2.1 Sustainable development process

Year	Event	Outcomes
Roots of Sustainability		
1950-1960s	Environmentalism developed	• People started being concerned with environmental problems
1968	First intergovernmental conference by UNESCO	• Reconciled environment and development • Led to the creation of UNESCO's Man and the Biosphere (MAB) Programme
1972	First United Nations conference on the environment, Stockholm, Sweden	• Agreed the Stockholm Declaration concerning the environment and development • Established United Nations Environment Programme (UNEP) to provide leadership and partnership in caring for the environment globally
Emergence of Sustainability		
1987	World Commission on Environment and Development	• First clearly defined 'sustainable development' • Promoted a framework of economic, social and environmental criteria for sustainable development
1992	Rio Earth Summit	• Produced Agenda 21 for implementing sustainable development globally • Analysed the impacts of human activities on the environment and provide guidance to manage them
1997	Kyoto Protocol	• Achieved first agreement to mandate reductions in greenhouse-gas emissions between nations • Set the principle of common but differentiated responsibilities to allocate responsibilities to developed nations
2000	United Nations Millennium Summit	• Set Millennium Development Goals (MDGs), covering issues of poverty eradication, environmental protection, human rights and protection of the vulnerable.
2002	Rio+10, Johannesburg Summit	• Considered problems of poverty eradication, consumption and production issues, and health concerns • Launch of partnerships in a new form, involving civil society and not just governments, aimed at implementing sustainable development
2009	UN Climate Change Conference, Copenhagen	• Formed formal decisions by consensus on climate changes
2012	Rio +20, Rio de Janeiro, Brazil	• Signed agreement on build a green economy to achieve sustainable development and lift people out of poverty; and improve international coordination for sustainable development

The timeline shows milestones across the history of sustainable development, it indicates that the global discussion moved forward to 'sustainable development' from 'environmental protection'. The concept of sustainable development links poverty, inequality, environmental degradation and other problems associated with development, and emphasises the relationships between economy, ecology and society. At the same time, the concept has been transformed from academic research theory into common guidelines for policies building on human development.

2.2.2 Definition of sustainability

With increasing awareness of sustainability, debates about its definition have arisen from different disciplines and perspectives including ecology, economics, sociology biology and so on (Bolis *et al.*, 2014). The concept of sustainability is given different interpretations by way of different perspectives. Many researchers argue that precisely defining sustainability has been considered a complex task, the meaning of the term often appears to be unclear and ambiguous (Dresner, 2008; Wuelser *et al.*, 2012).

Another question has arisen when people are trying to define the terms of sustainability and sustainable development: do they mean the same thing? Johnston *et al.* (2007) considered sustainability as the basis of sustainable development in international discussions. Blewitt (2014) argued that 'sustainable development' is preferred and described the development process to realise the goal of 'sustainability'. According to Dresner (2008), sustainability primarily concentrates on environmental issues, and sustainable development is focused on development methods. But many studies do not show any distinct differences between them. In most of the international conferences and documents such as the Brundtland Commission Report and Agenda 21, these two terms are used interchangeably (Dresner, 2008). The implication of this, at least for most researchers, is that sustainable development is the route to achieving true sustainability, with both terms being used interchangeably to describe the comprehensive approach required.

Sustainable development has its origins in the effort to protect ecology, and as an alternative to the traditional development pattern where increased material wealth damages the environment and natural resources (Fan and Jiang, 2015). It is used to investigate the relationship and interaction between human activities and the ecological environment (Sun, 2010). According to Rogers *et al.* (2006), sustainability means *'maintain the resilience and robustness of biological and physical systems*' which indicates that the development should not overwhelm the carrying capacity of the earth.

In practice, economic growth has traditionally been the priority of development with the objectives of increasing production, profit and materials, and driving social-economic transformation (Pieterse, 2009). From this perspective, sustainability is considered a more balanced approach to maximising economic income while maintaining or increasing the stock of capital. People in poverty will tend to take care of the environment when their per capita income rises, and then they will start to divert income to achieve sustainable development through the production of superior goods and services (Rogers *et al.*, 2006). '*Sustainable development involves devising a social and economic system, which ensures that these goals are sustained, i.e. that real incomes rise, that educational standards increase, that the health of the nation improves, that the general quality of life is advanced'* (Pearce *et al.*, 1989).

There is an increasing recognition that development also carries a connotation to include improving human health, quality of life and how to obtain the necessary resources, and create a more equal community (Fan and Jiang, 2015). The World Conservation Union (IUCN) and United Nations Environment Programme (UNEP) defined sustainable development from humanity's perspective as 'development which improves the quality of human life while living within the carrying capacity of supporting eco-systems' (IUCN and UNEP, 1991). And the most widely accepted definitions of sustainable development in the Brundtland Report emphasises that '*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs, in which every human being has the opportunity to develop in freedom, within a balanced society and in harmony with the environment'* (WCED, 1987).

The definition from WCED draws the link between the economy, environment and social well-being, a healthy economy requiring a healthy environment, and human beings' activities directly influencing the environment (Johnston *et al.*, 2007). It transmits a message with various considerations: equality between present and future generations, poverty within the current generation and balance between using national resources and environmental systems restoration (Wuelser *et al.*, 2012).

Sustainability is now accepted including economic, social and ecological viewpoints, from a technological perspective people cannot embark upon further development without appropriate technology to support it (Hill and Bowen, 1997). Therefore, sustainable development works towards cleaner and more efficient technology, closer to zero emissions, as far as possible, to reduce the consumption of energy and other natural resources (UNEP, 2014). Strong (1992) offered a definition as '*sustainable development involves a process of deep and profound change in the political, social, economic, institutional, and technological order, including the redefinition of relations between developing and more developed countries.'*

Various definitions contribute to clarification of the term sustainability but they can be open to interpretation (Yu and Cha, 2011). Bolis *et al.* (2014) argued that the concept of sustainability means different things to different people. This is at least partly due to the variation of economic, social and ecological conditions in different locations and situations, influencing how different nations set their development priorities (Barbier, 1987). Some governments focus on human development to improve human literacy and life expectancy, but others would concentrate on reducing poverty and solving other social problems (World Bank, 2004). Hence, IUCN and UNCP declared that nations can set up different development goals according to their own circumstances (IUCN and UNEP, 1991).

Integrating the varied interpretations and definitions derived from different perspectives, sustainability can be considered as guidance for development to ensure the future survival and advancement of humans. It provides a holistic approach to economic development, takes scientific and technological progress as a given, provides for the development of individuals and social cohesiveness to realise justice between inter-generation and intra-generation, and being in harmony between human beings and the eco-environment under the real conditions and circumstances of a region or nation.

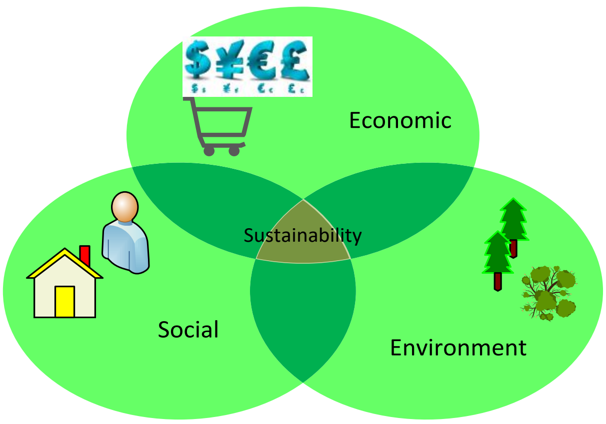
However, there is no precise definition of 'sustainable development', and the debate about this concept is continuing (Huang and Li, 2015). The international community must go well beyond the general considerations on social, economic and environmental issues, and advance a more holistic and integrated meaning of development.

2.3 Dimensions of sustainable development

The concept of 'sustainable development' has received increasing worldwide recognition, and the number of definitions has certainly increased. But the definition of sustainability has been regarded with some uncertainty. Also, there is no agreement on how to achieve sustainable development (Mitlin, 1992), thus, setting dimensions of sustainable development has become particularly important.

Economic growth, social development and environmental conservation are the basic requirements for sustainable development. As shown in Figure 2.1, these three elements are regarded as the common dimensions for setting principles of sustainable development.

Figure 2.1 Three elements of sustainability



Source: Elkington,1997

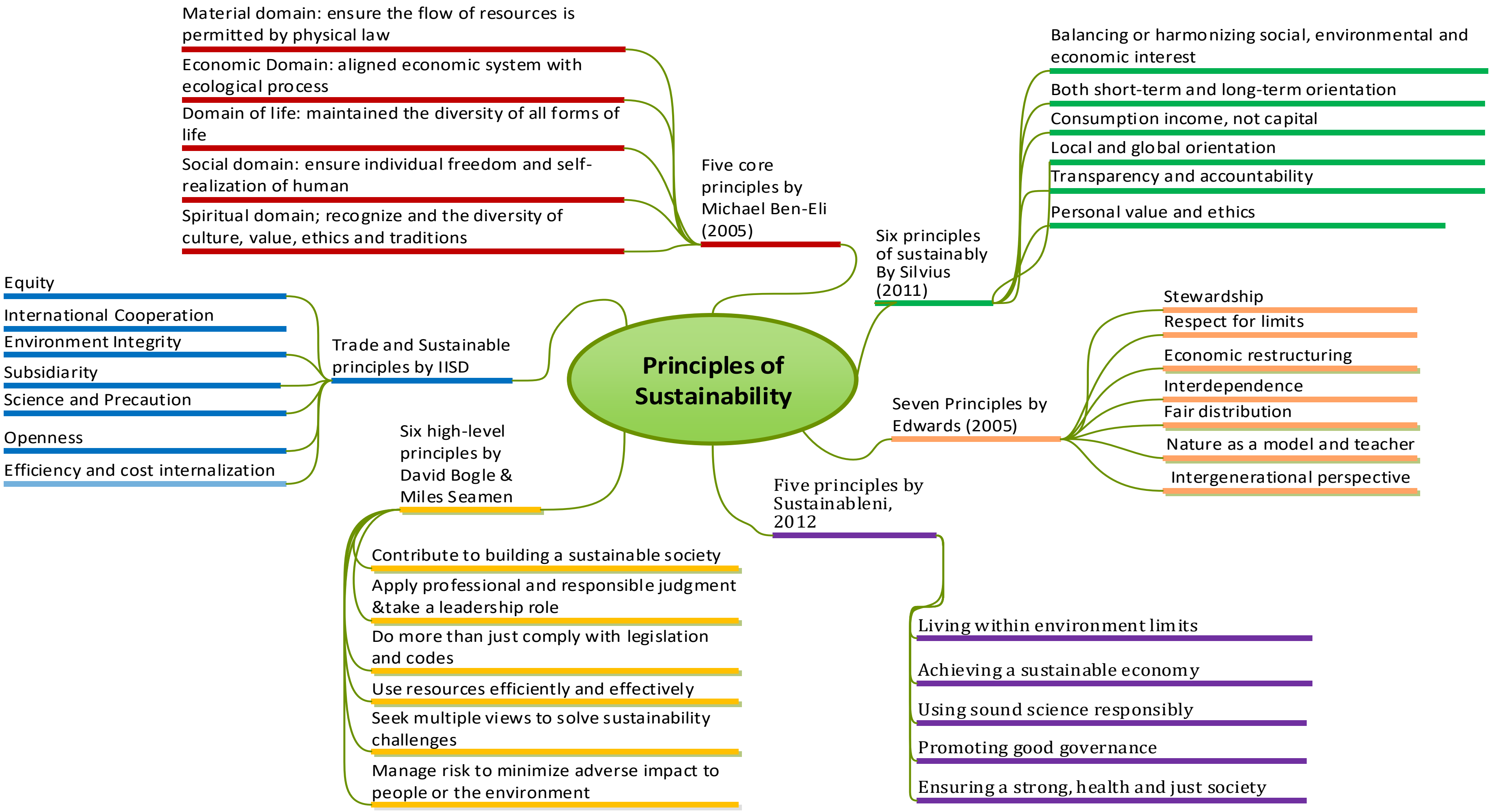
Economic sustainability means maximising the flow of income while maintaining the stock of assets (or capital); ecological sustainability aims to protect biological and physical systems; and social sustainability aims to stabilise social and cultural systems and to minimise destructive conflicts for both intra- and intergenerational equity (Munasinghe, 1993).These three elements are interrelated, disregarding any one of the elements would threaten the whole sustainability (Ciegis *et al.*, 2009). Development should not break the social code based on traditions, ethics, religion and morals. Also, the development should be based on constraints of the ecological environment, and consumption of natural resources which cannot exceed the level the environment will support (Elkington, 1997).

Yet many organisations and researchers argued that these three dimensions cannot adequately reflect the complexity of the real world. Additional factors are defined that can shape sustainable development. WCED (1987) argued that achieving sustainable development must rely on political decisions. Kardos (2012) pointed out that good governance is ‘commitment to the rule of law, human rights, transparency, participation, inclusion, and sound economic institutions that support the private, public, and civil-society sectors in productive and balanced manner’ (Sachs, 2012). The Global Change Open Science Conference of the Earth System Science Partnership (ESSP) argued that ‘an ethical framework for global stewardship and strategies for Earth System management are urgently needed’ (ESSP, 2001). Traditional ethics belongs to the category of interpersonal ethics, whereas sustainable development extends the boundary to the proper relationship between human beings and society, and natural environment. Additionally, UNESCO (2014) argued that science and technology are critical to coping with the challenges of sustainable development, it is through shifting the sustainable approach to include activities such as innovative engineering that energy efficiency will be realised. However, although many studies aim to illustrate the most important issues of sustainable development, there is no general agreement about the precise dimensions, so the key principles for sustainability must be addressed, as many researchers have clearly stated that the principles are the agreed guidance for setting strategies and actions for sustainable development (Shen,2013).

2.4 Principles of sustainable development

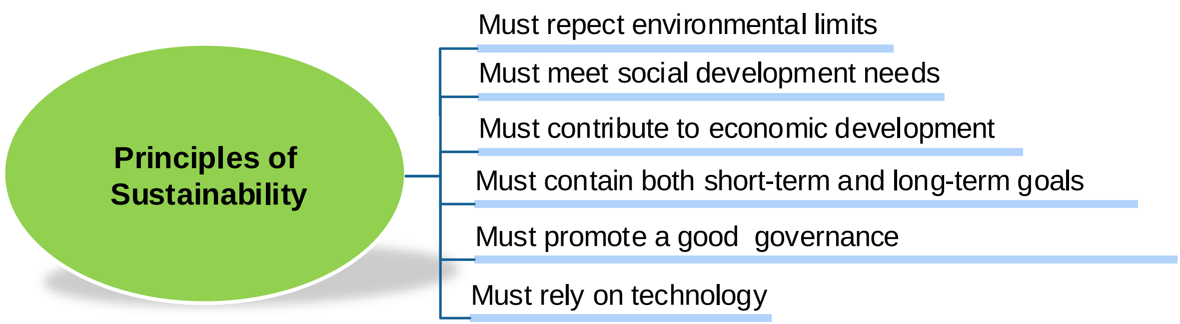
Numerous principles of sustainable development involving different levels have been established and proposed. Figure 2.2 lists six examples of sustainable development principles from governments, industries and projects.

Figure 2.2 Sustainability principles



The UK government adopted a framework from Sustainable Northern Ireland (Sustainableni), with five agreed principles which 'involve safeguarding and using existing resources in a sustainable way to enhance the long-term management of, investment in, human, social and environmental resources' (Sustainableni, 2012). For the purposes of basic humanity, Ainger and Fenner (2013) provided four fundamental principles for delivering sustainability in infrastructure. Hannover, Germany commissioned nine principles for EXPO 2000 which considered the impacts of building design on sustainability. The fundamental idea was based on setting priorities for the built environment and the 'long –term value' and interdependence of human activities and environment (McDonough and Braungart, 2012). Seven principles by Edwards (2005) and five principles from Ben-Eli (2005) were defined to serve as guidelines for policy decision and future activities. Silvius *et al*. (2012) provided six principles of sustainability in projects and emphasised that sustainability should care about the short-term and long-term interests, value and ethnic orientation. Although sustainable development principles abound on different levels and sectors, they represent the same values for sustainable development: using natural resources equitably and efficiently and achieving environmental integrity, building a just society with community spirit, producing economic development, considering both long-term and short-term value, having openness in governance, and using appropriate technologies. Through integrating the conditions and existing principles, a set of principles are proposed in Figure 2.3 as following.

Figure 2.3 Six principles of sustainability



Must respect environmental limits

The development must strive to protect and restore the environment in all activities. That is the fundamental level of the principles of sustainable development.

Must meet social development needs

The development must meet the diverse needs of all people in current and future generations. Maintaining social capital such as cultural heritage and beliefs, reduce harm to people, demonstrate care for health and safety, provide employment opportunities.

Must contribute to economic development

Maintaining economic capital and promoting economic growth. Increasing income and return on investment, and bring economic benefits.

Must contain both short-term and long-term goals

Sustainability must simultaneously be found in short and long-term objectives (Bolis *et al.*, 2014). The long-term goal of development is to meet the needs of future generations and reduce poverty (WCED, 1987), and short-term strategies such as increased Gross National Product (GNP) and Gross Domestic Product (GDP) growth, which are part of economic prosperity to support improving the social quality of life. In some case, the long-term development will impact the short-term benefits, e.g. improve energy efficiency and saving resources may reduce production costs, which will create short-time benefits. Therefore, development should always consider both long-term and short-term goals (Pierantoni, 2004).

Must promote good governance

Achieving the goals of sustainable development will depend upon on governments' political decisions (WCED, 1987)). Governance is a tool for decision-makers to build a systematic framework for coordinating and balancing the economic, social and environmental goals at national or regional level (Zhang, 2011). Good governance promotes accountability of policies and rules, and also ensures efficient management of human, natural, economic and financial resources (Zhou, 2010).

Must rely on technology

This principle relies on technology to provide solutions for sustainable development. It is apparent that development is inextricably linked to energy and natural resources, technology can improve energy and resource utilisation and also create alternative solutions (Zhou, 2010).

2.5 Conclusion

This chapter provided a literature review on the scale of sustainability and principles of sustainable development. It argued that since the term 'sustainability' was clearly defined in 1987, and research of the concept has achieved great significance and has become widely accepted, but it remains controversial because proper comprehension of the term can be challenging. The findings revealed that there are hundreds of definitions, each emphasising different aspects of sustainability, although the basic dimensions of economic, social and environmental development are generally accepted internationally. Additional elements were included for the concept of sustainability, the elements of sustainable development were considered, this chapter reviewed the sustainable development principles by recognising the long-term and short-term requirements of social, economic and ecological development with the support of good governance and technology. Technological issues are regarded as vital to the solution for economic, social and environmental development, good governance in sustainable development can assist in developing effective systems to implement sustainable development principles. The six principles established in this chapter which create a framework that can be employed in the sustainability assessment of highway infrastructure projects in later chapters.

CHAPTER 3 - SUSTAINABILITY IN CONSTRUCTION AND THE CHALLENGES IN HIGHWAY INFRASTRUCTURE PROJECTS

3.1 Introduction

The main purpose of this chapter is to review the sustainability issues for highway infrastructure projects, by first analysing their characteristics and their impacts, thus identifying the need for sustainability. An overview of the history of sustainable construction is taken and the notion of 'sustainable construction' explored. Finally, six sustainable development principles in highway infrastructure will be developed derived from the findings of Chapter 2 focussing on construction and providing an operational guide for sustainable construction.

3.2 Review of sustainable construction concept

3.2.1 Emergence of sustainable construction concept

Developing highway infrastructure projects brings economic benefits alongside social and environmental problems, there is now a widespread belief that adopting sustainable practices will have significant potential to solve the problems (Dong, 2013). This being the case, how to develop sustainable highway construction is a serious question that must be answered.

A few early scholars recognised the impacts of construction on the environment, in the 1930s, the American architect Fuller proposed that the construction process should show concern on how to achieve development objectives, demands, global resources and technologies by using dwindling resources to meet growing demand (Shi, 2007). In the 1960s, Paolo Soleri combined 'ecology' and 'architecture' to create a new concept 'arcology' which 'is capable of demonstrating the positive response to many problems of urban civilisation, population, pollution, energy and natural resource depletion, food scarcity and quality of life' (Soleri, 1973). These ideas envisioned that while designing a construction project, designers and engineers should increase cost effectiveness, minimise the consumption of energy, materials and resources, reduce waste and environmental pollution while maximising the social and economic benefits. These early ideas also introduced the relationship between construction and environment resulting in the initial theories of sustainable construction.

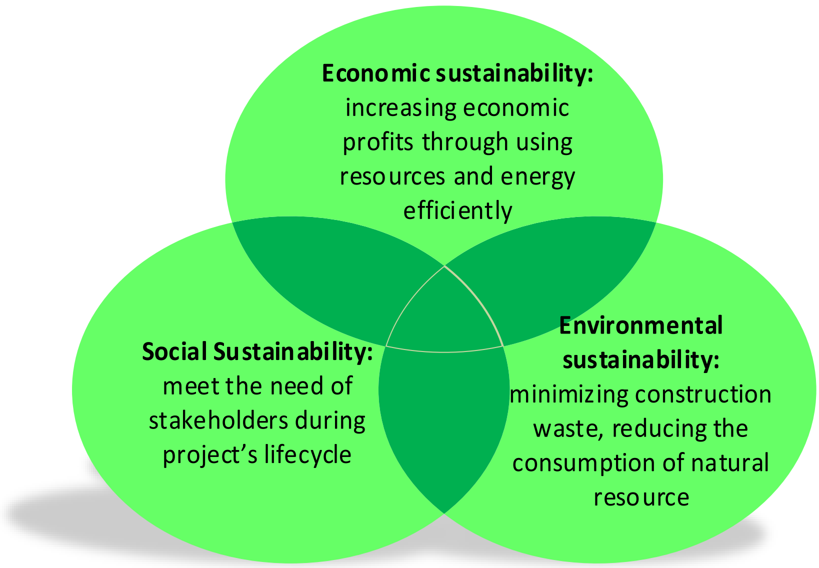
The 1970s saw the expansion of the concepts of sustainable development and sustainability, with a series of documents, such as 'Rio Declaration' and 'Agenda 21' formulating sustainable development strategies. Since then, sustainability has become a widely recognised and accepted development consideration. Given the enormous resource and energy consumption, in the construction industry, the need for sustainability has been emphasised in the development process (Comstock *et al.*, 2012). Under the guidance of the sustainable development principles, the architecture profession developed the 3Rs of building designing principles: reduce, reuse, and recycle, i.e. reduce the energy and material used, reuse or recycle waste materials (United States Environmental Protection Agency, 2008). The idea of the 3Rs provided a less environmentally damaging alternative to handle the growing wastes and the effects on the economy, ecological environment and society (Mohanty, 2011). It aligned the ideas of green construction and sustainability, and demonstrated an increasing environmental awareness of the underlying dangers caused by construction.

With increased attention on the environmental impacts from construction, the first international conference on sustainable construction was held in Tampa, Florida, USA, 1994. In the conference, Kibert defined the term 'sustainable construction' by presenting the comparison between the traditional criteria (performance, quality and cost) and sustainability criteria (resource depletion, environmental degradation and healthy environment), applying the sustainability principles to the construction process – planning, design, operation, renovation, and deconstruction phases (Kibert and Chini, 2006). The conference developed the concept by applying sustainability in construction from the perspectives of project whole lifecycle.

In the 1990s, the concept of sustainable construction made further progress, when in October 1998, in Canada, the international conference 'Green Building Challenge' was held. The conference established the idea of sustainable construction by providing a system of evaluation criteria for buildings called GBTool, a framework for assessing the energy and environmental performance of buildings (International Initiative for A Sustainable Built

Environment, 1998). In 2000, the International Conference on Sustainable Building (SB'2000) was held in Maastricht, Netherlands. In 2002, the World Congress of Sustainable Building (SB'02) took place in Norway. In 2005, the World Sustainable Building Conference (SB'05) was held in Japan (EU-Japan Centre, 2005). These conferences demonstrated the global progress in green building design, and developed the operational frameworks of building environmental assessment. The concept has moved forward and made tangible progress in these conferences to pave a surer path for improving sustainable construction. At present, law-making in respect of green buildings has become a global trend. Various studies throughout the world are exploring the methods and approaches to realise sustainable construction to maximise savings in resources and energy, preserve the ecological environment, satisfy the needs of people and provide healthy and comfortable living conditions. Hussin *et al*. (2013) proposed three elements of sustainable construction shown in Figure 3.1.

Figure 3.1 Elements of sustainable construction



Source: Hussin *et al.* (2013)

According to Hussin *et al.* (2013), it is important to balance the three elements of sustainable development - environment, economic and social aspects to achieve sustainability in construction. Economic sustainability involves increasing economic profits through using resources and energy efficiently, controlling lifecycle costs, considering alternative financing mechanisms and economic impacts on local community. Social sustainability meets the needs of stakeholders during the building lifecycle, which includes enhancing stakeholders' participation, promoting the development of appropriate institutional frameworks, and considering the impacts on health, quality of life and social framework. Environmental sustainability minimises construction waste, reducing the consumption of natural resource by using new technologies, and reducing the material demand and the energy required for transforming goods and supply services.

However, with increasing sustainable development awareness, sustainable construction has been receiving more attention, and has already resulted in a development and transformative trend for construction and construction engineering.

3.2.2 Definitions of sustainable construction

Studies have shown a growing emphasis on reducing the impacts on the natural environment and improving living standards, but some of the theories about sustainable development are not practical (Zabihi and Habib, 2012). In this case, many people and organisations have provided various definitions of sustainable construction, the classic definitions are summarised in Table 3.1.

Table 3.1 Definitions of sustainable construction

Definitions	Definer
Creating and operating a healthy built environment based on resource efficiency and ecological design.	Kibert, (2008)
The meanings of ‘sustainable construction’ would be represented by the same meaning of ‘sustainable development’ with four attributes – social, economic, biophysical and technical.	Hill and Bowen, (1997)
Sustainable construction is a holistic process intended to restore and maintain harmony between the natural and built environments, and create settlements that affirm human dignity and encourage economic equity.	Du Plessis, (2002)
Considering development in terms of its three-primary aspect (economic, environmental and social), while meeting the requirements for technical and functional performance.	ISO Standard 15392, (2008)
Buildings must concentrate on environmental conditions and minimise damage to nature from design to completion stage.	Zabihi and Habib, (2012)

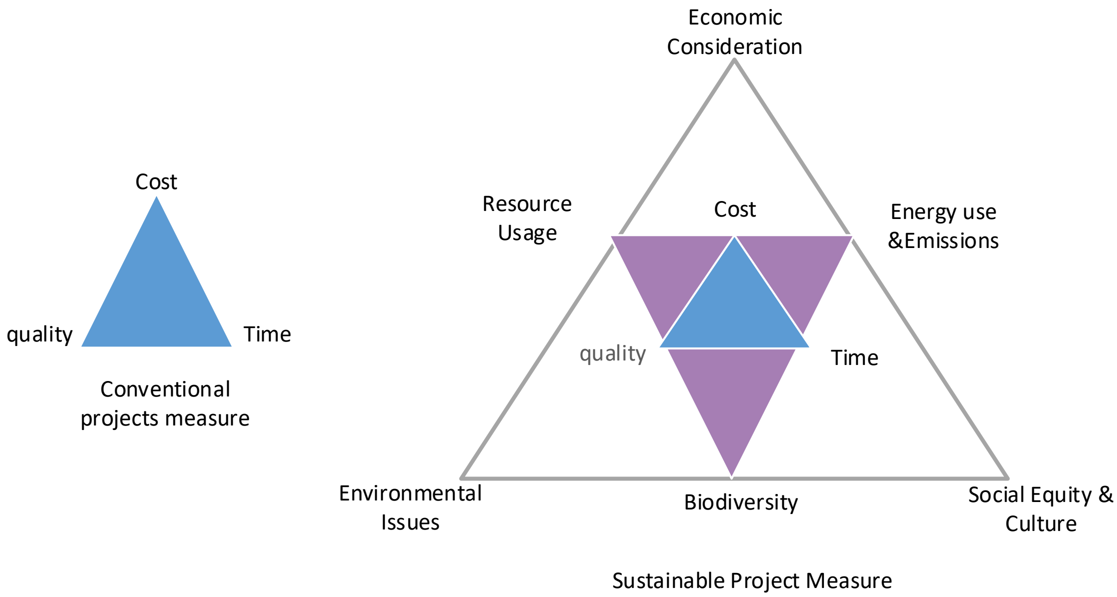
These definitions highlight the context of sustainable construction as the follow:

Firstly, the definitions not only highlight the importance of environment-oriented values and practices within construction, but also show that the concept of sustainable construction progressed from the initial meaning of environmental protection and energy saving, extending to the influences of the social and individual quality of life, health and safety of workers (Shi, 2007), the user’s health, comfort and safety (Alwan *et al.*, 2017) and maintenance of high and stable levels of economic growth (Zabihi and Habib, 2012). Thus, sustainable construction can be found to manifest in economic, social and environmental sustainability, because it is a subset of sustainable development, its practices should address the threes pillars of sustainability (Kibwami and Tutesigensi, 2016).

Additionally, the concept of sustainable construction has been linked to the whole lifecycle of the project. It not only focuses on specific stages – planning and design, construction and operation, but also permeates every aspect of the project, from approval, site selection, through to final demolition (Dong *et al.*, 2014). Shi (2007) found that a construction project needs a certain amount of investment, through forecasting, decision-making, implementation, design, construction and a series of processes, it is a one-time activity aimed at constructing fixed assets subject to certain constraints. A complete construction project should include raw materials acquisition, processing, and delivery of product, product sales, use, maintenance, recycling along with other stages (Dong *et al.*, 2014). According to the existing definitions, the term 'sustainable construction' can be concluded as: construction undertaken by implementing sustainable development ideas throughout the project whole lifecycle (planning, designing, construction, operation and demolition).

From the project management perspective, the project management processes, strategies, policies and initiatives must be improved by sustainable approaches. At the 2008 International Project Management Association (IPMA) World Congress, McKinlay argued that 'the further development of the project management profession required project managers to take responsibility for sustainability'(cited in Silvius *et al.*, 2012). The conventional standards for construction projects such as Project Management Body of Knowledge (PMBOK) Guide from the Project Management Institute (PMI) and Projects IN Controlled Environments Standard (PRINCE2) from the UK government both tend to focus on managing project quality, progress, investment, contract, communication and organisational coordination (Yan *et al.*, 2016). These conventional standards need to consider the elements of sustainability in construction. In Figure 3.2 the conventional construction project management triangle (Time-Quality-Cost) used to measure the project success has been amended to reflect a sustainable project measure.

Figure 3.2 Conventional project measure and sustainable project measure



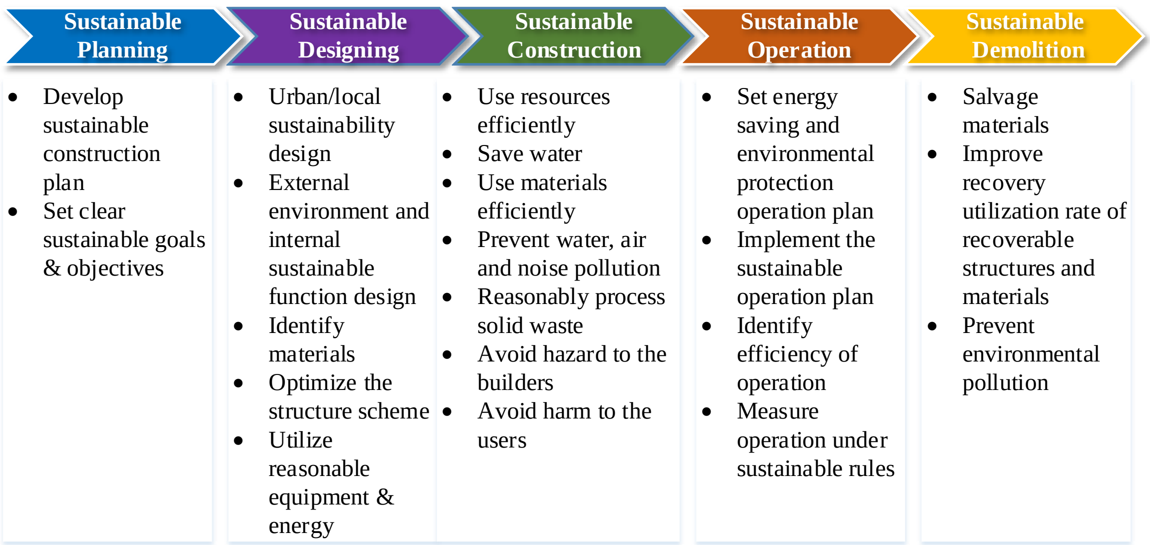
Sources: Cotgrave and Riley (2012)

A building may be completed on time with cheaper cost, but the construction activities may use abundant energy and cause high emissions: (e.g. energy on a construction site is usually provided by fossil fuel which is responsible for air emissions) (Sharrard *et al.*, 2007). So, on the basis of the conventional standards, Cotgrave and Riley (2012) suggested that reduced energy and resource consumption and enhanced biodiversity are the core issues of project design. They also discussed that three dimensions need to be added to address sustainability in building projects – economics, social equity & culture and environmental issues, and these three dimensions must be considered in a local context.

Additionally, the cost of the project is not only about the initial construction cost, but the overall cost of a project throughout its whole lifecycle (e.g. maintenance cost), and the impacts on environment and society will affect the project whole lifecycle (e.g. impacts on land cover or population and employment density change) (Kasrain *et al.*, 2015). Moreover, the consumption of energy by construction is not only in constructing buildings and other facilities, but also in the subsequent use of these buildings and facilities. The energy consumption can be controlled during in construction process, and the design can impact on the degree of subsequent energy use, therefore, the project lifecycle concept must be considered as part of the construction sustainability.

The construction process includes a series of activities including project planning, implementation, delivery, and disposal, it also includes the construction phase and operation of the eventual product, with all the activities for the whole process expected to impact on its sustainability. Figure 3.3 lists the main sustainability activities from conception to completion of a project or the end of its useful life.

Figure 3.3 Sustainable construction lifecycle

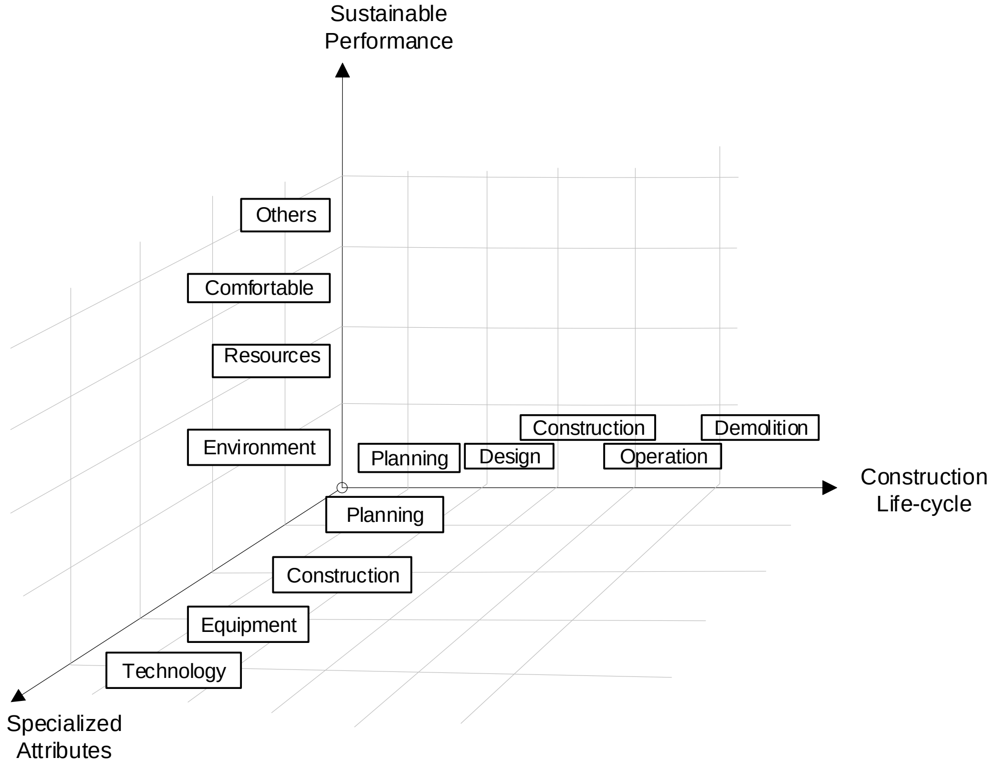


Source: Shi (2007)

Figure 3.3 shows that the construction project is expected to satisfy objectives specified by the owner and relevant stakeholders, and the sustainable goals and objectives will be set at the planning and design stage to maintain control of the quality, time, and other sustainable performance criteria. These criteria could include dust, wastewater, solid waste and noise control, energy saving, and using renewable resources such as wind and solar energy to replace non-renewable resources at the construction stage (Alwan *et al.*, 2017).

Sustainable construction is a complex process, its application throughout a project's lifecycle is fundamental in pursuing sustainability and improvements in the construction sustainability performance. At the same time, it requires appropriate techniques and systems to support it. From a holistic viewpoint, sustainable construction is a complex system, and it can be represented as a system as shown in Figure 3.4.

Figure 3.4 Framework of sustainable construction system



Source: Shi (2007); Li (2007)

As Figure 3.4 shows, a sustainable construction project is a system containing five stages: planning, design, construction, operation and demolition throughout the project lifecycle; four sub-systems: planning, construction, equipment and technology; and sustainable objectives: environmental protection, economic benefits, human needs amongst others (Shi, 2007). A sustainable construction project should consider achieving sustainable performance throughout the project lifecycle sub-systems. Each of the sub-systems may include a project lifecycle or a project process (Silvius *et al.*, 2012), and decompose into different tasks (Shi, 2007). For example, the planning system includes the tasks as defining project scope, project evaluation, setting project plans, reviewing and approving the project (Shi, 2007). Conjointly, there is a consideration in the rational utilisation of land resources in local planning where the local authorities' views about the energy and resource policies are considered (Malina, 2013). The sustainability objectives can be achieved through the planning system, requiring the use of appropriate equipment and technologies to reduce the effects on the environment and improve the efficiency of construction project. This can include increasing natural ventilation and light to reduce energy consumption, or using good temperature retention materials to reduce heat loss and improve energy efficiency

(Zhu and Yuan, 2002). The example above demonstrated that sustainable construction is a holistic concept, the project can be impacted at different stages of its lifecycle by designers, architects, contractors, sub-contractors and procurement teams, with the need to consider the sub-systems and stages of the project.

3.3 Principles of sustainable construction

As previous sections demonstrate, sustainability has become a significant issue for the construction and highway sector, but it does not seem to be widely practised (Xia and Zhang, 2015). The results of a survey of 200 civil engineers by Yang *et al.* (2014) showed that nearly all who responded agreed that sustainability is an important issue in construction, but relatively few actually applied or implemented it. Recent studies reveal that more sustainable practices in the construction stage are based on reducing energy and material consumption but not on the other stages of project lifecycle. The issues of construction technologies and innovation for logistics and communication, sustainability strategies for project implementation, still need to be strengthened (Alwan *et al.*, 2017). Building the principles of sustainable construction can help to achieve the objectives and compliance with sustainable development requirements, to improve the efficiency and effectiveness of the construction process for a balanced development approach.

Sustainable construction is a part of overall sustainable development, the principles of sustainable development need to be emphasized initially when the principles of sustainable construction are set (Gudmundsson and Höjer, 1996), therefore, most of the principles revert to the concepts of ‘sustainable development’, that is, the three main elements-economic, environmental and social sustainability.

On the bases of sustainable development principles, the International Council for Building defined seven Principles of Sustainable Construction (Table 3.2) which covered the entire lifecycle of construction, from the design and planning phase to disposal phase (Table 3.2) (Kibert, 2008). These principles highlighted the resources needed in each phase of the project, and from this it can be concluded that environmental management, energy efficiency, and whole lifecycle theories are major references to analyse and achieve sustainability in construction.

Table 3.2 Principles of sustainable construction from Kibert (2008)

1. Reduce: Reduce resource consumption
2. Reuse: Reuse resources
3. Recycle: Use recyclable resources
4. Nature: Protect nature
5. Toxics: Eliminate toxics
6. Economics: Apply lifecycle costing
7. Quality: Focus on quality

These principles from the project management perspective define the operational actions to achieve sustainability in construction by reducing material and resource utilisation, cost saving and improving quality. The central idea of ‘sustainability’ is appropriate, but the term ‘development’ must consider the needs of people, the issues of social development have been given scant attention with the main focus on the environmental and technical problems (Hill and Bowen, 1997).

Using the Republic of South Africa as an example, Hill and Bowen (1997) took the perspective of developing countries to offer a framework for sustainable construction with four pillars – social, economic, biophysical and technical, as shown in Table 3.3. Social pillar is based on the notion of social justice, the economic pillar is through using resources to achieve beneficial balance over the longer term, the biophysical pillar describes operating within the carrying capacity of supporting ecosystems, and the technical pillar relates to the performance, quality and service life of construction (Hill and Bowen, 1997).

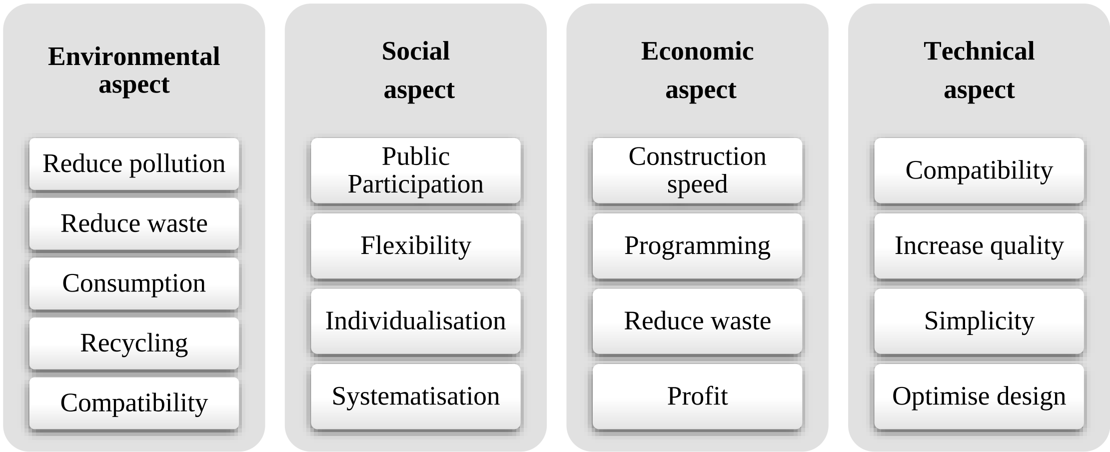
Table 3.3 Principles of sustainable construction from Hill and Bowen (1997)

Economic Sustainability	Biophysical Sustainability
Ensure financial affordability to gain benefits, increase job opportunities, and enhance competitiveness in the market place by adopting sustainability practices.	Reducing the use of non-renewable and generic resources – energy, water, materials and land. Minimize pollution in the environment and damage to sensitive landscape – scenic, cultural, historical and architectural.
Social Sustainability	**Technical Sustainability**
Improve the quality of human life, protect local cultural diversity, promote a healthy and safe working environment and enhance skills and capacity of working people and seek equitable distribution of the social benefits of construction	Good quality of built environment, and use serviceability to promote sustainable construction

The principles from Hill and Bowen provide certain rules to follow, but they may vary from country to country, particularly between developed and developing countries (Mihyeon Jeon *et al.*, 2006). Hill and Bowen's paper focussed on the Republic of South Africa taking the perspective of developing countries, but the principles were based on the experiences of developed countries (Ofori, 1998).

Ofori (1998) put forward different thoughts for the various circumstances found in the developing world, where several aspects of sustainability are considered as 'managerial sustainability' ensuring the construction process, and others as 'community sustainability' ensuring the local environment and livelihoods are maintained. These principles suffer from over-generalisation and a lack of guidance for practical application (Zabihi and Habib, 2012). Zabihi and Habib (2012) gave sustainable construction objectives and criteria for four groups of environmental, social, economic and technical issues as shown in Figure 3.6.

Figure 3.5 Sustainable construction criteria from Zabihi and Habib (2012)



The criteria identified in Table 3.6 are consistent with the principles and are useful in fulfilling the sustainability goals. Zabihi and Habib (2012) stressed that sustainable construction relies on the idea of increasing the construction quality and embracing the environment, and more flexibility, good planning and optimisation.

Thus far, several principles have been adopted for sustainable construction, but some of them are broad in scope, and they are made as general statements but do not go into details how to achieve sustainability (Gao, 2010) . The application of the principles depends on the extent to which decision-makers understand the specific sustainable principles that impact upon construction projects. Therefore, the sustainable principles of the construction project should enhance the awareness of stakeholders of sustainability (Zuofa and Ochieng, 2016). Chang *et al.* (2016) identified government regulatory pressure and managerial concerns as the key factors for adoption of sustainable construction practices in many countries. From the project management perspective, the construction project covers the whole lifecycle, and putting in place effective project governance is crucial (HM Treasury of UK, 2007). Project governance can make sustainable principles operable and practical (Yan, 2012) , it has been referred to 'the use of systems, structures of authority, and processes to allocate resources and coordinates or control activity in a project' (Pinto, 2014, p.383, cited in Gemunden, 2016). This has become a trend in construction projects, and regarded as a condition for construction sustainability in recent years (Yan, 2012).

Kibert (2008) argued that the principles for sustainable construction must cover the issues and be flexible enough to adapt to evolving technologies. They must also allow the easy evaluation of alternatives, and achieve the outcomes of environmental awareness and sensitivity. For the purposes of setting a common expression from various principles, in the context of the size and complexity of highway construction, and according to the triple-bottom line of sustainable development, the six principles discussed in Chapter 2 can be applied to highway construction as follows:

Must respect environmental limits

Environmental sustainability in highway infrastructure projects is referred to as the green highway which integrates ecological consideration to design and construct a roadway. (Liang *et al*., 2012). The purpose of this principle is to identify, measure and minimise use of chemicals, resources, materials and emissions affecting factors in all phases of the highway infrastructure construction (Ainger and Fenner, 2013).

Must meet social development needs

'Social sustainability' means that throughout project lifecycle, the project should not disrupt neighbourhoods as a consequence of relocating residents, increasing peoples' travel distances and expenditure and causing safety problems, creating visual intrusion and noise (Liu and Zhou, 2014). To reduce deterioration of the living environment it is important to avoid inadequate or unaffordable transport which leads to excessive building and population densities (UN, 2011b).

Must contribute to economic development

Creating economic benefit is the central task of highway infrastructure construction (Zhang, 2015). The economic sustainability of highways involves two approaches, one is creating direct economic benefit from the new-construction or re-construction of a highway, through using new technology or innovation to continuously improve the construction performance, capacity, and quality. The indirect economic benefit is the social and economic service capability which includes bringing local economic growth, driving the development of employment, catering services, commercial transportation, and increasing the income of residents. After completion, the improved traffic network will lead to local development by promoting regional communication and attracting capital investment (Yuan, 2007).

Must containing both short-term and long-term goals

Construction is a cradle-to-grave process, and the design needs to be concerned with the environmental consequences over the entire lifecycle from obtaining construction materials to its completion and eventual demolition. The short-term objective is to ensure timely completion of the construction project with optimal use of resources which not only influences profitability of the project, but also meet the quality requirements (Wang *et al.*, 2015). From the point of view of project management, the highway infrastructure project is a temporary or short-term project, but the benefit of a highway is mostly generated after the project has been completed (Silvius *et al.*, 2012). This would include the impact on overall economic activity, productivity, the number and types of job opportunities; production and way of life of local people are dependent on how the project develops. Furthermore, the impacts will be felt for many generations to come and that is considered the long-term goal of the project. Therefore, the highway infrastructure project incorporates both long-term and short-term objectives.

Must promote a good governance

The development of sustainable highway infrastructure project should include the impacts for all stakeholders over time (Busscher *et al.*, 2015). Due to the large number of stakeholders involved, open governance can help to enhance mutual communication and coordination of all departments, ‘it provides the critical links among people, ideas and information that are necessary for success’ (Rose, 2013). The aim of project governance is to set the structure for decision-making and managerial action within a project (Müller, 2012) including the project direction and objectives, project ownership and sponsorship, ensuring the effectiveness of project management, and stakeholders participations (HM Treasury of UK, 2007).

Must rely on technology

‘Technological sustainability’ ensures that through innovative technology, the construction products remain in effective and efficient use throughout their lives. Innovative technologies continue to challenge the construction industry, not only in construction techniques but also the innovative solutions for project management. For example, by using technologies to improve indoor and outdoor environmental quality, waste is reduced, and land resource utilisation increased. New digital technologies and software also have a role to play in construction; Alwan *et al.* (2017) applied Building Information Modelling (BIM) to support sustainable strategic development, and information technologies support the improvement of projects' performance, logistics, and strategies. In recent studies, green technologies have been regarded as a solution to the negative impacts of construction, and the construction industry has attempted to use them to enhance sustainability (Darko and Chan, 2016).

3.4 Effects of highway infrastructure construction

A highway infrastructure project has specific elements such as materials, equipment, investment and building methods, and involves different types of stakeholders including designers, builders, owners and users, which means that complexity is probably its main attribute (Rogers and Enright, 2016). This kind of project is designed by civil engineers, built by heavy construction contractors, and most of them are publicly funded and serve the public's needs (Gould and Joyce, 2009).

It is recognised that transportation infrastructure is an integral part of any modern economy, it not only provides a vital input into manufacturing processes but also permits individuals to enjoy a broad range of geographically disparate employment, social and leisure activities (Banister *et al.*, 1993). The benefits of highway infrastructure projects include saving travel time and vehicle operating cost, and improving mobility and availability of travel options (Wang *et al.*, 2013). On the national level, highway construction profoundly influences land use patterns and the suburbanisation of the population, and it causes positive economic outcomes for industries that use it most intensively (National Research Council, 2009). When the economy declines, and unemployment is high, the government can use the construction sector to increase public expenditure providing job opportunities (Ball and Wood, 1996). In particular large-scale transportation infrastructure projects, have been regarded as a frequently used tool by governments to encourage the local/national economy (Wang *et al.*, 2013).

Highway infrastructure projects have a number of characteristics, including capital intensity, asset durability, government or public organisation controlled, interdependence with other transportation components, and damage to the environment (Gould and Joyce, 2009). Typically, highway infrastructure can offer effective services only when it reaches a certain size, for example, the connection of two cities cannot be achieved if it is incomplete (Tan and Yang, 2013). That means the project process is irreversible, it cannot be restarted even if many problems exist.

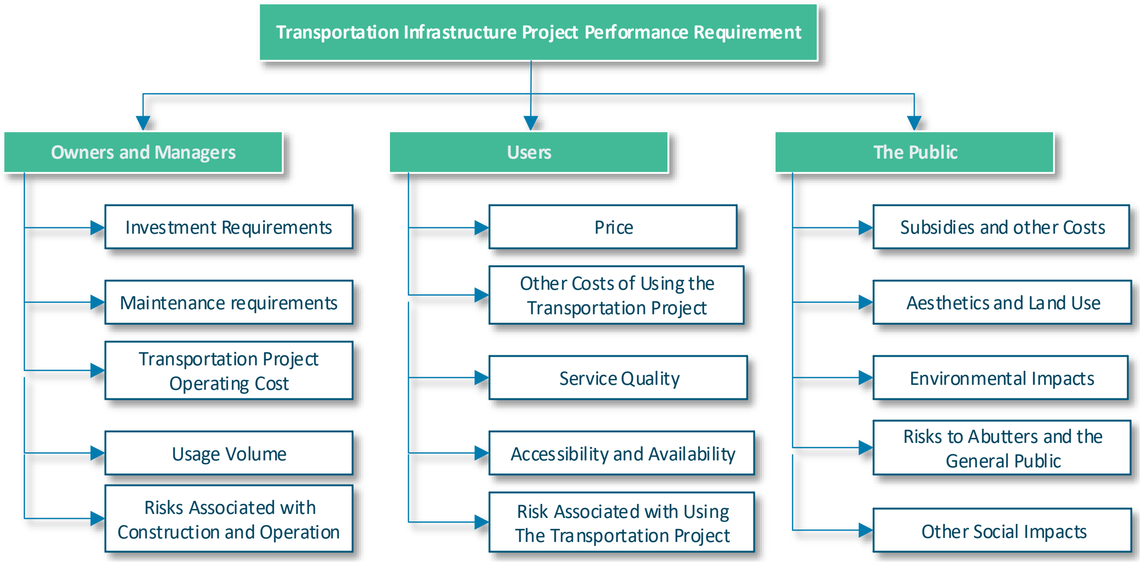
The highway projects development process encompasses phases of design, planning, construction, operation, maintenance and disposal, with activities such as site preparation, earthmoving, hauling material, paving roadway surfaces, building structures, and the application of architectural coatings (O'Flaherty, 2001). All of these activities have the potential to produce environmental and social problems (Lee *et al.*, 2013). To embark upon such large-scale construction project, large quantities of materials are required, and the production of building materials has high energy demands, as well as mineral resources, water and land (Dong, 2013). These projects also generate pollution such as noise and greenhouse gas emissions, air pollutants of CO2, CO, NOx, HC, SO2 and construction solid waste (Shen *et al*., 2010). In 2014, the Ministry of Environmental Protection of China (MOEP) disclosed that land pollution caused by highway construction exceeded 20.3% of the total for China, with the main pollutants being lead, zinc, arsenic and polycyclic aromatic hydrocarbons (MOEP, 2014). In addition, transportation such as roads, paths and trails were classified as 'disturbance corridors'(Forman, 1995). It can displace communities and livelihoods by land grabbing and cultural devastation, it results in habitat changes and fragmentation (Dong, 2013).

However, highway infrastructure is important for connecting and accessing social facilities and services, but it is also associated with negative impacts as: topography change, vegetation removal, erosion, sedimentation and soil compaction, dehydration and inundation, noise and visual disturbance, introduction of exotic species and so on (Dong, 2013). In recent decades, the minimisation of the negative impacts and achieving benign sustainable development of highways is a critical mission for many nations.

3.5 Sustainability in highway construction projects

Sustainable highway infrastructure projects share a common approach to sustainable construction used more generally for infrastructure projects (Fernández-Sánchez and Rodríguez-López, 2010). The satisfaction of the public for highway infrastructure is based upon its characteristics and impacts and as a result, the development of infrastructure is measured to meet human social and economic needs (Lu, 2012). A similar view is expressed by Martland (2012) who suggested that whilst highway infrastructure projects should be feasible from the engineering, financial and social perspectives, they should also be built to achieve economic benefits greater than the costs without negative externalities.

Figure 3.6 Infrastructure project performance requirements



Source: Martland (2012)

Figure 3.5 shows that successful infrastructure must deliver economic benefits to the owners and investors, but also consider the concerns of the public and users in terms of environmental and social aspects. This view integrates transport functionality and eco-environment sustainability in the highway infrastructure project to comply with the concept of sustainable development. It suggests that successful application of sustainable highway infrastructure projects should set goals and implement practices based on the triple-bottom line - economy, environment and community.

It can be summarised that the sustainable highway has two requirements. First, a highway infrastructure project should ensure sustainable development of itself. Second, all the activities associated with the project must meet the requirements of sustainable development, from the preliminary stages of decision-making, through to design, construction and maintenance operation and final disposal, involving construction technology selection, and dealing with construction waste to meet the requirements of environmental protection and reducing energy consumption to realise sustainable development. Accordingly, the sustainable highway project can be described as: achieving sustainability through the technological innovation and management transformation to realise the ecological, economic, and social objectives throughout the project lifecycle.

3.6 Conclusion

This chapter provided a brief overview of the development of the concept of sustainable construction, illustrated the characteristics of highway infrastructure project, and identified the ultimate goals of sustainable highway infrastructure. It indicated that construction activities have the capacity to make a major contribution to sustainable development. To the traditional evaluation criteria of time, quality and cost for construction projects must be added sustainability, and as whole, construction must take on more environmental and social responsibilities. The impacts of a construction project will occur throughout the whole project lifecycle, and sustainable construction involves issues such as planning, design and management of construction activities, construction technology and processes, energy and resource efficiency, operation and maintenance, the long-term and short-term impacts, and so on. Following on from this, throughout their lifecycles highway infrastructure projects must meet social needs and environmental concerns while achieving economic targets, and improving livelihoods, quality of life, human health, environmental protection, and saving resources. In order to be considered sustainable, the chapter outlined the principles to ensure construction sustainable development. The principles were focused on those actions which can contribute to improving the sustainable performance of construction, namely reducing energy use, increasing quality, recycling and reducing waste. Finally, six principles of sustainable development were applied to construction projects, aiming to deliver implementation guidance for sustainable construction.

.

CHAPTER 4 - REVIEW OF SUSTAINABILITY ASSESSMENT OF HIGHWAY INFRASTRUCTURE

4.1 Introduction

The purpose of this chapter is to review the current research on sustainability assessment of highway infrastructure projects, and underscore the principles that must be followed when assessing sustainability. It will go on to identify best practice in sustainability assessment and investigate the lessons learned from existing assessment methods, techniques and tools. Gaps in current sustainability evaluation measures will be identified leading to the further establishment of a sustainability assessment framework for highway infrastructure projects considering local conditions.

4.2 Review of sustainability assessment of highway infrastructure projects

With increasing awareness of the environmental impacts of highway construction, more effort is being made to build sustainable highway infrastructure and minimise environmental impacts. There are several studies on sustainability appraisal tools to support building and infrastructure projects decisions with a higher standard and broader scope than traditional project performance measurements and environmental assessment (Gibson *et al.*, 2005). These tools are necessary to achieve the sustainability goals of social, environmental and economic criteria, and explores the opportunity to introduce an evaluation model based on sustainable development principles (Lu and Yuan, 2013). For example, the European Road Transport Research Advisory Council (ERTRAC) provided a transport infrastructure strategic research agenda to enhance the sustainable principles in transportation infrastructure, resulting in a sustainable road with more efficient energy use, security of energy supply, better quality and environment, easier mobility, high safety and security (Furberg *et al.*, 2014). However, some limitations of the current studies have been identified by researchers. The current studies of sustainability in highway infrastructure projects are still not considered adequate when taken over the project whole lifecycle (Lu and Yuan, 2013). While the project management standards still occupy a mainstream position, and although the International Project Management Association (IPMA) proposed a standard for human health, safety and environmental factors, it did not include clear sustainable development issues (Rodríguez López and Fernández Sánchez, 2011; Silvius and Schipper, 2014).

4.2.1 Purposes of sustainability assessment

Sustainability assessment describes the application of sustainable development theories to highway infrastructure projects, and its purpose is primarily to provide a framework based upon the sustainability principles to guide the decision-making process (Gibson *et al.*, 2005). The main purposes of highway sustainability assessment are presented in Table 4.1.

Table 4.1 Purpose of highway sustainability assessment

- To standardise and guide sustainability in whole life process of highway projects;
- To provide evidence for highway planning and construction schemes based on sustainable development tendency and comparison to alternatives;
- To develop a preferred reference for measuring sustainability in highway infrastructure projects;
- To lead the development of highway projects using advance technologies towards sustainable transportation infrastructure, improve the quality of projects and satisfaction of the public.

Source: Gibson *et al.*, 2005; Shen, 2013; Tong, 2014

Defining the purpose of the assessment will form the boundaries and specification of the assessment (Sun and Li, 2013). In order to achieve this, it requires the structure, criteria and process of the assessment framework integrating the short-term and long-term influences on social, economic, and environmental aspects (Gibson *et al.*, 2005, Tong, 2014) through the use of appropriate methods and techniques to encourage overall improvement of project performance (design, construction, operation and disposal) towards sustainability (Ugwu *et al.*, 2006).

4.2.2 Practice principles of sustainability assessment

To increase the role of highway infrastructure in supporting sustainable development, many sustainability assessment models, methods and tools are being constantly developed based on changing sustainability aspects. Most of the evaluation methods consider the multi-dimensional nature of sustainable development as the decision-making criteria (Jeon *et al.*, 2013). In these methods and tools, the common rules and principles of sustainable development serve as a general guide, but each case will have its own demands. Therefore, an effective sustainability assessment should have a set of criteria and principles to guide the contexts and applications for a range of projects in different regions (Gibson *et al.*, 2005). Some of the principles in practice for sustainability assessment are listed in Table 4.2.

Table 4.2 Assessing sustainability: principles in practice

- Starts with a clear vision, goals and objectives of sustainable development;
- Sets an explicit set of categories or a framework that covers the whole systems and all parts to the application of sustainability criteria and principles;
- Defines the key sustainability performance factors for assessing the specific project, and standardises the measurement;
- Integrates the assessment in whole lifecycle of the project (design, construction, operation and disposal);
- Chooses a limited number of sustainability indicators that covers all potential initiatives, and both positive and negative consequences at all levels of a project;
- Critically examines the indicators and criteria by comparing values of targets, reference values, ranges, thresholds, or direction of trends;
- Proposes an appropriate method with explicit data collection, judgments, and interpretations;
- Facilitates efficient implementation;
- Ensures a broad participation on the assessment process by professional, technical and other stakeholders;
- Ensures the assessment complies with regulations and policies;
- Builds significant policies, rules and plans for assessing with opportunity for public review and comment.

Sources: Drexhage and Murphy (2010); Gibson *et al.* (2005); Sun and Li (2013)

According to table 4.2, the sustainability assessments consist of several principles as: first, identify assessment target (e.g. national level, local level, project level), namely defining what sustainability characteristics of the projects should be assessed before the assessment.

Second, establish sustainability relevance, criteria or indicators. Achieving sustainable development depends on a myriad of factors, and the assessment process requires defining and understanding those factors. The factors should be considered for implementation throughout projects' lifecycle, from conception through construction, operations, and maintenance. Third, according to the desirable features of the assessment and acceptability criterion to select appropriate assessment tools, identify the policy path to sustainability. Selecting assessment tools helps to define the essential elements (assessment scope, assumptions, values and precision) to be measured (Zijp *et al.,* 2015). Finally, the broad professional, technical and social groups should be involved in the assessment process to ensure recognition of diversity (Hardi and Zdan, 1997).

4.2.3 Sustainability assessment indicators

The vital role of indicators has found general acceptance, in 1992 the United Nations (UN) Conference on Environment and Development stated that 'indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems' (UN, 2011a). The international organisations recognised that indicators could help countries to make decisions on sustainable development. Sustainability of highway projects is a complex characteristic to assess, and indicators can simplify evaluation of the information in a quantifiable way, that in turn makes the information more straightforward to communicate to and help the decision-makers in making the necessary decisions to achieve sustainability (Sun and Li, 2013). Table 4.3 shows a checklist of sustainability indicators for highway infrastructure projects (Gao, 2016).

Table 4.3 A checklist of sustainability indicators

Environmental Sustainability	Water pollution Air pollution Noise pollution Waste disposal Energy used Landscape and visual effects Recycle resources used Materials saving Land used efficiency
Social Sustainability	Promotion of communication Improvement of education Protection of local culture and heritage Increasing employment Support for local populations health and safety
Economic Sustainability	Contribute to local development Return on investment

Source: (Gao, 2016)

In table 4.3, the indicators influencing highway sustainability were grouped into three categories which related to the triple bottom-line sustainable principles – environmental, social and economic sustainability, but it would include more specific indicators. Zhou (2012) introduced factors of project management and government system for assessing highway projects' sustainability in China besides the triple bottom-line principles. Sun and Li (2013) suggested that technology and project management should be considered when assessing sustainability in mega infrastructure projects. According to the sustainable construction principles demonstrated in Chapter 3, sustainable highway infrastructure projects are undertaken as follows: first, avoids resource waste and minimises the use of non-renewable resource during construction and use, wherever possible; second, avoids environmental pollution but also achieves good ecological benefits, social benefits and economic benefits; third, avoids negative impact on human life (Shi, 2007). All the objectives include long-term and short-term goals which require appropriate technologies and management systems to be realised. The sustainability objectives should be assessed throughout the project's lifecycle, from planning through construction, operation, maintenance and demolition (Wang, 2000). Thus, the factors should include the aspects of: environment, society, economy, technology and governance.

However, there are currently hundreds of indicator-based sustainability assessment frameworks, but there is also a question of uncertainty and subjectivity when selecting criteria, indicators and dimensions (Shi and Huang, 2015). To overcome this problem, the selection criteria for the industry should be based upon the general guidance for sustainable development and the relevant conditions and requirements (Silvius *et al.,* 2012).

4.3 Existing sustainability assessment methods and tools

4.3.1 Types of sustainability assessment methods

In the past two decades, extensive sustainability assessment methods for construction projects have been developed. Those methods cover local, national, regional and international approaches to sustainability assessment, environmental assessment, economic assessment (e.g. cost/benefit analysis) or social assessment (e.g. sustainable livelihoods), and some assessment methods are used before (pre-assessment), during or after (post-assessment) completing a project. These tools are used globally to support infrastructure decision-making. The International Federation of Consulting Engineers (FIDIC) groups the current sustainability assessment methods for infrastructure projects into four categories: Decision-Support Tools, Rating and Certification Tools, Calculators and Sustainability Guidelines (Guthrie and Konaris, 2012). The contents of summaries of these tools are listed in Table 4.4. Most of these methods use a set of indicators to evaluate sustainability,

Table 4.4 Four categories of sustainability assessment methods

Assessment methods categories	Contents
Decision-support tools	• Uses sustainability guidelines and methodologies to provide consulting support to decision-making around the project lifecycle. (e.g. Multi-criteria analysis methods; Cost-benefit analysis (CBA); Cost-effectiveness analysis (CEA); Lifecycle Assessment (LCA).) • Uses Multi-Criteria Analysis Methods to assess sustainability in different design options • Focuses on early design stage
Rating and Certification (R&C) Tools	• Developed to assess and reward sustainability performance. • Offers independent certification and focuses on ensuring that the claimed sustainability performance of a project is representative of the actual performance (e.g. Envision-USA for infrastructure; Greenroods, GreenLITES for Road; LEED –USA, BREEAM- UK for Construction.)
Calculators	• Provides inputs to other sustainability tools; • Through the calculators, weighting the environmental impact of different decisions. (e.g. Analytic Hierarchy Process (AHP); Ecological Footprint.)
Guidelines	• Provide formal documents to other sustainability tools on sustainability quality, standards, indicators or methodologies. (e.g. Organization for Economic Co-operation and Development [OECD] Pressure-State-Response Model; China Standard of sustainability assessment of building.)

Source: Guthrie and Konaris (2012); Bueno *et al.* (2013);Saurat *et al.* (2015).

The four types of tools by FIDIC summarise the current main existing instruments and techniques for assessing sustainable construction, provide a useful reference for industry for how the tools are applied, provide information of different types of tools available around the world and helps to inform tool selection. But these tools were not specifically related to highway infrastructure projects, Bueno *et al.* (2013) reviewed the four types of tools by FIDIC and identified three sustainability assessment methodologies for road infrastructure projects as:

Project appraisal methods for decision-making. The project evaluation techniques are used to achieve better project performance on spending decisions for capital and current expenditure. These methods also are employed in the assessment processes such as Cost Benefit Analysis (CBA), Multi-Criteria Analysis (MCA), and others. These techniques are essential for economic appraisal purposes and help in the decision-making process. They are not designed for initially assessing sustainability but are commonly used to appraise the project at the decision-making stage.

Techniques for assessing environmental/social impacts. Common environmental and social impacts assessment tools include lifecycle assessment (LCA) and social lifecycle assessment (SLCA), they provide information for decision-making under sustainability issues, but they are mainly focused on assessing the effects of the project on environmental and social aspects. These techniques have an obvious drawback in that they are not based on standardised methods of performance measurement.

Rating systems and certification tools. These methods use rating and certification (R&C) tools to rate and assess the project performance against relevant criteria and apply appraisal guidelines to inform sustainability regulations and specific technologies and strategies. The most significant strength of rating systems is that they use quantitative processes to evaluate sustainability of projects. But they also have some weaknesses, lack transparency and objectiveness in the definition of criteria and selection of weightings because the indicator selection and weighting allocations are heavily based on the opinions of experts. The rating systems do not address all the issues of sustainability (Bueno *et al*. 2013; Naganathan and Chong, 2017).

While the number of sustainability assessment tools and methods are increasing, and the nature of each tool and method varies, the following sections will provide information about the tools and methods and discuss the strengths of assessment tools and barriers to their use within highway infrastructure projects.

4.3.2 Standards and guidelines for sustainable highway

Legislation is a key mechanism for encouraging the efficient administration of sustainability assessment for highway infrastructure projects (Decleris, 2000). The provisions define the concept, principles, procedures, objectives and responsibilities of sustainability assessment for major projects including highway infrastructure. The necessary policies and regulations put the force of law behind the effort to advance sustainable development. Currently, the legal process for sustainability assessment of highway infrastructure projects focuses on Environmental Impact Assessment (EIA) which has been adopted in many countries (Zhu, 2014). There are currently hundreds of indicator-based sustainability assessment frameworks, but there is also a question of uncertainty and subjectivity when selecting criteria, indicators and dimensions (Zhang, 2013). Meanwhile, an increasing number of standards and guidelines for sustainable infrastructure have been developed since Agenda 21 was launched. The Sustainable Infrastructure Action Plan (SIAP) from the World Bank has been developed to support infrastructure investment in a sustainable way (World Bank, 2008). The United Nations Economic and Social Commission for Asia and the Pacific and the United Nations Economic Commission for Latin America and the Caribbean published the 'Guidelines for developing eco-efficient and socially inclusive infrastructure' which addresses the principles and strategies for infrastructure development (UN, 2011a). The Port Authority of New York and New Jersey in the USA published the 'Sustainable Infrastructure Guidelines' to optimise infrastructure project design through sustainable engineering practice (The Port Authority of New York and New Jersey, 2011). These directives and standards bring consistency and scalability to infrastructure development. Authorities and governments use the guidelines to set up the regulations and rules for infrastructure to improve the quality and performances of projects (UNEP *et al.*, 2010)

However, the application of sustainability varies significantly between different countries and in particular between developed and developing countries (Zhang, 2013). Developing countries are likely to emphasise social and economic development because the catalytic role of highway infrastructure in poverty reduction and economic growth is recognised (Diaz-Sarachaga *et al.*, 2016), and highway design and development are considered essential to meet the local needs and conditions (Brewer *et al.*, 2001). There is an argument against the guidelines in that currently some of them are voluntary (Bueno *et al.*, 2013).

The joint report from the UN Environment Programme KPMG, the Global Reporting Initiative (GRI), and Unit for Corporate Governance in Africa reveals that approximately two-thirds of the 142 standards from 30 countries could be classified as mandatory, one-third as voluntary (UNEP *et al.*, 2010).

4.3.3 Best practices methods for assessing sustainability in highway

4.3.3.1 EIA and SEA

Environmental Impact Assessment (EIA) is an assessment system for environment issues that may be associated with construction projects, it aims to mitigate the environmental impacts of planning, construction and implementation after completion of the project (Arts and Faith-Ell, 2012). More than 120 counties have implemented EIA through legislation (Thorne *et al.*, 2014). China created EIA legislation in the 1980s and today EIA has become a legal requirement for launching construction projects in China (Wang *et al.*, 2002). The International Association for Impact Assessment (IAIA) defines EIA as ‘the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals before major decisions being taken and commitments made’ (IAIA, 1994). In the EU, EIA is required through Directive 85/337/EEC of 1985, which was amended in 2003 (Directive 2003/35/EC), it is an institutionalised procedure for environmental assessment at the project level that ensures environmental implications are considered before making decisions (European Commission, 2016).

EIA evaluates if the project is in line with environmental standards, facilitating the decision-making process and enhancing the role of stakeholders in informing decision-makers of different views (World Bank, 2012b). It has been widely applied to construction projects, infrastructure projects, the energy industry, production and processing of metals and the extractive industry (European Commission, 2016), but the limitations of EIA for assessing sustainability has also been highlighted. It has been criticised in that it is a reactive approach for assessing the impacts at the planning stage but not at the end of the decision-making stage which causes limitation for reviewing the cumulative effects of the project’s whole lifecycle (Chen, 2002). It mainly emphasises mitigating the environment impacts without a comprehensive analysis of all the issues of sustainable development (Furberg *et al.*, 2014).

Based on the philosophy of EIA, the Strategic Environmental Assessment (SEA) was developed in the 1970s – a systematic decision support tool with complete coverage of the sustainable issues (Lee and Wood, 1978). Effective SEA can improve governance by providing information on policy, plan and programme (PPP) setting, with a structured and suitable assessment framework to support decision-making on sustainable development (Fischer, 2007). It provides assessment and analysis at the sectorial, regional, and national levels to promote sustainability which encompasses a spectrum of assessment tools such as Strategic Environmental and Social Assessment (SESA), Strategic Social Environmental Assessment (SSEA), Cumulative Impact Assessment (CIA), etc. (World Bank, 2012b).

SEA is used to evaluate a project's environmental impacts in the context of social and economic factors at the highest strategic level, and EIA is used to assess environmental impacts of a single project, with a narrower scope than SEA (World Bank, 2012b). SEA is related to long-term strategy and takes account of cumulative impacts (Tricker, 2007). Compared to EIA, it is a proactive approach (Bina, 2007) that takes environmental issues into account during the whole project process, from start phase, through to implementation and to the end of the project (World Bank, 2012b). In the case of meeting the requirements of sustainability, the SEA offers suggestions and methods to overcome the defects of EIA and encourage sustainable development.

After many years' development, criticism of SEA has extended to include its value and effectiveness (Li *et al.*, 2016). As a strategic -level assessment tool SEA should cover a wider area with a wide range of alternatives, this makes data collection and analysis more complicated. SEA also tends to focus on national-level issues, meaning that some of the local circumstances may be ignored (Mao and Hills, 2000).

However, SEA is rooted in EIA and it does not replace it. Instead, they are complementary and have different functions in sustainable development (Li *et al.*, 2016). SEA can be used at the strategic assessment level to inform strategic decision-making for the project, and EIA often takes place at the project- level assessment, giving details and information for decision making (Tricker, 2007). Therefore, the combination and application of all three - EIA, SEA and sustainable development is crucial in achieving a sustainable project (Mao and Hills, 2000). Both EIA and SEA are considered more applicable to a wide range of public plans and programme (e.g. land use, transport, infrastructure, agriculture, etc.) (European Commission, 2016).

4.3.3.2 Cost–Benefit Analysis (CBA)

Cost–Benefit Analysis (CBA) is the most common way to support decision-making in evaluating the social and economic impact of transport projects (Wijnen *et al.*, 2009; Kolosz and Grant-Muller, 2015; Söderqvist *et al.*, 2015). This method uses quantitative evaluation to assess the value of a public project's social benefits by comparing the full cost and benefits of the project. It is an economic decision-making method utilised in the government planning process to seek to optimise investment for the maximum benefit and minimum costs (Cao and Dong, 2012).

There are many publications identifying the potential role of CBA in determining the feasibility of transport projects. Stevens *et al.* (2006) used CBA to make decisions on transport infrastructure projects, the Asian Development Bank (2013) published a practical guide for the use of CBA in transport projects, Söderqvist *et al.* (2015) applied CBA in sustainability assessment. It has also been widely used by the US Environmental Protection Agency post-World War II (Anderson *et al.*, 2015).

On the other hand, CBA has its weakness for assessing sustainability (Thomopoulos *et al.*, 2009; Bueno *et al.*, 2015;). In the context of sustainability, a project's impacts can include social, environmental, and economic, but the expectation of sustainability has a broader meaning for transport infrastructure projects. CBA is unable to assess all the social, ecological and strategic issues (Furberg *et al.*, 2014), because its approach to assessment is based on economic analysis (Anderson *et al.*, 2015). It only quantifies the costs and benefits, which will cause some uncertainty, the social effects may not be properly assessed (Söderqvist *et al.*, 2015), which make this method unsuitable for addressing intangible factors and strategic concerns, in addition, some of the factors cannot be simply expressed in monetary terms (Thomopoulos *et al.*, 2009).

CBA offers a valuable method to appraise infrastructure projects, but it has significant limitations when assessing the sustainability of highway infrastructure projects.

Thomopoulos and Grant-Muller (2013) suggested that it is better to combine CBA with other assessment methods. As a quantitative method, it cannot be a comprehensive tool for assessing sustainability, and it would be better combined with qualitative methods such as Multi-Criteria Decision Analysis (MCDA).

4.3.3.3 Multi-Criteria Decision Analysis (MCDA)

The complex nature of highway infrastructure projects results in a complex decision-making process which requires the consideration of several criteria and a broad range of possible alternatives (Annema and Koopmans, 2015). Multi-Criteria Decision Analysis (MCDA) is a decision-making method for addressing high uncertainty and complex problems, defining multiple interests and perspectives, and, in particular, identifying the biophysical and socio-economic issues (Kowalski *et al.*, 2009).

Many studies suggest that MCDA is the most appropriate method for assessing sustainability in infrastructure projects. Oltean-Dumbrava *et al.* (2016) illustrated the use of MCDA to assess the sustainability of surface transport infrastructure (i.e. road and rail), Ugwu *et al.* (2006) used this method for an infrastructure project and Macharis and Bernardini (2015) reviewed its use for transport project sustainability. MCDA can identify the sustainability criteria of the infrastructure project (e.g., economic efficiency; total environmental impact; total equity impact), assign the weighting coefficients to each criterion for individual projects and rank the alternatives to support the decision-making process (Bueno *et al.*, 2015).

Compared to CBA, the most important advantage MCDA offers is that it can incorporate factors which cannot be easily expressed as a monetary value, or the criteria cannot be quantified, such as environmental impacts and other future impacts of the infrastructure (Gühnemann *et al.*, 2012). MCDA has advantages which CBA does not have, but MCDA also has its shortcomings. The main concerns expressed about this approach are aggregation and transparency issues, identified by various researchers. Gühnemann *et al.* (2012) commented that 'aggregation of impacts into one measure is seen as inadequate because it implies a potential compensation of effects and reduces the transparency of the results.' Qualitative assessment is the primary advantage of MCDA, but it is a subjective approach which may lead to bias and the lack of transparency discussed above (Munda, 2004; White and Lee, 2009). It is difficult to identify the significant factors of the project and the measurement tools in MCDA, it is also challenging to calculate the weighting of the criteria and all the issues that will affect the assessment results (Browne and Ryan, 2011).

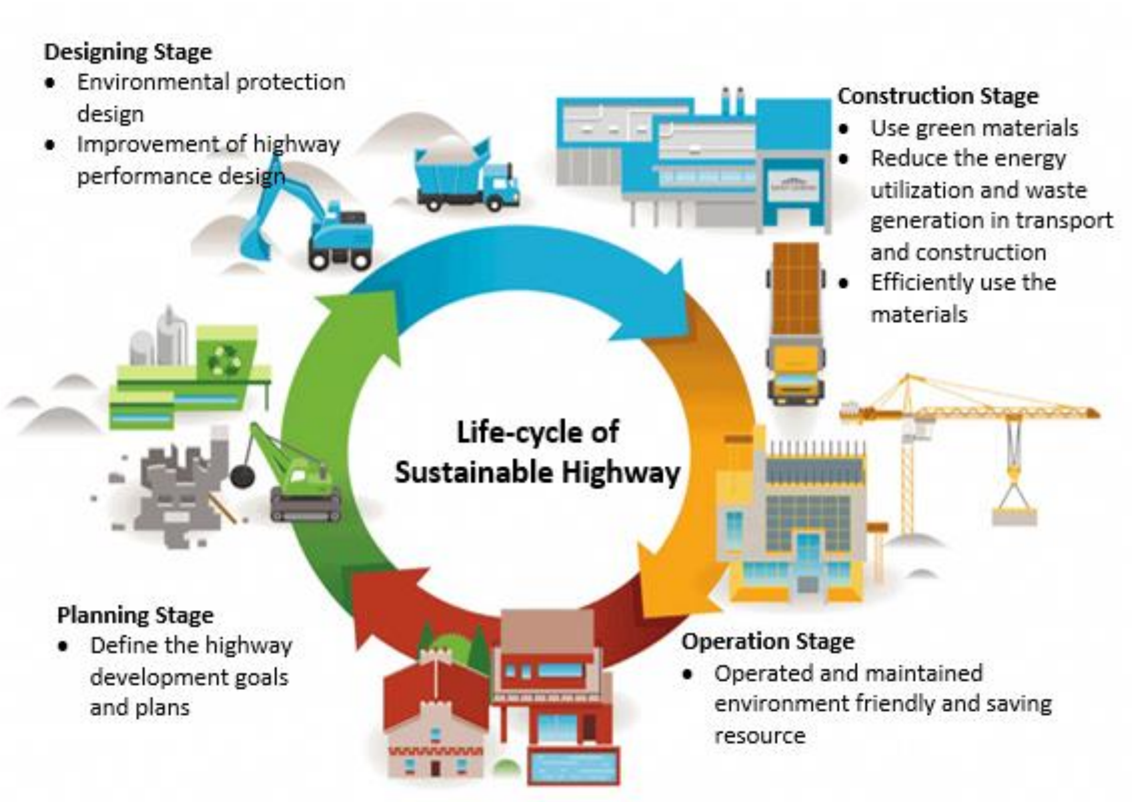
CBA and MCDA are the most common appraisal methods for the sustainability assessment of infrastructure projects, and there is a regular debate as to which method is the most appropriate. As discussed previously, both CBA and MCDA have advantages and limitations. The selection of an appropriate evaluation method must be based on the specific requirements of each individual project, and many studies suggest an integration assessment method which combines MCDA and CBA, i.e. the combination method for road infrastructure development projects proposed by Gühnemann *et al.* (2012).

4.3.3.4 Life-cycle Analysis (LCA)

It has only been over the past ten years that the concept of sustainable development has been seriously considered over the whole lifecycle of civil engineering projects (Zamagni *et al.*, 2012). UNEP defines LCA as ‘a tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its lifecycle’. It can be considered as a tool for examining environmental impacts from ‘cradle to grave’ of the process (Gong and Zhang, 2004).

The idea of LCA was first developed in the 1960s, and although there has been less progress on the development of the concept in 1970s and 80s due to the lack of standardisation, it has gained in importance since the 1990’s (Gong and Zhang, 2004). LCA has been the subject of many studies, and widely used to support the decision-making process in various areas. Axelsson *et al.* (2013) incorporated the sustainability principles contained in LCA (Zamagni *et al.*, 2012), Trinius and Borg (1999) formalised an environmental assessment in building and construction sectors based on LCA, Dong *et al.* (2014) applied the concepts of LCA to road projects, Stripple and Uppenberg (2010) used it for railways and rail transport, and other sectors. Fundamentally, real sustainability of construction projects requires a thorough understanding of the environment impacts at all stages of the lifecycle. Based on the lifecycle of construction projects shown in Figure 3.2, the application of LCA on highway infrastructure covers the lifecycle stages of planning, designing, construction and highway operation shown in Figure 4.1.

Figure 4.1 Sustainable highway project lifecycle



Source: Shi (2007)

LCA helps to overcome some of the problems created by the construction activities of buildings (Dong *et al.*, 2014). LCA consists of four steps: 1) goal and scope identification; 2) lifecycle inventory (LCI); 3) lifecycle impact assessment (LCIA); and 4) interpretation. LCA calculates and identifies the environmental impacts of a construction project, and compares and analyses several processes based on their environmental impacts, subsequently identifying opportunities for improvement (Gong and Zhang, 2004).

In spite of LCA being the most common analytical tool for environmental assessment of construction projects, there are some criticisms of it. The main problem is that it does not take into account the social and economic factors in sustainability terms (Berardi, 2012). It has the 'general objective of encouraging greater environmental responsibility within the construction industry, but not toward sustainability as whole' (Treloar *et al.*, 2004). The LCA is a complicated and time-consuming task (Thorn *et al.*, 2011), collecting the necessary data for LCA is difficult (Dong *et al.*, 2014), and some criteria such as biological factors are very difficult to quantify and are not included in the assessment process (Stripple and Erlandsson, 2004). These factors result in a complex criteria system, and the evaluation model is difficult to complete. Moreover, the focus of LCA on road projects is primarily on considering the use of materials and technologies on construction stage, but ignoring the energy consumption of the various highway designs (Bueno *et al.*, 2013).

4.3.3.5 Sustainability rating systems

Rating systems have emerged and helped to improve sustainability theory and practice. They are regarded as tools to assess, and award a rating for project performance within sustainability requirements (Guthrie and Konaris, 2012). In 1990, the UK launched BREEAM, the world's first sustainability assessment method for buildings (Parker, 2012), it demonstrated an increasing trend around the world to establish rating systems for building projects . Table 4.5 shows some of the more established systems. North America mainly adopt LEED (Leadership in Energy and Environmental Design) to assess the sustainability in the construction industry. BREEAM (Building Research Establishment Environmental Assessment Method) is the most influential tool in European countries. They are world's two leading tools for sustainability assessment in construction. Similar rating system assessment tools have also been developed in Asian countries, such as CASBEE (Comprehensive Assessment System For Building Environmental Efficiency) from Japan, GreenMark from Singapore, and ESGB (Evaluation Standard For Green Building) in mainland China (Mao *et al.*, 2015). These systems or tools are identical to other methods in so far as they provide a checklist of prerequisites and criteria required to evaluate the environmental performance of a building (Tsai and Chang, 2012). The use of such rating systems could involve grading sustainability from the lowest to the highest level to score whether a project is sustainable or not, and are now the most common approaches for assessing construction projects (Fernández-Sánchez and Rodríguez-López, 2010).

Table 4.5 International green building rating systems

System	Assessment sector	Country
BEAM	Buildings	HK
CASBEE	Buildings	Japan
ESGB	Buildings	China
GBC	Buildings	Canada
SBTool	Buildings	Europe
GRIHA	Buildings	India
BREEAM	Buildings	UK
DGNB	Buildings	German
GBI	Buildings	Malaysia
Green Globes	Buildings	Canada and US
Green Star (Au)	Buildings	Australia
Green Star (NZ)	Buildings	New Zealand
Greenship	Buildings	Indonesia
Green Star (SA)	Buildings	South Africa
LEED	Buildings	US
GreenMark	Buildings and General Civil Infrastructure	Singapore
BE2ST-In-Highwaystm	Highway	US
CEEQUAL	Infrastructure	UK
ENVISION	Infrastructure	US
Infrastructure Sustainability	Infrastructure	Australia
Greenroads	Transport	US

Source: Jiang *et al.* (2013); Furberg *et al.* (2014); Bueno *et al.* (2015);Guthrie and Konaris (2012)

These rating systems provide an efficient way to evaluate the performance of construction projects and buildings in respect of sustainability and they can also provide the initial sustainability assessment in the planning stage to design the project within sustainable development boundaries (Ma and Zhu, 2012). They have been found to be an effective way to address environmental problems caused by the construction process (Mao *et al.*, 2015). The assessment of rating systems encompasses the whole lifecycle of buildings from planning to in-use and refurbishment stages, responding to feedback from industry to support building the project in a sustainable way (Ma and Zhu, 2012). Moreover, these systems raise environmental awareness amongst designers, constructors, managers, owners and other stakeholders (Jiang *et al.*, 2013). For instance, the Building Research Establishment Environmental Assessment Method or BREEAM assesses the building using ten categories: Management, Energy, Health and Wellbeing, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution and Innovation, each category being weighted and set criteria. The project will be given a score according to the criteria and multiplied by different weighting coefficients, resulting in a total score reflecting its ranking. The rating systems provide a holistic approach and quantitative process to address sustainable issues of the projects based on sustainability philosophy (Bueno *et al*., 2013).

Although the rating systems are more frequently used in building and construction project assessment, they are not very commonly found in infrastructure projects at this time (Diaz-Sarachaga *et al.,* 2016). Clevenger *et al*. (2013) stated ‘to what extent sustainability is achieved remains uncertain since consensus does not exist as to the definition of sustainability for highway and infrastructure projects’ (Cited in Bueno *et al*., 2013), the rating system cannot measure the project on a standardized based. In addition, these systems are also costly to implement, the report from Building Services Research and Information Association (Parker, 2012) notes that fewer than half of those surveyed thought it was worth paying the cost for BREEAM, the majority of respondents thought the cost was unacceptable.

Several evaluation rating systems have been developed worldwide to assess the environmental and energy impacts of buildings. Table 4.6 compares the assessment criteria of the four methods and shows the common approaches in assessment categories.

Table 4.6 Assessment criteria of the four rating systems

Assessment Criteria	BREEAM	LEED	CASBEE	ESGB
Site suitability development				
Site suitability	0	0	0	0
Urban design and site development	-	0	0	0
Energy and resource consumption				
Total lifecycle primary non-renewable energy	0	-	0	-
Electrical peak demand	-	-	-	0
Environmental loadings				
Greenhouse gas emissions	0	-	0	0
Other atmospheric emissions	0	0	-	0
Other local and regional impacts	0	0	-	0
Materials use				
Materials	0	0	0	0
Solid wastes	0	0	0	-
Water use				
Potable water	0	0	0	0
Impacts on site	0	0	-	0
Rainwater, storm water and wastewater	-	0	-	0
Indoor environmental quality				
Indoor air quality	0	0	0	0
Ventilation	0	0	0	0
Air temperature and relative humidity	0	0	0	0
Daylighting and illumination	0	0	0	0
Noise and acoustics	0	0	0	0
Service quality				
Safety and security during operations	0	-	-	-
Functionality and efficiency	-	0	-	-
Controllability	0	0	-	-
Flexibility and adaptability	-	-	0	-
Optimization and maintenance of operating	0	0	0	0
Social and economic aspects				
Cost and economics	-	-	-	-
Social aspects	-	-	-	
Cultural and perceptual aspects				
Culture and heritage	-	-	-	-
Perceptual – different from 2 above?	-	-	-	-
Others				
Renewable energy	0	0	0	0
Transportation	0	0	-	-
Heat island effect	-	0	0	-
Management	0	-	-	-
Total	19	19	15	17

Source: Cong and ma (2011); Jiang *et al.* (2013); Mao *et al.* (2015).

The four rating systems in Table 4.6 all have criteria dealing with environmental protection and energy saving, but they don't all cover the effects on social and economic aspects such as cultural heritage and economic costs, and project lifecycle assessment is not sufficiently addressed. Some of the criteria in each category are different when assessing the projects, because they are principally based on the construction industry, technologies and economic development features which will all vary according to country and region (Ma and Zhu, 2012). Furthermore, each rating system has a procedure to evaluate sustainability (Khogali, 2016), and the criteria weighting method is different in each system (Furberg *et al.*, 2014). These tools provide an assessment framework and guidance on practices and performance, and these tools are designed for rating building projects. However, considering the particular impacts from infrastructure projects, specific rating schemes for evaluating sustainability of infrastructure and highway projects have been developed. These schemes share a number of common characteristics, they also have some unique features. Table 4.7 outlined four infrastructure sustainability rating tools – CEEQUAL, Envision, Infrastructure Sustainability and Greenroads.

Table 4.7 Four highway infrastructure projects rating systems

	CEEQUAL	Envision	Greenroads	**BE^{2}ST-in-Highways™**
Sustainability	· Project strategy; · Project management; · People & communities; · Land use & landscape; · The historic environment; · Ecology & biodiversity; · The water environment; · Physical resources; · Transport.	· Quality of life; · Leadership; · Resource allocation; · Natural world; · Climate change & risk	· Environmental review process; · Lifecycle cost analysis; Lifecycle inventory; · Quality control plan; · Noise mitigation plan; · Waste management plan; · Pollution prevention plan; · Low impact development; Pavement management system; · Site maintenance plan; · Educational outreach	· Greenhouse gas emission; · Energy use; · Waste reduction (including ex situ materials); · Waste reduction (recycling in situ materials); · Water consumption; · Hazardous waste; · Lifecycle cost; · Traffic noise; · Social cost of carbon saving
Key Notion	· Can be used for international projects outside the UK using different weighting factors for different geographic regions.	· It encourages the use of life-cycle analysis in planning, designing, construction, and operation to improve infrastructure project sustainability performance · It set a category of climate and risk which addresses emissions and resilience	· It provides a holistic means of considering and evaluating roadway sustainability (for new construction, reconstruction, and rehabilitation) through a quantitative method that informs decision making by project stakeholders; · It encourages innovation.	· It mainly focuses on quantifying the sustainability impact of using recycled materials in pavements; · It provides a comparison between sustainable and non-sustainable designs.
Project lifecycle covering	Planning, design, construction, operations and maintenance	Planning, design, construction, operations and maintenance	Planning, design, and construction	Planning and design

Sources: Bueno *et al*. 2016; Simpson *et al*. 2014; Greenroads, 2012; CEEQUAL, 2012.

Table 4.7 compares four international sustainable rating systems for infrastructure projects and reveals that these systems provide guidance to evaluate sustainability, as they cover most of the issues of sustainability. However, not all of them integrate sustainability over the project lifecycle, and each system differs from the others on objectives, design, methods and evaluation process, to what extent sustainability in highway infrastructure still exists is uncertain, because there is no consensus on the definition of sustainability and common assessment methods of highway and infrastructure projects.

4.3.4 Comparative analysis of exiting methods

From the above reviews, the current assessment methods, systems or frameworks have been shown to be beneficial for assessing sustainability in construction, but they are still limited by what they do not cover in terms of sustainability issues.

The sustainability standards, codes, policies and guidance vary depending upon individual countries' regulatory systems. Whereas sustainability is a broad concept, it involves many factors, and the factors may vary due to regional conditions and the standards are not linked to sustainability but more collaborative environmental protection.

CBA and the MCDA, the most common assessment methods, do not cover all the social, ecological and strategic issues due to their assessment processes being based mainly on the economic analysis. MCDA uses a qualitative approach to assess the project, and that helps to define the factors in sustainability, but it also leads to subjectivity.

The rating systems are used widely but focus more on environmental issues, with less consideration given to the social aspects. Finally, most of the sustainability assessment methods and systems do not directly relate to highway infrastructure projects.

Through comparison of existing popular methods, sustainability assessment in highway infrastructure project methods can be enhanced as: consider widely accepted sustainability factors for highway infrastructure to include three aspects of sustainability – environmental, social and economic, but also the existence of other factors impacting the project's sustainability; the assessment should include the whole lifecycle of the highway infrastructure projects; and the assessment process should increase the objectivity of the MCDA method.

4.4 Conclusion

On the bases of the literature review this chapter first defined the principles and criteria of sustainability assessment to guide the implementation of sustainability assessment. The existing tools and methods for sustainability assessment of highway infrastructure projects were then reviewed to identify the issues associated with current practices. The findings demonstrated that sustainable development of highway has been given international attention in recent years, meantime, the need for appraisal methods and tools to facilitate sustainable development at project level is becoming especially important. The review indicated that the assessment methods should have the ability to address the economic, social, environmental and other sustainability issues of highway infrastructure projects. There are many tools and methods intended to achieve the assessment requirements, including environmental standards, green building rating systems and economic benefit measures, and the codes of good practices in project whole lifecycle, but each fail to address all the issues associated with sustainable development, a comprehensive sustainability assessment method of highway infrastructure projects is still unachievable. The conclusion can be drawn that assessing the sustainability in highway infrastructure needs the development a systematic sustainability assessment framework under local conditions.

CHAPTER 5 - SUSTAINABILITY ASSESSMENT OF HIGHWAY INFRASTRUCTURE PROJECT IN YUNNAN

5.1 Introduction

The previous chapters give insight into the need for sustainability and the experiences of sustainability assessment in highway infrastructure projects. This chapter will review the economic, social and environmental background of Yunnan Province, and explain the functions of highways in its socio-economic development. After a brief overview of the conditions and future demands for highway infrastructure in Yunnan, the challenges of building highways in a sustainable way will be analysed. The need for sustainability assessment will be discussed following evaluation of the existing methods and tools available to Yunnan in order to draw lessons to establish a sustainability assessment framework for highway infrastructure projects.

5.2 Background of Yunnan

Yunnan Province is on the Yunnan-Guizhou Plateau in China's southwestern region and has complex geographical conditions. The location of Yunnan is shown in Figure 5.1. It is known for its bio-diversity, multiculturalism, frontier status and is less developed than other parts of China (Foreign & Commonwealth Office, UK, 2016). The area of Yunnan Province covers 394 thousand square kilometres, 84% of the total area is mountain and hills, plateaus make up 10%, basins called 'Bazi' are only 6% of the province's total area (Yeung and Shen, 2004). Yunnan is also home to 25 of the 56 recognised ethnic groups in China, 33.57% of its population are members of ethnic minorities (Yunnan Provincial Bureau of Statistics, 2016). The number of minority ethnic groups exceed all other provinces in China, and the multi-ethnic population makes for a distinct cultural diversity in this region (He, 2014). From the 2015 statistics, GDP per capita is $ 4.6 thousand in Yunnan which is lower than the national average of $ 6.1 thousand Yuan. Despite annual GDP growth over 8.7 % Yunnan Province started from such a low base that it is still ranked 23 out of China's 31 provinces for GDP per capita (People's Government of Yunnan Province, 2015). In 2015, the poor rural population in Yunnan was 5.74 million, accounting for 10% of the country's total (People's Government of Yunnan Province, 2015). Although Yunnan has dramatically changed in the past 30 years, its overall development is still lower than the national average. The remoteness and poor road infrastructure are the main causes hampering the increase in the population’s living standards and limiting economic growth in the Province (Chu, 2014).

Figure 5.1 Location of Yunnan Province

Source: ChinaMike Website (accessed on: www.China-Mike.Com)

As the Figure shows, Yunnan shares a border with the provinces of Guizhou, Guangxi, Sichuan, Chongqing, and Tibet Autonomous Prefecture of China. It is also borders on Burma (Myanmar), Laos and Vietnam. Since ancient times, Yunnan has been an important route to southeast Asia. The Central People’s Government (CPG) is trying to use Yunnan’s location to maximum advantage by pushing a regional integration scheme with neighbouring countries. In 2009, the Government of Yunnan Province started the Gateway Project as a direct response to ‘Open up to southeast Asia’ strategy of CPG, the main purpose of the Gateway Project is to build an international thoroughfare to neighbouring countries (Wang *et al.*, 2015).

5.3 Overview of sustainable highway infrastructure development in Yunnan

5.3.1 Highway construction in Yunnan

In the past ten years, there has been a notable advance in the development of highway infrastructure in Yunnan, which in turn, has supported significant gains in economic and social development (Transport Department of Yunnan, 2016b). By the end of the nation's 12th Five – Year Plan (2011-2015), the total highway mileage reached 236 thousand kilometres, an increase of 26 thousand kilometres from the 11th Five – Year Plan (2006-2010). As Table 5.1 shows, the highway mileage has had solid growth in the past five years.

Table 5.1 Highway mileage in Yunnan (Year 2011-2015)

	2015	2014	2013	2012	2011
Highway Mileage (Ten Thousand Kilometre)	23.60	23.04	22.29	21.91	21.45

Source: National Bureau of statistics of China (2016)

In the 13th Five-Year Plan (2016-2020), the CPG intends to build and re-build 74 highway infrastructure projects in Yunnan amounting to a total mileage of about 6,640 kilometres, when the plan is completed, the coverage rate of the national highway will increase to 100% from 54% (Transport Department of Yunnan, 2016b). The highway network will cover all 129 cities and districts throughout the province (Guan *et al.*, 2016).

As a Chinese proverb says, 'want to be rich, first build road', and this proverb is particularly important in Yunnan. Because the province is located on the plateau, with an average elevation is 2000m, the high elevation plus various forms of geological conditions have limited the development of railways and waterways, leaving road transportation as almost the only approach for transportation development in Yunnan (He, 2014). Table 5.2 compares five years' freight movement by the three main transportation modes in Yunnan.

Table 5.2 Freight by railway, highway and waterway

	2014	2013	2012	2011	2010
Railway freight volume (Ten thousand tons)	4823	5146	5031	5545	5497
Highway freight volume (Ten thousand tons)	103161	98675	63239	54186	45665
Waterway freight volume (Ten thousand tons)	560	508	465	439	402
Total (Ten thousand tons)	107608	108544	104329	68735	60170

Source from: National Bureau of statistics of China (2016)

The data shows that more than 90% freight in Yunnan is dependent on road transportation which illustrates the dominant position of highways in the province's transportation system (Transport Department of Yunnan, 2016a).

In 2012, the CPG officially declared Yunnan as the bridgehead (Qiaotoubao) for 'opening the country' to south and southeast Asia (National Development and Reform Commission [NDRC], 2012). In 2015, the Chinese Government launched the 'Belt and Road' initiative to develop infrastructure and inter-connections amongst neighbouring countries, with the important role of Yunnan being emphasised by the Government (Zhu, 2015). The cross-border cooperation strategy has resulted in pressure for highway infrastructure but has also intensified the effective demand for highway transportation (Transport Department of Yunnan, 2016a).

After ten year's development, highway infrastructure is entering a fast-developing period and faces new challenges in Yunnan, but there is still a large gap between total highway infrastructure network size, population increase and economic growth. The diverse climatic and special geographic conditions and social features challenge the development of sustainable highway infrastructure projects in Yunnan (Zhu *et al.*, 2014). Meanwhile, the Government is also faced with tackling rising pollution problems through a series of strategies and initiatives such as the carbon tax initiative. In 2013, the Ministry of Transport (MOT) issued the 'Guidance of Implementing Green Highway Construction' to apply the requirements of good construction quality, environmental protection, saving energy and resources, high efficiency and improvement of service to highway infrastructure project plans, construction, operation, maintenance and management processes, and ultimately achieve sustainable development of highway infrastructure projects (MOT, 2013). Since then, the idea of the 'Green Highway' has become the imperative for building highway infrastructure projects.

However, the highway network is far from meeting the demands of social development in Yunnan (People's Government of Yunnan Province, 2016). From the research report of Li (2014), the rural population accounted for 73.4% of the population in Yunnan, and communities have remained relatively isolated due to poor road conditions in mountainous areas with people unable to access health facilities because of the poor infrastructure in these areas (Li *et al.*, 2015). Currently in Yunnan, National-Grade and Provincial -Grade highway accounts for 27.05% of the road network, rural roads account for more than 49.05%, showing that the proportion of high-grade highway is low (Transport Department of Yunnan, 2016a). Meanwhile, the construction of highway infrastructure projects in Yunnan tends to emphasise short-term profits rather than long-term benefits, and this tendency is not consistent with the idea of sustainable development (Transport Department of Yunnan, 2016a). The report from the Transport Department of Yunnan (2016a) disclosed the main problems hampering highway infrastructure projects' sustainability in Yunnan including imbalanced development between different regions, unsuitable road network, lack of coordination among transportation modes, and poor serviceability rating of highways due to construction quality. The following section will illustrate the challenges for the sustainable highway building in the province and an expanding road network in Yunnan.

5.3.2 Challenges of building highway infrastructure projects

In the past three decades, and in particular over the last ten years, highway infrastructure construction in Yunnan has seen rapid expansion (Transport Department of Yunnan, 2016a). The population size, urbanisation level and traffic density are increasing and serve as a driver of demand for new highways, and with it, the construction tasks and management abilities require higher standards (Zhu *et al.*, 2014). Table 5.3 below gives some characteristics of the construction environment in Yunnan, and these features are regarded as challenges that regulate the sustainable development of highway infrastructure projects.

Table 5.3 Construction environment characteristics of highway in Yunnan

Social problems	Environmental problems
• Ethnic groups- based aggregation • Varied ethnic minority culture • Relatively low education level	• Complex geological and topographical condition • Frequent debris flow hazards • Biodiversity
Economic problems	**Technique problems**
• Unbalanced development • Short of funds • High construction and maintenance cost	• New technology and materials • Construction quality

Source: Zhu *et al.*, 2014; He, 2014; Lu and Yuan, 2013; Yang *et al.*, 2015

5.3.2.1 Challenges of socio-economic development

According to the Yunnan Province Highway Network Plan (2005-2020), new highway infrastructure projects are more concentrated in the less developed regions in the south and west mountainous areas of the province (People's Government of Yunnan Province, 2015). The main reason for this is to address the unequal development problem among regions (He, 2014). Most of the economic activities have been concentrated in the eastern region for many years. A mass of resources and investment has flowed into this region along with a well-educated labour force, advanced technology, better medical provision and improved urban infrastructure (He, 2014). The western region is lagging in terms of economic development and average living conditions. The eastern region of the province consists of undulating low mountains and round hills, in the west, the high mountains and valleys are closely spaced, and forms a steep, unusual, and dangerous landscape which restricts social and economic development. Highway construction inevitably needs slope excavation, embankment filling and tunnel excavation, which cost 3 to 5 times more than similar projects in other areas (Pan, 2015). The unbalanced allocation of investment also impacts on big cities and small towns causing disparities in the level and quality of public infrastructure such as roads, water supply etc. (World Bank, 2012a).

Another important challenge is the often uncoordinated or contradictory highway infrastructure project development plans of central and local government authorities (Cao, 2012). The highway development plans from central government are to consider first the cross administrative region functions, but local government is eager to achieve local development goals (Wang and Shi, 2011). Therefore, local planning consideration could materially conflict with the central development plan. Additionally, many regional highway infrastructures are built blindly due to governments overstating the benefits of highway construction. The study by Ansar *et al.* (2016) from Oxford University disclosed that 28% of road infrastructure projects in China overrun their budget after completion, and traffic volumes did not achieve the forecast. The study cited the case of Yuanjiang-Mojiang Highway in Yunnan where the budget over-ran by 24%, and only reached half of the predicted traffic volumes 12 years after its completion. The utilisation of most of the highways built in western areas is usually low, and it is regarded as an excessive expansion problem due to inappropriate development planning.

The various agencies have started to address the unsustainability of highway infrastructure in Yunnan. To begin with, the contribution of highway infrastructure projects to the improvement of the economy and social culture is not obvious, due to the extensive countryside and dispersed population in the south and west mountainous regions (Lu and Yuan, 2013). As discussed by Zou (2009), the highway's functions of spreading economic development benefits are not realised within the context of the weak regional economy.

Moreover, the highway construction can modernise local cultures, making it difficult to maintain cultural heritage (Lu and Yuan, 2013). Yunnan is inhabited by many ethnic minorities, highway infrastructure projects should consider the significant threat to culture diversity, where road construction cuts populations in half and fragments it (Chen, 2003). From another perspective, low educational achievement and skills is a demographic feature of minority areas. For the local population, the main source of income is agriculture, with the consequence that the public acceptance of large land occupation projects such as road building is low (Transport Department of Yunnan, 2014).

Finally, adequate financing is an essential factor in improving the sustainability of infrastructure (Martland, 2012). A shortage of capital for infrastructure development has already become the biggest challenge in China, especially in the towns (World Bank, 2012a). There is a significant funding gap caused by the single financing channel which is a serious problem in China, with funding provided from national finance (Cao, 2012). The government-led financing model has increased government debt significantly, and is not sustainable (Zuo *et al.*, 2012).

5.3.2.2 Challenges of ecological environmental

The natural geographical conditions of Yunnan pose a major obstacle to sustainable highway infrastructure projects. As already discussed, Yunnan has diverse geographical features, the terrain slopes sharp down from the northwest to the southwest with the highest point of the province reaching 6,740 metres and the lowest point 76.4 metres. The major landforms in Yunnan are mountains and highlands (94%). The major new highways will be built through high altitudes of mountainous ranges. The southern part of the province is covered with mountains, remote cultivated valleys, and forested ridges. This part has adequate rainfall throughout the year, but it can lead to floods and landslides. Northern Yunnan lies at the threshold of the Himalayas with high mountains, roadways get blocked due to landslide during each summer monsoon and heavy snowfall in wintertime (Shi *et al.*, 2011). Constructing and maintaining highways in these areas have been a challenge for engineers (Dai *et al.*, 2005). Additionally, the province is an earthquake zone, this is another challenge facing highways construction.

The geography has encouraged species diversification within the province. Yunnan provides half of China's total number of animal and plants species, and it possesses rich mineral resources and freshwater (Wang *et al.*, 2014a). However, the biodiversity is faced with damage as the result of excessive exploitation of resources and environmental impacts caused by construction activities (Yang *et al*., 2015). First, it results in habitat fragmentation and can be a source of pollution (Chen and Xiong, 2011). Second, as a mountainous province, the land resources are generally more valuable in Yunnan (Tong, 2016), the arable land represents 15.9% of the total area (Yunnan Provincial Department of Land and Resources, 2015). Highway infrastructure projects occupy a large area of land due to their scale (Zai *et al.*, 2016), they will permanently occupy agricultural land, green space, forest, wetlands and other land resources (Chen and Xiong, 2011). Finally, the construction of subgrade, bridges, culverts and tunnels can alter the original topography, damage vegetation, and cause soil erosion (Yang and Wu, 2003). Highway construction, with extensive excavations and backfill soil can cause geological disasters such as landslides, debris flows, collapses and etc. (Zhang *et al*., 2006).

The most serious existing problem of infrastructure construction in respect of sustainable development in China is the high resources use and waste (Miao, 2014). Data from the Centre for Energy and Development of China shows that in 2013, the construction energy consumption accounted for 20-40% of total energy consumption, and the energy consumption per unit area is 2-3 times that of developed countries (Dong, 2013).

5.3.2.3 Challenges of technological

The extensive mountainous areas and complicated geological formations require the construction of long tunnels, bridges, and high embankments as part of highway infrastructure projects. The construction is difficult and can take a long time. According to Yunnan Highway Development & Investment Co. Ltd (2016), the cost of each kilometre of highway construction in Yunnan is two-to-three times that of the central and east areas of China, also the highway maintenance cost is higher than other areas. New technologies and materials have become important for developing highway infrastructure project in Yunnan.

5.3.2.4 Challenges of sustainable awareness

The more recent advances in economic theory suggested that the quick development of highway infrastructure projects will drive economic growth. Economic growth therefore is a higher priority to developers than other objectives, at the same time builders are more focussed on project schedule in order to complete the construction quickly while ignoring environmental issues (Zou, 2009). A series of environmental protection regulations and building standards have been enacted, but some of them have not been implement due to environmental issues being a low priority for local authorities, and local people failing to realise the importance of sustainable development (Zhu, 2015). The obvious contribution to economic growth and social benefit can mean that the negative impacts are tolerated in some places (Xue *et al.*, 2014).

Lacking awareness of sustainable development has raised questions of unsuitable planning and design, and unsustainable construction and operation activities (Yang, 2016). Liang *et al.* (2012) argued that pollutants comprising of solid waste, waste water, waste emissions and smoke from construction have not been effectively controlled because there is no significant awareness of environmental pollution and sustainable construction. Zuo *et al.* (2012) studied the top 50 international construction companies in China, only a few of whom expressed any concern for sustainability issues, thus, sustainability awareness in construction needs to be improved in China (Sun, 2016).

5.3.2.5 Challenges on construction quality

Construction quality is regarded as an integral part of sustainability (Zhou, 2016), in China the construction quality problems such as foundation settlement, pavement cracking, leakage, seepage, jerry-building, plumbing leaks, poor materials, etc. (Zhao, 2011) have long been commented on by researchers (Zhao, 2011; Wang, 2014; Yan, 2016). The Global Competitiveness Report 2014 by the World Economic Forum (2014) disclosed the overall quality of infrastructure in China is ranked 64, and the quality of road construction is ranked 49 in the world.

Some builders considered that quality just needs to be ensured on the construction phase but the quality of site selection and building environment are seldom considered in the design and planning phase (Wang, 2014). Likewise, when the projects are subcontracted, it is hard to control the quality of highway infrastructure projects (Yan, 2016).

5.3.2.6 Example of Chu-Da Highway in Yunnan.

The highway from Chuxiong City to Dali City (Chu-Da Highway) is a fairly typical example which demonstrates the problems of highway construction in Yunnan. Chu-Da highway was open to traffic in 1998 after a total investment of $ 0.84 billion. It is the only highway to link the eight cities (Chuxiong, Dali, Dehong, Nujiang, Diqing, Lincang, Baoshan and Lijiang) in the west and northeast of Yunnan. It serves more than 13 million people, or about 1/3 of the province’s total population (Lin, 1996). There have been several significant problems since the highway was constructed, two years after its completion, surface subsidence appeared resulting in serious traffic congestion. The report of Government of Yunnan Province (2016) identifies high traffic volume as the main reason of pavement deformation, with the traffic increase due to economic development. Liu

(2015a) argued that the rationale of the road network plan in Yunnan was the primary factor for the high traffic volume, it was the only highway in western region covering 44.18% of the total area of the province, at the same time more investment on highways was allocated to eastern regions.

According to the Ministry, the highway life span should be 20 years, but the actual life of Chu-Da Highway has proved to be shorter than indicated by the Standards. The capacity of the highway has been long questioned, and in 2014, a replacement highway project was proposed by the government with total investment of $3.61 billion (Liu and Wang, 2008).

Highway design in China is based on four lanes, rather than projected traffic flow. This adherence to a four-lane design creates congestion, resulting in the need to rebuild or reconstruct the highway due to congestion (Cao, 2012). This ultimately results in higher costs, not only construction costs or the total investment but also in the reconstruction and maintenance cost.

The rapid development of Yunnan's economy has created significant demand for highway infrastructure projects, but the current networks and infrastructure cannot provide enough capacity (Cao, 2016). Highway construction should have a reasonable layout and design, and provide services to meet the needs of local people within the sustainable development requirements (Zhu *et al.*, 2014).

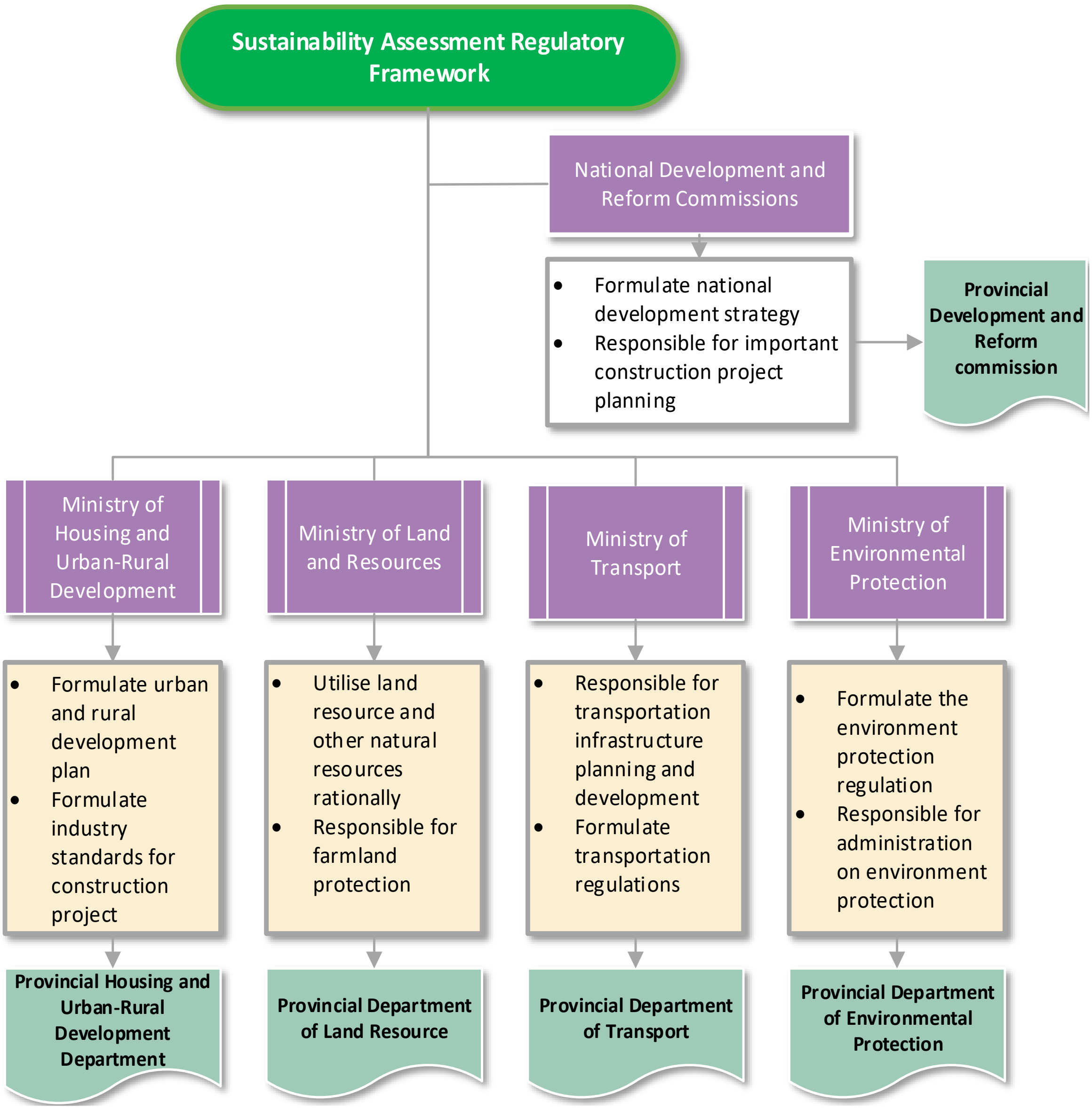
5.4 Sustainable highway assessment in Yunnan

Significant highway infrastructure projects have taken place in the past few years and more are planned for Yunnan, promoting sustainable construction has been identified as necessary by the central and local government, thus, sustainability assessment is considered effective in improving the performance of highway infrastructure projects. To reinforce the sustainability strategy, governments have legislated for sustainable construction and provided supporting standards to control the impacts from highway infrastructure projects on the environment and promote economic growth. These regulatory policies help decision-makers, developers, suppliers and other stakeholders to find a sustainable way to build highway infrastructure projects in China (Lu, 2015).

5.4.1 Regulatory system of highway infrastructure

The development of highway infrastructure projects involves different departments and authorities that will propose development goals and sustainability assessment. The related government departments for highway infrastructure project development is shown in figure 5.2.

Figure 5.2 Highway infrastructure project related departments



Source: Ministry of Transport of China (2006)

Figure 5.2 shows that highway projects planning by central government is coordinated by the National Development and Reform Commission (NDRC), where high-level policy bodies such as the Ministry of Environmental Protection (MOEP), the Ministry of Land and Resources (MOLR), and the Ministry of Housing and Urban-Rural Development (MHUD) work together with the Ministry of Transport (MOT) to ensure large projects are built within sustainable development parameters. The provincial governments and authorities also coordinate with the ministries to build highways that meet local requirements (MOT, 2016). For example, Yunnan Provincial Department of Transportation is responsible for implementing relevant traffic regulations, principles and policies of the state; developing a province-wide transport development strategy, regulations and policies; and monitoring the implementation of development plans (Transport Department of Yunnan, 2017).

One current problem in highway infrastructure development in Yunnan is that there are conflicts between different regulatory departments, NDRC and MHUD or MOT, also central and local government (Zhu *et al.,* 2014). First, the conflict between central governments - NDRC and MHUD or MOT. The scope of responsibility among different authorities are ambiguous, MHUD is the authority in charge of the whole construction industry, from design, and construction to supervision, cost control, and tendering agency activities. MOT sets policies and standards for building transportation infrastructure projects and providing network planning for transportation infrastructures (MOT, 2016).The NDRC is treated as a 'super ministry' as it is a macroeconomic management agency under the State Council. It formulates policies for economic and social development, maintains a balance of economic aggregates and guides the overall economic system restructuring (NDRC, 2016). The roles of NDRC include macro-economic planning, for example, coordinating China's 5-year plan process, but also project and investment approvals, resource pricing and the allocation of investment funds. In 2016, it developed the National 13th Five-Year Plan (2016-2020) which included the initiative of development of transportation projects and sustainable development. On the other hand, the NDRC oversees investments in all national fixed-assets (road, railway, airport, etc.), including planning, consultation, evaluation, project approval, and project management. The government involvement in highway development is high in China, and the structure of existing administrative system for highway infrastructure is complex. As shown in figure 5.2, the regulation of sustainability assessment of highway infrastructure projects is fragmented and undertaken by five departments, the involvement of many departments causes conflict and makes the responsibility unclear. For example, NDRC, MHUD and

MOT are all related to highway infrastructure projects constructions, and their responsibilities overlap.

Second, conflicts between central and local governments. Central government is eager to set sustainable goals and regulations to achieve environmental protection and energy conversation, and a balanced development plan for the nation. Correspondingly local government plays a major role in the implementation of the regulations, and local interests are given priority in the implementation process (Ai and Wei, 2013). Highway infrastructure has become the pillar industry of local government, it not only generates revenues, but also leads the development of other related industries, so local government's planning sets a priority for infrastructure construction (Xu, 2015).

5.4.2 Sustainable highway infrastructure policies

In 1989, China published the Environmental Protection Law, subsequently revised in 2014. The Law is formulated for the protection and improvement of the environment, preventing and controlling pollution and other public hazards, safeguarding public health, promoting civil improvement and facilitating sustainable economic and social development. It also sets rules for relevant ministries, and provincial, autonomous regional and municipal governments directly under the CPG to take into full account their environmental impacts when developing economic and technical policies. The law stipulates that construction project planning and implementation shall be subject to environmental impact assessment, it also requires the relevant departments to provide environmental, economic and technical standards and pollution control measures for construction projects (Environmental Protection Law, 2014). The promulgation and implementation of the Law demonstrates the government's efforts to protect the environment, and it can be the pre-requisite for sustainable development.

The Regulation on the Administration of Construction Project Environmental Protection was formulated in 1998 with a view to preventing construction projects from generating new pollution and damaging the environment (NDRC, 2014). In 2007, the Energy Conservation Law of China was revised to promote energy conservation across the whole of society. It enhances energy utilisation efficiency, protection and improvement of the environment, and coordinated sustainable economic and social development (Energy Conservation Law, 2007).

The Environmental Impacts Assessment (EIA) Law was issued by the CPG in 2002, and revised in 2016 to prevent harmful impacts of construction projects upon the environment after they have been undertaken. It sets the legal requirements for the assessment of sustainability in construction projects, including highway infrastructure projects, and enhances the implementation of the sustainability strategy (The Environmental Impacts Assessment Law, 2016). The Law not only provides legal protection and a favourable environment for sustainable construction, but also provides the legal basis for the sustainable assessment framework.

The EIA Law requires large-scale construction projects to provide an environment impact report prepared by an organisation qualified for conducting the work of environmental impacts assessment, so that the appropriate interventions can be taken for the proposed activities (NDRC, 2006). The scope of this environmental assessment report covers the adverse environmental impacts during the project construction process, in addition to social and economic impacts of the project lifecycle. The EIA report should include the following: 1) analysis, projection and evaluation on the potential environmental impacts resulting from implementation of the plan; 2) measures and countermeasures to prevent or alleviate adverse environmental impacts; and 3) conclusions of the EIA (Energy Conservation Law, 2007). The report is required to identify the negative impacts on the ecological environment, water, atmosphere, solid wastes, and social-economic environment, but also provide mitigation measures to restrict the environmentally damaging activities (Zhou and Wang, 2015). EIA helps reduce environment damage caused by construction projects, but it does not include all aspects of sustainability (Tang, 2016).

With the implementation of laws for environmental conservation, the environmental effects of building projects are reduced to a certain extent (Lu, 2015). Meanwhile, governments have undertaken a series of activities to prevent damage to the environment from highway construction.

5.4.3 Supporting standards

In order to set the optimum criteria for construction projects to function and operate in an environmentally acceptable manner, a series of standards was developed for the construction industry and infrastructure projects to produce more sustainable building practices within the legal limits. According to the MHUD (2014), there are 15 mandatory standards for new and existing construction projects. These standards require saving energy, construction safety, construction techniques and structures and so on. Sustainability issues are covered by the current standards, but none are specific to sustainable development.

In 2006, MHUD and the General Administration of Quality Supervision, Inspection and Quarantine (APSIQ) developed a voluntary rating system and updated it in 2014, the Assessment Standard of Green Building. The standard is regarded as the first national standards for sustainable building in China which covers not only residential buildings but also public construction (MHUD and APSIQ, 2014). This standard was based on LEED (Leadership in Energy and Design) from the USA, but emphasises the unique conditions in China. For instance, it encourages the use of rainwater or sea water for construction because China lacks freshwater resources (Dong, 2013).

The Standard includes six elements: Land savings and outdoor environment; Energy savings; Water savings; Materials savings; Indoor environmental quality; Operations and management. Each element has control items, and preference items. Control items are prerequisites of the building projects, and a project receives points when it meets the requirements of general or preference items. All elements need to be satisfied for a residential and public project. The system uses a checklist scoring scheme, which allows the project decision-makers to choose the most appropriate credits for the projects.

Unlike other countries, where green building rating systems e.g. BREEAM and LEED have been developed by organisations independent from government, the Standard in China is formalised as a national standard by the government (Chang *et al.*, 2016), it shows that Chinese government is pushing towards green building in the construction sector (Pan *et al.*, 2016).

With the growing attention upon environmental and energy consumption issues, many provinces use the Assessment Standard of Green Building as a model to establish the green building environmental assessment standard. Yunnan Housing and Urban-Rural Development Bureau formulated the Evaluation Standard for Green Building of Yunnan (DBJ53/T-49-2013) in 2013. It is more in line with the local conditions, and it emphasises that the green building assessment process should include the climate characteristics, poor economic foundation, and various minority cultures in Yunnan (Yunnan Housing and Urban-Rural Development Bureau, 2011). It acts as the guidance for designing, constructing and operating green buildings, and promotes the development of green building in Yunnan. But some problems appear in the practical application of the standard. Firstly, the standard is not mandatory for construction projects, most executive, middle management and practitioners in the construction industry are not aware of the need for green building (Song *et al.*, 2014). Second, a lack of qualified professionals and experience of green building is prevalent in the construction sector (Wang, 2016). Thirdly, there is no supportive policy framework for green buildings and green infrastructures (Song *et al.*, 2014). Finally, the cost of rating green building is high, the Green Building Certification in China is $ 8,000 which influences the implementation of Green Building in China (Pan *et al.*, 2016).

To facilitate highway infrastructure projects, the MOT issued the Specification for Environmental Impact Assessment of Highways (JTG B03-2006) to improve the effectiveness and efficiency of environmental impact assessment in highway construction (MOT, 2013). This Specification is dedicated to evaluating the environmental impacts of re-construction and new-construction of highway infrastructure projects. It provides a definitive standard and criteria for this activity with full concern for the social and ecological environment. Table 5.6 lists all the factors for the highway environmental assessment.

Table 5.4 Factors of Specification for Environmental Impacts Assessments

	Aspects	Factors
Specification for Environmental Impact Assessment of Highway	**Social impacts**	Impact on the social community, including: culture, population structure, economic development, barrier to communication with both sides of highway
		Impacts on quality of life and livelihood, including: resident's life style, livelihood, incomes and structure, hygiene and health, safety, education
		Impacts of relocation, including: impacts on living and production conditions for the affected population, impacts on the natural and social-economic conditions
		Impacts on other infrastructure, including: power and communication facilities, transport infrastructure, water supply, groundwater etc.
		Impacts on resources utilisation, including: land, mineral, tourism resources, and cultural heritages,
		Impacts on region development plan, including: urban, transport and economic development
	Eco-environmental impacts	Topographical features, degree of soil erosion
		Vegetation types and distribution; location and species of the affected trees
		Wildlife types and distribution, area of activity and migration routes
		Nature reserve science, forest landscape and scenery location and distribution
	Noise environmental impacts	Noise sources types, level and relations with highway location
		Existing traffic noise distribution
		Noise sensitive points distribution and population distribution
	Air impacts	Dust and waste in construction phases
		Automobile emission in operation phases

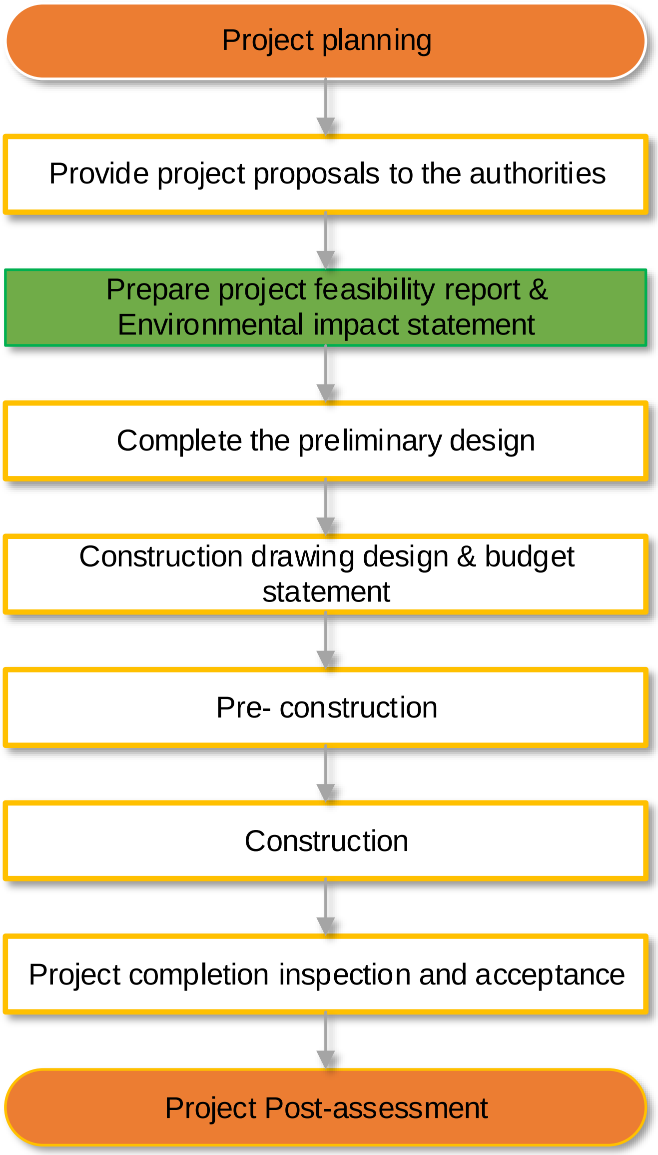
The Specification identifies measures related to social disruption, noise control, environmental impacts, and appropriate technical specifications for the highway. It is derived from the Assessment Standard of Green Building which aims to strengthen highway infrastructure project development activities. It provides engineering design and technical specification for highway projects, incorporating measures for environmental protection, but it also demonstrates that the economic benefits of the highway projects are not contained, only one factor reflects the impacts on local economic development.

To conclude, based on the regulations and laws, the relevant industry standards provide guidance for the approach of highway infrastructure projects to social impact evaluation and natural surroundings evaluation (MHUD and APSIQ, 2014). Government and authorities are continually improving the standards for the sustainability assessment of highway infrastructure projects, many evaluation frameworks and systems have been established under these standards. It is still faced with a series of problems, for example, CPG issues strict regulations on environmental and social impacts, but the actual monitoring and enforcement is mainly undertaken by local government, with more attention paid to economic growth. Chang *et al.* (2016) found that only a few local authorities investigated the implementation of laws, regulations and policies to promote sustainable construction. Another challenge of current policy frameworks is most them include environmental considerations, economic assessment and technical aspects, but give less consideration to social issues, and they tend to be targeted at new-construction projects. For re-construction projects, comprehensive sustainable development guidance has still not been produced, even though the MHUD developed the Standard for Green Performance Assessment of Existing Building Retrofitting (GB/T51141-2015) in 2015 (Song and Gong, 2016; Chang *et al.*, 2016)

5.4.4 Feasibility study

Highway infrastructure projects are public assets and invested in by various levels of government, in accordance with the Administrative Measures for the Government Confirmation of Investment Projects, public investment on projects is required to be approved by the Government (NDRC, 2014). Project appraisal is a crucial phase of highway infrastructure project decision-making, and the feasibility study report essential for project appraisal.

Figure 5.3 Highway infrastructure project development process



Source: NDRC, 2014

As shown in Figure 5.3, feasibility study and environmental impact assessment are the two primary steps to evaluate whether a highway infrastructure project is suitable, they are also regarded as the main sustainability assessment methods (NDRC, 2014). Through the feasibility study the authorities will evaluate the technical or economic necessity, reasonableness, feasibility of the project, the impacts of the project overall to society and the environment. It covers most areas of sustainable development, socio–economic benefit, financial benefits, market demand, land use and civil engineering general rules, technique and facilities, environmental protection, energy saving and workforce safety, project structure and labour, organisational structure and implementation schedule (Shi, 2007). Therefore, it has been regarded as the major sustainability assessment tools by decision-makers. The main evaluation requirements of the feasibility study are discussed below.

The evaluation of economic feasibility allows decision-makers and analysts to consider the project from the perspective of various stakeholders and to support that, the NDRC published an updated version of ‘Construction Project Economic Evaluation Approaches and Parameters’ in 2006. The standard was developed as a national provision for all construction projects. Financial and economic analysis are the two most important aspects of economic evaluation according to ‘Construction Project Economic Evaluation Approaches and Parameters’ (NDRC, 2006).

Economic analysis is the monetary evaluation of alternatives for meeting a given objective. The evaluation is based on a comparison of discounted costs and benefits over a fixed period. Alternatives can be summarised based on the ratio of total benefits to total cost (benefit-cost ratio) or equivalently, the total net benefits (Net Present Value) (Teng *et al.*, 2014).

Social impacts assessment (SIA) helps decision-makers to identify both positive and negative impacts of the highway project, and thus facilitates decision-making (UN, 2006). The purpose of SIA is to enhance sustainable outcomes associated with the project and reduce the negative impacts. Highway infrastructure is public capital which involves a great diversity of stakeholders, China has invested massive resources in building road infrastructure, and while the total length is increasing, the infrastructure-led development approach also causes social problems. By 2014, 40 million people had been subject to involuntary resettlement as a consequence of infrastructure projects, resulting in their livelihoods being disrupted through forcible relocation (Teng *et al.*, 2014). The practice of SIA in highway infrastructure started in the 1990s in China, and the qualitative and quantitative analysis methods are combined to evaluate the social issues of a project’s whole lifecycle. It enhances the awareness of impacts of highway infrastructure project, but there is still a gap between practice and theory (Zhao *et al.*, 2014). SIA is a large system with various complicated factors, and it is hard to define what changes in society are led by social development. Currently, there are no standards provided for SIA assessment in China. Teng *et al.* (2014) argued that the assessment results were influenced due to SIA not being explicitly required in China. Some studies associate social impacts to the contribution of economic growth (Zhao *et al.*, 2014), others include the national economic analysis and EIA with SIA (Liu and Li, 2012).

The feasibility study is undertaken at the start of the project to identify future issues to support a better understanding of the construction project (Fratila, 2009). Although the information from the feasibility study will contribute to implementing sustainability in highway construction, it is used at the planning stage and the focus may vary due to the impacts of different investment approaches, the construction site, and other reasons (Shen *et al.*, 2010). Also, the feasibility study mainly focuses on planning phases, the information for controlling the construction phases may not be complete. Thus, the feasibility report cannot adequately reflect all related elements of sustainability in highway construction, and it should embrace more elements of sustainable development principles to benefit society and the environment, not just the economics of the project (Shen *et al.*, 2010)

5.4.5 Current studies of sustainability assessment of highway infrastructure projects in Yunnan

Along with the government embracing sustainability strategies, much research has been conducted to provide sustainability assessment methods for highway infrastructure projects nationwide. These studies provide practical advice and experience for the development of sustainability evaluation in Yunnan. Peng (2011) developed a sustainability evaluation method which put forward a cost-benefit analysis approach for a comprehensive evaluation system for highway development. Liu (2015b) identified the sustainable indicators based on density of road traffic, economic benefits and population served to assess highway sustainability. However, the research in this particular area is limited in Yunnan where evaluation has been mainly focussed on economic analysis and environmental impact (Wang and Zhao, 2016).

The current practical application of sustainability assessment to highway infrastructure projects in Yunnan is by integrating sustainability concepts into the existing evaluation system and improving the current project appraisal methods to meet the sustainable requirements (Huang, 2015). This includes taking the economic cost and benefit of environment impacts into account through conventional cost-benefit analysis (Shi and Huang, 2015), adding public participation to the EIA to strengthen the social objectives of sustainability (Zhang *et al.*, 2007), and improving the EIA process by integrating lifecycle analysis (Chen *et al.*, 2016), etc.

The most popular method used by existing studies is the integrated indicator-based assessment tool. This method comprises a set of indicators based on sustainable principles and a systematic analysis tool (Huang, 2015) and is a powerful strategy for working towards sustainable development, but the indicator selection tends to have bias, currently there are no agreed standards for indicator selecting (Yan *et al.*, 2013, Huang, 2015).

As stated previously, the impacts of highway construction are significant, Yunnan has a complicated topography with a wide variety of flora and fauna as well as cultural diversity, all of these issues should be included in the assessment process (Xu and Wang, 2013). On the other hand, China has long focused on quantification of construction projects, rather than quality and sustainability, sustainability assessment is only just beginning in China (Pan *et al.*, 2016). Research into the sustainability of highway infrastructure projects in Yunnan is less advanced than other areas of China. Some studies have expounded the importance of sustainability assessment, but a theoretical system to guide the practice has not yet been developed.

However, sustainability assessment is an integrated system and should capture the impacts on environment, society and economy, nevertheless, there is a lack of comprehensive recognised sustainability assessment methods in Yunnan (Lu, 2012; Zhu *et al.*, 2010), and some of the evaluation methods concentrate on planning or completion stages, and do not cover the whole lifecycle of the projects (Huang, 2015).

5.5 Conclusion

Highway infrastructure is the critical component for development in Yunnan, and it has gradually started to incorporate sustainability considerations into its provision. This chapter examined the conditions in Yunnan including geographical location, topography, cultural traits, etc. With the local factors considered within the context of current highway construction in Yunnan, the challenges faced by sustainable highway construction were analysed and assessed. The findings indicated that with rapid economic growth, the demands on highway infrastructure are continuously increasing in Yunnan, as a landlocked, mountainous and less developed province in China, it has its own emphases for sustainable development. Sustainability assessment can help the development of highway infrastructure projects to achieve sustainability. While this chapter concentrated on studying the current assessment tools and methods, the results established that Yunnan had not developed a systematic evaluation standard to endorse sustainable development for highway infrastructure projects. The regulations and industry standards are more focussed on environmental impact. The feasibility study of the project and environmental impact assessment are the main sustainability assessment methods, but both methods cannot reflect all the issues of sustainability. In parallel with the current situation identified in the literature, it can be concluded that it is necessary to build a systematic sustainability assessment framework for highway infrastructure projects in Yunnan.

CHAPTER 6 - RESEARCH METHODOLOGY

6.1 Introduction

Following the literature review in previous chapters, this chapter will focus on the philosophical assumptions and the research design approaches underpinning this research. The initial section will describe approaches to data collection methods comparing the strengths and weaknesses of the methods, follow by the reason for choosing the research method of data collection and data analysis with respect to the research questions. This chapter will explore the methods for the three phases of building the sustainability assessment model for highway infrastructure projects in the local context of Yunnan Province. In phase 1 a literature review is used to collect data. In Phase 2 the quantitative and qualitative approaches will be implemented. Some optional sustainability indicators of highway infrastructure projects were obtained from the construction project standards and previous studies on highway infrastructure projects. The indicators will be determined through a questionnaire completed by three groups of experts. In phase 3, data will be collected through a semi-structured interview.

6.2 Research aim and scope

The aim of this research is to develop a suitable sustainability assessment model for highway infrastructure projects in Yunnan Province of China. The research also aims to make a significant contribution to the improvement of public awareness of sustainability assessment.

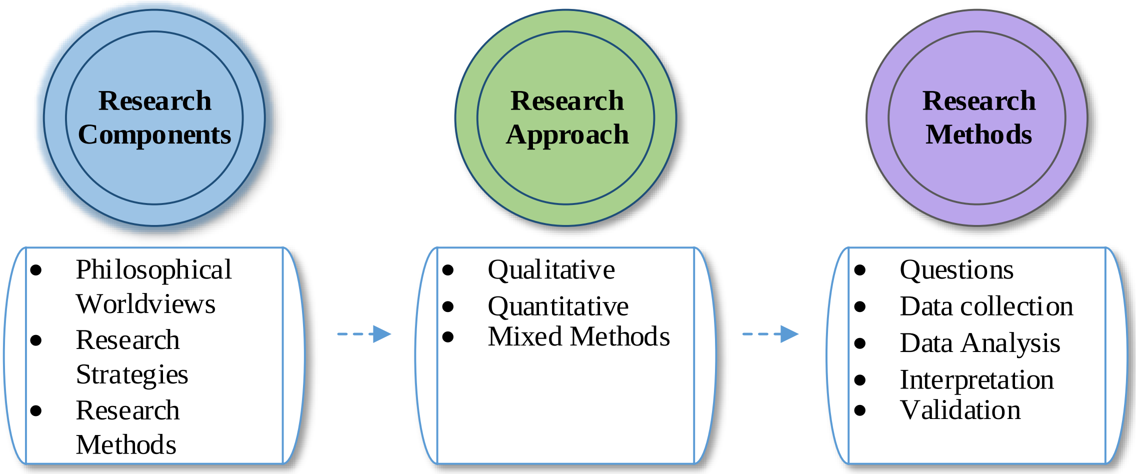
The scope of the model consists a set of criteria and standards based on the principles of sustainable development and local conditions to evaluate the sustainability of a highway infrastructure project throughout its whole lifecycle. The scope requires appropriate research approaches and techniques to collect and analyse data.

6.3 Research theories and design

Research is a systematic process to study, explain and discover new knowledge or phenomena (Zhang, 2016b). The nature of the knowledge varies and reflects the different research objectives, as some objectives endeavour to build systematic comparisons, whilst others seek to explain the phenomena in detail (Yang *et al.*, 2011). The different intentions involve a series of planned activities with appropriate research strategies and approaches. Research methodology defines and explains the specific problems, test hypotheses and develop appropriate means of collecting and analysing data (Zhang, 2016b).

Research design describes setting the strategies and includes a series of decisions on how the research will be conducted. Burns and Grove (2009) defined research design as 'a blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings'. Parahoo (2006) described research design as 'a plan that describes how, when and where data are to be collected and analysed'. The study designs vary with the structure of the research situation and the flexibility of the research methods (Polit and Hungler, 1995). Creswell (2007) provided a research design framework shown in Figure 6.1, to guide the researcher in the design of a research methodology for any given project.

Figure 6.1 Research design process



Sources: Creswell (2007)

Figure 6.1 describes three stages in the research design process research philosophy, research approaches and specific methods for data collection and analyses. This research follows the framework developed by Creswell and each step of the research process is explained in the following sections.

6.3.1 Research philosophy

It is important to clarify the structure of the inquiry and methodology of the research, and the first step is to explore the research philosophy to adopt the appropriate paradigm for the study because the research philosophy manages the source, nature and development of the knowledge (Bajpai, 2011).

The research philosophy refers to the set of beliefs concerning the nature of the reality being investigated (Bryman, 2012). Beliefs and perceptions which are related to how people consider the reality are the starting point for addressing and formulating the research beliefs and assumptions (Saunders *et al.*, 2009). These beliefs or assumptions are called paradigms and these describe the nature of scientific patterns and social reality formalisation process (Bhattacherjee, 2012). It is necessary to consider the appropriate theory or philosophy when designing the research because these paradigms would influence and constrain people's thinking and research activities. Flick (2011) stated that the assumptions created by a research philosophy provide the justification for how the research will be undertaken. Hence, understanding the research philosophy can help to explain the assumptions inherent in the research process and select the appropriate methodology to fit the research.

Research philosophy has many branches related to a wide range of disciplines. Two particular beliefs are positivism and interpretivism (Galliers, 1991). Positivism epistemological perspective was formulated by French philosopher Auguste Comte (1798-1857). Comte believed that human history is a process progressing from superstition to science, and that science is descriptive, deductive and controlled. This idea dominated through to the mid-to-late 20th century, when philosophers and scientists revised positivism and developed post-positivism (Gao, 2011).

Positivists believe it is possible to observe and describe reality from an objective viewpoint (Gao, 2011). As noted by Collins (2010), ‘as a philosophy, positivism is in agreement with the empiricist view that knowledge stems from human experience. It has an atomistic, ontological view of the world as comprising discrete, observable elements and events that interact in a noticeable, determined and regular manner’. The underlying ground theory of positivism assumes that X is the cause of Y. The task of research is considered as the scientific method required to establish the nature of the cause of the relationship between X and Y. To satisfy scientific requirements, the information must be measured, and that leads to the objective features of positivism. The research data is collected through objective methods and the research findings are observable and quantifiable under the positivism philosophy.

Interpretivism, or interpretivist philosophy assumes that researchers believe that the reality is formed by people’s subjective experiences of the external world. It is ‘associated with the philosophical position of idealism, and is used to group together diverse approaches, including social constructivism, phenomenology and hermeneutics, and approaches that reject the objectivist view that meaning resides within the world independently of consciousness’ (Collins, 2010). Interpretivism focuses on reflecting on different aspects and opinions, and usually uses the qualitative research approach.

Positivism and interpretivism are two important but different approaches to sociological research. The primary differences between these two approaches are listed in Table 61.

Table 6.1 Differences between positivism and interpretivism

	Positivism	Interpretive
Basic Notions	• Objective • Generalisability • Scientific • Value-free approach to science • Observer is independent	• Subjective • Individual motives • Humanistic • Observer is regarded as a part of the object
Research Approach	• Quantitative approach with large samples	• Qualitative approach with small samples but in-depth analysis
Research Methods	• Mathematical Modelling and simulation • Controlled experiments • Field experiments • Quasi experiments • Testing • Surveys: questionnaires and interviews • Observation	• Case study • Focus group • Ethnography • Documents and artefacts studies • Unstructured Interviews

Source: Crowther and Lancaster (2008); Collins (2010); Gao (2011)

To contrast both research philosophies, positivism relies on knowledge gained through observation with statistical quantitative data, usually adopting a deductive approach, and using scientific methods to allow searchers to gain objective data. It is related to the viewpoint that research must focus on facts. Interpretivism concentrates on human interest and consciousness, it generally adopts an inductive approach using qualitative data, and knowledge is not 'value-free' or 'objective', but is transmitted to researchers through ideas, discourses and experiences (Crowther and Lancaster, 2008).

The studies are based on particular philosophical perspectives depending on the type of research. In this research, the underlying philosophical assumptions include both positivist and interpretive. This research aims to build a sustainability assessment model based on statistical measurement and quantifiable data. Moreover, the research includes social and human experiences of sustainable development and highway infrastructure projects, through individuals' knowledge of the social context of their understanding to construct the new sustainability assessment model that is interpretive.

6.3.2 Research approaches

The research approach is the particular direction of the research design derived from the research philosophy. Creswell (2007) identified three approaches; quantitative, qualitative and mixed methods.

The quantitative approach investigates the observable phenomena via statistical, mathematical or computational techniques. It is one of the most common approaches to conduct social research because it is widely accepted that the quantifiable result can support opinions and concepts. The qualitative approach gathers in-depth information about human behaviour and various aspects of social life. It uses words rather than numbers to describe people and research phenomena in natural situations (Amaratunga *et al.*, 2002). Each approach uses specific research techniques e.g. survey for quantitative research, content analysis for qualitative research. The mixed methods approach recognises that quantitative and qualitative approaches both have limitations, and when both are implemented in the same piece of research, one supplements the shortcomings of the other. Table 6.2 shows the differences of the three approaches.

Table 6.2 Quantitative, qualitative and mixed methods approach

Quantitative approach	Qualitative approach	Mixed methods approach
• Generally associated with Positivism • Involves collecting and converting data into numerical form • Data collection follows a strict procedure and preparation for statistical analyse • Based on a representative sample of the wider population/group to collect data • Objective	• Generally associated with Interpretivism • Involves obtaining rich and complex personal experience which cannot be gained from large groups • Involves a smaller number of participants • More subjective	• Incorporates both qualitative and quantitative approaches • Use appropriate data collection and analysis methods depending on the nature of the question • Has the advantages of triangulation

Source: Creswell (2007); Babbie (2012); Li (2004)

Quantitative research focuses and relies on measurement and calculation, and qualitative research focuses on the description of the meaning, features and symbols of study subjects, moreover, quantitative approach is more structured, and the qualitative approach is less structured (Feng, 2013). Therefore, most researchers use both in a complementary way to improve the research quality. Ragin (1994) explained that ‘most quantitative data techniques are data condensers. They condense data in order to see the big picture. Qualitative methods, by contrast, are best understood as data enhancers. When data are enhanced, it is possible to see key aspects of cases more clearly’. Patton (2002) stated that the quantitative methods require the use of standardised measures for many responses, and qualitative methods can facilitate the study in depth and detail. The varying perspectives and experiences from the qualitative inquiry can fit into a limited number of predetermined responses. Both quantitative and qualitative research have their strengths and weaknesses (Table 6.3).

Table 6.3 Strengths and limitations of two approaches

	Strengths	**Limitations**
Quantitative Research Methods	• Provide wide ranging information • Collect data fast and economically • Use statistical techniques to aggregate large amounts of data which can help the decision-making	• Tends to be inflexible and artificial • Not very effective in understanding processes and peoples’ thoughts • Not helpful in developing theories • Not best suited for decision-making about future changes
Qualitative Research Methods	• More natural approach to data collection • Offers guidance on processes, and provides information for adjusting the issues • Provides an understanding of people’s attitudes and real meanings • Makes contribution on theory generation	• Take long time and large resources to collect data • Difficult to analyse and interpret data • Low credibility to decision-makers

Sources: Amaratunga *et al.* (2002)

The primary consideration of research method selection is to answer the questions raised by the research. To meet the needs of the research, many researchers combine quantitative and qualitative methods to gain a full understand of complex problems (Hyland, 2016). Mixed methods approach involves collecting and analysing data through integrating quantitative and qualitative approaches. This approach provides both breadth and a better understanding of the research question (Creswell, 2014), the greatest advantage of this approach is the possibility of triangulation by using several methods, data sources and researchers to examine a single problem (Bazeley, 2004). The case for a combined research approach in evaluations or assessment has been convincingly demonstrated, for example, the World Bank used a mixed approach for developing poverty assessments in 1990 (Garbarino and Holland, 2009).

This research combined quantitative and qualitative research to collect a wide range of data relating to the sustainability of highway infrastructure projects. A qualitative approach was first used to identify and select the preliminary indicators from existing evaluation systems or frameworks. Using the preliminary indicators system, a quantitative approach was undertaken to obtain the perceptions of professional groups on sustainability in highway infrastructure projects. The determination and weighting of indicators for the sustainability assessment model needs a large sample, and this can be achieved using a quantitative approach. The goal of the quantitative approach was to determine the relative indicators, but the results only focus on current and recent projects, therefore a qualitative approach is required to discover why and how. The final step in data collection adopts a qualitative approach to examine the opinions of experts associated with sustainable highway infrastructure projects.

According to Appleton and Booth (2005), when using the integrated research approach of combining quantitative and qualitative methods, their comparative advantages must be understood. However, this research used a quantitative approach to collect data that can be aggregated and analysed to describe the significance of the individual factors of sustainable highway infrastructure projects. The qualitative approach helped to probe and explain those indicators and their relationships. It was possible to interpret observed patterns and trends, and to analyse the different understanding of the dynamic development of sustainable highway infrastructure projects rather than the static results produce by the quantitative approach.

6.4 Research framework

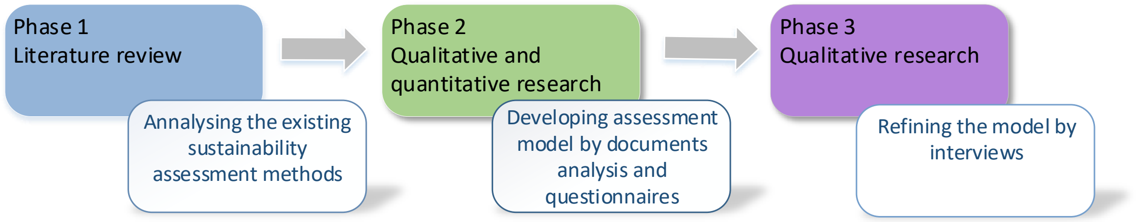
Currently, there are two main approaches used to build the assessment indicator systems in China: one approach is to select indicators through a literature review. With this approach, Dai *et al*. (2004) developed an indicator system to evaluate sustainable transportation in Shanghai, China. A literature review is undertaken to identify the indicators included in industry publications, articles in journals and government documents, and an indicator is defined as frequently used if it appeared five or more times. This is a common approach but has drawbacks as some indicators are not suitable for local requirements, and it lacks scientific evidence (Sun and Li, 2013). Another approach is to identify indicator using experts, Sun and Li (2013) built an indicator system for infrastructure projects by convening experts' meetings. Indicator selection with this approach is strongly dependant on experts' knowledge and experiences, it cannot avoid the problems of subjectivity which can threaten the credibility of the research (Jiang, 2013). However, it is suitable for use in the early stage of identifying operational indicators, and it needs quantitative information to support identifying the most appropriate indicators (Nie, 2002).

This research chose mixed method as the research approach, the value of this approach is increasingly recognised as it can capitalise on the strengths of both qualitative and quantitative methods and techniques. There is a question in using mixed method as the result can be differentiated due to the sequence of qualitative and quantitative occurrences and the emphasis given to each method (Morgan, 2006). The current research on sustainability assessment in China is to use the preliminary qualitative method to generate a hypothesis or a concept, and a questionnaire approach is used in a follow-up quantitative study to test the hypothesis or concept. The emphasis is on quantitative data analysis. Conversely, this research initially uses a questionnaire to build the assessment model and examine in-depth with a follow-up interview. This strategy is conducive to understanding the research objective in the context of larger-scale objective samples (Zhu, 2012). The research focused on a balance of qualitative and quantitative approaches to generate more complete data and corroborative findings.

Research is a systematic process, Figure 6.2 below breaks the research process down into 3 phases. Phase 1, analysing the theoretical background by means of the literature review;

Phase 2, developing the sustainability assessment model through quantitative and qualitative methods; Phase 3, through qualitative methods refining the developed model.

Figure 6.2 Research process



6.4.1 Phase 1 - Literature review

In order to identify the sustainable development issues of highway infrastructure projects, a literature review was extensively and critically undertaken at the initial stage of this research. The literature review provides the foundation to intensively explore a topic while data mining using a quantitative and/or qualitative research approach. It is an overview and critical evaluation of a specific research area which relates to the study of the larger, ongoing dialogue in the literature, fills in gaps and extends prior studies (Creswell, 2007, p.27). As Fink (2005) stated, the literature review is a systematic method for identifying, evaluating and interpreting of the existing body of knowledge. The literature review serves several important functions: demonstrates the knowledge of the research problem, illustrates the understanding of the theoretical and research issues related to the research question, provides new theoretical insights or develops a new model as the conceptual framework for the research (Xie, 2012, p.113).

The sources of literature included reports of international organisations, governments and authorities, journal articles, books, conference proceedings, etc. The main emphasis was focused on the emergence of international efforts at sustainable development, sustainability of construction, sustainability assessment methods, limitations of current assessment methods or models and future possibilities in sustainable highway infrastructure project assessments. The various methods of measuring sustainability include green building assessment systems, e.g. LEED, BREEAM, SB Tool and the Green Building Evaluation Standard of China were evaluated and compared.

The literature review presented the background to sustainable highway infrastructure and interpreted the challenges and success factors for realising sustainability in highway infrastructure projects in the conditions of Yunnan Province of China. Several sustainability assessment tools, techniques and frameworks were critically analysed which allowed an appropriate sustainability assessment model to be developed in the following phases.

6.4.2 Phase 2 - Qualitative and quantitative research

The tasks in phase 2 of the research included collecting both qualitative and quantitative data. Qualitative data was obtained from existing sustainability assessments or evaluation frameworks and were used to build the assessment indicators. This provided the basis of the questionnaire survey in the next step.

The purpose of using the qualitative method is to build the preliminary indicators of the sustainability assessment model. In light of the concepts found in existing assessment methods and frameworks, and other data available from the existing literature, the most relevant factors for the sustainability assessment model for highway infrastructure projects were selected. In addition, the standards, specifications, regulations and policies for the construction industry and highway infrastructure projects were used as guidance in choosing the indicators.

Subsequently, a questionnaire survey to collect quantitative data was undertaken to determine the indicators. A questionnaire is a simple tool for collecting information about a particular issue (Creswell, 2014), and it has been considered a popular quantitative method in social science. It is commonly used to collect factual and straightforward information and data to classify the basic attitudes or opinions relating to an issue of a group of people. For example, to measure a group of customers' satisfaction with a service (Xie, 2012).

Questionnaire is used because it is a practical method with the strength of collecting a large quantity of data and information quickly, and where all participants can be given the opportunity to provide feedback anonymously which encourages openness. It can also facilitate the analysis of a survey and improve the accuracy of the answers by allowing the respondents more time to consider their responses, particularly where the questions are challenging or contentious (Xie, 2012). Sustainability assessment of highway infrastructure projects has a holistic and multi-dimensional nature with several factors, the participants can provide valuable data by means of a questionnaire. The results can be quantified which is both objective and scientific, and the quantified data can be easily used to compare and measure changes (Zheng, 2014). In this research, to compare and select the indicators, a significant volume of data was required and the questionnaire would help to rank the sustainability indicators.

However, the limitations presented by questionnaires may influence the results. The respondents may give the answer based on social desirability and the language of the questionnaire should be appropriate to the background of the respondents. The responses may misrepresent the current development patterns of highway infrastructure projects to present a more sustainable development approach because of social expectation, rather than reflecting the current reality. Since the questionnaire was translated into Chinese, it may also result in misunderstanding due to the questionnaire wording. Some researchers also argue that some forms of responses such as emotions, behaviour, feelings and beliefs cannot be quantified, meaning that the questionnaire may fail to properly collect this information (Zheng, 2014). The questionnaire is an empirical study method, but it has its inevitable weaknesses and for this reason, it is advisable to use additional research methods to support the research (Su *et al.*, 2015).

In order to quantitatively analyse the data, the questionnaire was designed using a Likert scale, the most common used scale in social research. A Likert scale is a simply way of gauging specific opinions, it also easy to construct (Su *et al.*, 2015) . For example, in a Likert scale questions like ‘yes’ or ‘no’ can be categorize in a numeric scale 1 and 2 and it allows to use a quantitative approach to analyse the data. Likert scale was developed by Likert (1932) and it is based on the principle of asking people to respond to a series of statements about a topic. They respond in terms of the extent to which they agree or disagree, which enables the researcher to delve into the cognitive and affective elements of the respondent’s attitude. To ensure comparability of data, and so that results can be considered in the same general context, this research adopted a common, five-point Likert scale.

6.4.3 Phase 3 - Interviews

The third phase of this research was to collect the opinions of experts in respect of the developed assessment models identified in phase 2. A qualitative study is deemed to be the most appropriate approach to collect this data, involving the use of in-depth interviews which serve to obtain information which is then used to inform the development of a questionnaire. Punch (2009) stated that 'interview is the most prominent data collection tool in qualitative research.' Real experiences drive the use of this approach rather than principles, motivated by the perceived limitation of quantitative methods alone to address the complexity of research in highway infrastructure sustainable development, as well as other more strategic decision-making activities. Currently, the study of sustainability in highway infrastructure projects is not extensive, therefore the quality of data collected can be examined in detail by means of the experts' responses.

Expert sources of information are valuable because they can provide current information that journal articles and reference books cannot due to their publishing timeframes (Björk and Bröchner, 2007). It is a better way to exploit complex and detailed information, to obtain data about personal opinions, feelings, emotions, experiences and sensitive issues (Denscombe, 2010). In phase 2, some comments for adding, omitting and replacing the indicators were obtained by the questionnaire method, but the reasons for these comments were unclear. Therefore, the interview is regarded as an instrument to improve the assessment model with valid reasons based on the responses.

In this research, the interview method allows for the examination of the assessment models to determine if they are suitable or not in respect of the sustainability of highway infrastructure projects in Yunnan Province. Because of the limitations of the questionnaire, misunderstandings can occur, and it is usually difficult to contact the respondents by conventional methods. In this case, an interview can increase the response rate and help to tease out the information which might be neglected in a questionnaire survey. The data was collected by means of a semi-structured interview to fulfil the research objective. It was based on many key questions to help to define the research areas, but also allowed the participants to give their thoughts in more detail.

The interview was used as a non-neutral additional tool as the data is based on personal interactions which lead to negotiated and contextually-based responses, it was possible for some respondents to give precise answers because they believe they are socially expected (Podsakoff *et al.*, 2003), this could certainly impact upon testing the model. However, combining the questionnaire and interview methods is the most appropriate way to produce more credible quality research, while questionnaires can provide evidence of patterns amongst large populations, qualitative interview data often gathers more in-depth insights on participant attitudes, thoughts, and actions (Kendall, 2008).

6.4.4 Sample design

The population and sample are the most important factors following the methodology design. The researcher uses a sample to examine a proportion of the population associated with the research, for inferring information about the population as whole (Creswell, 2014) because it is often not possible to survey an entire population for reasons of practicality and cost (Brewerton and Millward, 2001). There are various types of sampling, the two most common being random/probability sampling and non-random sampling/purposive sampling (Bryman, 2012). Under random sampling, each element in the population is given an equal and independent chance of selection (Kumar, 2011), and the non-random sampling is based on the researcher’s subjective experience and other circumstances to choose the population (Zhang, 2016a).

The original intention of this research was to build a sustainability assessment model for highway infrastructure projects to match the local environment of Yunnan Province. The study was mainly conducted based on the conditions in Yunnan rather than the whole country, due to the unique and distinctive national and geological features in the Province. In this respect, purposive sampling of organisations involved in highway infrastructure projects with experience and knowledge of sustainable development in Yunnan Province was adopted.

The sample was chosen from companies, government departments and institutions with experience in highway infrastructure development. They are either known to the researcher

through work-related connections and activities or are identified and recommended by the people who are working in the same organisations and are known in this research area.
The samples were first selected from the government departments and authorities that are involved in highway infrastructure development, planning and construction, mainly from two departments: the Development and Reform Commission of Yunnan and the Transport Department. Second, qualified project managers, planners, architects and engineers were invited from Yunnan Highway Development and Investment CO., LTD., Yunnan Construction and Investment and Holdings Group CO., LTD., and organisations which are operating highway development, construction, management and operation. Academics with a recognised knowledge of sustainability were an important part of the experts group, they came primarily from the top universities and research institutes such as Yunnan University of Finance and Economic, Yunnan University, Kunming University of Science and Technologies and Yunnan Academy of Social Sciences. The backgrounds of the sample included urban study, landscape planning, environmental protection, resource management, built environment, sustainability, resource management, national economy accountancy, etc., and most of them held relatively high-ranking positions including professor, department director or deputy director. The selection criteria were: 1) over five years' relevant experience in construction of projects; 2) knowledge of sustainability and able to provide experience and feedback of the model; and 3) able to answer the questions posed by the researcher (participant's information sheet is attached).

The sample size was dependant on the time and resources available to the research. According to the literature study, while there may be significant research discussing sustainability assessment in highway infrastructure projects, there much less research from Yunnan Province which resulted in a limited opportunity to realise a large population to participate in the research. In addition, the questionnaire method aimed at determining the sustainability assessment indicators relied upon experts scoring the various indicators, and to do so, the experts were required to have appropriate experience and knowledge in this area. This requirement also resulted in a relatively small population. To ensure the accuracy of the data, 100 questionnaires with a list of optional sustainability assessment indicators were distributed to the respondents in these organisations by email or hand-delivered. To facilitate the further statistical analysis, some questions about the respondents' professional backgrounds were included in the questionnaire. The respondents involved in appropriate projects and in the general area of research were asked to confirm their interests and participation through phone calls and email conversations, at the same time, the questionnaire's distribution channel was established. This step helped to identify experts based on the information provided during these conversations, also to reduce the possibility of a low response rate to the questionnaire. The questionnaire was then sent directly sent to the respondents, who also further distributed some.

According to Burns and Grove (2009), qualitative research is focused on obtaining quality information, rather than the size of the sample. There is no need to determine the number of interviews at the beginning of the research, but by the information required. If the information from the participants cannot provide enough details for the research question, then new participants and information will be added (Streubert and Carpenter, 1999, p.23).Twelve participants undertook interviews in the research based on their responses, the details for the interviews are discussed in Chapter 8.

6.4.5 Pilot study

The pilot study can be considered 'the early development and pilot testing' of the research (De Vos *et al.*, 2002, p.409). It is the preliminary test of the research undertaken with fewer participants in order to improve data collection methods and check the appropriateness of the standard methods (Wu, 2009), including questionnaires or interview schedules (Van Teijlingen and Hundley, 2002). It can be described as an 'investigation designed to test the feasibility of methods and procedure for later use on a large scale or to search for possible effects and associations that may be worth following up in a subsequent larger study' (Everitt, 2006).

The main advantage of conducting a pilot study is to test for problems and errors in the research design. It can be carried out by quantitative and qualitative methods before the main survey is conducted (Van Teijlingen and Hundley, 2002). The pilot study of the research commenced by drafting the questionnaire and a set of interview questions to facilitate feedback from supervisors to ensure the questions were constructed correctly. Second, the questions were translated into Chinese and sent to the five academics in China to check if the translation was accurate, and help to refine the questions in Chinese. For the third stage, twenty people were selected to receive the pilot survey. The selection was not random but included junior and senior staff from the academic research institutes and construction industry who were likely to provide feedback on the questions and design of the form. The participants in the pilot study were asked to identify any difficulties with instructions, layout, relevance and clarity of the questionnaire and the time taken to complete it. During this stage, twenty questionnaires were all returned, and according to the feedback, it was found that the participants would take fifteen minutes to complete the questionnaire. Following the pilot study, the Chinese translation was improved.

For the final stage, two participants from the academic research institutes and two from the construction industry joined the pilot testing of the interview survey. This stage mainly tested if the participants could understand the questions and ensure all the participants could understand the terminology in the questions, and identify the information that would help to define keywords and the interests of participants. Each interview took an average of fifty minutes, and some modifications were made to the questions.

6.5 Data analysis

Data analysis is the process of examining raw data using various analytical methods. The discussion of the analysis of the findings from the questionnaire will be presented in Chapter7. The qualitative data will be analysed and presented in Chapter 8.

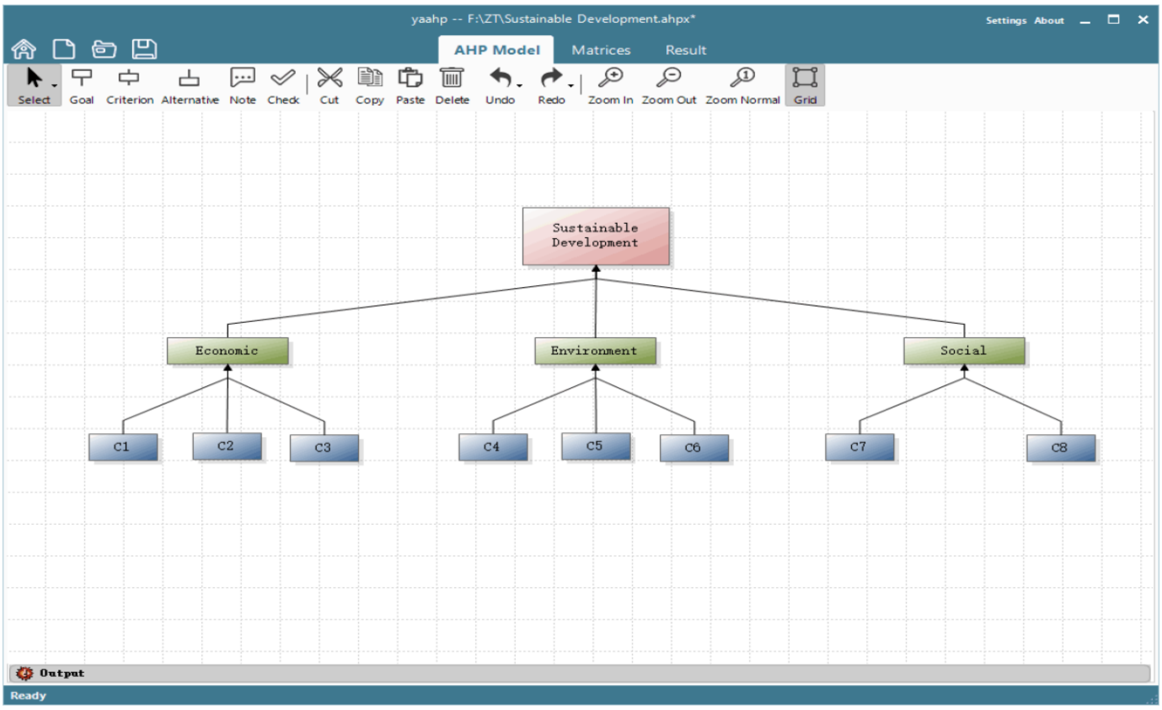
6.5.1 Quantitative data analysis

Data from the questionnaire was analysed using SPSS (Version 23), EXCEL (Version 2016), and YAAHP (Version 10.0). Using Cronbach's Alpha to test the reliability of the survey, EXCEL was used to calculate and compare the score from different groups, and YAAHP was used to weight each indicator by the Analytic Hierarchy Process (AHP) method.

Analytic Hierarchy Process (AHP) method was developed by Saaty in the 1970s and has been extensively used for complex decision-making, it is 'a theory of measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales' (Saaty, 2008). Currently, it is used extensively in sustainability assessment. Through the AHP method, the complex and difficult multi-criteria decision-making problems are regarded as a holistic system and then broken down into sub-objectives or factors to construct several layers with different multiple influence indicators, aimed at ordering the qualitative indicators into the single level and whole system using fuzzy quantification. Thus, it becomes a systematic decision method for optimising plans under multiple-criteria (Jiang, 2013). In effect, AHP systemises complicated problems and structures and the related data, information, and thoughts into a hierarchy, and through the hierarchical structure helps decision-makers understand the importance of variables.

Through comparing different software, YAAHP was used to compute the indicator weightings determined by AHP. This software has been used extensively with AHP to evaluate problems, according to China Academic Journals Databases, there are more five thousand references of literature to this software. A sample using YAAHP is shown by the following diagrams. The computation of indicator weighing by YAAHP for this research will be provided in Chapter 7.

Figure 6.3 Building hierarchical structure



AHP hierarchy is represented by YAHHP as shown in Figure 6.3. There are three main factors to achieve sustainable development – economic, environmental, and social. Each factor has a set of criteria (C1, C2…C8). Once the hierarchy is built, it is necessary to evaluate the importance of each criterion to achieve sustainable development by comparing them to each other, two at a time.

Figure 6.4 shows how the software will parse the data and generate judgement matrices. Judgment matrices data can be inputted using a variety of methods: slider input method or direct input method. Figure 6.5 displays the weighting of each criterion to sustainable development.

Figure 6.4 Judgement matrix generation and comparison data input

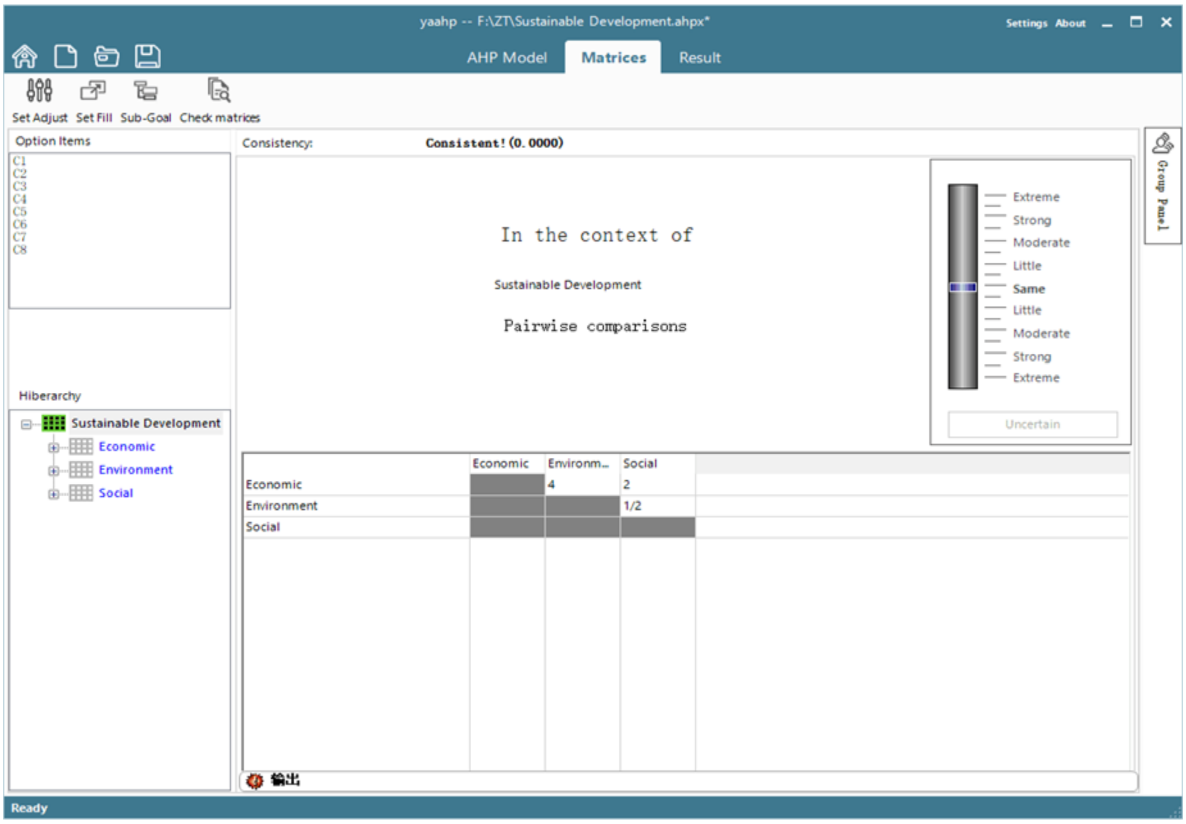
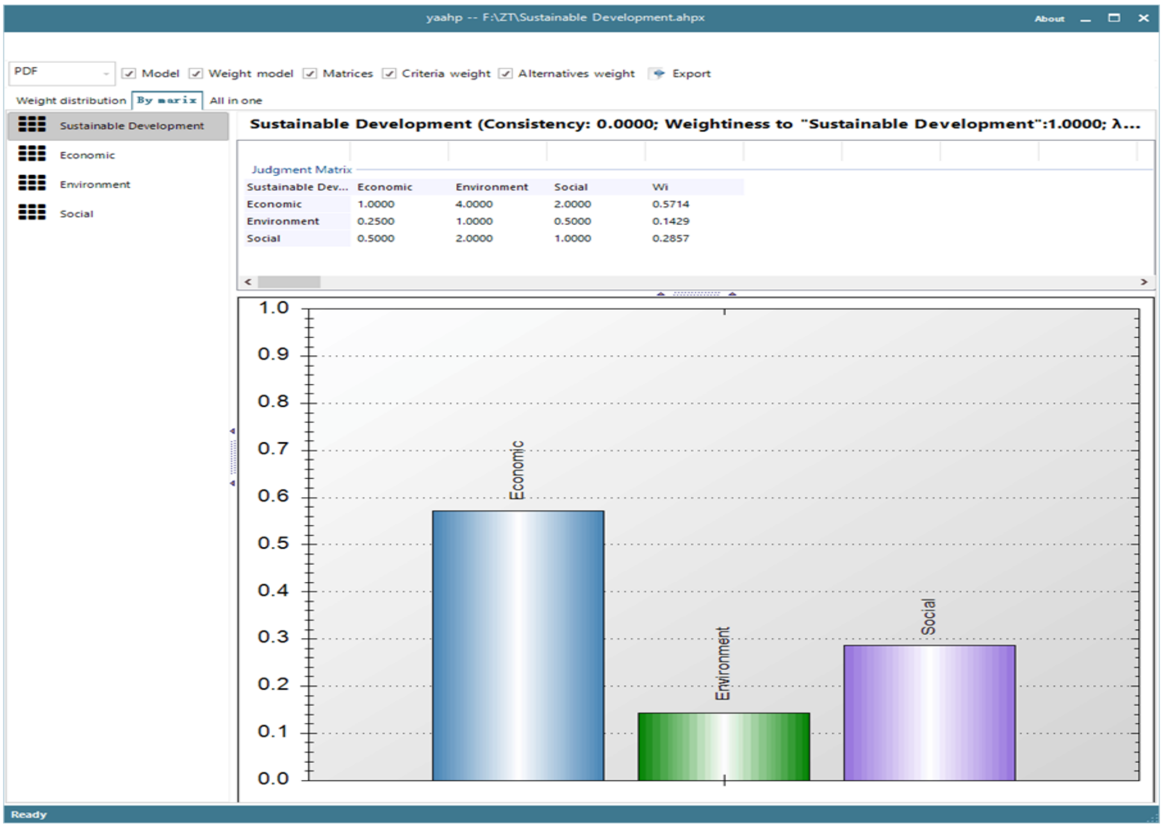


Figure 6.5 Weight calculation



6.5.2 Qualitative data analysis

The qualitative data in this study consisted of secondary data from the previous studies of sustainability assessment, construction projects, infrastructure projects and highway infrastructure projects. The data collected will determine the indicators of the sustainability assessment model. Other qualitative data included the response from the interviews which were used to refine the sustainability assessment model. The qualitative data was analysed by content analysis.

Titscher (2000) suggested that content analysis is 'the longest established method of text analysis among the set of empirical methods of social investigation.' As a flexible method for analysing text data, content analysis is widely used in qualitative studies (Cavanagh, 1997). It summarises any form of content by counting various aspects of the content, such as letters, articles, speeches and other written text, but also text in the visual media including video and film. This method allows an objective evaluation of the qualitative data by comparing content. Researchers believe that it offers the advantages of both quantitative and qualitative approaches, and it is usually used to examine the contents of written documents and transcripts of interviews (Berg, 1998).

In the study, the indicators from the previous studies of sustainability assessment frameworks and standards of highway infrastructure projects were first categorised, then coded and counted. Once the assessment model was developed, the interviews were used to refine the model. The interviews were recorded and transcribed, and then content analysis was used to analyse the transcripts. This analytical process was done conventionally without using any software programmes.

6.5.3 Reliability and validity

In order to ensure the research method achieved the greatest accuracy of response, it is important to check the reliability and validity of the research instruments. Reliability and validity are extremely important when conducting data analysis, both focus on the relationship between the measurement tools and results (Li, 2009). The two ideas are inextricably linked. Reliability tests how consistent or stable the instrument is, and validity is used to answers the question of how well does the measure or design do what it purports to do (Rosnow and Rosenthal, 2013)

Reliability

Reliability is the degree of consistency of research (Joppe, 2000). There are two types of reliability, internal reliability and external reliability. Internal reliability measures the result consistency of all items using an identical scale, and external reliability tests whether the study results are same over time. Reliability test methods include: split-half reliability which divides the test into two parts and measures each separately, and then, estimates the reliability of the whole test. Test-retest reliability is used to evaluate the consistency of a measure twice using the same participants. Equivalent-Forms reliability (also called parallel forms reliability) is used to assess the consistency of the results with two-tests constructs (Zeng and Huang, 2005). It uses two equivalent forms but different questions to measure the same construct with the same sample of people, and calculate the reliability from the two sets.

The most frequently used approach to measure reliability is Cronbach's alpha, developed by Lee Cronbach in 1951, which is a way of measuring the strength of the internal consistency in the test items (Tavakol and Dennick, 2011). It is considered a measure of scale reliability, and it is not a statistical test - it is a coefficient of reliability (Santos, 1999). The value of Cronbach's alpha coefficient is between 0 and 1, if all the test items are completely irrelevant, then the alpha coefficient = 0; if all the items are perfectly correlated, then alpha coefficient will approach 1 as the number of items in the scale approaches infinity. In other words, a higher the alpha coefficient indicates that the items have high correlations (Adamson and Prion, 2013). If the coefficient is less than 0.6, it will be considered that the internal consistency reliability is inadequate. When the coefficient achieves a value of between 0.7 and 0.8, the research has reliability. A coefficient between 0.8 and 0.9 means high reliability (Kline, 2000, p.13).

Validity

Validity refers to the degree of authenticity and accuracy of the study, it is defined as 'the degree to which a test measures what it claims, or purports, to be measuring' (Brown, 1996). Validity includes content validity, criterion-related and construct validity (Brown, 1996). Content validity refers to the extent to which the test questions represent contents or facets of a given construct. The aim is to test the adequacy of the individual questions and to explore the difference of each question by different responses (Wang, 2011). In this research, the content validity of the questionnaire was determined by the literature reviews and documents analysis, as well as experts' feedback in the pilot study.

Criterion-related validity examines the relationship between variables and criterion. The criterion is the outside criteria of the behaviour which is required to be tested (Wang, 2011). The validity in quantitative research is normally described as 'construct validity' (Wainer and Braun, 1988), it defines the corresponding degree of operational structure and is measured by the test results.

6.6 Ethical consideration

In social research, ethical consideration has been identified as one of the most important factors. Besides selecting suitable research approaches and strategies, it is important to consider the ethical issues of the research from the area (topic selection), data collection and analysis to the presentation of the result (Creswell, 2014, p.77). Ethical consideration was necessary in order to promote research quality and guard against inappropriateness and also to protect the participants and their organisations as mentioned by Creswell (2014). This research was undertaken with a high respect for the integrity and the confidentiality of the participants. The participants were informed that the information gathered would be treated confidentiality. The anonymity of individuals participating in this research was ensured. Ethical approval was obtained from the University's Ethics Committee before contacting the participants.

6.7 Conclusion

This Chapter presented the rationale for the methods adopted in this research and described the various stages of the research process. The research approaches and methods, data collection and data analysis, both quantitative and qualitative, were discussed in this chapter. The combined research approach was used to address the overall aim and objectives of the study. The results of quantitative research were based on larger sample sizes that are representative of the population, and the qualitative approach can provide a deeper understanding of the investigation. A questionnaire survey for determining the indicators and interviews to probe the experts' opinions on the sustainability assessment of highway infrastructure projects were undertaken. This chapter not only discussed in detail the methods used, but also the conditions of each data collection phase, including design and administration of questionnaires and interviews, the pilot study, sampling and ethical considerations. Data analysis will be provided in the following chapters.

The graphical representation of the research methods in this study is illustrated in Figure 6.6. The framework details the sequence of research activities, specifies all the data collection and analysis methods, and lists research results from each stage of the study.

Figure 6.6 Research diagram

Stage	Data Collection	Data Analysis	Results
Stage 1 Literature review	• Reviewed the theories of sustainable development and sustainable construction • Reviewed the secondary documents (national and local standard and regulations), journal articles and studies about sustainability assessment in highway infrastructure project	• Content analysis, coding the themes of the indicator	• Form the preliminary indicator system
Stage 2 Quantitative Research	• Pilot study • Questionnaire survey • Professionals from academic government and construction firms in Yunnan Province	• Statistics analysis by SPSS 23 and EXCEL 2016 • Reliability and Validity measure	• Scored the significances of the assessment indicators • Determined the indicator • Weighted the indicators by YAAHP 10.0 software
Stage 3 Qualitative Research	• Interview survey • Semi-structured, open-ended question • Professionals from academic government an construction firms in Yunnan Province	• Content analysis for interview transcripts	• In-depth qualitative data • Validated the assessment model; • Refined the assessment model

CHAPTER 7 - DEVELOPMENT OF SUSTAINABILITY ASSESSMENT MODEL FOR HIGHWAY INFRASTRUCTURE PROJECT

7.1 Introduction

The previous chapter demonstrated the need to build an evaluation system for sustainability in the context of highway infrastructure projects in Yunnan. This chapter will build the sustainability assessment model in four steps: the first step is to develop an indicator system for the sustainability assessment model. The data used to develop the preliminary indicators will be derived from existing sustainability assessment frameworks or systems. The second step is to determine the appropriateness of the indicators through questionnaire with three groups of experts, academic professionals, government officers and construction engineers. Analytic Hierarchy Process will be then used to weight indicators based on a questionnaire survey. Finally, an expert grading method will be employed to assess the sustainability of highway infrastructure projects in Yunnan.

7.2 Sustainability assessment model building process

The assessment goal is to achieve sustainability of highway infrastructure projects and the rules of the assessment practice defined in Chapter 4 are used to guide the development of the indicator system and assessment method selection. The sustainability assessment model building steps are outlined in Figure 7.1.

Figure 7.1 Sustainability assessment model building steps

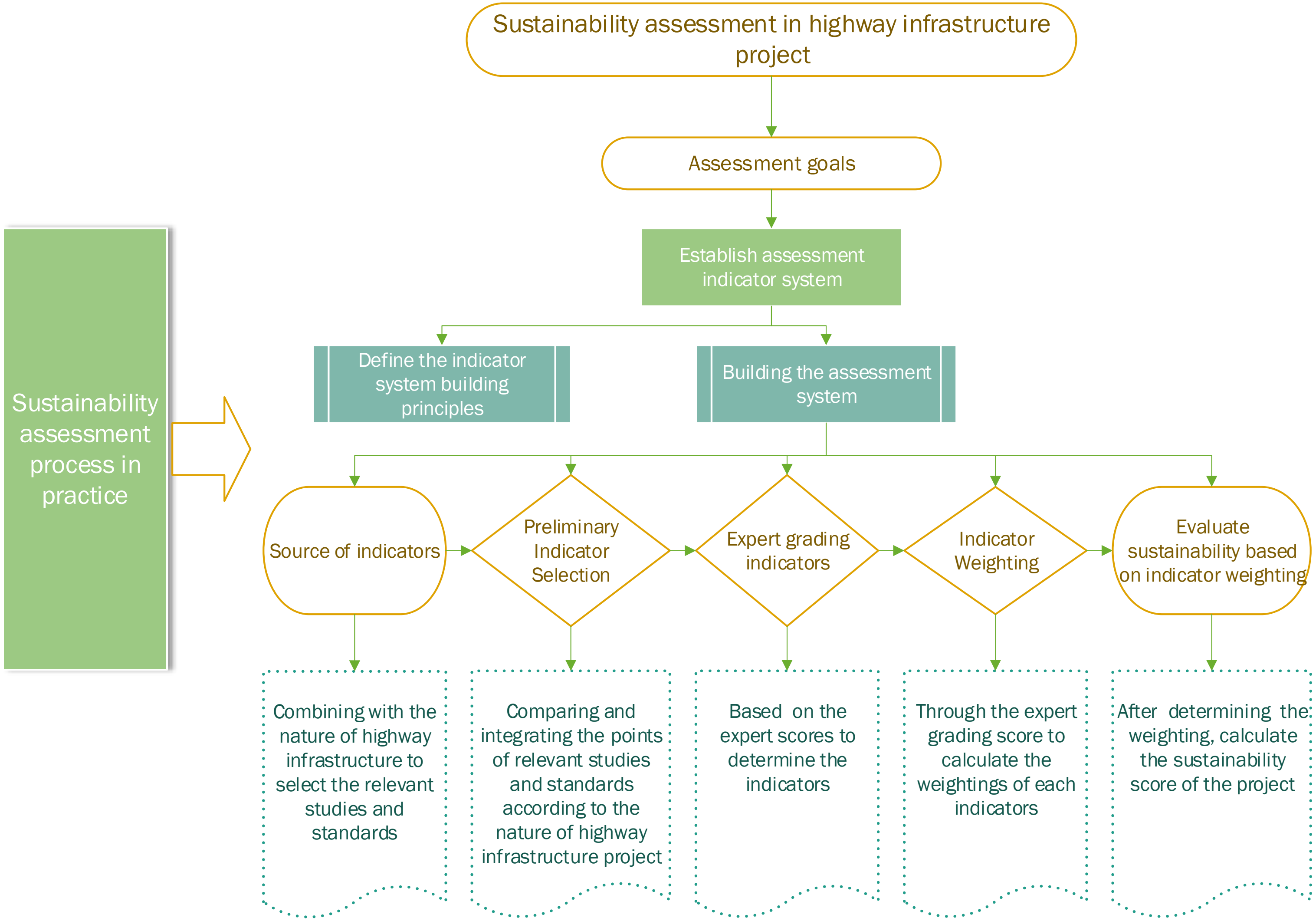


Figure 7.1 will be described step by step. The purpose of this research is to build a sustainability assessment model to provide a solution for current highway infrastructure projects in Yunnan. The assessment goal is to examine how activities related to highway infrastructure projects can make an optimal contribution to sustainable development in Yunnan. An indicator system will be built to achieve this goal with a set of indicator selection principles. The indicators were originally chosen from national standards and previous studies of construction projects and highway infrastructure projects. This step defines the local conditions and governments' requirements for highway infrastructure project development. The preliminary indicators are selected by experts through the questionnaire. The purpose of this step is to establish industry consensus on the importance of indicators and determine their weightings. Finally, based on the weighting of each indicator to evaluate the project sustainability.

7.3 Assessment goal and objectives

A sustainable highway infrastructure project should satisfy the lifecycle functional requirements of economic benefits, social development and environmental protection by technical innovation and good governance. It involves issues such as project structure design, urban development, road network planning, transportation network efficiency, social-economic adaptability, environmental impacts, resource utilisation, project management process, construction materials and technology, stakeholder participation, and other factors (Ma and Yang, 2001). The aim of sustainability assessment of highway infrastructure projects is to pursue the development plan and activities of highway construction in a sustainable way, taking into account all factors (Feng, 2009). According to the development trends in China and the circumstances in Yunnan, the objectives of sustainability assessment of highway infrastructure projects are: 1) provide evidence for decision-makers to achieve the sustainability goals; 2) guide the builders to construct the project in a sustainable way; and 3) improve sustainability awareness.

1) Provide evidence to decision-makers

Sustainability issues are encountered daily, and the government's regulatory framework recognises this problem. It is not limited to China, many nations set laws and regulations that require the construction industry to protect and enhance the environment, social development and economic growth. Legislation is in place requiring sustainable development as a decision-making strategy to ensure that there is a baseline for highway construction, in so far as it recognises that resources are finite, becoming progressively harder to extract or recycle (Ma and Yang, 2001). Whilst the regulations recognise the effects of construction on the environment, society's decision-makers will need evidence from the sustainability assessment to implement them.

2) Guide the builders to construct the project in a sustainable way

The sustainability assessment will guide the activities throughout the highway infrastructure project lifecycle, but also provides an alternative approach encouraging the use of new technology and materials.

3) Improve sustainability awareness

Using sustainability assessment to review the relevant activities for highway infrastructure projects will improve the environmental awareness and sustainability in the construction sector

7.4 Indicator system of sustainability assessment model

7.4.1 Purpose of the indicators

The indicators provide a measure of the value representative of the relevant phenomenon being considered. In general, indicators quantify information by aggregating different and multiple data, and the resulting information is therefore synthesised. In short, indicators simplify information to reveal complex phenomenon (European Commission, 2002).

In this research, the indicators can be referred to as the criterion for the sustainability assessment of highway infrastructure projects. They illustrate and reflect the development level of highway infrastructure projects, the conditions of the project lifecycle, and measure the importance of influencing factors (Nie and Chen, 2008). In order to achieve these outcomes, the indicators must be representative, independent, credible, transparent, practical and easy to obtain (Shao *et al.*, 2004).

7.4.2 Indicator selection principles

The indicators cover all potential factors affecting the sustainable highway, so the indicator selection can strongly influence the accuracy of the assessment results (Shi, 2007). In order to produce effective measurement, principles for indicators selection are being proposed. Currently, there are many principles for sustainability assessment indicator selection, on the basis of findings from the previous studies, three principles are presented below.

Sustainable development principles

The purpose of the assessment is to achieve sustainability in highway infrastructure projects, so sustainable development principles are first used to guide the design of an assessment indicator system. Underlying economic, social, environmental, technological and governance components of the sustainable development should be considered. Furthermore, highway infrastructure projects involve many stakeholders with different requirements and expectations which must be considered to ensure the sustainability assessment criteria meets their demands.

Consider local conditions

Different regions have different conditions that result in various development targets and strategies. The main standard for sustainable building, the Evaluation Standards for Green Buildings of Yunnan (2011) proposed a general rule that the assessment should consider the local conditions when evaluating any construction projects, including resources, climate, natural environment, social, economic, building technologies and other aspects. For example, Lu and Lei (2013) selected as an indicator of the number of bridges and tunnels built across the Yangtze River in sustainability assessment indicator system of highway infrastructure projects. Because the Yangtze River cuts through Hubei from west to east with length of 1,062 kilometres, highway construction is faced with many bridge and tunnel projects, and the construction costs and quality requirements for these projects are higher than road pavement (Editorial Department of China Journal of Highway and Transport, 2015). In the study by Ma *et al.* (2010), the authors identified indicators for the development of minority areas and ethnologic culture protection in the sustainability assessment indicator system in Xinjiang Province. The province, also called Xinjiang Uyghur Autonomous Region, it is the largest Chinese administrative division and home to many minority groups including the Han, Kazakhs, Tajiks, Hui, Uyghur, Kyrgyz, Mongols, and Russians, accounting for 59.9% of the total population. Compared to Hubei Province, the province contains large areas of desert and pastureland, scarce water resource is the main problem of province, and the indicator of construction of desert highways is considered more important. On the other hand, the biggest ethnic group in Hubei is Han, which is the majority group in China, with only 4.3% of the population from minority groups. Therefore, the factor of minority groups was not included in the indicator system for assessing sustainability in Hubei.

Operational principle

The overall operational principle of highway infrastructure projects sustainable assessment is operability, which means adopting a simple and straightforward indicator selection process to make the data collection and quantity indicator process uncomplicated and reliable (Liang, 2016).

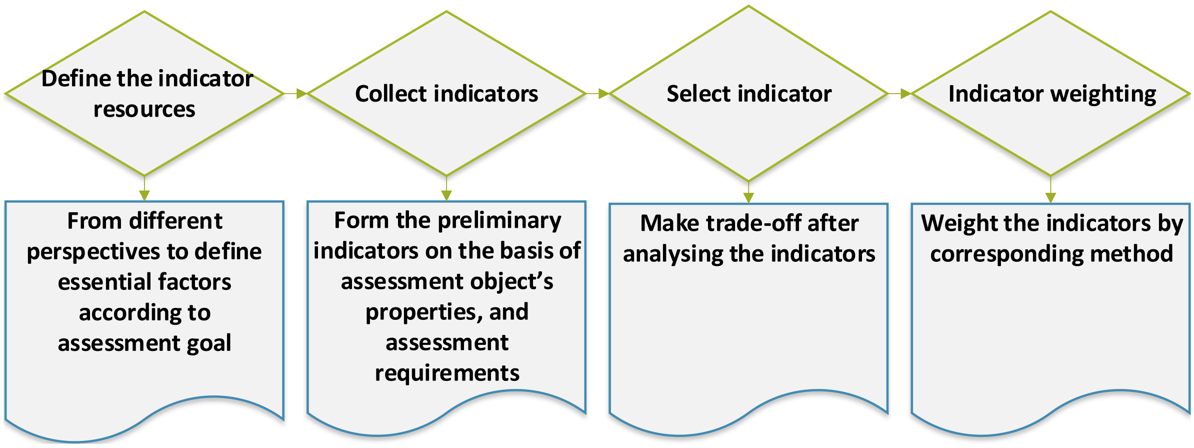
Relevance principle

In order to be useful for evaluating sustainability in highway infrastructure project, the indicators must be relevant. Yan *et al.* (2013) stated that relevant indicators are useful and needed for decision-making, and should be linked to sustainability goals and objectives of the assessment.

7.5 Indicators formulation process

The indicator system is designed to generate information by using a set of indicators working together to facilitate the assessment process and achieve maximum sustainability in highway infrastructure projects (Ma *et al*., 2010). The indicator development process in this study firstly considered the sustainability requirements associated with highway infrastructure projects in Yunnan based on the above indicator selection principles. Then, guided by the assessment objectives and goals, the formulation of the indicator system was a selection process, and also a relationship building process between different indicators. Figure 7.2 shows the indicator formulation process which includes four steps.

Figure 7.2 Indicators formulation steps



There are numbers of indicators for measuring sustainability, but no standardized indicators are available, and the local conditions and value systems are diverse. The indicators originate from existing data and information which can reflect the characteristics of the sustainable highway infrastructure projects. Indicators are identified and validate through a focused exercise using both questionnaires and interviews with experts from government, academia and the construction industry. The process provided knowledge and experience from various perspectives by different groups of people. The questionnaire allows quantification and more precise estimation of probabilities, the interview provided a better understanding of each of the indicators.

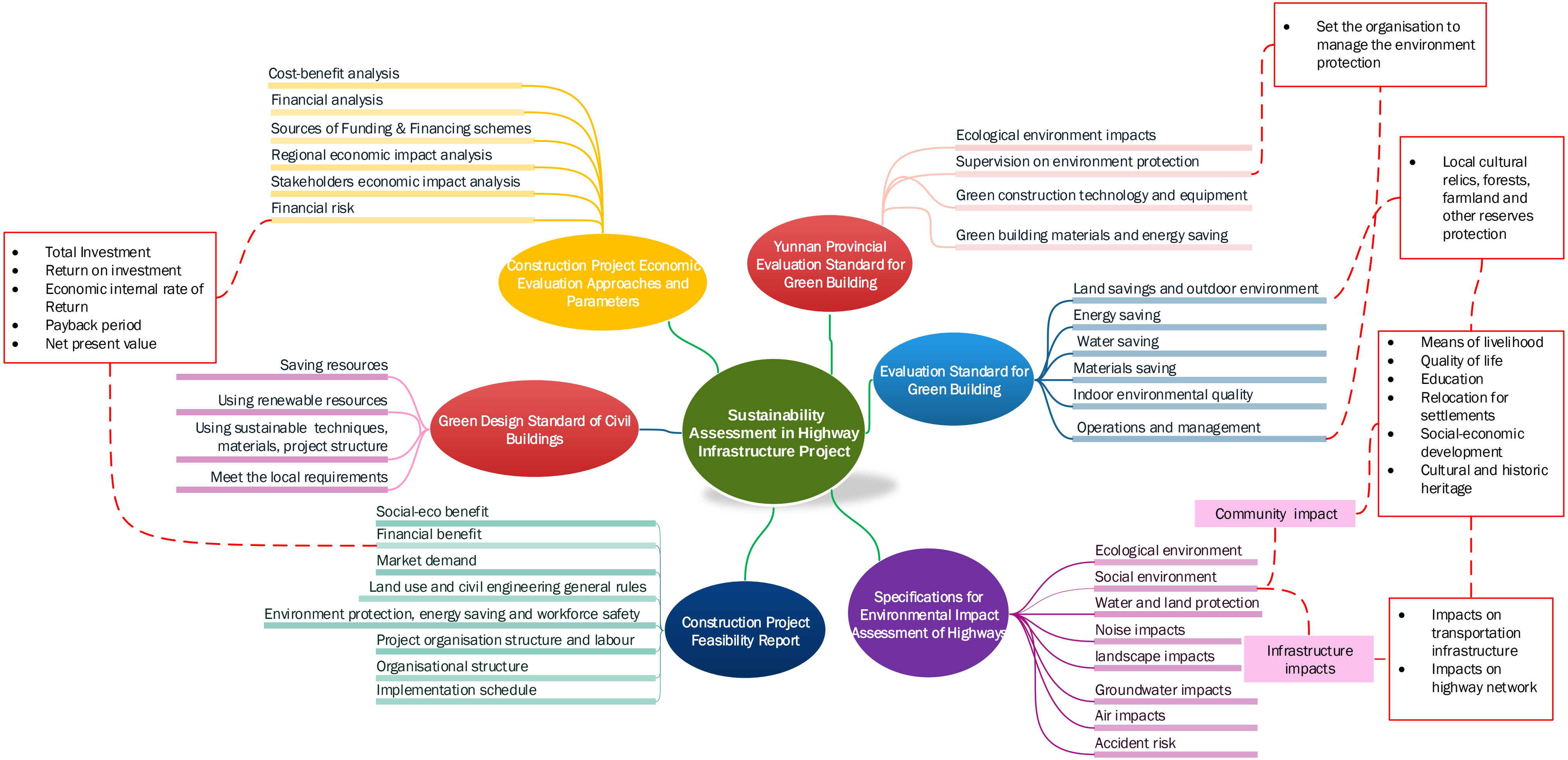
7.5.1 Indicator resources

The first step of indicators formulation is to define the indicator resources. Seven standards of highway infrastructure projects construction in China and Yunnan Province were initially used to select the indicators (Table 7.1). These standards are from official documents which can provide the basis for sustainability assessment and help to achieve the accuracy of the preliminary indicators selection.

Table 7.1 Main sustainable construction standards in China

Standards	Projects	Evaluation Aspects
Evaluation Standard for Green Building GB/T50378-2014 (2014)	Building project	Provide general principles and basic provisions for: outdoor environment, energy-saving and energy, water conservation and utilisation of water resources, the use of material resources, indoor environmental quality, construction management, operations management, improvement and innovation.
Green Design Standard of Civil Buildings JGT/T229-2010 (2010)	Infrastructure project	The formulation of the standard is to reflect the basic keystone for sustainable development in civil buildings. On the condition of meeting the construction requirements to realise resources saving and environmental protection in the project lifecycle.
Construction Project Economic Evaluation Approaches and Parameters (2006)	Construction project	Permits decision-makers and analysts to look at a project from the perspective of various stakeholders, particularly the implementing agency, and society in general. Mainly considers the aspects of the economic analysis of the construction project.
Specifications for Environmental Impact Assessment of Highways JTG B03-2006	Highway infrastructure project	To ensure the environmental impact assessment of highway infrastructure projects set this specification. It evaluates the socio-economic impact, environmental impact, noise impact and air quality impact.
Technical instructions for Green Building Evaluation (Planning and Design Section) (2015)	Construction project	A supplement to the Evaluation Standard for Green Building (2006); applies to planning and design stage, and Evaluation Standard for Green Building applies to construction and operation stage.
Yunnan Provincial Evaluation Standard for Green Building (2011)	Residential and public buildings construction	The key aspects include green building design technology, energy-saving technology and equipment, building integrated renewable energy devices technology
The Guideline of Investment Project Feasibility Study (2002)	National Development and Reform Commission	Defines the scope and techniques of feasibility study for engineering projects, and guides the preparation of feasibility study report. It not only covers the project backgrounds, market forecasting, project economic benefits, institutional organisation and human resource assignment, but also concerns the impacts on the environment, people and local community.

Figure 7.3 Key assessment factors from industry standards



The key factors from the standards and regulations of sustainability assessment for highway infrastructure projects are showed in Figure 7.3. These standards are issued by national and local authorities and are usually recommended as guidelines for the sustainability assessment of highway infrastructure projects. The emphasis of these standards is on saving energy and resources, reducing noise, air and water pollution, increasing social and economic benefits, using new technologies and building an appropriate organisational structure. Finally, the emphases from standards were thematically categorised in the five aspects by the content analysis method as shown in Table 7.2.

Table 7.2 Assessment indicators categories

Code	Category	Sub-category
A	Environment aspect	A1 Land use
		A2 Energy and resource use
		A3 Environmental pollution
B	Social aspect	B1 Coordination with overall development plan
		B2 Impacts on social life
C	Economic aspect	C1 Cost and economic benefits
		C2 Financial benefits
		C3 Impact on local economy
D	Technological aspect	
E	Governance aspect	

The sustainability assessment of highway infrastructure project aims to examine whether the project development process is undertaken in a sustainable way. Therefore, the six sustainable development principles of construction projects in Chapter 3 were used to guide the indicator selection, including respecting environmental limits, meeting social development needs, contributing to economic development, promoting good governance and containing both short-term and long-term goals. In this research, the six principles were used to focus the categories of indicators to: environmental, social, economic, technological and governance aspects. The long-term and short-term goals were included for the impacts on environment, social and economic aspects through technological capability and project management. For example, reducing energy and resource use can reduce the long-term environment impacts, it also can reduce the construction costs. It is important to understand that the contributions and impacts of a highway project on the local economy and environment sometimes take decades to realise, and investment on highway infrastructure project is taken with a long term view. Indeed, sustainability of highway projects take a long term view when most society models are typically based on short term financial benefits.

The standards tend to focus on the environmental impacts and project economics. Even where there is some reference to human life, more emphasis on sustainability needs to be included in the assessment criteria. Also, the trends at the local level need to be included in the assessment. Therefore, seventeen existing sustainability assessment frameworks and systems for highway infrastructure projects, construction projects and transportation infrastructure projects were used as alternative indicator resources (Table 7.3).

According to the China Integrated Knowledge Resources Database, there are no studies on sustainability assessment of highway infrastructure projects in Yunnan, therefore, seventeen assessment indicator systems were selected from other provinces to identify the most suitable for determining the sustainability of projects. According to China Integrated Knowledge Resources Database, these seventeen studies chosen have been cited over 100 times and are representative studies in this area, they can provide the references to build the sustainability assessment model for Yunnan. For example, Sichuan Province is the neighbouring province to Yunnan and shares a similar culture and environment. Hubei Province has complex landscape, like Yunnan with several rivers running through the region. Xinjiang is a border province of China with multi-ethnic groups, again, like Yunnan. Shanghai, the most developed area in China, was the first to build a sustainability assessment system for highway infrastructure projects and has a more comprehensive approach than other places. The experiences in sustainability assessment can be built upon by Yunnan Province. Table 7.3 lists indicators from the studies of other provinces in China.

Table 7.3 Relevant studies of the sustainability assessment indicators

Relevant studies	Study area	Related indicators
Shen *et al.* (2011)	Sustainability of infrastructure project	Financial risk, lifecycle benefit/profit, public safety, effects on local development, provision of ancillary amenities to local economic activities, effects on air quality.
Chen and Liao (2009)	Road project	Road network density, road network connectivity, regulation support capacity, clean energy use rate, technology innovation, safety, noise impact.
Shi (2007)	Construction project	Site selection, planning, construction, operation management.
Sun and Li (2013)	large-scale transportation infrastructure	Financial net present value (NPV), financial internal rate of return (IRR), national economic benefit, natural resources consumption, application of new technology, the rationality of the planning.
Lu *et al.* (2009)	Highway Project	Impacts on local, regional and national socio-economic development, price of inputs and outputs; benefit to transportation network.
Chen and Fu (2009)	Highway project	Site management, feasibility of uses of renewable resources, construction costs, owner commitment, stakeholder management, cost-benefit analysis, decision for conservation, impact on adjacent property, land use, sensitivity of site, reuse of building, structure, resources.
Zhang *et al.* (2005)	Highway project	Cost/benefit ratio, NPV, IRR, utilisation of energy and non-renewable resources, attract investment.
Peng (2010)	Highway project	Increased labour demand and employment opportunities, reduced travel time, contribute to road network and transportation network.
Chen and Tian (2008)	Highway project	Enhance the internal governance and management, communication capability, social and economic development, environmental impacts control.
Zhu *et al.* (2010)	Construction project	Impacts on landscape, water, air and eco-environment, waste control, energy saving, public infrastructure and facilities setting.
Ge *et al.* (2006)	Highway project	Promote the political stability, social and economic development, enhance sustainability awareness, pollution control and environmental protection.
Lu and Yuan (2013)	Highway project in Hubei Provinces	Yangtze River bridge /tunnel numbers, adaptation of local culture.

Relevant studies	Study area	Related indicators
Liang (2016)	Highway project	Improve the capability of services, contribution to economic and social development, save resources and energy, coordination with other transportation methods and organisations.
Liang (2014)	Highway project In Shanxi Province	Construction project finance indicators (static payback time, profitability, solvency and ability to resist risks, cost etc.), impacts on local economic and social development, and environment.
Feng (2009)	Highway project Sichuan Province	Contribute to social development and political stability, improve the project quality by new technology and management, coordination with other transportation methods, regulations and governance system.
Ma *et al.* (2010)	Highway project Xinjiang Province	Bring a coordinated development of regional economies, reduce unemployment, promote strategic restructuring of the economy, increase state revenue, promote population increase, promote equity and competitiveness, to strengthen the military defence level, bring development of minority areas and protection of ethnologic culture.
Dai *et al*. (2004)	Transportation project Shanghai City	Population growth rate, GDP per capita, traffic congestion time, transportation facilities, land resources, fuel types, traffic accessibility.

7.5.2 Collecting indicators

There are total sixty-seven indicators included in the twenty-four standards systems and existing assessment frameworks (Table 7.4). The sixty-seven indicators were coded and classified with content analysis by EXCEL.

Table 7.4 Indicator resources

Related Indicators	Code
A. Environment aspects	
A1. Land use	
Impacts on farmland	*S1*
Impacts on forests	*S2*
Pollution on land	*S3*
Project site suitability	*S4*
Overall plan of urban development	*S5*
A2. Energy and Resource use	
Total lifecycle primary non-renewable energy use	*S6*
Electrical peak demand	*S7*
Materials use	*S8*
Renewable energy use	*S9*
Ecological resources use	*S10*
Resources and materials recycle	*S11*
A3. Environmental pollution	
Greenhouse gas emissions	*S11*
Other atmospheric emissions	*S12*
Solid wastes	*S13*
Other air pollution	*S14*
Waste water pollution	*S15*
Pollution of groundwater	*S16*
Pollution of rivers	*S17*
Pollution of potable water	*S18*
Noise pollution	*S19*
Electromagnetic pollution	*S20*
Light pollution	*S21*
B. Social aspects	
B1. Coordinating with overall development plan	
Project function	*S22*
Project multiple uses	*S23*
Improvement on road network efficiency	*S24*
B2. Impacts on social life	
Political stability	*S25*
Reduced travel time	*S26*
Providing job opportunities	*S27*
Improvement of public health	*S28*
Effects on development of local education	*S29*
Protection of cultural and natural heritage related to the project	*S30*
Resettlement work	*S31*
Acceptable to different stakeholders	*S32*
Coordination with various organisations	*S33*
Serviceability	*S34*
Impact on quality of life	*S35*
Impacts on local culture	*S36*
Impacts on landscape	*S37*
Impacts on means of livelihood	*S38*
C. Economic aspects	
C1. Cost and economic benefits	
Lifecycle cost	*S39*
Return on Investment (ROI)	*S40*
Net Present Value (NPV)	*S41*
Cost/benefit ratio	*S42*
Internal Rate of Return (IRR)	*S43*

Related Indicators	Code
Lifecycle profit	*S44*
C2. Financial benefit	
Project financing channel	*S45*
Project investment planning	*S46*
Financial risk	*S47*
Payoff period	*S48*
Project budget	*S49*
C3. Impacts on local economy	
Contribution to improvement of people's income and living standards	*S50*
Contribution to local economy development	*S51*
Attract investment	*S52*
Increase tax income	*S53*
D. Technological aspects	
Controllability	*S54*
Advantage of project technologies	*S55*
Improvement of road network efficiency	*S56*
Maintainability	*S57*
Extendibility	*S58*
Disaster prevention capability	*S59*
Flexibility and adaptability	*S60*
Project quality	*S61*
New energy use	*S62*
E. Governance aspects	
Administrative rules	*S63*
Rationality of project design and planning	*S64*
Rationality of organisational structure design	*S65*
Sound governance systems	*S66*
Employees performance assessment	*S67*

According to Cao *et al.* (2010), the number of indicators depends on the nature of the evaluated project and evaluation purposes, it should not only choose relevant indicators but also avoid using indicators which may result in duplication. Therefore, the duplicated indicators were combined, any individual indicators which appeared over seven times (occurrence rate 25%) were formulated into a preliminary indicator list. The Specifications for Environmental Impact Assessment of Highways JTG B03-2006 integrates pollution of groundwater, pollution of rivers and pollution of potable water into one indicator – impacts on water. In the same manner, impacts on farmland and impacts on forests were combined into one indicator- impacts on land. In total, thirty-nine duplicated indicators were selected as shown in Table 7.5 and grouped into five categories, there were thirteen indicators covering economic sustainability, eight indicators dealing with social sustainability, nine indicators involved with environmental sustainability, six indicators were within technological sustainability and three indicators are governance sustainability.

Table 7.5 Preliminary list of indicators

Aspects	Code	Indicators
Economic aspect	*S1*	Lifecycle cost
	S2	Project budget
	S3	Project financing channel
	S4	Project investment planning
	S5	Lifecycle profit
	S6	Financial risk
	S7	Return on Investment (ROI)
	S8	Net Present Value (NPV)
	S9	Payoff period
	S10	Internal Rate of Return (IRR)
	S11	Cost/benefit ratio
	S12	Contribution to local economy
	S13	Contribution to improvement of people's income and living standards
Social aspect	*S14*	Providing job opportunities
	S15	Improvement of public health
	S16	Effects on development of local education
	S17	Protection of cultural and natural heritage related to the project
	S18	Resettlement work
	S19	Suitable to different stakeholders
	S20	Coordination on various organisations
	S21	Serviceability
Environmental aspect	*S22*	Effects on land (e.g. Land consumption and land pollution)
	S23	Effects on ecological environment (changes on climate and local geology)
	S24	Effects on air quality
	S25	Effects on water quality (produced waste water, consumption of water resource, potential contamination)
	S26	Noise pollution
	S27	Waste disposal
	S28	Use of green energy sources
	S29	Energy saving
	S30	Effects on natural landscape and historical sites
Technological aspect	*S31*	Advantage of project technologies
	S32	Coordination with other transportation projects
	S33	Improvement of road network efficiency
	S34	Maintainability
	S35	Extendibility
	S36	Disaster prevention capability
Governance aspect	*S37*	Rationality of project design and planning
	S38	Rationality of organisational structure design
	S39	Sound governance systems

Each aspect listed in Table 7.5 can be expanded upon as follows:

Economic sustainability assessment

Economic sustainability assessment tends to emphasise the impacts on two levels, that is, public and project. In other words, the evaluation is to ensure a sound financial basis for the project to maintain value in the development process, and determine if the highway infrastructure project development brings economic benefits to the local area (Peng, 2010).

The impacts on local economics were reflected by the indicators of support for the improvement of living standards and enhancing the benefits to all members of society.

The project financial data was used to evaluate the economic benefits of a project, including indicators lifecycle cost and profit, project budget, project financing channel, project investment planning, payoff period, financial risk, Internal Rate of Return (IRR), Net Present Value (NPV) and Cost-benefit ratio. The financial analysis of major infrastructure projects has traditionally emphasised the decision-making process, it can be used to estimate project outputs (Moutinho and Lopes, 2011). The goal of project financial analysis is to determine whether to take on the project, to calculate its profits and to ensure stable finances throughout. In other words, financial analysis evaluates project liquidity and profitability. The evaluation of the economic performance at the project level is unlikely to proceed if it is financially unviable based on the financial indicators (National Development and Reform Commission [NDRC], 2006).

Social sustainability assessment

Social sustainability assessment refers to the systematic appraisal of impacts on the quality of life of local people affected by highway infrastructure projects. It focuses on improving public health, employment opportunity and education, protection of cultural and natural heritage, meeting the demand of commodity circulation, immigration resettlement by highway infrastructure project land requisition, means of livelihood, transportation and communication of people along the highway, improvement of transportation system and other issues related to social development.

Environmental sustainability assessment

The environmental indicators focused on environmental protection, reducing impacts on wildlife and forest land, reducing noise impacts and natural resources utilisation, reducing impacts on water, land and air and reducing greenhouse gas emissions. At the same time, improving health and safety, encouraging eco-renovation and cost-effective techniques for new construction, improving the efficiency of land use and rationalising the land use structure, establishing a comprehensive ecological strategy.

Technological and governance sustainability assessment

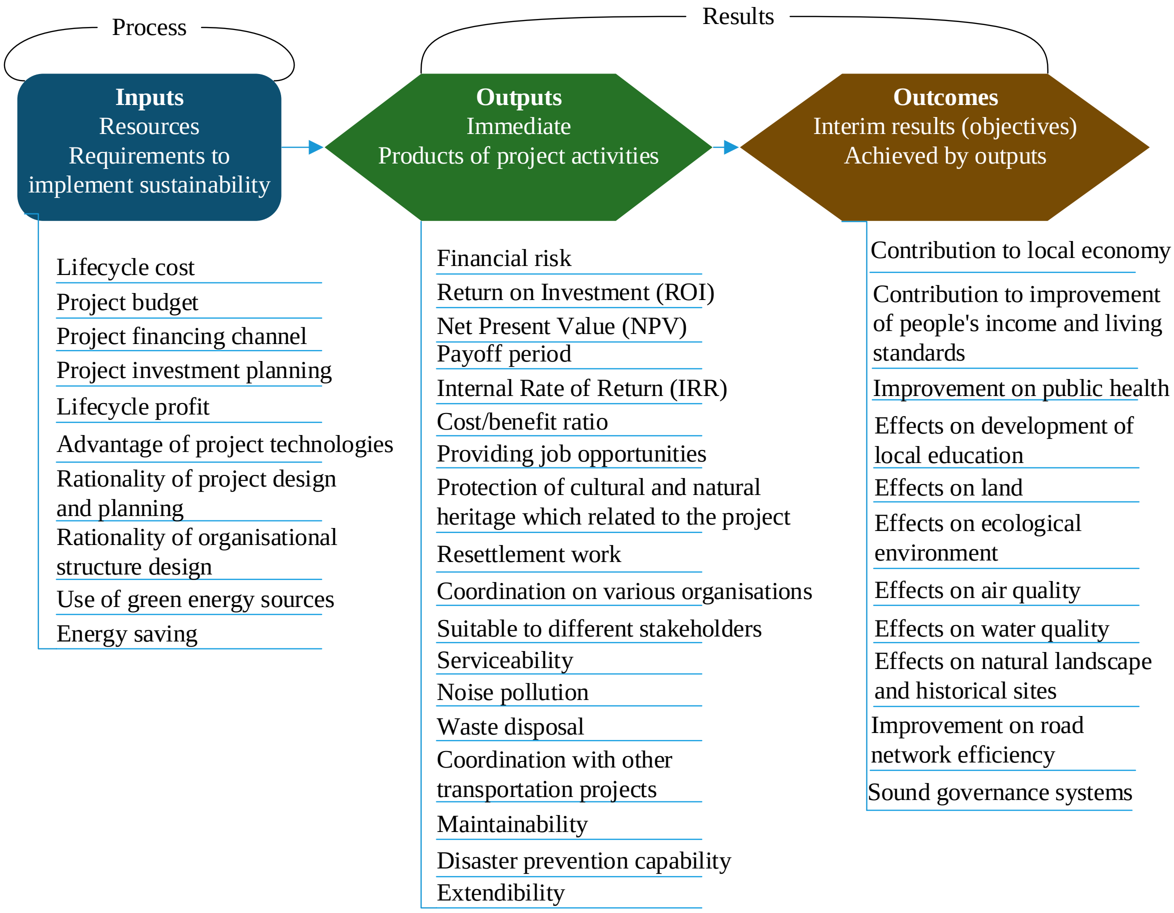
Technological sustainability assessment includes the influences on the road network, services provided by highway and impacts on other aspect caused by the techniques and technologies. The governance sustainability assessment tended to evaluate the management efficiency of the highway infrastructure project from pre-development stage to post-operation stage including the project planning and design, organisational structure and governance systems.

7.5.3 Types of indicator

The indicators of the aspects related to the design of the route, pavement, subsoil, bridge construction and traffic facilities use of the highway infrastructure project are based on the rationale used to construct the project through a sound management system, well organised structure and advanced technologies and techniques. This will eventually achieve the goal of saving time and improving safety, reducing construction cost and increasing benefits, and efficiency of the highway infrastructure (Peng, 2010). Evaluating if the project construction meets the design goals were focused on maintainability and extendibility of the project, coordination with other transportation projects, improvement in road network efficiency, and the capability of preventing project risks (e.g. natural disasters).

Indicator development in this study was based on the following rules: firstly the sustainability requirements associated with highway infrastructure projects in Yunnan were considered based on the above indicator selection principles. Then, guided by the assessment objectives and goals, the sustainability assessment in highway infrastructure project evaluated the conditions and activities (input) in project lifecycle improvement results (output) of the project. Therefore, evaluation of sustainability should include the process and results indicators (Cao and Wang, 1998). Inputs ensure that it is possible to deliver the intended results of a project; outputs are the direct immediate results associated with a project. In other words, they are usually what the project has achieved in the short term. The assessment also evaluated not only the input and output, but also the outcomes, that is, the medium or long-term consequences of the project. Figure 7. 4 shows the result chain of sustainability assessment indicators, it provides a theoretical model for defining the interrelated indicators of a highway infrastructure project required for its sustainability.

Figure 7.4 The result chain of indicators



As Figure 7.4 shows, input indicators are the requirements to implement sustainability in project, if the necessary input requirements are not available the project cannot be constructed using a sustainable approach. For example, in a sustainability highway infrastructure project, input can be ‘use of green energy source’, it can reduce the effects on the ecological environment, reduce the effects on land, and ‘an appropriate investment planning’ can reduce the financial risk and contribute to the local economy and improve people’s living standards. Sustainability assessment not only evaluates the use of external sustainable inputs in a project’s lifecycle, but also enhances the reduction of inputs and moves towards sufficiency. The input indicators calculate the financial investment (e.g. lifecycle cost, budget, financing channel and etc.), energy (e.g. use of green energy sources) and elements of management (e.g. project design and planning and organisational structure) introduced into the project development. It evaluates to what extent the production process depends on these inputs.

The project output and outcomes are both the result of the project, there is often confusion about the two terms. To distinguish between them is to consider whether the indicator describes project effectiveness. Outputs are the products or services delivered by the inputs and outcomes are the short and medium-term benefits that those products deliver. For example, reducing the financial risk and producing cost are outputs; they offer no indication of whether the project investment improves effectiveness. The outcomes for a project, their medium or long-term effects, may include development of the local economy, improving people's living standards, and reducing effects on the ecological environment.

The output indicators produce some of the classic indicators of highway infrastructure project construction efficiency (e.g. Return on Investment, Net Present Value, cost/benefit ratio, and etc.), and also includes specific sustainability requirements (e.g. coordination with other transport projects, improvement of the road network, extendibility and so on).

7.5.4 Indicators validation by questionnaire

Since this research is intended to develop a new sustainability model, different indicator systems already in existence, experts' experiences and knowledge were obtained using a questionnaire to help in the determination of the most appropriate indicators. The assessment indicators were initially selected through the mean scores from the participants' opinions on the relative importance of each indicator, and considering the comments or adjustments made by the participants. Secondly, the findings from the questionnaire were used to assign a weighting to each selected indicator, the calculation process of which is explained in the following sections.

7.5.4.1 Questionnaire design

The questionnaire was designed and then distributed to experts in Yunnan to measure their perception of the sustainability assessment indicators of highway infrastructure projects (Appendix I). There are two parts of the questionnaire, the first part was personal information of the participants including nature of employment and number of years of work experience. These questions can determine if the respondents have experience in dealing with sustainability in highway infrastructure projects. The second part created a score for the thirty-nine indicators. The participants graded the indicators using a five-point Likert scale which allowed them to express the significance of the preliminary indicators.

A score of ‘7’ indicated very high significance, ‘5’ indicated high significance, ‘3’ average significance, ‘1’ low significance, and ‘0’ not relevant. If the participants considered that there were omissions or changes were needed for the indicator, they could give comments. At the end of this part of the questionnaire, a blank space was provided for respondents to provide general or specific comments about the indicators.

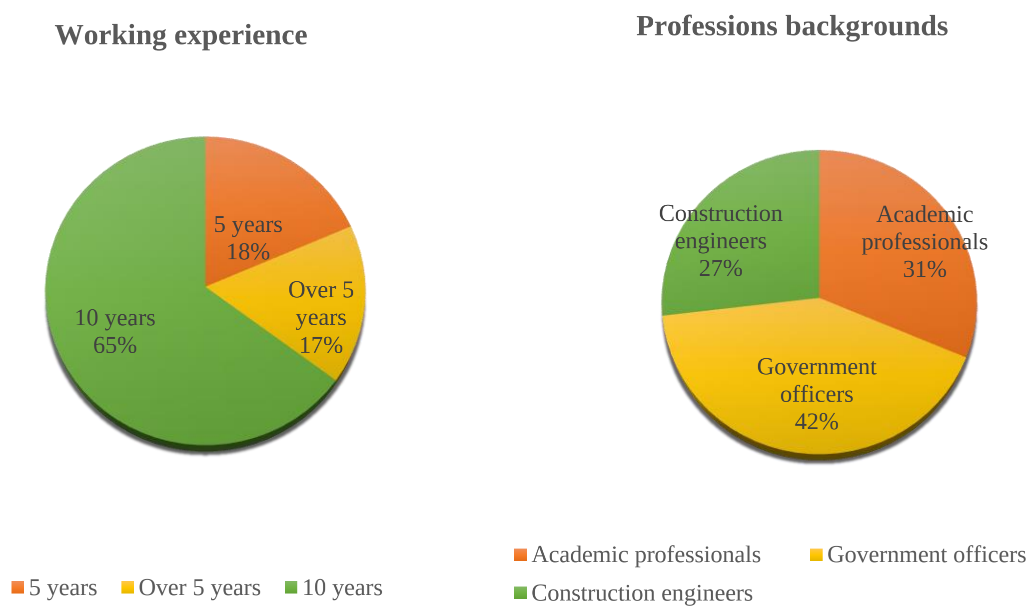
The length of the questionnaire was three pages, in general, long questionnaires get fewer response (Galesic and Bosnjak, 2009), it could be assumed that the length of the questionnaire used in the study would not affect the response rate. Twenty questionnaires were sent to participants from industry and Yunnan University of Finance and Economics to test the research process. According to the participants’ feedback, they needed fifteen minutes to complete the questionnaire, email and hand delivery were both acceptable distribution methods for the participants.

100 professionals participated in the survey to identify any missing indicators and validate the proposed indicators. Thirty-four questionnaires were sent via the internet, with the remaining sixty-five questionnaires hand delivered. Senior managers of Yunnan Highway Development and Investment Co., Ltd with 17,000 employees and Yunnan Construction and Investment Holding Group Co., Ltd with 7000 employees were contacted first. The two companies are major highway construction contractors in Yunnan Province, involved in activities related to road building, maintenance, supervision, investment and providing transport services for highway construction. After gaining approval by the managers, the survey was distributed to senior staff members with relevant experience in this area. This approach was also used for the Transport Department, Development and Reform Commission of Yunnan Province. Two department directors from government were contacted first, and with their help the questionnaire was sent to other regulators, decision-makers and consultants in the government.

7.5.4.2 Participants analysis

The respondents of this study comprised of three groups of experts including academic professionals, government officers, and construction engineers, all practicing in the relevant area of highway infrastructure projects in Yunnan Province. By the end of November 2016, a total of eighty-eight questionnaires were returned, of which sixty- seven were valid, giving a response rate of 88%, and an effective questionnaire return ratio of 67%. Fifteen respondents indicated no experiences in sustainability even though they had over five years working experience in the construction industry, and six questionnaires were incomplete, so their responses were not used in the study. Among the sixty-seven respondents, twenty-one were academic professionals, twenty-eight were government officers and eighteen were construction engineers. Twenty-seven respondents had five years working experience, twenty-four respondents had working experiences more than five years, and sixteen respondents had ten years or more working experiences (Figure 7.5). They all have knowledge and experience of the research area ensuring the response quality.

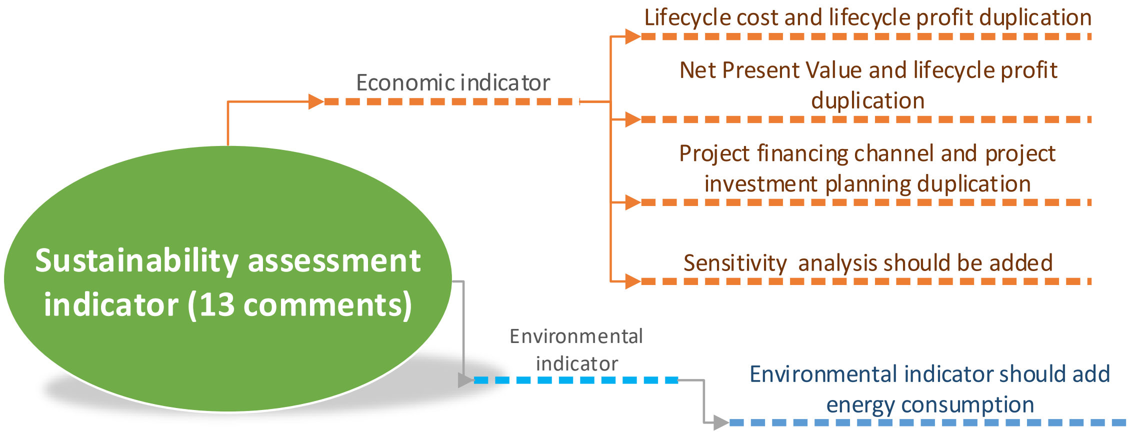
Figure 7.5 Backgrounds of the experts



7.5.4.3 Comments on indicators

The data analysis of the questionnaire commenced with comments on indicators to ensure all the important indicator were included in the survey. Thirteen (19.4%) responses suggested that the indicators needed correction. The comments were grouped according to the specific problems shown in Figure 7.6

Figure 7.6 View of comments about indicators



The comments focused on economic and environmental indicators. The Construction Project Economic Evaluation Approaches and Parameters (NDRC, 2006), Specification on Compiling Feasibility Study Report of the Construction Project (2006) and relevant standards and studies were reviewed to address these comments.

Six responses commented that the indicator of ‘Lifecycle profit’ (LCP) duplicates ‘Lifecycle cost’ and ‘Net Present Value (NPV)’. LCP is regarded as the project investment profit, the analysis of LCP is included in Lifecycle cost (LCC) analysis, cost/benefit analysis and Net Present Value (NPV) analysis (Cao and Dong, 2012). According to Shi and Huang (2015), the large-scale construction project economic assessment of profit includes NPV, Return on Investment (ROI), Payoff Period, cost/benefit ratio, and the LCP is a part of LCC. Therefore, the ‘lifecycle profit’ was removed in this study.

Five responses suggested that ‘Sensitivity analysis’ should be added. As a technique for investigating the impact of changes in project variables, it is an indicator for evaluating economic sustainability (Iloiu and Csiminga, 2009). Sensitivity analysis is an economic analysis indicator in the project feasibility report for making a judgement on project risk, using the IRR, NPV, Payoff Period and relevant financial indicator to analyse the uncertainty factors of the project (Lang, 2007). In this study, IRR, NPV, Payoff period and Financial risk were included as assessment indicators, and the indicator of ‘Financial risk’ includes break-even point analysis and sensitivity analysis (NDRC, 2006). For this reason, 'Financial risk' was retained and 'Sensitivity analyses' was not added.

The indicators of 'Project financing channel' and 'Project investment planning' should be merged according to six responses. Specification on Compiling Feasibility Study Report of the Construction Project (2006) required that simple project economic evaluation must include the investment plan which contains the project financing channel (NDRC, 2006). Thus, the advice from the responses was accepted and these two indicators were merged into one 'Project investment planning.'

Five responses recommended that the 'Energy consumption' should be added to the environmental aspect. In the Design Standard for Energy Efficiency of Public Buildings (2005), reducing energy consumption is considered as a part of resource saving, and it is included in energy saving in the Evaluation Standard for Green Building (2016) notes. Thus, energy consumption will not be included in the indicator system.

Taking into account the responses of participants, and reviews of official documents, thirty-seven indicators were selected.

7.5.4.4 Indicator score

The average value of the significance of each indicator was calculated using EXCEL and illustrated in Table 7.6. The average value of all thirty-seven indicators were obtained for assessing the sustainability performance of highway infrastructure projects. It shows that the score of economic indicators are higher than social and environmental indicators. This result is in line with the development tendency of China where economic development is put in the top position of national development. Yunnan is an undeveloped area in China, its financial and economic status lags the national experience and the economic development was given most importance. The result also can be found from the score of *S10* (Contribution to local economy) and *S11* (Contribution to improvement of people's income and living standards), the scores of these two indicators were given a high value by all three groups. However, the score for each aspect from different response groups varied. Table 7.7 shows the difference in scoring from three response groups calculated by SPSS.

Table 7.6 Mean of the indicators

	Code	Indicators	Mean
Economic aspect	*S1*	Lifecycle cost	4.7313
	S2	Project budget	4.5821
	S3	Project investment planning	4.5373
	S4	Financial risk	4.9104
	S5	Return on Investment (ROI)	5.0896
	S6	Net Present Value (NPV)	5.0299
	S7	Payoff period	4.9403
	S8	Internal rate of return (IRR)	4.9701
	S9	Cost/benefit ratio	5.0448
	S10	Contribution to local economy	5.1642
	S11	Contribution to improvement of people's income and living standards	5.0299
Average			4.9118
Social aspect	*S12*	Providing job opportunities	3.4478
	S13	Improvement on public health	3.1493
	S14	Effects on development of local education	3.4179
	S15	Protection of cultural and natural heritage which related to the project	3.5821
	S16	Resettlement work	4.0448
	S17	Suitable to different stakeholders	3.0746
	S18	Coordination with various organisations	2.6866
	S19	Serviceability	4.0149
Average			3.4273
Environmental aspect	*S20*	Effects on land (Land consumption and land pollution)	4.4627
	S21	Effects on ecological environment (changes on climate and local geology)	4.5821
	S22	Effects on air quality	4.5522
	S23	Effects on water quality (produced waste water, consumption of water resource, potential contamination)	4.5522
	S24	Noise pollution	4.1642
	S25	Waste disposal	4.1343
	S26	Use of green energy sources	4.1791
	S27	Energy saving	4.1493
	S28	Effects on natural landscape and historical sites	4.0299
Average			4.3118
Technological aspect	*S29*	Advantage of project technologies	4.2388
	S30	Coordination with other transportation projects	4.7015
	S31	Improvement on road network efficiency	5.0299
	S32	Maintainability	5.0000
	S33	Extendibility	4.7910
	S34	Disaster prevention capability	4.3582
Average			4.6866
Governance aspect	*S35*	Rationality of project design and planning	4.8105
	S36	Rationality of organisational structure design	4.5241
	S37	Sound governance systems	4.7819
Average			4.7055

Table 7.7 Experts' group score of indicators

Indicator	Mean of Indicators		
	Academic Professional	**Government officer**	**Construction engineer**
S1	4.0276	4.2181	5.9483
S2	4.3678	4.9154	4.4630
S3	4.3045	5.3283	3.9791
S4	4.0162	4.9686	5.7464
S5	4.6690	4.4309	6.1690
S6	4.4770	4.8818	5.7310
S7	5.2075	5.6123	4.0012
S8	3.6130	5.0177	6.2796
S9	4.0832	5.8094	5.2419
S10	5.7991	5.0610	4.6324
S11	5.7336	4.6860	4.6702
Average	4.5726	4.9936	5.1693
S12	4.3592	3.0219	2.9624
S13	3.4469	2.7683	3.2326
S14	3.2513	4.1560	2.8465
S15	3.5504	4.0504	3.1456
S16	4.8755	4.2723	2.9866
S17	3.5402	3.1275	2.5560
S18	2.5477	2.9881	2.5239
S19	5.3310	3.4937	3.2199
Average	3.8628	3.4848	2.9342
S20	4.9336	4.6003	3.8543
S21	5.0636	4.3969	4.2858
S22	4.7453	5.1064	3.8048
S23	4.8538	4.2705	4.5324
S24	3.3480	4.1258	5.0187
S25	5.1555	4.2031	3.0444
S26	4.2029	3.6315	4.7029
S27	4.6096	3.4668	4.3715
S28	3.6357	4.8976	3.5563
Average	4.5053	4.2999	4.1301
S29	4.9249	3.9421	3.8495
S30	4.6936	4.9555	4.4555
S31	4.8659	5.8024	4.4214
S32	4.3730	5.1111	5.5159
S33	5.7778	5.2143	3.3810
S34	4.3000	5.0778	3.6968
Average	4.8225	5.0172	4.2200
S35	4.7782	5.0653	4.5878
S36	4.8839	3.2569	5.4315
S37	4.7370	4.4909	5.1179
Average	4.7997	4.2710	5.0457

As Table 7.7 shows, academic professionals gave higher importance (3.8628) to social indicators than construction engineers (2.9342). *S16* 'Resettlement work' was the most obvious difference between the two groups. The construction of large-scale infrastructure projects usually requires the acquisition of large tracts of land, and 'withdrawing this land from production eliminates the main means of livelihood for its owner, and that land often cannot be easily replaced nearby' (Picciotto *et al.*, 2001). This indicator was rated higher than other social aspect indicators by academic professionals, because resettlement is associated with many problems including legal issues, such as human and property rights, appropriate compensation, restoration or improvement of livelihoods (Yan, 2015). Resettlement is not the only problem associated with highway infrastructure projects, other social issues have become major concerns for both academic professionals and government officials. As China's official press agency Xinhua stated (2013, cited in Shi *et al*., 2014), construction of infrastructure often causes conflicts between the local community and the project developers which can subsequently result in cancellation or postponement. Even worse, it can cause community conflicts that can affect social stability.

The difference was also shown in environmental aspect. Environmental crises are increasing in China and how to solve them has become a subject of academic study, with people demanding government action to address the problem, the academics and government officers rated the environmental issues higher than the construction engineers (Yan *et al*., 2013). Green construction has been encouraged for more than ten years in China, but the awareness of environment protection is still weak due to the promotion of economic growth that enabled owners and construction companies to tend towards reducing cost by relying upon traditional construction methods (Huang, 2017). This tendency is also reflected in the score of economic aspect.

The indicators score in economic aspect from the construction engineers and government officers was higher than the academic group. The construction engineers included project investment director, project manager, construction controller, project inspector and decision-maker for the project, gave more importance to the project benefit. Construction engineers scored project profit indicators (IRR, ROI and NPV) higher than other indicators and as a result, the economic aspect was given a higher score than others. Not only that, because the technological and management systems support measures to ensure the construction quality of the project, the score of these two aspects were put in the second place. Building and construction techniques developed to reduce energy and materials consumption have been encouraged in recent years, reflecting a global trend (Zabihi and Habib, 2012). Through improving technologies and using efficient techniques the sustainability performance of the project can be improved (Peng, 2010).

The average score of all five aspects by the academic group showed a relatively small difference between them, which could indicate a more balanced approach to the overall factors of highway infrastructure project construction.

7.5.4.5 Reliability analysis

This research used Cronbach's Alpha coefficient method to test the data reliability. As table 7.8 shows Cronbach's Alpha coefficient for all indicators was 0.850, the indication of a good level of overall consistency, and the data was considered reliable.

Table 7.8 Cronbach's Alpha coefficient result

Cronbach's Alpha	N of Items
0.850	37

Cronbach's Alpha coefficient was computed by SPSS.

7.5.4.6 Validity analysis

The design of the survey not only combined the knowledge of sustainable development, project management and construction but was also tested by the pilot study. The contents were considered to be valid. The respondents to the questionnaire were all familiar with the development of highway infrastructure projects and had experiences and knowledge of sustainability, giving the results validity.

7.5.5 Indicator weighting

Weighting indicates the relative degree of importance of the indicator in the overall evaluation system, it is used to measure the value of each factor's relative importance in the evaluated project (Zhu and Yuan, 2002). Give that the indicator weighting is a crucial part of the sustainability assessment, a significant weighting would directly influence the assessment. The methods available to confirm the indicator weighting are varied, but can be summarised in two categories, subjective weighting and objective weighting. Subjective weighting methods mainly rely on the experts' understanding of the indicator importance, and objective weighting methods are produced through mathematical calculation (Nie, 2002).

Analytic Hierarchy Process (AHP) is the preferred indicator weighting technique for Multi-Criteria Decision Analysis (MCDA) sustainability assessment tools (Kumar *et al.*, 2015). Sun and Li (2013) and Gao and Yu (2014) used it in sustainability assessment of large-scale infrastructure projects; Barbosa and Gomes (2015) used it to assess efficiency and sustainability in the chemical industry; Mani *et al.* (2014) evaluated supplier selection using social sustainability based on AHP. As Zhang (2015) stated, AHP is not only used in public construction projects, but also dominates environmental management for the power and energy industry, transportation industry, and healthcare. It shows that this method can be adapted to a wide range of topics.

Some studies argue that AHP calculates weightings subjectively, there are more objective methods used for assessing sustainability in China. Zhang *et al.* (2009) applied the Entropy method to evaluate sustainability in cities, Mei (2014) used the Entropy method to assess sustainable development for the Bohai Sea region in China. Through these studies, researchers found the reliability of weighting by objective methods are higher than subjective methods. However, Li *et al.* (2004) pointed out that objective methods' intention is to evaluate the quantity of information and determine the contribution of the variables which requires abundant quantitative data, such as statistical data from government and authorities, which is lacking in this research.

The selection of indicator weighting methods in this study needs to establish a match between the objectives and results, the effectiveness of the results, and the ability of the researcher. After taking into account the factors of cost, time, practicality and efficiency, AHP was chosen to assign weightings to the indicators due its advantages of less cost, simple principles and straightforward calculation.

7.5.5.1 Analytic Hierarchy Process

AHP has the advantage of in-depth analysis and implementation (Zhang *et al.*, 2005). The decision-making and implementation process benefits through the evaluation of the influencing factors and the internal relations between the factors, combined with the quantitative analysis to realise the decision-making process quantification. AHP can effectively evaluate project uncertainty and subjectivity, and can be used in the decision-making process where results are difficult to quantify (Dai *et al.*, 2014b). Both quantitative or qualitative information can be evaluated using the AHP method.

Steps of AHP

Fundamentally, AHP breaks down a complex situation into several parts or criteria and puts them into a hierarchy using synthetic judgments to determine which part or criterion is more important for the situation. AHP can be implemented in three consecutive steps:

- Constructing pairwise comparison matrix.
- Computing the relative weightings of the compared factors using the judgement matrix.
- Computing indicator weightings at all levels.

The details of each step will be described below.

Constructing pairwise comparison matrix

A matrix of pair wise comparison between criteria is used to evaluate the importance of the criteria. A pairwise comparison matrix *A* is an *nxn* matrix which is used to compute the weightings for the different criteria, *n* is the number of factor $a_{1,} a_{2,....} a_n$. Each entry a_{ij} of the matrix *A* represents the importance of the factor i relative to the factor j. Then the judgment matrix A which contains pairwise comparison value a_{ij} for all $i, j \in \{1, 2\ldots n\}$ is given as follow:

$$A = \left(a_{ij}\right)_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & & & \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

The value of a_{ij} is based on statistical data, decision-makers' opinions and experts' experiences. All the criteria in the comparison matrix are positive, $a_{ij}>0$, and should meet the requirements of:

$$a_{ii} = 1 \ ; \ a_{ij} = \frac{1}{a_{ji}} \quad (i, j = 1,2,\ldots,n)$$

e.g. if criterion i is more important than criterion j, $a_{ij}=5$ (Strongly important) and $a_{ji} = 1/5$. The importance of each criteria is based on the comparison matrix, and the pairwise comparisons of the criteria are made with the grades ranging from 1-9 (Table 7.9). The basic assumption is that if criteria A is more important than B and is rated at 9, then B must be less important than A and is graded as 1/9.

Table 7.9 Scale of relative importance (Saaty, 1980)

Intensity of importance	**Definition**
1	*j* and *k* are equally important
3	*j* is slightly more important than *k*
5	*j* is more important than *k*
7	*j* is strongly more important than *k*
9	*j* is absolutely more important than *k*

Accordingly, Saaty's 1-9 scale was used to create the example of pairwise comparison matrix *A* shown in Table 7.10.

Table 7.10 Example of pairwise comparison matrix *A*

A	C_1	C_2	C_3
C_1	1	2	3
C_2	1/2	1	4
C_3	1/3	1/4	1

Reading the matrix of pair comparisons in Table 7.11, there are three factors C_1, C_2 and C_3 which are compared between with each other, all representing criteria. Row 1, column 3 (shows 3): criterion C1 is “slightly more important” than criterion C3; This evaluation is in good agreement with the evaluation from row 3, column 1(shows 1/3): criterion C3 is “slightly less important” than criterion C1. Comparison matrix shows importance levels of factors to each other within a certain logic framework, it can help to determine the percentage importance distribution to matrix, namely weighting.

Computing the weighting of each indicator

Weighting refers to the importance of the criterion, and there are several methods for calculating it, this research used the root method to calculate the weightings. It is referred as weighted geometric mean method (Saaty, 2008) where each alternative is a weighted geometric mean of individual judgements. The steps are as follows:

1) Product of M_i by multiplying together all the entries in each row of the matrix and normalising the eigenvector: $M_i = \prod_{i=1}^{n} P_{ij}$ *(i=1, 2…. n).*

2) Calculate the n^{th} root of M_i: $\overline{W}_i = \sqrt[n]{M_i}$

3) *Normalize* $\overline{W}_i$: $W_i = \frac{\overline{W}_i}{\sum_{j=1}^{n} \overline{W}_j}$ *, (i=1, 2…. n).*

Therefore, $W = [W_1,\ W_2,\ W_3,\ W_4,\ W_5,\ W_6]^T$ is the eigenvector, and it is the weighting of the criterion. The calculation process is shown in Table 7.11.

Table 7.11 Example of computing AHP weight

A	C_1	C_2	C3	Geometric Mean	Weighting
C_1	1	2	3	$\sqrt[3]{1 \times 2 \times 3}$= 1.817	1.817/3.514= 0.517
C_2	1/2	1	4	$\sqrt[3]{0.5 \times 1 \times 4}$=1.26	1.26/3.514= 0.359
C_3	1/3	1/4	1	$\sqrt[3]{0.33 \times 0.25 \times 1}$=0.437	0.437/3.514 =0.124
					1.000

Matrix *A* for *n* (=3) criteria; (for $n=n^2-(n/2)$); $M_i=C_1 \times C_2 \times C_3$; $\overline{W_i} = \sqrt[3]{C_1 \times C_2 \times C_3}$

Table 7.11 shows simple calculations to determine the weighting for each criterion: the weightings are absolute numbers between 0 and 1, and the total weightings add up to 1. Weightings are distributed over a hierarchy, and their values depend on information related to each factor. The calculation is similar to an average, firstly multiply the numbers of each criterion together and take the root of the combined number.

For a hierarchy with more than one level, the overall weightings must be considered. Table 7.12 shows the overall weightings for alternative calculations. Column "Weightings of Criterion' shows the weighting of this *Criterion* with respect to the analysis goal. Column 'Weighting for Alternatives' show the weightings of this *Alternative* with respect to this *Criterion*. The 'Overall Weightings' is the global weighting of this *Alternatives* with respect to the goals.

Table 7.12 Overall weight of AHP

Criterion	Weights of Criterion	Alternatives	Weight for Alternatives	Overall Weights
C_1	W_{c1}	C_{11}	W_{11}	$W_{c1} \times W_{11}$
		C_{12}	W_{12}	$W_{c1} \times W_{12}$
		C_{13}	W_{13}	$W_{c1} \times W_{13}$
C_2	W_{c2}	C_{21}	W_{21}	$W_{c2} \times W_{21}$
		C_{22}	W_{22}	$W_{c2} \times W_{22}$
		C_{23}	W_{23}	$W_{c2} \times W_{23}$
C_3	W_{c3}	C_{31}	W_{31}	$W_{c3} \times W_{31}$
		C_{32}	W_{32}	$W_{c3} \times W_{32}$
Value	1.000		1.000	1.000

Overall weighting combined as a weighted sum taking into account the weighting of each criterion and assigning the overall weighting of the alternatives. The alternative with the highest overall weightings constitutes the most important factor in the criterion.

Consistency index and consistency ratio

Because of the complexity of the factors, the results cannot be completely consistent when comparing in pairwise, and that may lead to deviation from the weighting. So, the final stage of AHP is to calculate the Consistency Ratio (CR) to measure the relative consistency of the comparison matrix to large samples of purely random judgment (Sun, 2010). For complete consistency, comparison matrix A has $\lambda_{\max}$ = *n*, but in real life the comparison matrix cannot be completely consistent. Close consistency is acceptable. The steps for calculating consistency can be shown as:

Computing the Consistency Index (*CI*):

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

The appropriate Consistency Index *(CI)* is referred to as the Random Consistency Index (*RI*), Table 7.13 below, from Saaty, shows the Random Consistency Index.

Table 7.13 Random consistency index (RI)

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

The Consistency Ratio *(CR)* is calculated by

$$CR = \frac{CI}{RI}$$

If the value of Consistency Index is smaller than 0.1, the inconsistency is acceptable. Example of Consistency Ratio calculation for the judgment matrix A are as follow:

A	C_1	C_2	C_3	Weighting
C_1	1	2	3	0.517
C_2	1/2	1	4	0.359
C_3	1/3	1/4	1	0.124

$$AW=\begin{bmatrix}1 & 2 & 3\\0.5 & 1 & 4\\0.33 & 0.25 & 1\end{bmatrix}\times\begin{bmatrix}0.517\\0.359\\0.124\end{bmatrix}=\begin{bmatrix}1.607\\1.114\\0.386\end{bmatrix}$$

$$\lambda W=\begin{bmatrix}1.607/0.517\\1.114/0.359\\0.386/0.124\end{bmatrix}=\begin{bmatrix}3.108\\3.103\\3.113\end{bmatrix}$$

$$\lambda_{max}=\frac{3.108+3.103+3.113}{3}=3.108$$

$$CI=\frac{(3.108-3)}{3-1}=0.027$$

The number of items in judgement matrix is 3, according to *RI*, 0.58 is used to calculate the *CR*.

$$CR=\frac{0.027}{0.58}=0.047$$

Following the steps discussed above, the calculation of indicator weighting for this research using the AHP method is shown in the following pages.

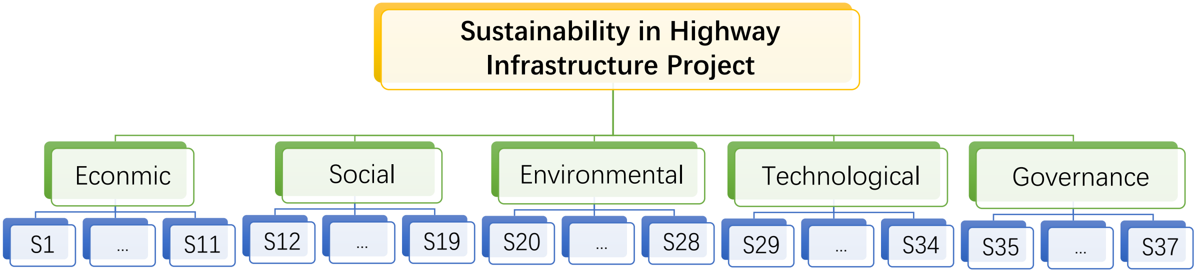
7.5.5.2 Application of AHP

As previously discussed, AHP is a standard technique for multiple choice decision-making, with the scores obtained from the questionnaires, and YAAHP 10.0 used for ranking the importance of the indicators. The application process and results are explained as follows.

Constructing the hierarchy

Building the hierarchy can help to establish the values or importance of the different factors for sustainable highways. The AHP hierarchy for sustainability in highway infrastructure projects was constructed using YAAHP software shown in Figure 7.7.

Figure 7.7 Sustainability in highway infrastructure project's hierarchy



The hierarchical structure of the sustainability assessment indicator system was divided into two layers, the first layer includes the five aspects *E= {Economic, Social, Environmental, Technological and Governance}*, the second layer contains thirty-seven indicators: E_1= *{S1, S2…S11}*; E_2= *{S12, S13…S19}*; E_3= *{S20, S21…S28}*; E_4= *{S29, S30…S34}*; E_5= *{S35, S36, S37}*.

Constructing pairwise comparison matrix

The relative importance of each indicator followed Saaty's 1-9 scale. Six judgment matrices (Table 7.14-7.19) were constructed based on the mean provided by experts in their responses to the questionnaire.

Table 7.14 shows the Level 1 judgement matrix. According to the experts' scores, E_1 *(Economic aspect) = 4.9118*, E_5 *(Governance aspect)* = 4.9055, E_4 *(Technological aspects) = 4.6866*, E_3 *(Environmental aspect) = 4.3118*, E_2 *(Social aspect) = 3.4273*. The score was entered to Software YAAHP10.0 software to calculate the weighting, with the consistency test ensuring its validity.

Table 7.14 Level 1 judgment matrix

Consistency Ratio：0.0074; Weight：1.0000; λmax：5.0612

Sustainability	Economic	Social	Environmental	Technological	Governance	Priority Vector
Economic	1	4	3	2	2	0.376
Social	0.25	1	0.5	0.3333	0.3333	0.0738
Environmental	0.3333	2	1	0.5	0.5	0.1209
Technological	0.5	3	2	1	1	0.2147
Governance	0.5	3	2	1	1	0.2147

The sum weightings of five aspects is 1, and λmax is 5.0612. The consistency index was 0.0074 which less than 0.1%, so the result was consistent. The economic factor was assigned a weighting 0.376, because it has been cited as the most important factor for sustainable highway infrastructure projects. The importance (weighting) of each indicator in Level 2 relative to its aspect in Level 1 was ordered according to the judgement matrix Table 7.15-7.19.

Table 7.15 Economic judgment matrix

Consistency Ratio：0.0133; Weight：0.3760; λmax：11.2021

Economic	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*	*S11*	*Wi*
S1	1	2	2	0.5	0.3333	0.5	0.3333	0.5	0.3333	0.25	0.3333	0.0449
S2	0.5	1	1	0.5	0.3333	0.5	0.3333	0.3333	0.3333	0.25	0.3333	0.0355
S3	0.5	1	1	0.5	0.3333	0.5	0.3333	0.3333	0.3333	0.25	0.3333	0.0355
S4	2	2	2	1	0.5	1	0.5	1	0.5	0.3333	0.5	0.0674
S5	3	3	3	2	1	2	1	2	1	0.5	1	0.1215
S6	3	3	3	2	1	1	1	2	1	0.5	1	0.1139
S7	2	2	2	1	0.5	1	1	1	1	0.5	1	0.0855
S8	2	3	3	1	0.5	1	0.5	1	0.5	0.3333	0.5	0.0737
S9	3	3	3	2	1	1	1	2	1	0.5	1	0.1139
S10	4	4	4	3	2	2	2	3	2	1	2	0.1945
S11	3	3	3	2	1	1	1	2	1	0.5	1	0.1139

Table 7.16 Social judgment matrix

Consistency Ratio：0.0090; Weight：0.0738; λmax：8.0893

Social	*S12*	*S13*	*S14*	*S15*	*S16*	*S17*	*S18*	*S19*	Wi
S12	1	2	1	1	0.3333	3	3	0.3333	0.1098
S13	0.5	1	0.5	0.5	0.25	1	2	0.25	0.0591
S14	1	2	1	1	0.3333	2	3	0.3333	0.1028
S15	1	2	1	1	0.3333	2	3	0.3333	0.1028
S16	3	4	3	3	1	4	6	1	0.2666
S17	0.3	1	0.5	0.5	0.25	1	2	0.25	0.0568
S18	0.3	0.5	0.33	0.33	0.1667	0.5	1	0.1667	0.0355
S19	3	4	3	3	1	4	6	1	0.2666

Table 7.17 Environmental judgment matrix

Consistency Ratio:0.0014; Weight：0.1209; λmax：9.0164

Environmental	*S20*	*S21*	*S22*	*S23*	*S24*	*S25*	*S26*	*S27*	*S28*	*Wi*
S20	1	1	1	1	2	2	2	2	3	0.1572
S21	1	1	1	1	2	2	2	2	3	0.1572
S22	1	1	1	1	2	2	2	2	3	0.1572
S23	1	1	1	1	2	2	2	2	3	0.1572
S24	0.5	0.5	0.5	0.5	1	1	1	1	2	0.0812
S25	0.5	0.5	0.5	0.5	1	1	1	1	2	0.0812
S26	0.5	0.5	0.5	0.5	1	1	1	1	2	0.0812
S27	0.5	0.5	0.5	0.5	1	1	1	1	2	0.0812
S28	0.3	0.33	0.33	0.33	0.5	0.5	0.5	0.5	1	0.0464

Table 7.18 Technological judgment matrix

Consistency Ratio：0.0029; Weight：0.2147; λmax：6.0184

Technological	*S29*	*S30*	*S31*	*S32*	*S33*	*S34*	*Wi*
S34	1	0.5	0.33	0.33	0.5	1	0.0817
S35	2	1	0.5	0.5	1	2	0.1485
S36	3	2	1	1	2	3	0.2698
S37	3	2	1	1	2	3	0.2698
S38	2	1	0.5	0.5	1	2	0.1485
S39	1	0.5	0.33	0.33	0.5	1	0.0817

Table 7.19 Governance judgment matrix

Consistency Ratio：0.0000; weight：0.2147; λmax：3.0000

Governance	*S35*	*S36*	*S37*	*Wi*
S35	1	2	1	0.4
S36	0.5	1	0.5	0.2
S37	1	2	1	0.4

The consistency ratio of each judgement matrix was less than 0.1 which indicated that the weighting of indicators was consistent with the importance of each indicator from the average calculation. The priority vector (*Wi*) was obtained from pairwise comparisons, and used by YAAHP 10.0 to calculate the overall weighting of each indicator.

7.5.5.3 Result of AHP weighting

The overall weighting of each factor is shown in Table 7.20, the result was considered acceptable because it included the intentions and preferences of experts.

Table 7.20 Indicators weighting by AHP method

	Code	Indicators	Mean	Weight
Economic aspect	*S1*	Lifecycle cost	4.7313	0.0169
	S2	Project budget	4.5821	0.0133
	S3	Project investment planning	4.5373	0.0133
	S4	Financial risk	4.9104	0.0253
	S5	Return on Investment (ROI)	5.0896	0.0457
	S6	Net Present Value (NPV)	5.0299	0.0428
	S7	Payoff period	4.9403	0.0322
	S8	Internal rate of return (IRR)	4.9701	0.0277
	S9	Cost/benefit ratio	5.0448	0.0428
	S10	Contribution to local economy	5.1642	0.0731
	S11	Contribution to improvement of people's income and living standards	5.0299	0.0428
Social aspect	*S12*	Providing job opportunities	3.4478	0.0081
	S13	Improvement on public health	3.1493	0.0044
	S14	Effects on development of local education	3.4179	0.0076
	S15	Protection of cultural and natural heritage which related to the project	3.5821	0.0076
	S16	Resettlement work	4.0448	0.0197
	S17	Suitable to different stakeholders	3.0746	0.0042
	S18	Coordination with various organisations	2.6866	0.0026
	S19	Serviceability	4.0149	0.0197
Environmental aspect	*S20*	Effects on land (Land consumption and land pollution)	4.4627	0.019
	S21	Effects on ecological environment (changes on climate and local geology)	4.5821	0.019
	S22	Effects on air quality	4.5522	0.019
	S23	Effects on water quality produced waste water, consumption of water resource, potential contamination)	4.5522	0.019
	S24	Noise pollution	4.1642	0.0098
	S25	Waste disposal	4.1343	0.0098
	S26	Use of green energy sources	4.1791	0.0098
	S27	Energy and materials saving	4.1493	0.0098
	S28	Effects on natural landscape and historical sites	4.0299	0.0056
Technological aspect	*S29*	Advantage of project technologies	4.2388	0.0175
	S30	Coordination with other transportation projects	4.7015	0.0319
	S31	Improvement on road network efficiency	5.0299	0.0579
	S32	Maintainability	5.0000	0.0579
	S33	Extendibility	4.7910	0.0319
	S34	Disaster prevention capability	4.3582	0.0175
Governance aspect	*S35*	Rationality of project design and planning	4.8105	0.0859
	S36	Rationality of organisational structure design	4.5241	0.0429
	S37	Sound governance systems	4.7819	0.0859
Total				1 .0000

7.6 Assessing sustainability based on the AHP weight

The method of assessing sustainability is based on experts grading each indicator using a Likert Scale to reflect their judgment of the indicators on project performance: 9 is excellent; 7 is good; 5 is moderate; 3 is pass, and 1 is weak. The weighted arithmetic mean was used to determine the final result of the evaluation. This is most common method for measurement of central tendency, its main advantage being fast and easy to calculate and easy to work with and use in further analysis (Liu, 2008). The arithmetic mean is commonly known as the average, i.e. the mean obtained by adding several observations together and dividing the sum by the number of observations, and can be shown as:

$\bar{S}$ is the symbol of the arithmetic mean, thus the mean of *n* observation $S_1 + S_2 + \cdots + S_n$ is given by:

$$\bar{S} = \frac{(S_1 + S_2 + \cdots + S_n)}{n}$$

A_i = Weighting of indicator i, S_i = the value of indicator i ; and: $\sum_{i=1}^{n} A_i = 1$; $0<Ai<1$

$Si = \bar{S} * A_i$

The total grading of the project sustainability performance *S* can be shown as:

$$S = \sum_{i=1}^{n} A_i S_i$$

The process can be simply explained as: multiply the value of individual indicators supplied by the experts with the weighting, and sum them to give the total value of the sustainability index of the project.

7.7 Other consideration

Based on the literature review, there are only a few pieces of research specifically related to sustainability assessment of highway infrastructure projects in Yunnan. This research focusses on developing an approach which is straightforward to use and will not incur additional costs for the developer. The indicators of the model cover a wide range of sustainable issues and fill in the gap of the studies on green highway which are more focused on environment impacts and economic benefits. Also, the indicators cover the project whole lifecycle such as project investment planning, lifecycle cost and benefits, maintenance, and impacts during lifecycle. The indicator selection tends to have a bias as a consequence of its reliance on current studies which, in turn, mainly rely on experts' opinions, this research addressed this problem through the use of questionnaires to obtain objective data.

Dai *et al.* (2014a) concluded that AHP provides a subjective way to weight the indicators, and its objective influence is less than in other methods. It focuses on the subjective intention of experts and the significance of the indicators. Chen *et al.* (2015) developed a method through using AHP together with Entropy to assess sustainability. The study proved that the method reduced the randomness and subjectivity of the determination of the weighting of the evaluating indicators which produced a rational result for the sustainability assessment. The Entropy method was used as a test weighting method and the result of indicator weightings indicated that the weighting of social indicators was more important than indicators from other aspects, and the results were not consistent with the importance of each indicator measured by average calculation. Zhang *et al.* (2010) suggested that this arises because the variability of the indicators is small, and entropy is big, which results in the weighting of high score indicators being less than low score indicators. Accordingly, this method has not been used in this research.

7.8 Conclusion

This chapter discussed the development of an indicator-based sustainability assessment model for highway infrastructure projects in Yunnan mainly using a questionnaire survey. The foundation of the method to select indicators was based on a review of various existing indicator systems and relevant sustainability standards for construction projects and highway infrastructure projects. The first impression in this chapter was that the sustainability of highway infrastructure projects involves a wide range of factors, and the sustainability assessment of highway infrastructure projects is regarded as a complex task. In order to determine the quality of assessment indicators and give an appropriate weighting for each indicator, this chapter provided questionnaires for completion by experts to provide evidence for indicator selection and help to develop quality indicators for the assessment model.

The step of collecting optional indicators showed a paucity of research dealing specifically with sustainability assessment of highway infrastructure projects in Yunnan, thus, the study chose the assessment systems of other provinces with similar conditions to Yunnan. According to sustainable development principles, the initial indicators were categorised into five groups, the results of the questionnaire were consistent with the current development trends in China as economic development was given highest priority. Also, there were some responses which emphasised that environmental and social problems were not considered by the respondents as important as economic indicators. It indicated that current development in Yunnan maintains an imbalance between society, economy, and environment.

AHP was utilised to weight the indicators because it is the most common method for assigning weightings to indicators, with the experience from other studies helping to build an appropriate indicator system. After comparison with Entropy methods, AHP was used since it has the advantage of stability and flexibility regarding changes within, and additions to, the hierarchy. In addition, AHP can show the importance of each indicator by using the hierarchy of the criteria. However, AHP also has some limitations, one of its major drawbacks is its subjectivity. After comparison with entropy weighting methods, it was concluded to be an appropriate method for determining the importance of indicators, and regarded as useful for this study.

CHAPTER 8 APPLICATION OF THE SUSTAINABILITY ASSESSMENT MODEL

8.1 Introduction

This chapter aims to validate the rationale of the sustainability assessment model developed in Chapter 7 through the knowledge and experience of the experts from three groups, academic professionals, government officers and construction engineers. To further test its feasibility and applicability, the model will be applied to the case of KQ No.4 highway infrastructure project.

8.2 Refining the assessment model by interview method

This stage aims to acquire more information about the sustainability assessment issues of highway infrastructure projects in Yunnan, and validate the sustainability assessment model through contextualising the values and opinions of respondents. The tool used for refining the model was a semi-structured open-ended interview with twelve experts engaged in the development process of highway infrastructure projects in Yunnan Province. This tool allows the participants to respond to the questions with more freedom and creativity (Patton, 2002). Furthermore, the study of the sustainability assessment of highway infrastructure projects in Yunnan is still at an early stage with little information available, and the interview method can be effective in exploring essential information for this research.

Initially, an invitation email was sent to fifteen experts inviting them to participate in the interview at the beginning of December 2016, and twelve agreed to do so. The participants consisted of four construction engineers from highway construction companies involved with project supervision, design, investment and construction activities, four academic professionals from the research institutes in Yunnan who were engaged in research of sustainable construction and project management, and four directors from the government departments involved in the decision-making and approval process of highway infrastructure projects in Yunnan. All participants have at least ten years relevant working experience ensuring they were able provide the necessary information to improve the sustainable assessment model. The participants' selection was based on their professional experience and knowledge of highway infrastructure project planning, design, construction and operation, and sustainable or green building, plus the seniority and level of understanding of the topic necessary to ensure the quality of responses. The summary of the interviewees is listed in the Table 8.1.

Table 8.1 Summary of the interviewees

Position of Interviewees	Background	Organisations
Professor 1	In the field of sustainable construction	Kunming University of Science and Technology
Professor 2	In the field of project management	Kunming University of Science and Technology
Professor 3	In the field of environment	Yunnan University of Finance & Economics
Professor 4	In the field of construction	Yunnan University of Finance & Economics
Government officer 1	Director of infrastructure project approval	Transport Department of Yunnan
Government officer 2	Director of infrastructure project investment	Provincial Development and Reform Commission
Government officer 3	Director of infrastructure project design approval	Provincial Development and Reform Commission
Government officer 4	Director of infrastructure project approval	Transport Department of Yunnan
Construction engineer 1	Civil engineer	Yunnan Highway Development Investment Co. Ltd
Construction engineer 2	Project manager	Yunnan Highway Development Investment Co. Ltd
Construction engineer 3	Civil engineer	Yunnan Construction and Investment Group
Construction engineer 4	Construction designer	Yunnan Construction and Investment Group

The interviews were undertaken from the middle of December 2016 to early January 2017. Before the interviews commenced, the developed model was sent to the participants to ensure they had enough time to properly consider it. To ensure the accuracy of comprehension, interviews were conducted in the experts' native language, Chinese, by telephone and recorded with the permission of the participants. The transcripts in Chinese were mailed to the participants to verify the contents and then translated into English. Through this method, the participants' answers helped to build a better picture of sustainability assessment of highways in Yunnan and provided additional information for developing the evaluation model. Both English and Chinese interview questions are provided in Appendix II.

8.3 Results of the interviews

The interview data was analysed using the content analysis method described in Chapter 6. The themes in the transcription of the interviews were defined according to the issues and their characteristics indicated in the responses. After clustering and analysis, the themes were categorised into three groups: 1) perception of the development of highway infrastructure projects in Yunnan; 2) understanding of the sustainability assessment in highway infrastructure projects; and 3) suggestions for refining the developed model.

8.3.1 Perception of highway infrastructure project development in Yunnan

In the first part of the interview, the participants were asked to describe the current situation of highway infrastructure development in Yunnan. This part helped to identify the gap between current development trends and sustainability of highway infrastructure projects. According to the responses of the participants, the perception of highway infrastructure project development was grouped into two sub-themes: the achievements and the critical problems.

First, all twelve participants agreed that highway infrastructure in Yunnan had achieved major strides in the past few years, with much more room for future development. As the participants stated:

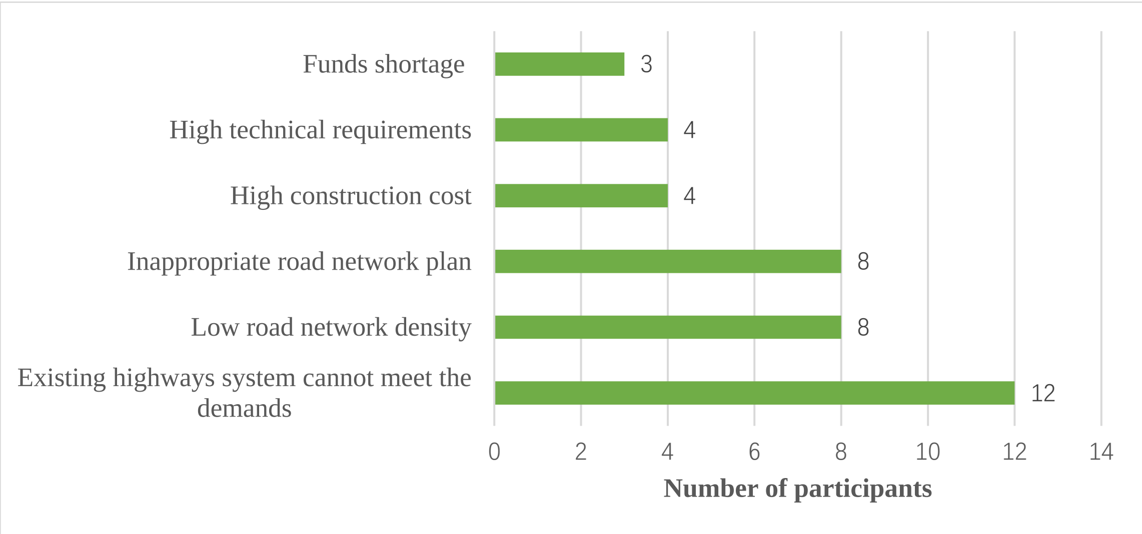
'Currently, the highways connect 84% of the townships and villages in Yunnan and have made certain achievements.' (Government officer 1)

'The highways construction is the priority of the development strategy in Yunnan, in 2014-2016, 26 projects were built to support the national highway network.' (Government officer 3)

Highways fulfil the primary transportation role in Yunnan due to its the topography and geology (Pan *et al.*, 2016). The MOT (2016) reported that in the past five years (2010-2015), Yunnan had a rapid expansion of the road network to integrate rural and remote areas, and provide local people with improved access to jobs, health facilities, education and social services. The Province's highway infrastructure investment in January-March period of 2017 reached $4.72 billion, compared with an increase of 49.13% in the same period last year, and ranked first in China (Transport Department of Yunnan, 2017). The development was not only focused on the domestic roads, but also included activities for the construction of an international highway. In 2016, China, Laos, Thailand and the Asian Development Bank jointly constructed the Kunming-Bangkok international route to link China and south eastern Asian countries, and improve the road network in the northwest of Yunnan (Ministry of Transport [MOT], 2016). This illustrates that development of highway infrastructure in Yunnan has consistently been a key focus for the government.

At the same time, the development of highway infrastructure projects brings with it many problems, and the main problems defined by the participants are shown in Figure 8.1.

Figure 8.1 Problems of highway infrastructure project development in Yunnan



The most frequently mentioned problem from the participants (100%) in the survey is that the 'Existing highway system cannot meet the demands'. As Academic Professor 1 stated:

'The highway infrastructure development in Yunnan is lagging behind the economic development and the growth of transport demand.'

The current highway system cannot satisfy the increasing traffic demands associate with another problem 'Low road network density', which was cited by 67% of the respondents.

The western region of China is less developed than the eastern region. Yunnan is a frontier province in the western region of China, 95% of the territorial area is mountainous and semi-mountainous, and because of historical and geographical reasons, highway infrastructure construction lags behind other regions (Wang and Zhu, 2015). According to the National Bureau of Statistics of China (2016), in 2016, there were 57 districts in mountainous areas with no direct highway connection, accounting for 44.2 % of the total of 129 districts, which illustrates that the existing road system cannot meet the needs of rapid transit (Transport Department of Yunnan, 2016b). The low density of road networks indicates that the length of road per unit of geographical area cannot meet the requirements for connectivity and accessibility (Vaidya, 2003).

Imbalanced development results in 'Inappropriate road network plan', and was cited by 67% of responses.

The structure of road network plan is inappropriate, and this problem is especially pronounced with the imbalanced distribution of highway.' (Government officer 1)

Imbalanced development is a long-standing issue in Yunnan and it is a major contributor to low network density. Imbalanced development exists not only between different regions but also between urban and rural areas. According to the report of the Government of Yunnan Province (2016) a quarter of the province's GDP is from the capital city - Kunming and half is from the central area. Because of the major economic contribution made by these areas, the investment in transportation infrastructures is higher than other parts of the Province. Meanwhile, the study from Ansar *et al.* (2016) shows that whilst major routes are congested, some routes have little traffic volume which is a common problem in China indicating that resources have been misallocated.

The 'High construction cost' and 'High technical requirements' were both cited by 30% of the respondents.

'Being difficult, it costs more to build highways in the mountainous and high elevation terrain. Due to these areas requiring the construction of many large beam bridges and tunnels in the mountains. The proportion of bridges and tunnels is more than 50% in northern mountain area. Also, these areas receive heavy rain and snowfall over the whole year, and the crest of mountains drop precipitously meaning that it costs a great deal to build the highway in such terrains.' (Construction engineer 1)

'Not only the construction costs, but also the maintenance costs are higher than less mountainous areas.' (Construction engineer 3)

The participants agreed that building a highway in mountainous areas incurs higher costs and investment. Similarly, all four construction engineers believed that the construction technology of highway infrastructure project in Yunnan is more demanding than other provinces due to its topographical characteristics.

The participants also argued that high cost is the main reason for the low density of highway network in Yunnan, followed by limited financial investment. According to the Transport Department of Yunnan (2016b), the cost per kilometre of highway increased nearly 1.8 times in the past ten years, the major factors include topography along the alignment, land acquisition costs, and more viaducts, bridges and tunnels. Due to the high cost, new highway infrastructure projects bring significant social benefits but small economic benefits in Yunnan making it difficult to obtain investment. The past three years' asset–liability ratio for thirty-one highways is about 75% in Yunnan, higher than the acceptable level 40%-60%, together with low solvency and return on investment, these have become the main factors that restrict highway infrastructure project development (MOT, 2016). The low utilisation rate of new technologies and techniques, especially energy saving and emission reduction technologies also results in higher costs (Yu, 2014). In China, the financing environment is weak, the financing channel is relatively unitary, apart from fiscal revenue of central and local governments, highway infrastructure investment largely relies on bank loans, the irrational financing structure results in company financing difficulty, it raises the problem of 'Funds shortage' (Kao *et al.*, 2014). This factor has become the key obstacle for the development of highway infrastructure projects in Yunnan, cited by 33% of interviewees.

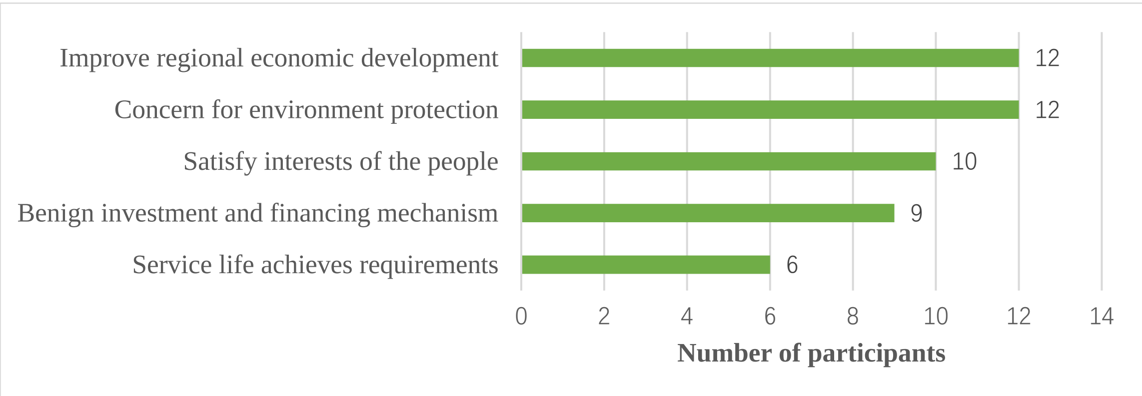
8.3.2 Understanding sustainability assessment in highway infrastructure projects

The responses in this theme were categorised into five sub-themes: 1) the meaning of sustainable highway infrastructure projects; 2) the importance of sustainability in highway infrastructure projects; 3) important factors for achieving sustainable highway infrastructure projects; 4) the influence of sustainability assessment for highway infrastructure projects; and 5) the current methods and systems for sustainability evaluation in highway infrastructure projects.

8.3.2.1 Meaning of sustainable highway infrastructure project

According to the responses of interviews, the keywords used to describe the meaning of sustainable highway infrastructure project are shown in Figure 8.2.

Figure 8.2 Keywords of sustainable highway



All interviewees (100%) stated that sustainable highway infrastructure projects should drive the development of the region's economy, and 'satisfy the interests of the people', such as improving efficiency of travelling and distribution of goods.

83% of the participants expressed concern for environmental protection, they pointed out that sustainable development of highway infrastructure should reduce its contribution to environmental damage throughout the project lifecycle.

50% of participants included 'Service life should achieve requirement' for sustainable highway infrastructure project.

'The highway design should be concerned with life-time service, some projects cannot satisfy the need of transportation demands a few years after completion, and the old project cannot be extended meaning that there is a need to start again.' (Academic professor 1)

25 % of participants considered that a good highway investment and financing mechanism is a sustainable attribute, as one academic professor explained:

'The highway construction involves a massive investment, and the government must explore ways to safeguard these critical investments.' (Academic professor 2)

'The government is using infrastructure construction as a countercyclical policy tool to stimulate economic development, that results in blind investment in highway infrastructure projects, and lacks comprehensive studies on the transportation networks.' (Academic professor 2)

Yunnan is one of the less-developed areas in China in terms of its overall economic power, due to its mountainous terrain and poor communications with the outside world. Agriculture is the main industry in Yunnan. According to statistics, in 2015 the rural population was 56.6 % of the total population in Yunnan (National Bureau of Statistics, 2016). The highway infrastructure can increase mobility, it makes it easier for agricultural products to reach markets with cheaper prices and increases the market size, provides more job opportunities, improves access to health and education facilities for local people, improves the local economic base and brings higher income. Investing in highway infrastructure projects is regarded as an economic development strategy by central and local governments. In 2015, the construction industry had become the main contributor to economic growth in Yunnan, with large proportion from highway infrastructure construction (Transport Department of Yunnan, 2016b). According to Transport Department of Yunnan (2017), in 2016, highway infrastructure investment reached $12.87 billion in Yunnan, takes 52% of the total investment, this implies an annual commitment of about 7.6% of provincial GDP. However, it also results in negative environmental and social impacts, including water, air and noise pollution during construction and transporting building materials, soil erosion, disturbance of flora and fauna, population displacement and resettlement and so on (Yang, 2016). It demands appropriate development planning to reduce the negative impacts and to establish mechanisms for dealing with the long-term problems. Meanwhile, since highway infrastructure is provided as a tool for economic stimulus by the government, its influence on economic growth is overstated (Wu, 2013). It results in over-investment in unproductive projects, high debt burdens and deficits and instability in financial markets in China (Ansar *et al.*, 2016). Most of the new construction projects are built in remote mountainous regions, the traffic volumes are smaller than other regions which makes it difficult to recover investment costs, while the funding risk is increased (Wu, 2013). Thus, optimising the financing structure can promote better development of highway infrastructure projects in Yunnan.

8.3.2.2 Importance of sustainability in highway infrastructure projects

All interviewees agreed that sustainability is an important issue and an increasing trend for highway infrastructure projects. Academic professor 3 stated that:

‘Sustainability *should be the reason for building highway infrastructure, the construction should cause the least amount of harm on environment and society.’*

From the responses of participants, a sustainable approach will bring benefits as follows:

Avoid reputational harm. This applies to both developers (government) and constructors. ‘*A sustainable approach can reduce risks associated with a project, make the project more desirable and satisfy the clients and public. It is like a positive image of caring about the environment and employees can endear a company to the public; damage to the* *environment may threaten the company's operations as the investor may worry about the project's disruption.' (Government officer 1).*

Avoid penalties. '*The owner and constructor who build the project in a sustainable way will avoid legal penalties (Construction engineer 4).* The government recognised that construction is not a purely economic activity, green construction has become part of standards, values and principles (Wang, 2013). The construction process must comply with any laws and community interests for environmental protection, an unsustainable approach will be punished by the regulations.

Cost savings in project lifecycle. A sustainable approach will reduce the materials required, waste generation and result in lower maintenance costs, it also reduces the cost to the government of protecting the environment (Wang, 2013). Construction engineer 1 stated that '*the reputational damages of the company can quickly translate into financial losses, such as lost investment and lead to government fines. On the other hand, sustainable buildings typically have lower annual costs for energy, water, maintenance and other operating expenses.'*

Build good relationships with local communities. The concept of sustainable building is to prevent pollution, save energy, natural resources and cost, and improve quality of life, and **'***adopting sustainable building concept is regarded as good corporate citizenship that will build a good relationship with local communities. If the government builds the road taking a sustainable approach as we consider the people's needs properly, bring the benefits to them, we can easy to get support from the public' (Academic professor 3).*

8.3.2.3 Factors of sustainable highway infrastructure projects

In this question, each participant was asked to give five or more key factors of sustainable highway infrastructure projects, these key factors were then consolidated into a list of ten and are shown in Table 8.2 below.

Table 8.2 Factors of sustainable highway infrastructure project

Factor	Code
Appropriate plan	1
Lifecycle profit	2
Increase productivity	3
Improvement on road network efficiency	4
Maintainability	5
Extendibility	6
Resettlement work	7
Environment impacts	8
Technology	9
Open the inaccessible area to development	10

Participants	1	2	3	4	5	6	7	8	9	10
Professor 1		√			√	√	√	√	√	√
Professor 2	√	√	√		√		√	√		√
Professor 3	√		√	√	√	√		√	√	√
Professor 4			√	√	√	√		√		√
Government officer 1		√			√	√	√	√		√
Government officer 2	√	√	√	√	√	√		√		√
Government officer 3			√	√	√	√	√	√		√
Government officer 4	√	√	√	√	√	√	√	√		√
Construction engineer 1	√	√	√	√				√	√	√
Construction engineer 2	√	√	√		√	√	√	√	√	√
Construction engineer 3	√		√						√	√
Construction engineer 4	√	√	√						√	√

‘Increase productivity’ and ‘Open the inaccessible area to development’ were identified as the most important factors for highway construction and were cited by 92% of interviewees.

‘Yunnan Province is one of the twelve less developed provinces of western China, and highway is the essential infrastructural facilities to speed-up its economic growth and catch-up with developed eastern regions.’ (Academic Professor 2)

‘Resettlement work’ was of significant concern to the six participants (67% of responses). At present, more attention is paid by the government and public to land expropriation and relocation, because it is one of the major costs for highway infrastructure projects, and it also brings social problems (Shi, 2016).

‘The development of highway infrastructure projects inevitably occupies arable land which is the most fundamental guarantee for farmers’ lives.’ (Academic professor 2)

From the project management perspective, resettlement is an important and sensitive aspect of project development and it can be a risk for project delay (International Hydropower Association, 2016). From the social development perspective, ‘*the resettlement is regarded as the factor of social stability.’ (Government officer 4)*

The new highway projects are built in rural areas, and rural collectives own land resources, once the collective-owned lands are expropriated, farmers get compensation less than market value of their loss in long-term benefits (Zou *et al.*, 2014). At the same time, the low compensation standard presents problems for local government, because they have to ensure that the migrant’s living standards are same as before (Habich, 2015). Sometimes, it is difficult for the migrants to maintain their former standards of living due to resettlement from fertile land to regions with both limited land availability and land that is less fertile (Habich, 2015). Some people may move to urban areas, but they are unable to get work without skills training (Zou *et al.*, 2014). These factors result in risks to social stability if the resettlement plan does not provide an appropriate compensation method (Gao *et al.*, 2014).

Environmental issues such as impacts on the landscape and historical sites, air pollution, water pollution, farm land occupation, deforestation, and impacts on minority culture were all problems mentioned by the interviewees.

'Economic development is the basis of society, but must change the development pattern of 'polluting first and cleaning up later', the development strategy must be based on protecting the ecology.' (Academic professor 1)

Academic professor 2 argued that '*the economic development should not harm the environment, and Yunnan is one of the tourist regions in China with unique characteristics, the construction of highway infrastructure projects should not destroy the rich natural scenery and ethnic folklore.'*

The government officers also recommended that the authorities should ensure environmental protection during the highway construction process. Greater attention should be paid to the environmental issues such as emissions during the construction process, impacts on the local community through soil erosion and problems with water quality and flow.

The construction engineers were more concerned about the project management process:

'*The developer must provide the environmental protection report which includes the effect on land, air, noise and water, also the disposal of waste, the use of energy and non-renewable resources. Without this information, the project won't be approved by the government.'* (*Construction engineer 2)*

Furthermore, in contrast to the academic professionals, the construction engineers paid more attention to the microeconomic benefit over the project lifecycle. As they explained:

'The fundamental obligation of the enterprise is to ensure the shareholder's interests.' (Construction engineer 2)

'The primary purpose of the investment is to generate profit.' (Construction engineer 3)

They were more concerned with financial sustainability, for the revenue stream to maintain the asset, the gains and losses of the project, debt repayment, construction and maintenance cost. The criteria of project budgetary impact, 'Return on Investment', 'Cost/benefit Ratio' and 'Financial risk' were cited as important by the construction engineers.

The project 'Maintainability' and 'Extendibility' were also cited respectively by 75% and 67% of interviewees, and these two factors are related to the project benefits.

'*High maintainability and extendibility will reduce the reconstruction cost of the highway.' (Construction engineer 2)* And *'the technological factor was cited by all construction engineers, it is because technology is the basis for achieving high maintainability and extendibility.' (Construction engineer 4)*

Another factor, 'Appropriate plan' was mentioned by 65% of participant, and 'Improving the efficiency of the road network', was put forward by 50% because inappropriate road network plans lead to low utilisation rate, inappropriate highway capacity and increasing travel time and cost (Huang, 2016).

The responses of the participants included environmental, social and cultural, economic and technological issues, which illustrate that the experts' opinions are consistent with sustainable development principles. Moreover, the responses showed that the results of interviews in this chapter and the questionnaire in Chapter 7 agreed that participants from construction industry are more concerned about the project's economic benefits, but the academic professionals and government officers are more focused on environmental and social issues.

8.3.2.4 Current sustainability assessment methods in highway infrastructure projects

The experts' feedback on sustainability assessment methods for highway infrastructure projects showed that they are focused on the environmental aspects and rely on government policies and regulations, and industry standards and instructions, any requirements beyond the framework of the law are given less importance.

Environmental Protection Law, Environmental Impacts Laws, Regulation on Energy in Civil Buildings were the most relevant documents. The construction engineers all referred to the Evaluation Standard for Green Building GB/T50378-2014 and the feasibility report of the project. That is because the Environmental Impact Assessment is an essential part of the feasibility report which must be approved by the government (MOEP, 2002). The government officers emphasised the standards of construction in highway projects including the Specifications for Environmental Impact Assessment of Highways (JTG B03-2006), the Yunnan Provincial Evaluation Standard for Green Building (2011), the Standards for Construction Safety Inspection and Design, the Technical Standard of Highway Engineering (JTG B01-2003).

Typical existing project performance evaluation methods including Economic Analysis, Financial Analysis, Social Impact Assessment and Lifecycle Analysis were referred to by the participants. Including Environmental Impact Assessment, these methods evaluate highway infrastructure project performance in multiple dimensions of sustainability, they are used separately but all were included in the feasibility study report.

'The future assessment could use the experiences of other countries to build a comprehensive assessment method for highway infrastructure projects, such as LEED and BREEAM.' (Academic professor 1)

From the responses of the interviews, the current evaluation frameworks, environmental impact assessment or project performance evaluations do not adequately accommodate sustainability in highway infrastructure, and there is a need to develop a comprehensive sustainability assessment method.

8.3.2.5 Barriers to sustainability assessment of highway infrastructure projects

Following up the final question, the participants were asked to describe barriers to the implementation of the sustainability assessment of highway infrastructure projects in Yunnan. According to the responses, the barriers were grouped into four categories: 1) political barriers; 2) awareness barriers; 3) governance barriers; and 4) financial barriers.

1) Political barrier

The theme of ‘Lack of legislation and enforcement’ appeared 10 times, 83% participants thought this was the main barrier to undertaking sustainability assessment.

‘The sustainability assessment will increase the cost, without the requirement of the government, it will not be used.’ (Construction engineer 1)

Also, lack of relevant laws and standards to assess sustainability was identified as political barrier by 50% of respondents. Currently, sustainability in highway infrastructure projects does not have an adequate or supportive political framework in China, and the environmental protection laws and regulations are not sufficiently robust for developing highways in a sustainable way (MOEP, 2002). Therefore, the government must develop and implement laws to address sustainable development issues and assessment standards.

2) Awareness barrier

The second most cited category of barriers falls under ‘People’s lack of awareness of sustainability’ which represented 80% of the responses. According to these responses, the term sustainable development has not fully captured the imagination of most people in Yunnan, and the concept is not applied to project governance. This barrier included two aspects: the decision-makers and engineers.

50% of responses considered that the decision-makers lack awareness on incorporating sustainability assessment in the project development process. *‘Sustainability assessment was introduced into the project planning later than other provinces due to the decision-makers ignorance, and it cannot make an effective influence on project design and plan.’ (Academic professor 2)*

A significant trend is that the economic benefits of the highway infrastructure projects have been taken seriously in Yunnan. Despite the government’s requirements for environmental sustainability, and the political framework putting pressure on construction companies, only a few highway infrastructure projects have been constructed based on sustainability requirements (Yan *et al.*, 2013). *‘People’s awareness of sustainability in highway infrastructure projects is lacklustre and overshadowed by project economic benefit’*

(Academic professor3), and 'the construction activities are accepted if those activities do not extend beyond the legal requirements and exceed the law' (Government officer 1).

30% of participants mentioned that project construction and management teams lack an understanding of building sustainable highway infrastructure projects.

'The civil engineers care more about the activities in the construction stages, their targets are to complete the project under the schedule and quality requirements, but less concern is shown about the long-term impacts of the project.' (Construction engineer 1)

The construction companies lack facilities to account for long-term natural environmental costs and social impacts but instead focus on the short-term project financial pressures (Yang, 2016). New technologies are used to achieve the traditional project scopes of quality, time and cost, since it can reduce cost and improve quality, but the new technologies are not perceived in terms of sustainability, and neither were the techniques for achieving sustainability included at the design stages. Qualified construction engineers, project managers and project supervisors are experienced in highway infrastructure project development, but they are not required to be qualified in sustainable building (Tang, 2016). However, Yunnan still lacks a skilled work force for sustainable highway construction.

3) Governance barrier

60% of the participants cited governance system lacking integrated approval and management processes for highway infrastructure projects in Yunnan.

'The functions interaction and overlapping between the government departments is seriously harmful in developing highway infrastructure projects.' (Government officer 2)

The development process for highway infrastructure projects is complex and involves different levels of government and government departments. The departments maintain a strong role in highway network planning, financing and policy coordination, such as the National Development and Reform Commission (NDRC) and the Ministry of Transportation (MOT). They provide the broad plan for the provincial and local governments to produce development frameworks in a local context. The MOT is responsible for formulating the national road network development plan. In 2013, it announced the National Highway Network Plan for 2013-2030 to improve highway coverage in urban and rural areas. This plan was approved by NDRC which is responsible for formulating the strategy for economic and social development, it is also responsible for infrastructure projects deployment and formulating project investment policies. Under the plan, the Provincial Transport Department has made recommendations for highway provision in Yunnan Province, and the projects development proposals are approved by the provincial government. The approval is then submitted to the MOT. Meanwhile, the Ministry of Housing and Urban-Rural Development (MHUD) is responsible for setting the construction standards for highway construction, such as construction energy use, greenhouse gas emissions, dust, waste water and solid waste disposal and other requirements. The Ministry Environment Protection Department (MOEP) also has a responsibility to supervise ecological and environmental protection, and its responsibility also covers greenhouse gas emissions, waste disposal and so on. Finally, the Land and Resource Department is responsible for the planning, administration, protection and rational utilisation of land in China (MOT, 2016).

'The objectives of different departments are varying, such as the Transport Department seeking road network improvement, the Provincial Department is more focussed on economic growth through highway construction, compared to Environmental Protection Department, they both express less concern for land use, energy saving and other environmental objectives.' (Construction engineer 4)

Management system redundancy and duplication of function leads to objectives discrepancy and different emphases on project assessment that cause difficulties in clearly defining the management scope and functions for different departments (Lei, 2016). In addition, one participant argued that insufficient transparency in decision-making is one of the main barriers to the development of highway infrastructure in Yunnan. Two participants believed that more transparent governances would make the development of highway infrastructure more effective.

4) Financial barrier

Lack of financial resources and support is another major barrier to providing sustainability assessment. The uncertain return on investment is an obstacle to obtaining private investment for highway infrastructure. The additional financial cost of adopting sustainability evaluation in highway projects has been cited by 50% of participants.

'There is no internal added cost for implementing the sustainability assessment.' (Construction engineer 3)

'Construction companies have no internal capital allocation for sustainability assessment.' (Academic professor 1)

8.3.3 Suggestions of refining the developed model

This theme focussed on the comments of the developed model in this research. The interview questions covered the following aspects: if the developed model covers all the issues of sustainable highway infrastructure project in Yunnan; if the developed model is easy to communicate; if the developed model has applicability; and if the developed model is useful for assessing sustainability in highway infrastructure projects in Yunnan.

8.3.3.1 Coverage of sustainable issues

This theme was divided into two parts: 1) if the assessment indicators selection is reasonable; and 2) should anything be added to the assessment model.

The indicator system was sent to the participants to comment on the level of importance of each indicator with a request for suggestions for any missing or redundant indicators before the interview was held, and the comments were discussed during interviews. From the responses of the participants, the results for the total thirty-seven indicators were as follows:

- Thirteen indicators were rated as important criteria of sustainability assessment by 50% of participants;

- Twenty-three indicators were rated as relevant to sustainability assessment by 50% of participants;
- One indicator was suggested to be omitted;
- One indicator was suggested to be added (shown in Table 8.3).

Table 8.3 Comments on the individual indicators

Indicator	Comments	Number of Participants
Coordination with various organisations	Omitted	5
Toll system design	Added	2

More explanations were provided by the participants as follows:

25% of comments suggested the indicator of 'Coordination with various organisations' should be omitted. Academic professor 2 commented it has same meaning of *'Suitable to different stakeholder', both are evaluating if the project can be accepted by different stakeholders'.*

The problem of tolling highway infrastructure project was proposed by two participants (16%).

'The biggest difference on highway infrastructure project between China and other countries is the toll.' (Academic professor 1)

'As the economic benefit, the tolling system is required to be described in the feasibility report.' (Construction engineer 3)

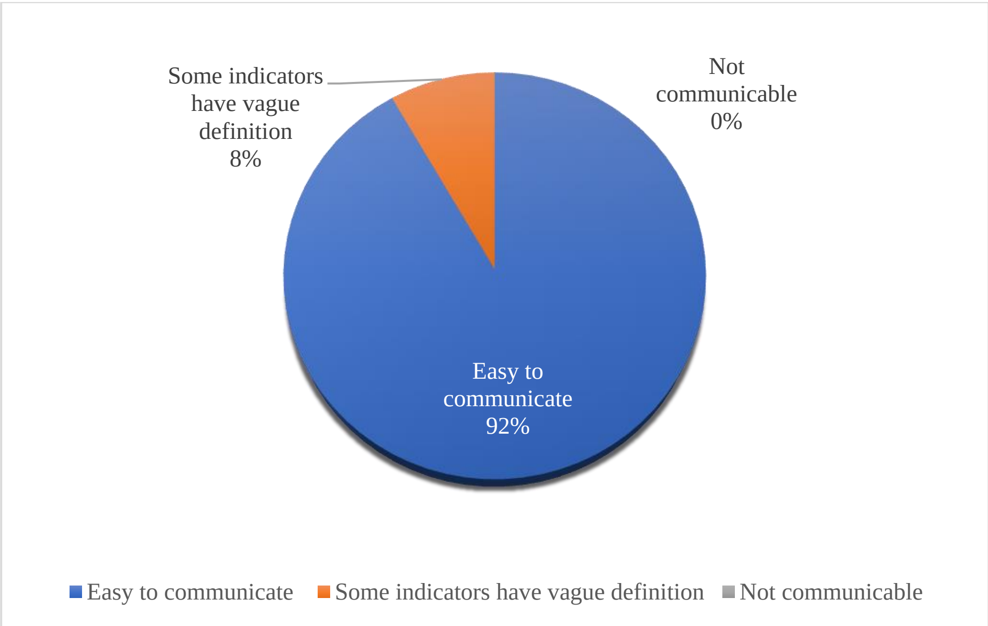
According to an academic professor, in China, 90% of the highways are charged, capital inadequacy is the primary factor that restricts highway development. Under the policy of 'build road with the load, return the load by tolling', China adopted BOT (Build- Operate-Transfer) investment model to solve the shortage of funds, so toll financing is a method for rapid expansion of the road system in China. The road maintenance fees were collected from the toll under the rationality of 'who uses, maintains' (The Law Library of Congress, 2015). Tolling is a critical part of operational revenue, and the highway investment decision will be made by reviewing the projected revenue (Gao, 2014). It is evident that the toll is the primary consideration in highway economic performance.

Three participants suggested that the assessment model should take the opinions of a broad range of the stakeholders, referring primarily to the public. The explanation from Professor 1 was that *'highway is a public infrastructure project, its construction is within a broader social context, as a social issue it should be accessible to people'.*

8.3.3.2 Communication difficulties of this model

Effective communication of the assessment model will ensure that it is understood by the users. The participants were asked to give their opinions and recommendations about the use of the model to assess communicability. The results as the Figure 8.3 shown.

Figure 8.3 Communicability of the model



92% of participants agreed that there are no communication difficulties for this model. One participant suggested that some of the indicators are too specialised. The English word

‘Serviceability’ is easy to understand by academics, but for a construction professional, it could be too ‘specialised’.

8.3.3.3 The applicability of the model

When the participants were asked if the model is applicable locally, twelve participants all affirmed its positive effect on highway infrastructure project development.

‘It would provide a reference for current development pattern of highways, and solve the negative problems in the development process’ (Academic professor 3)

80% of participants agreed that the model is easy to use, most stating that its themes are ‘Easy to use’, and ‘Has applicability in Yunnan’, but some of the positive responses were qualified.

‘The indicator selection and determination and assessment method strongly relied on the experts’ experience that led to fuzziness in the assessment process.’ (Academic professor 4)

From four construction engineers’ viewpoints, sustainable assessment will cause additional management and labour cost, they argued that companies will only implement the model when the benefits of sustainable assessment exceed the costs. The common responses of the other eight participants were that sustainable assessment will cause some costs, but the benefits are higher than the costs.

Two academic professors commented that the assessment ‘must stand on the issues of Yunnan’. The model used the most common method, that is, an indicator-based assessment to evaluate the sustainability of highway infrastructure projects in Yunnan, but the circumstances and conditions of Yunnan are not fully accounted for by the indicators, e.g. the influence on ethnic minority groups. According to the participants, to better accommodate the local conditions, the assessment method should be more comprehensive. Besides, the data and information should include statistics from local government and documents from authorities and other relevant organisations. The application of the developed model should include field investigation of the project to collect data and information.

The assessment model is regarded as a tool to improve sustainability in highway infrastructure project development. The construction engineers felt that the model is good in theory, but it has difficulty in the broad practical application in Yunnan, since a full awareness of the sustainable development concept has not yet been established. Without enforcement by the government, it is less likely to be implemented by industry. In the opinion of construction engineer 3, sustainability assessment is not currently mandatory for highway infrastructure projects, and consequently, sustainability assessment will be regarded as a voluntary burden for the developer and owner.

8.3.3.4 Usefulness of the developed model

The responses to this question were unanimously positive, all twelve experts agreed that the developed model will help to ensure sustainable highways in Yunnan. One participant stated that this model gives consideration for current highway development patterns, it will benefit highway infrastructure, but it needs to be enforced by government. At some point of time in the future, when China establishes an appropriated policy framework, the usefulness of the model will be established.

8.3.4 Sustainability assessment in highway infrastructure projects

Yunnan is a mountainous region in the southwest of China with some of the most diverse topography and biodiversity in China. It is also a frontier area between China and south and southeast Asian countries meaning that its economic and geographical location is significant, but current development is lagging other areas in China. The highway is the primary transportation method in Yunnan, and it is the most critical infrastructure for economic growth and social development. Sustainability assessment enables the evaluation of different impacts for an investment project, ultimately enhancing the sustainability of highway infrastructure projects.

Over several decades, extensive studies have introduced the principle of sustainable development to the construction industry. Various sustainability assessment systems have been established to evaluate the overall performance of highway infrastructure projects at the planning and design, construction, operation and disposal stages. However, to date there is no efficient and systematic evaluation method for measuring sustainable highway infrastructure projects in China, particularly in less developed areas such as Yunnan. On the other hand, development of the province cannot happen without highway infrastructure, at present many road projects are being constructed or planned to be built. In this situation, the promotion of sustainability assessment for highway infrastructure projects must be an important part of the process to realise sustainable development of the area.

The aim of sustainability assessment in highway infrastructure projects is to evaluate sustainability at the project decision-making stage from a sustainable development perspective and choose the optimal solution to reduce or eliminate negative impacts. It assesses the social, environmental, and economic impacts of a project over its whole lifecycle (planning and design, construction, operation and disposal stages), and it is regarded as an efficient method to implement a sustainable development strategy for highway infrastructure projects.

8.4 Improving the sustainability assessment model

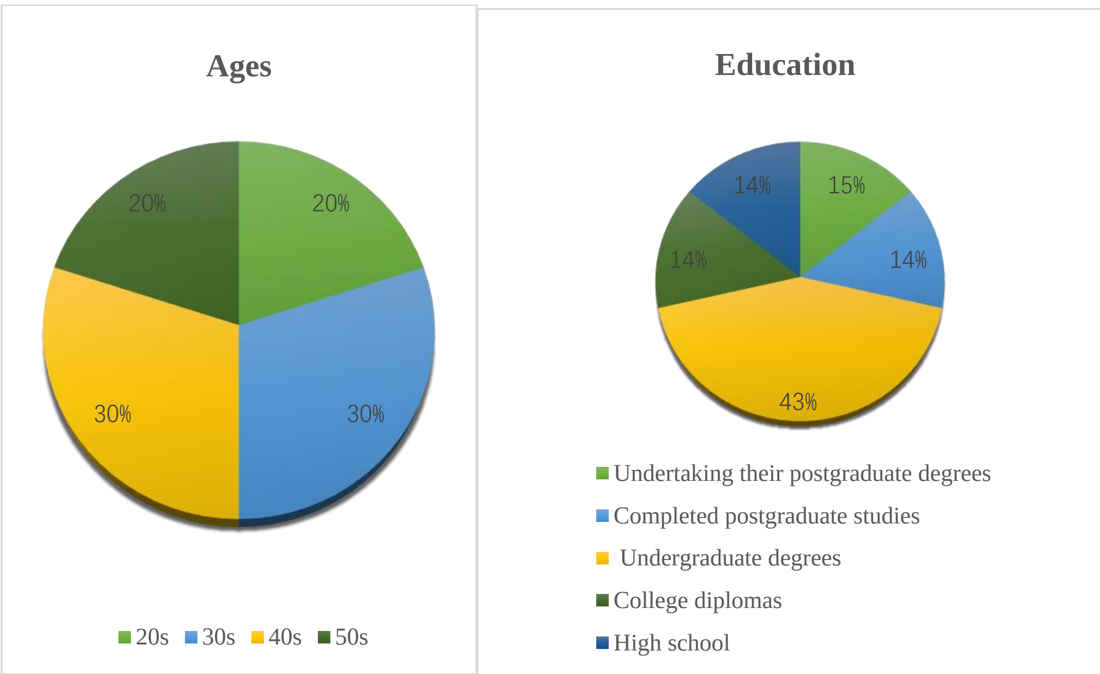
The model was improved based on the responses of the interviewees.

8.4.1 Public participation test

Based on the responses from the experts, the original intention was to distribute twenty questionnaires to members of the public to ensure participation by more stakeholders of highway infrastructure projects. In the implementation process, problems were raised in inviting the public to participate in the survey. Determining the study sample was the most significant problem when engaging the public in the research, and most people found it difficult to complete the questionnaire due to their lack of knowledge on sustainability assessment of highway infrastructure projects.

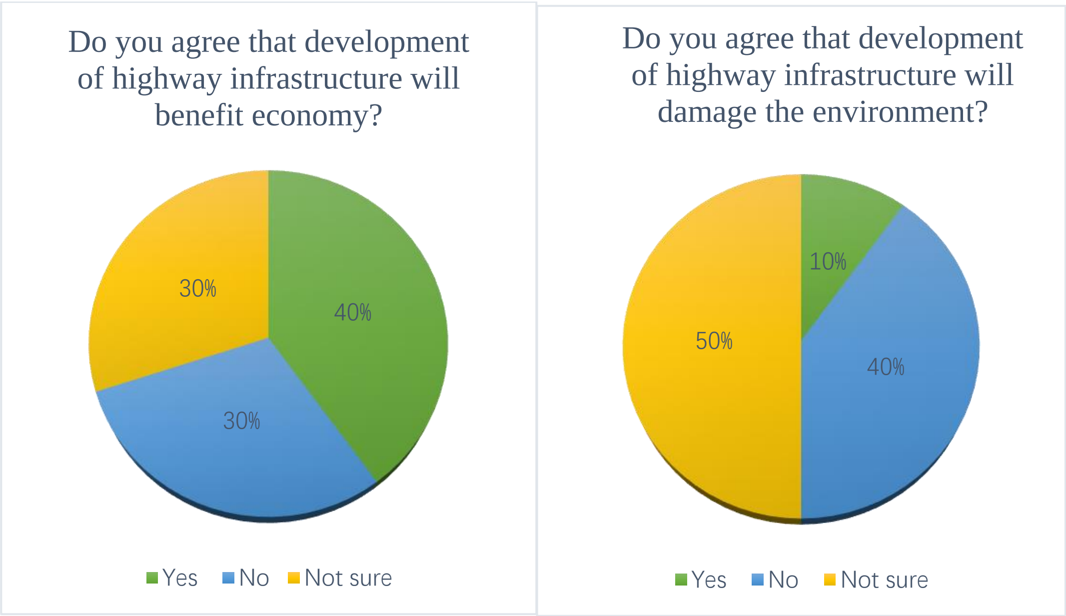
A project manager of an under-construction highway project identified twenty people involved in the project. Twelve people were working in the same construction organisation and eight people were living along the project area. The initial feedback from the participants showed that only one person had postgraduate education background and understood the meaning of sustainability assessment of highway infrastructure projects. 90% of participants found the meaning of some of the indicators in the assessment model difficult to understand, such as ROI, NPV, transportation network, maintainability, etc. The meaning of sustainability assessment was explained to the participants one by one to help them to understand what is meant by sustainable highway infrastructure projects. In the end, all twenty subjects agreed to give their opinions on the development of highway infrastructure projects. The participants ranged in age from 25 to 50 years old. Four participants were in their 20s, six were in their 30s, six were in their 40s, four were in their 50s. Two participants are undertaking their postgraduate degrees, two had already completed their postgraduate studies, six held undergraduate degrees, two had college diplomas, two had high school education experience, six participants were not educated to high school level. Figure 8.4 shows the participants age and education backgrounds.

Figure 8.4 Participants' backgrounds



The survey was completed in the middle of February 2017 and revealed that people are more interested in sustainability issues if they are educated, and only people who had received a high level of education were concerned the long-term effects of construction activities. Young people, in their 20s-30s, were more engaged in sustainable development issues and environmental problems of highway construction.

Figure 8.5 Public understanding of highway infrastructure influence on economy and environment



When asked whether they understood that development of highway infrastructure will influence the local economy and environment (Figure 8.5), eight (40%) agreed that highway infrastructure will bring economic development, one participant stated that: '*Yunnan is a frontier province of China, most areas are undeveloped and highway infrastructure is the engine for economic development.'*

Six people agreed that construction of highways can bring economic benefits, but felt that too much money was spent on highway infrastructure construction, going on to state that in recent years the government has imposed higher public taxes. They argued that the government should spend money on education and medical infrastructure projects. Another six participants were not sure if highways benefited the local economy, one participant stated that:

'Pursuit of economic growth is the intention of the government, but food, clothes and shelter are the biggest concerns of the public.'

Six participants were very environmentally aware, worrying about the current environmental problems in Yunnan. One participant recollected:

'I swam in the Dianchi Lake of Kunming 30 years ago, but now the water of the lake is like green paint'.

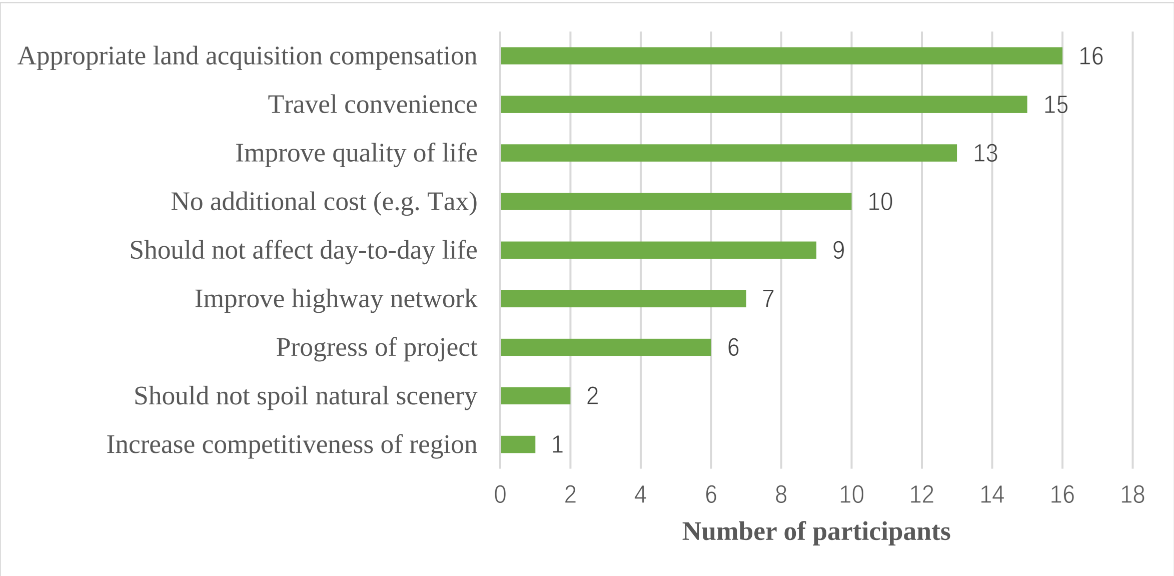
The pollution of Dianchi Lake is not directly related to highway construction, but the participants believed that the urban over-expansion will cause environmental problems.

The other four worried if sustainable highways were costing too much, as one participant said:

'The development can take the road to obtaining economic growth as 'pollute first, treatment later.'

After providing more details of the sustainability assessment of highway infrastructure projects to the twenty participants, they identified the critical factors for satisfying their expectations of developing the highway infrastructure projects as shown in Figure 8.6.

Figure 8.6 Factors of highway development



The factors from the public indicated that most of them support the government in investing in more highways, but they preferred for the projects' construction works not to influence their daily life, such as increasing travel time and cost in the construction stage. The results also showed that the public want appropriate investment and planning for developing highways, avoiding high risk investment and achieving a real improvement to both the highway infrastructure project and local communities.

'The benefits of highway infrastructure projects' construction should not only be a way to increase the government revenues but should also prevent corruption.' (Participant)

'After completion, the project should improve the quality of life, solve the problems of congestion and transportation chaos, and provide a convenient way to travel.' (Participant)

Four participants raised concern about the land acquisition compensation problem because the highway project required their land. Two people felt that highway construction should not spoil the natural scenery because the most attractive aspect of Yunnan is the natural landscape. One aspect of economic development, 'Increasing the competitiveness of region', was mentioned by one participant.

Finally, the feedback from the public participants was discussed with two construction engineers and two academic professors. Academic professors deemed that all the factors identified by the twenty public participants had already been included in the indicator system of the assessment model in Chapter 7. The factor of 'Should not spoil natural scenery' can be viewed as 'Effects on natural landscape and historical sites', 'Improve the quality of life' falls under 'Contribution to improvement of people's income and living standards', 'Increasing the competitiveness of region' can be related to 'Contribution to local economy', 'Land acquisition compensation' is included in 'Resettlement work'. Therefore, the assessment model to all intents and purposes includes the public expectation of highway infrastructure projects.

The feedback from the public participants revealed that the sustainability assessment of highway infrastructure projects which includes all stakeholders' requirements is still a theoretical concept for the public at large. Extensive public participation is necessary for sustainability assessment, but it is unrealistic in practice at present.

8.4.2 Improving indicator system

The toll system for the highway produces the operational revenue which is included in the financial analysis of the feasibility report. The requirement of Article Three of the Highway Construction Project Economic Assessment Method published by the MOT provides that a highway construction project must evaluate the national economic impact and financial benefits, all toll projects must have a project economic evaluation (MOT, 2014). '*The operational revenue is reflected in a range of economic indicators as cost-benefit ratio, financial risk and project investment planning' (Construction engineer 1)*. Therefore, the indicator of 'toll system design' will not be added to the sustainability assessment model.

The suggestion of omitting the indicator of 'coordination with various organisations' is consistent with the results of the questionnaire survey in Chapter 7. The average value of this indicator from the questionnaire was 2.343 which is lower than 3 'average significance' level. Hence, it was omitted from the indicator system. The other thirty-six indicators in the assessment model were retained. The updated indicator system is shown as Table 8.4, with the weightings of the indicators assigned by the AHP method.

Table 8.4 Updating indicator system

	Code	Indicators	Mean	Weight
Economical aspect	*S1*	Lifecycle cost	4.7313	0.0235
	S2	Project budget	4.5821	0.0235
	S3	Project investment plan	4.5373	0.0235
	S4	Financial risk	4.9104	0.0235
	S5	Return on Investment (ROI)	5.0896	0.0471
	S6	Net Present Value (NPV)	5.0299	0.0471
	S7	Payoff period	4.9403	0.0256
	S8	Internal rate of return (IRR)	4.9701	0.0448
	S9	Cost/benefit ratio	5.0448	0.0471
	S10	Contribution to local economy	5.1642	0.0471
	S11	Contribution to improvement of people's income and living standards	5.0299	0.0471
Social aspect	*S12*	Providing job opportunities	3.4478	0.0111
	S13	Improvement on public health	3.1493	0.0111
	S14	Effects on development of local education	3.4179	0.0111
	S15	Protection of cultural and natural heritage which related to the project	3.5821	0.0098
	S16	Resettlement work	4.0448	0.0222
	S17	Suitable to different stakeholders	3.0746	0.0111
	S18	Serviceability	4.0149	0.0222
Environmental aspect	*S19*	Effects on land (Land consumption and land pollution)	4.4627	0.0142
	S20	Effects on ecological environment (changes on climate and local geology)	4.5821	0.0142
	S21	Effects on air quality	4.5522	0.0152
	S22	Effects on water quality (produced waste water, consumption of water resource, potential contamination)	4.5522	0.0152
	S23	Noise pollution	4.1642	0.0092
	S24	Waste disposal	4.1343	0.0076
	S25	Use of green energy sources	4.1791	0.0076
	S26	Energy saving	4.1493	0.0068
	S27	Effects on natural landscape and historical sites	4.0299	0.0111
Technological aspect	*S28*	Advantage of project technologies	4.2388	0.0222
	S29	Coordination with other transportation projects	4.7015	0.0222
	S30	Improvement on road network efficiency	5.0299	0.0444
	S31	Maintainability	5.0000	0.0444
	S32	Extendibility	4.7910	0.0444
	S33	Disaster prevention capability	4.3582	0.0222
Governance aspect	*S34*	Rationality of project design and planning	4.8105	0.1000
	S35	Rationality of organisational structure design	4.5241	0.0500
	S36	Sound governance systems	4.7819	0.0500

However, it should be noted that the suggestion of enhancing the regulatory enforcement and sustainability awareness by project participants in order to overcome the barriers to adopting sustainability assessment are too broad for this research.

8.5 Application of the sustainability assessment model – A case study

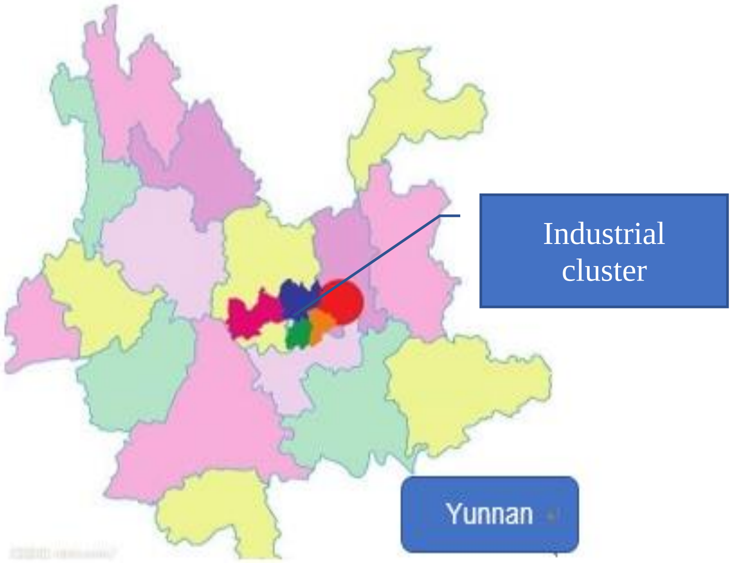
To further examine the rationality and feasibility of the sustainability assessment model, the developed model was applied to a case study - KQ No.4 Highway in Yunnan. The primary reason for selecting this case is the availability of data which would be collected in any case. It is important to note that the project feasibility report was the main source of information on the sustainability performance of the case study.

.

8.5.1 Background of the KQ No.4 highway

In May 2012, Government of Yunnan Province proposed a strategic plan for the construction of an industrial cluster in the central area of Yunnan including the three areas of Kunming, Yuxi and Chuxiong, shown in Figure 8.6. It has a total area of 18,156 square kilometres, with a total population of 2.5 million including 19 minority groups, the establishment of the industrial cluster can contribute significantly to provincial economic development, employment, exports, and improvement of life quality (Management Commission of Central Area of Yunnan, 2016).

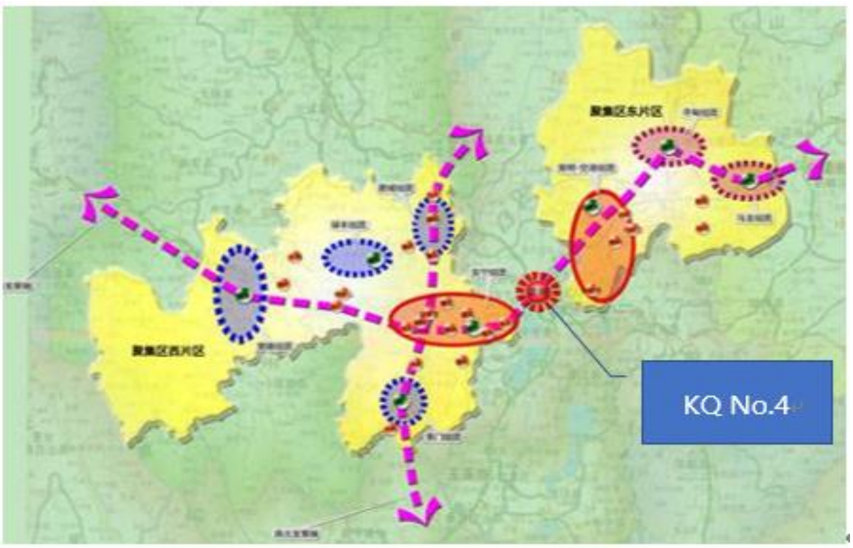
Figure 8.7 Location of the industrial cluster



Sources from: Management Commission of Central Area of Yunnan (2016).

The highway links the capital city of Yunnan, Kunming and the second largest city Qujing, it was approved by the provincial government, and KQ No. 4 is a part of the highway (Figure 8.7) with a total length of 21 kilometres. The total budget of the project is $1.63 billion and the first phase of the project was completed in 2015.

Figure 8.8 Location of Kunming –Qujing highway



Sources from: Management Commission of Central Area of Yunnan (2016).

8.5.2 Impacts of KQ No.4

The project is regarded as the strategic transport infrastructure project for promoting the development of industrial clusters in Yunnan Province and realising the sustainable development in this area.

Economic impacts

Economic impacts arising from KQ No.4 highway not only contribute to industry and project itself but also the nation and region. 35% of the total amount of investment for this project is from government with the remaining 65% borrowed from banks. The internal economic rate of return is 11.26%, cost/benefit ratio is 1.509, the NPV is $6.96 billion (IC=8%). A positive NPV follow that the yield is above the minimum and the project is investment worthy (Edwards *et al.*, 2003).

Currently, there are only two highways (G5 and G85) that link Yunnan, Sichuan and Chongqing, for many years the road network coverage has been limited in the east of Yunnan which in turn has limited the development of this area. KQ No.4 project is expected to significantly increase transportation capacity and improve the road network in Yunnan, finally contributing to local development, dispersing traffic load and easing traffic pressure on current main roads.

Social impacts

The highway directly influences regional agricultural development, greatly reducing the transportation time of fresh agricultural products from producers to consumers, expanding the market, and promoting production and processing. The development of the agricultural economy can increase the income of residents and improve their quality of life (MOT, 2016). The upgrading and improvement of highway infrastructure not only encourages increased regional competitiveness but also realises human development. At the time of writing, only 15% of the population completed high-school education in the project's area, this results in an abundant labour force, since the working-age proportion in the population is over 70%. The construction of the project can stimulate improved educational resources input and local job output, and increase employment opportunities.

Environmental impacts

The most notable environmental problem is that the new project is in relatively close proximity to the Yaoshan National Nature Reserve (220 square kilometres). The Reserve has special geological formations and complicated landforms, but is also famous for its peculiar and widely admired scenery, and its rich ethnic cultures. The project provides improved transportation for 274 households with 1093 people at Yaoshan Village in the Reserve, but it's construction could result in environmental damage during the construction process, including noise, air, and water pollution (Gao, 2016). Another problem is that the forest coverage rate along the project is only 25%, and highway construction and other human activities related to the projects could result in deforestation. Moreover, the project crosses three rivers, JinshaJiang, Niulanjiang, Yilihe with total length 649 Kilometres and the construction has a significant effect on water quality and hydrology along the route of the road (Ma and Zhu, 2012).

Techniques and governance issues

The relevant compulsory criteria of the industry standards determine the techniques for the project. The implementation of the project is conducive to local economic development and improving the social environment, which gains support from local and central government and various organisations, and the project planning, construction and supervision are strictly governed by the relevant authorities.

However, due to the topographical location, natural conditions, and other unfavourable geological conditions, the construction area of the project is susceptible to landslides and debris flows. A number of bridges and tunnels are required, and the complex conditions require high-tech construction methods and high-quality construction (Wang, 2013).

8.5.3 Sustainability assessment of the KQ No.4 highway

The feasibility report is the primary document for gaining approval for the project from the authorities. The information found in the feasibility report was used to assess the sustainability of the project. The available information and data included:

- General background of the project
- Status of socio-economic and transportation development
- Analysis of traffic flow and forecasts
- Technical standards
- Construction plans
- Investment estimation and financing channel
- Economic evaluation
- Implementation plans
- Land utilisation evaluation
- Environmental impact evaluation
- Energy saving analysis
- Social evaluation
- Risk analysis
- Project management team

It is important to note the feasibility report for this case study did not contain all the data needed for the sustainability assessment model resulting in a less precise assessment, but the application of the model can be justified on the basis of the information and data available.

8.5.3.1 Assessment process

Postal questionnaires and interviews were used in the assessment process. For the first step, six experts were invited to use the indicator system in Table 8.4 to score the sustainability performance of the case study based on the information in the feasibility report. The participants consist of two academic professionals, two directors of the government departments, and two senior managers of the construction firm. All six participants have been working in the highway construction for more than five years and they were familiar with the requirements, regulations and standards of highways infrastructure project construction.

The sustainability assessment used a five-point Likert scale to grade the indicators, ‘9’ is excellent; ‘7’ is good; ‘5’ is moderate; ‘3’ is a pass; and ‘1’ is weak. To facilitate the scoring process, the feasibility report was sent to the participants with the Likert scale (Appendix III) at the end of February of 2017, and six responses were received within a week. The data was analysed by using EXCEL. According to the weighted evaluation method in Chapter 7：

$S = \sum_{i=1}^{n} A_i S_i$; for i=1, 2, 3…36

S= Total sustainability performance value

A_i=Weighting of i

S_i=The value of indicator i

And:

$\sum_{i=1}^{n} A_i = 1$;

$0 < A_i < 1$

The six experts’ scores for each individual indicator were multiplied by the weighting, and summed to give the total value of the sustainability index of the project. The total score was 5.974 which indicates that the sustainability performance of the project is considered as between good and moderate. The result is shown in Table 8.5.

Table 8.5 Assessment result

	Code	Indicator	Value	Weight	Score
Economic aspect	*S1*	Lifecycle cost	6.857	0.0169	0.116
	S2	Project budget	6.429	0.0133	0.086
	S3	Project investment planning	5.286	0.0133	0.070
	S4	Financial risk	6.143	0.0253	0.155
	S5	Return on Investment (ROI)	5.143	0.0457	0.235
	S6	Net present Value (NPV)	5.000	0.0428	0.214
	S7	Payoff period	6.714	0.0322	0.216
	S8	Internal rate of return (IRR)	6.429	0.0277	0.178
	S9	Cost/benefit ratio	7.714	0.0428	0.330
	S10	Contribution of local economy	7.857	0.0731	0.574
	S11	Contribution on improvement of people's	4.429	0.0428	0.190
Sub-total					2.364
Social aspect	*S12*	Providing job opportunities	4.143	0.0083	0.034
	S13	Improvement on public health	4.429	0.0044	0.019
	S14	Effects on development of local education	4.571	0.0077	0.035
	S15	Protection of cultural and natural heritage	4.429	0.0077	0.034
	S16	Resettlement work	4.714	0.0208	0.098
	S17	Suitable to different stakeholders	4.143	0.0042	0.017
	S18	Serviceability	4.429	0.0208	0.092
Sub-total					0.331
Environmental aspect	*S19*	Effects on land (e.g. Land consumption and	3.286	0.019	0.062
	S20	Effects on ecological environment (changes	3.857	0.019	0.073
	S21	Effects on air quality	5.143	0.019	0.098
	S22	Effects on water quality (produced waste	5.714	0.019	0.109
	S23	Noise pollution	5.143	0.0098	0.050
	S24	Waste disposal	5.571	0.0098	0.055
	S25	Use of green energy sources	5.714	0.0098	0.056
	S26	Energy & materials saving	5.714	0.0098	0.056
	S27	Effects on natural landscape and historical	4.429	0.0056	0.025
Sub-total					0.584
Technological aspect	*S28*	Advantage of project technologies	6.429	0.0175	0.113
	S29	Coordination with other transportation	6.857	0.0319	0.219
	S30	Improvement on road network efficiency	6.571	0.0579	0.380
	S31	Maintainability	5.429	0.0579	0.314
	S32	Extendibility	5.143	0.0319	0.164
	S33	Disaster prevention capability	6.429	0.0175	0.113
Sub-total					1.303
Governance aspect	*S34*	Rationality of project design and planning	5.286	0.0859	0.454
	S35	Rationality of organisational structure	6.429	0.0429	0.276
	S36	Sound governance systems	7.714	0.0859	0.663
Sub-total					1.392
Total					**5.974**

The second step was to hold interviews with six experts by phone call to further investigate details of the project's sustainability performance. Each interview lasted for 15 minutes.

8.5.3.2 Interview results in analysis

The overall sustainable performance of the KQ No.4 highway project was acceptable according to the experts' opinions. From the responses of the experts, the project was suitable for social and economic development under local conditions.

Economic performance

The results demonstrated that the average score for the economic aspect was higher than other indicators. For economic indicators, the project financial indicators obtained a higher score than other indicators.

'Based on the feasibility report, every 1-yuan investment on highway construction generates 3-yuan total social output value, and creates 0.4-yuan gross national product (GNP), the financial performance is good.' (Construction engineer 1)

'On the national economy perspective, the internal returns to the national economy of the project is 10.74% which is greater than the social discount rate of 8%, and the risk resistance capacity of national economy is strong. Furthermore, the project builds a connection across the Yangtze river to link Yunnan-Sichuan-Chongqing, and it improves the comprehensive transport capacity and traffic saw a sharp rise in the southwest area of China. Therefore, from the economic aspect, the project economic sustainability is good' (Director of Government 1).

The responses of participants also indicated that the score of economic performance was higher than other aspects because the information about the economic benefits was more detailed.

Social performance

The social performance was given lower score than other aspects, one of the major reasons being the scarcity of data for social impacts.

'There were no concrete plans for the problem of most concern 'resettlement work.' (Academic professor 1)

According to the responses of the experts, there were some suggestions for social aspects which consisted of: 1) optimising the planned highway route to reduce land occupation and population relocation; 2) setting up an acceptable policy for demolition and land acquisition compensation; and 3) making suitable provision to ensure a sustainable source of income for relocated people.

'The project developer should look especially to the vulnerable groups of farmers who are relocated. To help the people who cannot maintain a basic standard of living through land redistribution to undertake industrial transfer, develop production and development, and reduce the social risk of the project.' (Academic professor 2

In addition, the information available showing improvement of local education, public health and job opportunities was qualitative with no standardised measure to evaluate it, entirely depending on the experts' subjective judgement.

Environmental performance

For environmental aspects, the average value of two indicators *S22* (effects on land) and *S23* (effect on the ecological environment) were lower than the other 35 indicators. Academic professor 1 explained that:

'The project crossed three counties, Malong, Huize and Dongchuang, where agricultural industry is predominant, and all the economic activities are based on farming. But the farmland resources are limited, meanwhile the project occupied some of the arable land resource resulting in ecological destruction'.

Base on the feasibility report, forests and farmland are the main land uses in this area, but farmland occupies less than 25%, so its permanent loss should be a major concern (Table 8.6-8.8).

Table 8.6 Land-use situation of Malong County (hundred meter2, %)

	Total	Agricultural land				Building land		Others	
		Farmland	Garden	Forest	Meadow	Construction purpose	Infrastructure purpose	Water area	Unused land
Area	319684	75774	4863.7	117269	6519.1	22487	4571.1	846.8	19.6
Percentage	100%	23.70%	1.52%	36.68%	2.04%	7.03%	1.43%	0.26%	0.01%

Table 8.7 Land-use situation of Huize County (hundred meter2, %)

	Total	Agricultural land				Building land		Others	
		Farmland	Garden	Forest	Meadow	Construction purpose	Infrastructure purpose	Water area	Unused land
Area	322781.62	130096.26	2275.14	370436.86	8047.06	13701.01	5122.87	8649.14	47071.88
Percentage	100%	22.22%	0.39%	63.28%	1.37%	2.34%	0.88%	1.48%	8.04%

Table 8.8 Land-use situation of Dongchuan County (hundred meter2, %)

	Total	Agricultural land				Building land		Others	
		Farmland	Garden	Forest	Meadow	Construction purpose	Infrastructure purpose	Water area	Unused land
Area	186569.81	32617.95	1720.35	61479.27	60736.11	4820.20	2120.73	4413.35	18661.85
Percentage	100%	17.48%	0.92%	32.95%	32.55%	2.58%	1.14%	2.37%	10.00%

Sources from: Feasibility report

In addition, the score of *S30* (effect on natural landscape and historical sites) was lower than point 5, below the moderate score. *'It is because there was no clear description of the protection measures for the Yaoshan Nature Protection Area along the highway'* (Academic professor). Six experts pointed out that data was not available and to some extent that would influence the assessment results.

Technology and governance performance

On the aspects of technology and governance, the organisational structure and management system, project design and plan all met the project development requirements. The score of indicator *S36* (Rationality of project design and planning) was above the moderate level, but lower than the other two indicators of governance aspects. Construction engineer 2 noted that: *'the project passed across complex terrain, the design stage should enhance the geological investigation and strengthen overall design'.*

The feedback given by the participants also mentioned that the construction process of highway infrastructure is complex, it is necessary to adopt new equipment, new materials, new technologies, etc., at the same time there is also a need to provide training to employees, especially on sustainable construction concepts.

8.6 More recommendations

Through applying the sustainability assessment model to evaluate the sustainable performance of the case study, the results show that the model is a valid method to support decision-making for developing sustainable highway infrastructure projects in Yunnan. Additionally, the assessment took place using experienced experts holding senior positions thus ensuring the credibility of the results. But it should be noted that the model has some limitations. The model aims to support the decision-making process of highway infrastructure project development, and it requires a range of information for its successful application, but some data and information of highway infrastructure project is contained in internal documents of the government and construction firms. This research was unable to obtain all the information about the case study, so data omissions could raise questions regarding the accuracy of some aspects of it

Furthermore, some information in the feasibility report complied with the standards and regulations and could be used by the experts to evaluate the project taking a standardised approach. But some data was not quantified, and the subjectivity of the qualitative data would influence the results, most notably in identifying the impacts on social improvement. Therefore, one Academic professor suggested that in addition to statistics and feasibility reports, first-hand information from the field investigation would improve the reliability of the sustainability assessment.

'*The field investigation provides a scientific method for direct observation and collection of data, it will tell how the highway achieves the expectation of the people' (Academic professor).*

As Bryman (1988) argued, the research results may be influenced by participants' perceptions of research aims, their responses may be influenced by their characteristics, race, age, gender and other factors, field investigation will help to address the potential subjectivity of data collected from stakeholders (Webb *et al.*, 1966, cited in Bryman, 1988, p112).

In this research, the field investigation required permission from relevant organisations and agreement from the key stakeholders responsible for the sites. Due to time and cost constraints, field investigation by experts was not undertaken for this case study and this could influence the assessment score.

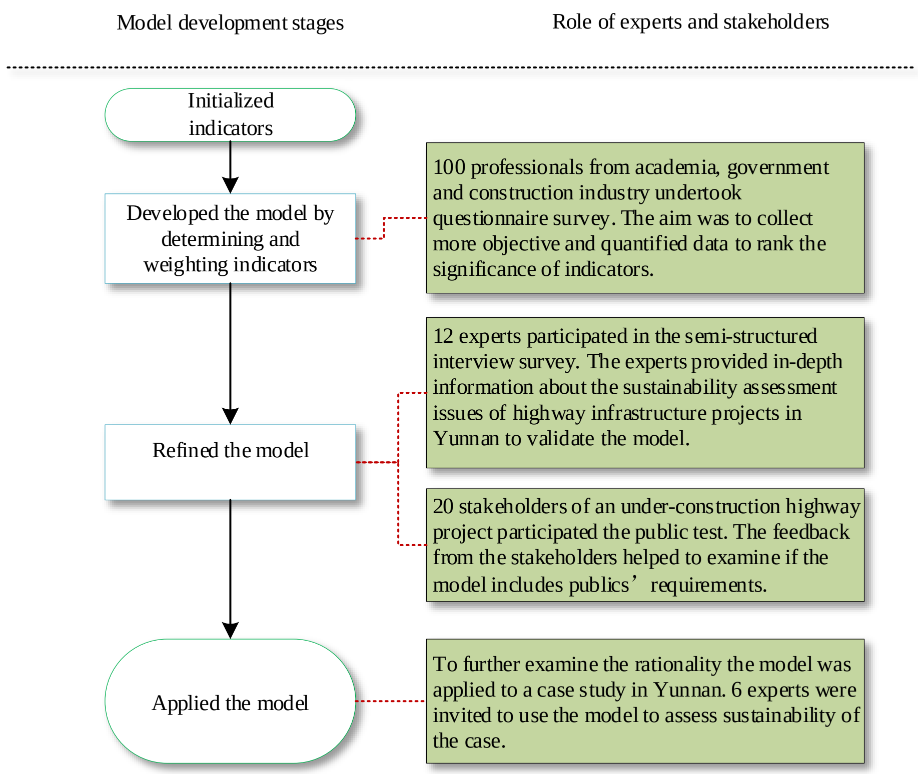
8.7 Conclusion

This chapter, through interviews with academic professionals, government officers and construction engineers refined the sustainability assessment model for highway infrastructure projects developed in the previous chapter. The responses of the interviews revealed problems of the model but also reflected the current situation of sustainability assessment of highway infrastructure projects in Yunnan Province. The imbalanced transportation network makes Yunnan's economy less developed than other regions. Over the last 5 years the province has built more new roads than most provinces in China which have contributed to economic growth and social development, but the highway system expansion also raises concerns in many studies by various government departments about sustainability. Sustainability assessment is an important tool for promoting sustainable highways, but its implementation faces challenges in Yunnan, and it would be more effective if the various government bodies involved in the process or responsible for formulating regulations for sustainability assessment of highway infrastructure projects enforced existing requirements more effectively.

According to the responses, there was general agreement that the indicator systems and evaluation process can be used to promote sustainable highways. Most of the indicators did indeed reflect the core issues of sustainable highways. Furthermore, this chapter tested public participation based on the responses of the experts that the sustainability assessment needed to integrate the views of all interested parties. The results indicated that the level of public involvement in sustainability assessment of highway infrastructure projects in Yunnan is low. Sustainable development and sustainability assessment are new concepts for local people, and it is necessary to increase the public's awareness of environmental and sustainability issues.

Finally, this chapter applied the model to an actual case study in Yunnan to test its practical application. The results of the assessment showed near compliance with the current situation and the tendency for highway infrastructure project development in Yunnan. However, whilst the application of the model to the case study showed that the assessment model is practicable, the process also demonstrated that for future use, additional data and information is required from government departments, developers and construction companies, and field investigation can increase the accuracy of assessment result. Figure 8.9 shows the role of experts and stakeholders at different stages of the model development process.

Figure 8.9 Role of experts and stakeholders during model development process



CHAPTER 9 - CONCLUSIONS

9.1 Introduction

This chapter will interpret the main finding of the research and present the conclusions and recommendations and recommend further study relating to the research results.

9.2 Research process

Highway infrastructure expansion is a key part of the government's plan for Yunnan, and it will bring significant benefits to the province, not only for economic growth but also for social development. The sustainable development concept is now widely accepted, and much more attention is paid to the impacts of highway construction on the environment and society. It also requires further studies on reducing damage to the environment whilst at the same time, supporting economic and social development through highway construction.

Based on previous studies, this research examined the importance of sustainability in highway infrastructure construction, assessed sustainability assessment, and analysed the experiences from existing systems and methods in order to develop an evaluation model to support sustainable development in highway infrastructure projects in Yunnan. This study set out to achieve the following objectives:

1) Critically evaluate sustainability issues relating to highway infrastructure based on the principles of sustainable development theories and practices.

2) Determine the status of existing assessment models and compare them to current sustainability initiatives in Yunnan.

3) Develop a suitable sustainability assessment model to be used at the feasibility stage by construction professionals involved in highway infrastructure.

4) Test and refine the model by obtaining and comparing experts' opinions from a variety of professional groups.

The research was conducted in three steps. The first step of the study was the literature review where the concept of sustainability was applied to highway infrastructure projects (objective 1), existing assessment systems, models and methods were evaluated, and the sustainability practice in the local context of Yunnan Province was explored (objective 2). This step identified the key factors of sustainability assessment for highway infrastructure projects in Yunnan which laid a foundation to build the model in the second step.

The second step was to develop an indicator system for sustainability assessment (objective 3). In this step, the experts in highway infrastructure projects were invited to participate in a questionnaire survey for building the evaluation indicator system. The score of indicator significance was used to determine and weight the indicators.

For the final step, a qualitative approach involving 12 open-ended interviews was employed to refine the model (objective 4).

9.3 Conclusion of the study

This research examined the key concepts of sustainability in highway infrastructure projects, reviewed the current sustainability assessment systems and methods for highway infrastructure projects, and developed a sustainability assessment model for highway infrastructure projects in consideration of the local conditions in Yunnan. The key findings from the research are presented in the following sections.

9.3.1 Concept of sustainability in highway infrastructure projects

This study examined the current situation and development trends of highway infrastructure projects in Yunnan, and how the sustainable development concept can be applied in a local context. The construction of highway infrastructure projects is one of the most harmful construction activities for the natural environment, it is also one of the greatest consumers of energy and resources. Highway infrastructure projects are large construction projects with significant investment, long construction periods and long-term impacts. They can increase the pace of economic development, promote other industrial development requiring building materials, communication equipment, transportation etc. They can also better serve as China's trade hub linking south and southeast Asian countries. Finally, highway project construction is a labour-intensive industry which brings employment opportunities to the region. For these reasons, highway infrastructure projects have become one of the priorities for the development of Yunnan.

At the same time, the major effects on the environment from highway construction have been widely recognised worldwide, and the notion of sustainable highway infrastructure project has been raised in the field of construction. Previous studies suggest that sustainable highway infrastructure is a multidisciplinary concept in nature and includes areas such as economics, the environment, construction, engineering, city planning and designing, and so on.

Under the triple bottom line principles (economic, social, and environment) of sustainable development, WCED (1987) defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' According to this definition, sustainable highway infrastructure projects will not cause long-term damage to the environment, and must meet the needs of local community and people living with it. There is a great reliance on technology to achieve the economic, social, and environmental development of the local area and nationally. In addition, project governance plays a significant role in sustainable construction by creating appropriate incentives for building a project in a sustainable way. Therefore, development principles of highway infrastructure project sustainability consist of economic, social, environmental, technological and governance sustainability.

However, the highway infrastructure project is complex with many different stages, each stage associated with various activities and constraints. There are many studies that combine project lifecycle theory with the concept of sustainable highway infrastructure, using sustainable development principles to guide project construction activities during the project lifecycle (planning and designing, construction, operation and disposal stages), maximising energy saving, reducing costs, increasing resource utilisation rate, reducing waste, minimising the damage to society and the environment.

9.3.2 Conditions of sustainability assessment of highway infrastructure projects

The purpose of sustainability assessment is to ensure highway infrastructure projects are built in a sustainable way, and to resolve problems arising from highway construction. The result is to achieve sustainability throughout the lifecycle of the project. The aim of the whole process is to have minimum negative impacts on the ecological environment, and bring economic, social and environmental benefits. The first step is to establish the assessment indicator system, standard, method and application model.

A highway infrastructure project is complex, the sustainability of the project includes ecological and environmental protection, resource and energy utilisation, social and economic development and many other aspects. The application of the assessment must have operability, thus, should obey the following principles: straightforward and easy evaluate, based on the current situation and understanding of the key of principles of sustainable development.

A set of complete and valid parameters is needed to accurately describe the real conditions of highway infrastructure projects. This is the basis for building an indicator system for the sustainability assessment model. The assessment indicator system should put emphasis on individual project attributes but also consider some common characteristics of various projects, such as their large-scale, and involvement of numerous stakeholders. All types of construction project should be based on the principles of sustainable development.

Sustainable development has temporal characteristics where the requirements vary at different stages of the project, the understanding of sustainability is from an environmental orientation to the direction of balance on economic, social development and environmental protection. It also has a spatial characteristic which means it has a different focus in the various regions and nations. As a result, the sustainability assessment standards are strongly related to the local social, economic, environmental and cultural circumstances.

9.3.3 Current sustainability assessment system

At present, different sustainability assessment frameworks and systems for highway infrastructure projects have been or are being developed worldwide, including

Environmental Impact Assessment, Lifecycle Assessment and various rating and certification tools (e.g. LEED and BREEAM).

China has made progress in promoting sustainability assessment in highway infrastructure projects, the government has not only improved policies and regulations for sustainable construction and environmental protection but also developed the necessary evaluation systems such as economic and financial assessment, environmental impact assessment and social impact assessment. The government has issued requirements and standards for engineering and highway infrastructure projects, including the Specifications for Environmental Impact Assessment of Highways (2006), Construction Project Economic Evaluation Approaches and Parameters (2006), Evaluation Standard for Green Building (2014), and so on. These standards, codes and requirements provide standardised criteria and methods for the sustainability assessment of new and existing construction and highway infrastructure projects. Under the requirements of the various standards and codes, many sustainability assessment systems have been established across China. These systems can be grouped into decision-support tools (Cost-Benefit Analysis, Multi-Criteria Decision Analysis amongst others), rating systems and techniques for assessing environmental or social impacts (Environment Impacts Assessment and Social Impacts Assessment). These sustainability assessment systems provide significant theoretical and practical approaches to reduce impacts of highway infrastructure projects on the environment and society. But these existing methods are criticised as being more focussed on environmental assessment or one particular aspect of sustainable development and failing to properly evaluate the economic and social aspects, and specific regional circumstances are not covered.

As a frontier province, Yunnan differs greatly in geographic conditions, natural resources, and historical backgrounds when compare to other parts of China, but also in respect of economic development. Historically, the development of Yunnan has lagged most other provinces in China and while sustainability assessment in highway infrastructure has become more widely accepted in recent years, local government in this region has not introduced a comprehensive assessment system to reflect the specific local context.

Highway infrastructure projects have a close relationship with national, local and industrial development, they also have different characteristics, inconsistent focus and direction. Along with the rapid expansion of highway infrastructure in Yunnan, establishment of a suitable assessment system and evaluation model is required to strengthen the sustainable development of highway infrastructure projects in Yunnan

9.4 Contribution of this research

The contribution made by this study is divided into two main parts: theory and methodology.

The theory finding contributes to an understanding of sustainable development and sustainability assessment of highway infrastructure projects. It also contributes to an understanding of the sustainability of highway infrastructure projects in the context of Yunnan. In addition, the research not only provides an assessment process for highway construction, it also provides a reference for other infrastructure projects.

The main methodology contribution of the study has been the combination quantitative and qualitative methods. The questionnaire survey considered the subjective nature of qualitative research and explored if the indicators are suitable for Yunnan. The interviews experts were used to refine the developed model, this method resolved the problem of the scarcity of data dealing with sustainability assessment in Yunnan. The mixed method improves understanding of the gap between sustainability assessment theories and practice, and provided experience for other studies on determining indicators of sustainability in the context of developing countries.

9.5 Recommendation for the sustainability assessment model

Highway infrastructure are complex projects involving many different activities and stakeholders which has led to various assessment methods. This study strives to develop a comprehensive indicator-based assessment model, but it has not proved possible to build a system which meets the requirements of all highway infrastructure projects. The research findings revealed that although there are many frameworks, systems and methods of sustainability assessment of highway and other infrastructure projects, a standard method does not exist. There are many recommendations for enhancing the sustainability assessment model and these can be summarised as follows:

Firstly, the study method can be improved. The study used questionnaires to determine the indicator selection. This approach helped to obtain significant data as the response rate was 88%, and 67% of the responses were valid. There are a number of reasons for this response including the distribution methods. 80% of the questionnaires were sent by a group - its subsequent administration and the respondents background in sustainability of highway projects was not well identified. Different distribution methods could be used to further improve the response rate and the validity of the responses. furthermore, a qualitative approach, such as the Delphi method, could be used in the indicator selection process to support assessment indicators determination.

Secondly, the model would be improved by optimising data and information on the evaluation process. In the study, the information was mainly from the project feasibility report and some information was not available, such as the demographic data of residents along the highway project. Field research can improve the effectiveness of the assessment result. Besides, the determination of indicator weighting by AHP is dependent on experts' judgement and experiences which results in a high level of subjectivity. Objective methods can be introduced such as entropy, based on objective data, information and documents from government departments, developers and construction companies.

Finally, regulations and rules can guarantee sustainability assessment implementation. The organisation and government should build a set of rules to determine the purpose of the sustainability assessment of the highway infrastructure project. Currently, there are many standards and guidance, but there is not a systemic and uniform standard for sustainability assessment. There should be standardisation of sustainability and sustainability assessment within highway infrastructure project construction.

However, it is essential to have experienced and skilled experts with sustainability knowledge and familiarity with highway construction standards and techniques to assess the project sustainability.

9.6 Recommendation for the further study

The following areas should be considered for further study:

1) The research defined the factors influencing sustainability assessment implementation, but it was not entirely resolved, so further study should be undertaken to investigate how to overcome the barriers, such as political, awareness, governance and financial barriers.

2) Assessment indicators should reflect the requirements of different stakeholders, and further study should investigate how to deal with public participation in selecting indicators of sustainability assessment.

3) China is building the world's largest high-speed rail network, and Yunnan is an important part of the network. Further study should explore the sustainability assessment issues for high speed rail in Yunnan.

4) Yunnan is a mainly mountainous and hilly land, further development of a specific sustainability assessment model for this type of topography would be beneficial for other regions.

5) The economic benefits of the highway infrastructure project were the priority; a more effective financing model could be developed in the future taking into account the requirements for developing a sustainable highway infrastructure project.

REFERENCE

Adamson, K. A. and Prion, S. (2013). Reliability: Measuring Internal Consistency Using Cronbach's A. Clinical Simulation in Nursing, 9(5), pp.179-180.

Ainger, C. and Fenner, R. A. (2013). Sustainable Infrastructure-Principles into Practice. London: ICE publishing.

Ai., M. and Wei M. (2013). The Benefits Dependency and the Policy Conflict between the Central Government and the Local Government. Journal of Chongqing Techonology and Business University (Social Sciences Edition). 1 (30). pp. 80-86

Al-Harbi, Al-Subhi, K. M. (2001). Application of the AHP in Project Management. International Journal of project management, 19(1), pp.19-27.

Allen, C. and Clouth, S. (2012). A Guidebook to the Green Economy. Issue 1: Green Economy, Green Growth, and Low-Carbon Development – history, definitions and a guide to recent publications. Division for Sustainable Development, UNDESA UN Division for Sustainable Development.

Alwan, Z., Jones, P. and Holgate, P. (2017). Strategic Sustainable Development in the UK Construction Industry, through the Framework for Strategic Sustainable Development, Using Building Information Modelling. Journal of Cleaner Production, 140, pp.349-358.

Amaratunga, D., Baldry, D., Sarshar, M. and Newton, R. (2002). Quantitative and Qualitative Research in the Built Environment: Application of “Mixed” Research Approach. Work Study, 51(1), pp.17-31.

Anderson, M., Teisl, M., Noblet, C. and Klein, S. (2015). The Incompatibility of Benefit–Cost Analysis with Sustainability Science. Sustainability Science, 10(1), pp.33-41.

Annema, J. A. and Koopmans, C. (2015). The Practice of Valuing the Environment in Cost-Benefit Analyses in Transport and Spatial Projects. Journal of Environmental Planning and Management, 58(9), pp.1635-1648.

Ansar, A., Flyvbjerg, B., Budzier, A. and Lunn, D. (2016). Does Infrastructure Investment Lead to Economic Growth or Economic Fragility? Evidence from China. Oxford Review of Economic Policy, 32(3), pp.360-390.

Appleton, S. and Booth, D. (2005). Strong Fences Make Good Neighbours: Survey and Participatory Appraisal Methods in Poverty Evaluation and Poverty Reduction Strategy Monitoring. In: Holland, J.and Campbell, J., eds. Methods in Development Research: Combining Qualitative and Quantitative Approaches. London: ITDG

Publications, 2005.
Arts, J. and Faith-Ell, C. (2012). New Governance Approaches for Sustainable Project Delivery. Procedia-social and behavioral sciences, 48, pp.3239-3250.
Asian Development Bank. (2013). Cost-Benefit Analysis for Development: A Practical Guide. Mandaluyong City, Philippines: Asian Development Bank.
Axelsson, R., Angelstam, P., Degerman, E., Teitelbaum, S., Andersson, K., Elbakidze, M. and Drotz, M. K. (2013). Social and Cultural Sustainability: Criteria, Indicators, Verifier Variables for Measurement and Maps for Visualization to Support Planning. Ambio, 42(2), pp.215-228.
Babbie, E. R. (2012). The Practice of Social Research. 13th ed. Belmont, CA: Wadsworth Publishing Co.
Bajpai, N. (2011). Business Research Methods. Pearson Education India.
Ball, M. and Wood, A. (1996). Does Building Investment Affect Economic Growth? Journal of Property Research, 13(2), pp.99-114.
Banister, D., Button, K. J. and Button, K. (1993). Transport, the Environment and Sustainable Development. London: Spoon.
Barbier, E. B. (1987). The Concept of Sustainable Economic Development. Environmental conservation, 14(2), pp.101-110.
Barbosa, L. C. and Gomes, L. F. A. M. (2015). Assessment of Efficiency and Sustainability in a Chemical Industry Using Goal Programming and AHP. Procedia Computer Science, 55, pp.165-174.
Bazeley, P. (2004). Issues in Mixing Qualitative and Quantitative Approaches to Research. Applying qualitative methods to marketing management research, pp.141-156.
Ben-Eli, M. (2005). Sustainability: The Five Core Principles. New York: The Cyberice consulting group, Inc.
Berardi, U. (2012). Sustainability Assessment in the Construction Sector: Rating Systems and Rated Buildings. Sustainable Development, 20(6), pp.411-424.
Berg, B. L. (1998). Qualitative Research Methods for the Social Sciences. 3rd ed. Boston: Allyn and Bacon.
Bhattacherjee, A. (2012). Social Science Research: Principles, Methods, and Practices. 2nd ed. CreateSpace Independent Publishing Platform.
Bina, O. (2007). A Critical Review of the Dominant Lines of Argumentation on the Need for Strategic Environmental Assessment. Environmental Impact Assessment Review, 27(7), pp.585-606.

Björk, B.-C. and Bröchner, J. (2007). The Value of Construction Management. Journals to Submitting Authors. In: Construction Management and Economics 25th Anniversary Conference, 2007, pp.16-08.

Blewitt, J. (2014). Understanding Sustainable Development. London:Routledge.

Bolis, I., Morioka, S. N. and Sznelwar, L. I. (2014). When Sustainable Development Risks Losing Its Meaning. Delimiting the Concept with a Comprehensive Literature Review and a Conceptual Model. Journal of Cleaner Production, 83, pp.7-20.

Brewer, J., German, J., Krammes, R., Movassaghi, K., Okamoto, J., Otto, S., Ruff, W., Sillan, S., Stamatiadis, N. and Walters, R. (2001). Geometric Design Practices for European Roads (Technical Report, No. Fhwa-Pl-01-026). US. Department of Transportation International Technology Exchange Program.

Brewerton, P. M. and Millward, L. J. (2001). Organizational Research Methods: A Guide for Students and Researchers. UK: Sage Publication Ltd.

Brown, J. D. (1996). Testing in Language Programs. Upper Saddle River, NJ: Prentice Hall Regents.

Browne, D. and Ryan, L. (2011). Comparative Analysis of Evaluation Techniques for Transport Policies. Environmental Impact Assessment Review, 31(3), pp.226-233.

Bryman, A. (1988). Quantity and Quality in Social Research. London: Routledge.

Bryman, A. (2012). Social Research Methods. 5th ed. Oxford: Oxford University Press.

Bueno, P., Vassallo, J. and Cheung, K. (2013). Road Infrastructure Design for Optimizing Sustainability. Spain: Transport Research Centre, University Politecnica De Madrid.

Bueno, P. C., Vassallo, J. M. and Cheung, K. (2015). Sustainability Assessment of Transport Infrastructure Projects: A Review of Existing Tools and Methods. Transport Reviews, 35(5), pp.622-649.

Burns, N. and Grove, S. K. (2009). The Practice of Nursing Research: Appraisal, Synthesis, and Generation of Evidence. 4th ed. St. Louis, Mo: Saunders Elsevier.

Busscher, T., Tillema, T. and Arts, J. (2015). In Search of Sustainable Road Infrastructure Planning: How Can We Build on Historical Policy Shifts? Transport Policy, 42, pp.42-51.

Butler, J. (2003). The Second Earth Summit. Geography Review, 16(5), pp.2-5.

Cao, B. (2012). The Current Situation of Highway Developable in Henan Provinces of China. China Economic & Trade Herald, 10, pp 68-71.

Cao L., Wang H.(1998). A Study on the Principle and Method of Installation of Sustainable Development Assessment Index. Acta Scientiae Circumstantlae Vol. 18. No. 5. pp.

526-537

Cao, B., Lin, J. and Cui, S. (2010). Review on Assessment Index of Sustainable Development. Environmental Science & Technology, 33(3), pp.99-105.

Cao, J. (2016). The Analysis of Current Problem of Highway Planning. Journal of Huaibei Professional and Technical College, 2, pp.23-26.

Cao, S. and Dong, C. (2012). The Lifecycle Cost and Benefit Evaluation of Green Building. Journal Tsinghua University (Sci & Tech), 52(6), pp.19-26.

Cavanagh, S. (1997). Content Analysis: Concepts, Methods and Applications. Nurse Researcher, 4(3), pp.5-13.

CEEQUAL. (2012c, 2012). CEEQUAL Version 5 Methodology. Available at: http://www.ceequal.com/structure.html. Accessed on: 26th March, 2018

Chang, R. D., Soebarto, V., Zhao, Z. Y. and Zillante, G. (2016). Facilitating the Transition to Sustainable Construction: China's Policies. Journal of Cleaner Production, 131, pp.534-544.

Chen, B. and Liao, X. (2009). Research on Evaluation Index System of Highway Transportation Sustainable Development. China Journal of Highway and Transportation, 22(5), pp.111-117.

Chen, C. and Fu, H. (2009). Appraisal Method on Sustainable Development for Highway Project. Journal of Herbin Institute of Technology 41(4), pp.253-257.

Chen, J. and Tian, Y. (2008). The Study on Highway Construction Project Sustainability Evaluation Index System and Method Based on Sustainable Development Objective. Technology, Economic and Market, 12, pp.24-26.

Chen, N., Xu, Z. and Li, Q. (2016). Study on Environmental Impacts and Decision-making Analysis of Building Construction. Journal of Engineering Management, 30(2), pp. 64-67

Chen, W., Xu, X., Wang, H. and Wang, W. (2015). The Evaluation of Water Resources Sustainable Utilization in Beijing Based on Improved Rank Correlation Analysis. Journal of Natural Resources, 30(1), pp.164-176.

Chen, X. and Xiong, J. (2011). Analysis of the Key Factors Impacting the Environment of Yunnan Gaohai Highway. Value Engineering, 40(6), pp.1006-4311.

Chen, Y. (2003). Approach to Several Issues of Countermeasures on Sustainable Development of Highland Mountainous District -Expressway Construction and Ecological Environment During Western China Development. Journal of Kunming University of Science and Technology (Science and Technology), 28(2). pp. 97-101.

Chen, Z. (2002). Environmental Impact Assessment and Sustainability. Chinese Railways, 9, pp.22-25.

Cheng, G. and Wang, X. (2007). Study on the Indicator System of Environment Influence Evaluation in Highway Construction. Journal of Anhui Institute of Architecture & Industry, 15(2), pp.101-104.

China-Mike. (2012). Available at: http://www.china-mike.com/china-travel-tips/tourist-maps/china-provinces-map/. Accessed on: 6 March 2017

Chinese Academy of Engineering and Ministry of Environmental Protection of China. (2011). The Study of China Macro-Environmental Strategy: Synthesis Report. Beijing: China Environmental Science Press.

Chu, C. (2014). Highway in the Mountains-the Western Yunnan Roads Development Project. The Asian Development Bank.

Ciegis, R., Ramanauskiene, J. and Martinkus, B. (2009). The Concept of Sustainable Development and its Use for Sustainability Scenarios. Engineering Economics, 62(2), pp.28-37.

Clevenger, C. M., Ozbek, M. E., & Simpson, S. (2013). Review of Sustainability Rating Systems Used for Infrastructure Projects. Paper Presented the 49th ASC Annual International Conference Proceedings, San Luis Obispo, CA.

Collins, H. (2010). Creative Research: The Theory and Practice of Research for the Creative Industries. AVA Publishing.

Comstock, M., Garrigan, C., Pouffary, S., Feraudy, T. D., Halcomb, J. and Hartke, J. (2012). Building Design and Construction: Forging Resource Efficiency and Sustainable Development. United National Environmental Program (UNEP).

Cong, Y. and Ma, Y. (2011). Comparative Analysis on Evaluation Standard for Green Construction and Leed. Tianjin University of Finance and Economics, 2011(11), pp.20-23.

Cotgrave, A. and Riley, M. (2012). Total Sustainability in the Built Environment. Palgrave Macmillan.

Creswell, J. W. (2007). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Tranlated by Cui, Y. China: Chongqing University Press

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. 4th ed. United States of America: Sage publications.

Crowther, D. and Lancaster, G. (2008). Research Methods: A Consice Introduction to Research in Management and Business Consultancy. Oxford: Butterworth-

Heinemann.

Dai, J., Song, T., Guo, R., Wu, F., Fang, Y. and Liu, G. (2014a). The Application of AHP and Entropy in the Sustainability Evaluation in Disease Control Agencies. Chinese Journal of Health Statistics, 31(6), pp.1051-1053.

Dai, R., Jin, J. and Yang, P. (2005). On Environmental Protection in Yunnan Highway Construction. Journal of Kunming Metallurgy College, 21(5), pp.29-33.

Dai, Y., Chen, C., Huang, C., Wang, H., Zhao, J. and Ling, H. (2004). The Study of Sustainability Assessment on Shanghai Transportation Projects. Energy Research and information, 20(4), pp.187-189.

Darko, A. and Chan, A. P. (2016). Critical Analysis of Green Building Research Trend in Construction Journals. Habitat International, 57, pp.53-63.

De Vos, A. S., Strydom, H., Fouche, C. B. and Delport, C. S. L. (2002). Research at Grass Roots: For the Social Sciences and Human Services Professions. Pretoria: Van Schaik.

Decleris, M. (2000). The Law of Sustainable Development-General Principles. Luxembourg: Office for Official Publications of the European Communities.

Denscombe, M. (2010). The Good Research Guide: For Small-Scale Social Research. 4th ed. New York: Open University Press.

Diaz-Sarachaga, J. M., Jato-Espino, D., Alsulami, B. and Castro-Fresno, D. (2016). Evaluation of Existing Sustainable Infrastructure Rating Systems for Their Application in Developing Countries. Ecological Indicators, 71, pp.491-502.

Djankov, S. and Miner, S. (2016). China's Belt and Road Initiative: Motives, Scope, and Challenges. Peterson Institute for International Economics.

Dong, C. and Zhou, M. (2012). The Study of Highway Sustainable Development in China. Enterprises Herald, 1, p.78.

Dong, X., Pan, W., Song, Z. and Wang, J. (2014). Analysis of Highway Project Envrionmental Cost Based on Lifecycle Theory. China Journal of Highway and Transport, 27(10), pp.109-114.

Dong, Y. T. (2013). The Research of Construction Energy Consumption. OCED Working Paper Series. China Centre For Energy and Development, Peking University: Beijing, China, No. 20130504.

Dresner, S. (2008). The Principles of Sustainability. 2nd ed. London: Routledge.

Drexhage, J. and Murphy, D. (2010). Sustainable Development: From Brundtland to Rio 2012. United Nations Headquarters, New York, pp.9-13.

Du Plessis, C. (2002). Agenda 21 for Sustainable Construction in Developing Countries. CSIR Report BOU E, 204.

Editorial Department of China Journal of Highway and Transport. (2015). Review on China's Tunnel Engineering Research: 2015. China Journal of Highway and Transport, 28(5), pp.1-65.

Edwards, A. R. (2005). The Sustainability Revolution: Portrait of a Paradigm Shift. Gabriola Island, BC: New Society Publishers.

Edwards, D. J., Harris, F. C., McCaffer R. (2003). Management of Highway Plant and Equipment. London: Spon Press, p.92.

Elkington, J. (1997). Cannibals with Forks - Triple Bottom Line of 21st Century Business. Stoney Creek, CT: New Society Publishers.

Earth System Science Partnership. (2001). The Amsterdam Declaration on Global Change. [Online]. Available at: http://www.essp.org/index.php?id=41&type=98&l=0%2f%2fassets%2fsnippets%2f%20%ef%bf%bd%c5%a0%2f%2f%3f_phplib%5blibdir%5d%3d. Accessed on: 23 June 2014.

Energy Conservation Law of the People's Republic of China, 2007 [Online]. Available at: http://www.gov.cn/flfg/2007-10/28/content_788493.htm. Accessed on: 9 October, 2016

Environmental Protection Law of the People's Republic of China, 2014. [Online]. Available at: http://www.npc.gov.cn/npc/xinwen/2014-04/25/content_1861279.htm. Accessed on: 9 October, 2016.

Environment Impacts Assessment Law, 2016. [Online] . Available at: http://www.mep.gov.cn/gzfw_13107/zcfg/fl/201609/t20160927_364752.shtml. Accessed on: 11 October, 2016

EU-Japan Centre. (2005). Sustainable Building and Construction Sector in Japan and Analysis of Opportunities for European Firms. [Online]. Available at: http://www.eu-Japan.eu/sites/default/files/publications/docs/sustainableconstruction_final.pdf. Accessed on: 12 June 2015.

European Commission. (2002). Note and Questionnaire to the Members of the Cafe Working Group on Target Setting and Policy Assessment. DG ENV-C1/AZ D(02)410819.

European Commission. (2016). Strategic Environmental Assessment -SEA. [Online].

Available at: http://ec.europa.eu/environment/eia/sea-legalcontext.htm. Accessed on: 28 August, 2016.

Everitt, B. S. (2006). Medical Statistics from A to Z: A Guide for Clinicians and Medical Students. 2nd ed. Cambridge: Cambridge University

Fan, J. and Jiang, Z. (2015). Trend of Human-Economic Geography in Relation to the Future Earth Initiative for Systemic Solutions of Regional Sustainable Development. Progress in Geography, 34(1), pp.1-9.

Feng, N. (2009). Countinuous Development Index System and Evaluation Method of the Higheay Construction Project. Shanxi Architecture, 35(33), pp.203-204.

Feng, X. (2013). Social Research Methods. 4th ed. Beijing: China Renmin University Press.

Fernández-Sánchez, G. and Rodríguez-López, F. (2010). A Methodology to Identify Sustainability Indicators in Construction Project Management—Application to Infrastructure Projects in Spain. Ecological Indicators, 10(6), pp.1193-1201.

Fink, A. (2005). Conducting Research Literature Reviews: From the Internet to Paper. Thousand Oaks: Sage.

Fischer, T. B. (2007). Theory and Practice of Strategic Environmental Assessment. London: Earthscan.

Flick, U. (2011). Introducing Research Methodology: A Beginner's Guide to Doing a Research Project. London: Sage.

Foreign & Commonwealth Office, UK. (2016). Overseas Business Risk - China. [Online]. Available at: https://www.gov.uk/government/publications/overseas-business-risk-china. Accessed on: 15 January, 2017.

Forman, R. T. (1995). Land Mosaics: The Ecology of Landscapes and Regions. Cambridge: Cambridge University Press.

Fratila, D. (2009). Evaluation of Near-Dry Machining Effects on Gear Milling Process Efficiency. Journal of Cleaner Production, 17(9), pp.839-845.

Furberg, A., Molander, S. and Wallbaum, H. Furberg, A., Molander, S. and Wallbaum, H. (2014). Literature Review of Practices in Sustainability Assessment of Transport Infrastructures. [Online]. Available at: http://publications.lib.chalmers.se/records/fulltext/219183/local_219183.pdf. Accessed on: 4 June, 2015.

Galesic, M. and Bosnjak, M. (2009). Effects of Questionnaire Length on Participation and Indicators of Response Quality in a Web Survey. Public Opinion Quarterly, 73(2), pp.349-360.

Galliers, R. D. (1991). Choosing Appropriate Information Systems Research Approaches: A Revised Taxonomy. In: Nissen, H.-E., Klein, H. K.and Hirschheim, R., eds. In Proceedings of the Ifip Tc8 Wg8. 2. The Netherlands: Elsevier Science Publishers B.V.

Gao, H. (2014). The Problems of Tolling Highway in China. Inner Mongolia Science Technology & Economy, 303(5), pp.35-38.

Gao, J. and Yu, J. (2014). Research on Sustainability Assessment of Large-Scale Public Building Based on AHP- Fuzzy. Computer Engineering and Applications, 50(13), pp.19-23

Gao, R., Zhang, J. and Wu, X. (2014). Design and Study on Resettlement Planning for Wudongde Hydropower Station. Yangtze River, 45(20), pp.106-109.

Gao, S. (2010). The Analysis of the Trends of Green Building Development. Journal of Shenyang Jianzhu University（Social Science), 12(3), pp.296-299.

Gao, T. J. (2016). The Analysis of the Importance of Engineering Project Quality Management. China High Tech Enterprises, (5), p. 63.

Gao, X. (2011). Discussion of Positivism. Journal of Taiyuan Urban Vocational College, 3, pp. 33-37

Gao, Z. S. (2009). The Study of Ethnic Minority Regions Economic Development in Yunnan. Journal of Yunnan Finance & Economics University, 25(1), pp. 24-26

Garbarino, S. and Holland, J. (2009). Quantitative and Qualitative Methods in Impact Evaluation and Measuring Results. Governance and Social Development Resources Centre,UK.

Ge, L., Xin, H. and Ma, J. (2006). Evaluation Indices System and Model of Highway Transportation Sustainable Development. Highway, (6), pp.20-23.

Gemunden, H. G. (2016). Project Governance and Sustainability: Two Major Themes in Project Management Research and Practice. Project Management Journal, 47(6), pp.3-6.

Gibson, R. B. (2006). Beyond the Pillars: Sustainability Assessment as a Framework for Effective Integration of Social, Economic and Ecological Considerations in Significant Decision-making. Journal of Environmental Assessment Policy and Management, 8(03), pp.259-280.

Gibson, R. B., Holtz, S., Tansey, J. and Whitelaw, G. (2005). Sustainability Assessment: Criteria and Processes. London: Routledge.

Gong, Z. and Zhang, Z. (2004). Life Cycle Assessment and Management Towards Sustainable Construction Industry. Journal of Qinghai University, 22(2), pp.24-29.

Gould, F. E. and Joyce, N. E. (2009). Construction Project Management. 3rd ed. New Jersey: Pearson Education, Inc.

Government of Yunnan Province. (2016). Outline of the 13th Five-Year Plan for the National Economic and Social Development of Yunnan Province.

Government of Yunnan Province. (2017). GDP Growth in First Three Quarter 2016. [Online]. Available at: http://www.yn.gov.cn/yn_zwlanmu/yn_tjdt/201610/t20161023_27297.html. Accessed on: 26 March, 2017

Greenroads. (2012a, August 23, 2012). About the Greenroads Rating System. Available at: http://www.greenroads.org/347/about-the-greenroads-rating-system.html. Accessed on: 26th March, 2018

Greenroads. (2012b, August 23, 2012). How Greenroads Works. Voluntary Credits. Available at: http://www.greenroads.org/1429/browse-the-online-manual.html

Guan, Q., Wang, Z. and Ren, J. (2016). Analysis on the Growth Rate of Yunnan Highway in the 13th Five-Year Plan. Value Engineering, 4, pp.47-49.

Gudmundsson, H. and Höjer, M. (1996). Sustainable Development Principles and Their Implications for Transport. Ecological economics, 19(3), pp.269-282.

Gühnemann, A., Laird, J. J. and Pearman, A. D. (2012). Combining Cost-Benefit and Multi-Criteria Analysis to Prioritise a National Road Infrastructure Programme. Transport Policy, 23, pp.15-24.

Guthrie, P. and Konaris, T. (2012). State of the World Report 2012: Sustainable Infrastructure. International Federation of Consulting Engineers (FIDIC).

Haapio, A. and Viitaniemi, P. (2008a). A Critical Review of Building Environmental Assessment Tools. Environmental impact assessment review, 28(7), pp.469-482.

Habich, S. (2015).Dams, Migration and Authoritarianism in China: The Local State in Yunnan. New York: Routledge. p.90

Hardi, P., and Zdan, T. (1997) Assessing Sustainable Development: Principles in Practice. The International Institute for Sustainable Development. Canada

Handl, G. (2012). Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration), 1972 and the Rio Declaration on Environment and Development, 1992. United Nations Audiovisual Library of International Law, 11.

Harris, L. R. and Brown, G. T. (2010). Mixing Interview and Questionnaire Methods: Practical Problems in Aligning Data. Practical Assessment, Research & Evaluation, 15(1), p.2.

He, J. (2014). A Temporal and Spatial Analysis of Regional Differences of Economic Development Quality in Yunnan Province. Journal of Yunnan Agricultural University, 8(6), pp.21-27.

Hill, R. C. and Bowen, P. A. (1997). Sustainable Construction: Principles and a Framework for Attainment. Construction Management & Economics, 15(3), pp.223-239.

Hsieh, H. F. and Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. Qualitative health research, 15(9), pp.1277-1288.

Huang, D. and Li, M. Y. (2015). The Evolution of Sustainable Development Definition. Knowledge Economy, 18, pp.21-22.

Huang, J. L. (2015). An Overview and Trend of Sustainability Assessment Methodologies. Ecological Economy,, 31(1), pp.18-23.

Huang, Y. (2016). The Features of Highway Planning in Mountainous Area. Economic Research Guide, 12(293), pp.41-43.

Huang, H.,D.(2017).Research on the Function of Green Building Construction Management in Construction Management. Low Carbon World, 3. pp.170-171

HM Treasury of UK (2007). Project Governance: A Guidance Note for Public Sector Projects. [Online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225314/01_ppp_projectgovernanceguidance231107.pdf. Accessed on: 12 November, 2016.

Hussin, J. M., Rahman, I. A. and Memon, A. H. (2013). The Way Forward in Sustainable Construction: Issues and Challenges. International Journal of Advances in Applied Sciences, 2(1), pp.15-24.

Hyland, K. (2016). Methods and Methodologies in Second Language Writing Research. System, 59, pp.116-125.

International Association for Impact Assessment. (1994). Principles of Environmental Impact Assessment Best Practice. [Online]. Available at: https://www.iaia.org/uploads/pdf/principlesea_1.pdf. Accessed on: 12 November, 2015.

Iloiu, M. and Csiminga, D. (2009). Project Risk Evaluation Methods-Sensitivity Analysis. Annals of The University of Petroşani, Economics, 9(2), pp.33-38.

International Initiative for a Sustainable Built Environment. (1998). GBC’98 in Brief. [Online]. Available at: http://iisbe.org/gbc98cnf/brief/brief.htm. Accessed on: 10 July, 2015.

International Union for Conservation of Nature., Natural Resources. and World Wildlife Fund. (1980). World Conservation Strategy: Living Resource Conservation for Sustainable Development. Gland, Switzerland: IUCN.

ISO Standard 15392. (2008). Sustainability in Building Construction - General Principles.

International Union For Conservation Of Nature, United Nations Environment Programme. (1991). Caring for the Earth: A Strategy for Sustainable Living. Gland, Switzerland, October, 1991.

Jeon, C. M., Amekudzi, A. A. and Guensler, R. L. (2013). Sustainability Assessment at the Transportation Planning Level: Performance Measures and Indexes. Transport Policy, 25, pp.10-21.

Jiang, B., Cheng, Z., Gao, D., Guo, Z. and Deng, G. (2013). Comparative Analysis on Breeam and Domestic Evaluation Standard for Green Construction. Quality of Civil Engineering and Construction, 10, pp.27-31.

Jiang, Q. F. (2013). Study on Performance Evaluation of Standardization Strategy for Construction Enterprises. Wuhan University, p.113.

Johnston, P., Everard, M., Santillo, D. and Robèrt, K. (2007). Reclaiming the Definition of Sustainability. Environmental Science and Pollution Research International, 14(1), pp.60-66.

Kao, J.C.M., Sung W., Chen, R. (2014). Green Building, Materials and Civil Engineering. London: CRC Press.

Kardos, M. (2012). The Reflection of Good Governance in Sustainable Development Strategies. Procedia-Social and Behavioral Sciences, 58, pp.1166-1173.

Kasraian, D., Maat, K., Stead D., Van Wee, B. (2015). Long-term Impacts of Transport Infrastructure Networks on Land-Use Change: an International Review of Empirical Studies. Transport Reviews, 36(6). pp 771-792

Kendall, L. (2008). The Conduct of Qualitative Interview: Research Questions, Methodological Issues, and Researching Online. In: Coiro, J., Knobel, M., Lankshear, C.and Leu, D. J., eds. Handbook of Research on New Literacies. New York: Lawrence Erlbaum Associates, pp.133-149.

Khogali, H. a. M. (2016). Comparison of Four Global Sustainable Building Rating Systems Carried out with Focus on Hot and Dry Climate. Journal of Sustainable

Development, 9(2), pp.1-26.

Kibert, C. and Chini, A. (2006). Integrating Sustainability into Construction Programs. American Council For Construction Education. [Online]. Available at: http://www.acce-hq.org/images/uploads/accesustainablepresentation-2feb26sandiego1.pdf. Accessed on: 12 July, 2015.

Kibert, C. J. (2008). Sustainable Construction: Green Building Design and Delivery. 2nd ed. New Jersey: John Wiley & Sons.

Kibwami, N. and Tutesigensi, A. (2016). Integrating Clean Development Mechanism into the Development Approval Process of Buildings: A Case of Urban Housing in Uganda. Habitat International, 53, pp.331-341.

Kline, P. (2000). Handbook of Psychological Testing. 2nd ed. London: Routledge.

Kolosz, B. and Grant-Muller, S. (2015). Extending Cost–Benefit Analysis for the Sustainability Impact of Inter-Urban Intelligent Transport Systems. Environmental Impact Assessment Review, 50, pp.167-177.

Kowalski, K., Stagl, S., Madlener, R. and Omann, I. (2009). Sustainable Energy Futures: Methodological Challenges in Combining Scenarios and Participatory Multi-Criteria Analysis. European Journal of Operational Research, 197(3), pp.1063-1074.

Kumar, R. (2011). Research Methodology a Step-by-Step Guide for Beginners. 3rd ed. London: SAGE Publications, Inc.

Kumar, R., Madhu, E., Dahiya, A. and Sinha, S. (2015). Analytical Hierarchy Process for Assessing Sustainability: Indicators of Public Transportation Systems, Pedestrians and Feeder Services in Developing Countries. World Journal of Science, Technology and Sustainable Development, 12(4), pp.281-293.

Lang, M. (2007). The Study of Construction Project Economic Evaluation. Career, 6, p.58.

Lee, J., Edil, T. B., Benson, C. H. and Tinjum, J. M. (2013). Building Environmentally and Economically Sustainable Transportation Infrastructure: Green Highway Rating System. Journal of Construction Engineering and Management, 139(12), p.A4013006.

Lee, N. and Wood, C. (1978). EIA-a European Perspective. Built Environment, 4, pp.101-110.

Lei, Y. (2016). The Necessarily and Changing Direction of Highway Project Management Institutions Reformation. Transportation Enterprise Management, 2(318), pp.17-19.

Levine, J. H. (1993). Exceptions Are the Rule: An Inquiry into Methods in the Social Sciences. Boulder, Colorado: Westview Pr.

Li, C. and Zhou, X. B. (2012). Comparison Between the Green Building Evaluation Standard of China and Breeam of UK. Green Building, 42(10), pp. 86-88

Li, H. R. (2009). Reliability and Validity in the Qualitative Research. Journal of Harbing Engineering University, 13(11), pp. 27-33.

Li, H. Z. (2004). Research Methodology for Management. 21st ed. Xi'an: Xi'an Communication University Press.

Li, J. X. (2014). The Present Situation and Suggestions of Ethnic Minority Teenager's Education in Yunnan. Education For Chinese After-School (Theory), 2, pp.36-37.

Li, T., Wang, H., Deng, B., Wei, R. and He, X. (2016). Strategic Environmental Assessment Performance Factors and Their Interaction: An Empirical Study in China. Environmental Impact Assessment Review, 59, pp.55-60.

Li, X. H., Li, Y. M., Gu, Z. H. and Yang, W. D. (2004). Competitive Situation Analysis of Regional Logistics Development Based on AHP and Entropy Weight. Journal of Southeast University (Natural Science Edition), 34(3), p. 26.

Li, Y. (2007). Discuss on Sustainable Development Architecture. Shanxi Architecture, 33(4), pp.50-53.

Li, Y. Q., Yuan, T. A. and Zhang , Y. B. (2015). The Study of Xi-Shi Highway on Social-Economic Impacts. Times Finance, 7, p. 131

Liang, H., Zhang, F. and Liang, J. Q. (2012). An Important Engine for China's Economy to Achieve Green Transformation: Green Building Industry Planning and Development. Urban Development Studies, 10, p.30.

Liang, J. (2014). The Post Evaluation of Expressway Sustainable Development Based on Fuzzy Combination. Value Engineering, 17, pp.79-80.

Liang, T. (2016). Indicator and Assessment Methods of Sustainable Highway. Jiangxi Finance and Economics, 18, pp.169-171.

Likert, R. (1932). A Technique for the Measurement of Attitudes. Archives of Psychology, 140, 1–55

Lin, Y. G. (1996). Construction of Chu-Da Highway in Yunnan. Yunnan Communication Science and Technology, 3, pp.105-107

Liu, C. and Zhou, L. A. (2014). Highway Construction and Regional Development: Example of Rural Area in China. Economic Science, 2, pp.55-67.

Liu, J. (2015a). The Problems and Suggestions of Highway Accident in Yunnan. Journal of Yunnan Police officer Academy, 102(2), pp.61-64.

Liu, J. and Li, H. (2012). The Study of Social Impacts Assessment of Public Investment

Project. Relation, Society and Science, 199(1), pp.119-122.
Liu, Y. and Wang, C. (2008). The Problems and Suggestion on Highway Planning and Construction in China. China Chief Financial Officer, 9, pp. 99-106.
Liu, Y. (2008). Construction Project Management. Bejing: Tsinghua University Press
Liu, Z. F. (2015b). Study of Sustainable Methods on Highway Plan and Indicators. Transport World, 353(11), pp.64-65.
Lu, D. and Yuan, E. (2013). Some Thoughts About Sustainable Development of Ordinary Highway in Hubei Province. Highway, 11, pp.133-136.
Lu, D. and Lei, L. (2013). The Study on Sustainability Assessment Method of Hubei Province Highway. Journal of China & Foreign Highway, 33(4), pp.354-358.
Lu, M. L. (2012). Construction Environment and Sustainable Development. Heihe Journal, 183(10), pp.16-174.
Lu, S. (2015). The Improvement of Environment Impacts Assessment Law in China. Coastal Enterprises and Science & Technology., 164(1), pp. 54-57
Lu, Y., Zhang, H., Fan, J. H. and Wang, L. Z. (2009). A Study of Building a Post-Evaluation System of Western Highway Project. Journal of Changsha University of Science & Technology, 24(3), pp.25-28
Ma, J. S. and Zhu, Y. H. (2012). Comparison Bet Ween Evaluation Standards F or Green Building of China and for Breeam of Uk. Building Energy Efficiency, 3, p.42.
Ma, R. and Yang, L. (2001). Study of the Sustainable Goal Assessment of Freeway. Journal of Xian Highway Univeristy, 21(3), pp.30-32.
Ma, X. S., Eli, I. and Zhou, J. Z. (2010). Sustainable Development Evaluation Research of Highway Construction Project in Xinjiang. 4, pp.154-159.
Macharis, C. and Bernardini, A. (2015). Reviewing the Use of Multi-Criteria Decision Analysis for the Evaluation of Transport Projects: Time for a Multi-Actor Approach. Transport policy, 37, pp.177-186.
Malina, M. (2013). Delivering Sustainable Buildings: An Industry Insider's View. UK: Wiley-Blackwell.
Management Commission of Central Area of Yunnan. (2016). Brief Introdution of Yunnan Dian Zhong New Area. [Online]. Available at: http://www.dzxq.gov.cn/E_NewsList.aspx?Classid=c0ba22ae-990d-448e-8a99-1a8f120c42e7. Accessed on: 2 Februry, 2017
Mani, V., Agrawal, R. and Sharma, V. (2014). Supplier Selection Using Social Sustainability: AHP Based Approach in India. International Strategic Management Review, 2(2),

pp.98-112.

Mao, L., Huang, W., Chen, J., Chen, Y. and Zhang, Y. (2015). Green Building Design Strategy Based on Three Certificate Systems in Shanghai Star Harbour. Green Construction, 5, pp.13-16.

Mao, W. and Hills, P. (2000). Environmental Impact Assessment, Strategic Environmental Assessment and Sustainable Development. China Environmental Science, 20, pp.90-94.

Martland, C. (2012). Toward More Sustainable Infrastructure: Project Evaluation for Planners and Engineers. New York: John Wiley and Sons.

Maxwell, J. A. (1998). Using Qualitative Research to Develop Causal Explanations. Harvard Project on Schooling and Children, Harvard University.

Mcdonough, W. and Braungart, M. (2012). The Hannover Principles: Design for Sustainability, 20th Anniversary Edition. [Online]. Available at: Available at: http://www.mcdonough.com/wp-content/uploads/2013/03/hp-20_email_121023.pdf. Accessed on: 18 June, 2014.

McKinlay, M. (2008). Where Is Project Management Running To ? In: Keynote Address at the 22nd World Congress of the International Project Management Association, 2008, Rome, Italy.

Meadows, D., Randers, J. and Behrens, W. (1972). The Limits to Growth. New York: Universe Books.

Mei, F. (2014). Entropy Evaluation of Sustainable Development for Bohai Sea Region. Sustainable Development UN. GSDR Brief No. 9CN.

Miao, K. (2014). Analysing the Impact of Highway Infrastructure Project on Region. Enterprise Reform and Management, 13, pp.81-82.

Mihyeon Jeon, C., Amekudzi, A. A. and Vanegas, J. (2006). Transportation System Sustainability Issues in High-, Middle-, and Low-Income Economies: Case Studies from Georgia (US), South Korea, Colombia, and Ghana. Journal of urban planning and development, 132(3), pp.172-186.

Ministry of Environmental Protection of China. (2014). The Soil Pollution Condition Investigation Communique. [Online]. Available at: http://www.mlr.gov.cn/xwdt/jrxw/201404/p020140417573876167417.pdf. Accessed on: 9 August, 2015.

Ministry of Housing and Urban-Rural Development and General Administration of Quality Supervision Inspection and Quarantine. (2014). The Assessment Standard of Green

Building. Beijing: China Architecture & Building Press

Ministry of Housing and Urban-Rural Development of China. (2015). Technical Instructions for Green Building Evaluation (Planning and Design Section) (2015). Beijing: China Architecture & Building Press

Ministry of Transport of China. (2006). JTG B03-2006: Specifications for Environmental Impact Assessment of Highways. Beijing: China Architecture & Building Press

Ministry of Transport of China. (2013). Guiding Opinions of Accelerating the Advancement of the Development of Green, Circular and Low-Carbon Transportation. Available at: http://www.moc.gov.cn/2013wangshangzhibo/2013third/xiangguanlianjie/201512/t20151231_1970490.html. Accessed on: 28 October, 2016.

Ministry of Transport of China. (2014). JTG Bol-2014: Highway Engineering Techniques Standards of China. Beijing: China Architecture & Building Press

Ministry of Transport of China (2016). The Summary of 12th Five -Year Plan of Transportation Industry in Yunnan Province. [Online]. Available at: http://www.moc.gov.cn/st2010/yunnan/yn_tongzhigg/tzgg_guihuatj/201512/t20151214_1946926. Accessed on: 15 July, 2016

Mitlin, D. (1992). Sustainable Development: A Guide to the Literature. Environment and Urbanization, 4(1), pp.111-124.

Mohanty, C. (2011). Reduce, Reuse and Recycle (the 3rs) and Resource Efficiency as the Basis for Sustainable Waste Management. In: Synergizing Resource Efficiency with Informal Sector Towards Sustainable Waste Management. CSD-19 Learning Centre: UNCRD.

Moutinho, N. and Lopes, M. D. S. (2011). Non-Financial Analysis in Project Appraisal–an Empirical Study. In: 2011European Financial Management Association Annual Conference, 2011, Braga, Portugal: European Financial Management Association. Available at: http://hdl.handle.net/10198/5685. Accessed on: 8 June, 2016.

Morgan, D.L.(2006) Connected Contributions as A Motivation for Combining Qualitative and Quantitative Methods. In: Curry L, Shield R, Wetle T, eds. Improving Aging and Public Health Research: Qualitative and Mixed Methods. Washington, DC: American Public Health Association and Gerontological Society of America. pp. 53–63

Müller, R. (2012). Project Governance. Surrey, UK: Gower Publishing, Ltd.

Munasinghe, M. (1993). Environmental Economics and Sustainable Development.

Washington, DC: World Bank Publications.

Munda, G. (2004). Social Multi-Criteria Evaluation: Methodological Foundations and Operational Consequences. European journal of operational research, 158(3), pp.662-677.

Naganathan, H., and Chong, W., K. (2017). Evaluation of State Sustainable Transportation Performances (SSTP) Using Sustainabe Indicators. Sustainable Cities and Society, 35, pp. 799-815.

National Bureau of Statistics of China. (2016). China Statistical Yearbook 2016. [Online]. Available at: http://www.stats.gov.cn/tjsj/ndsj/2016/indexch.htm. Accessed on: 11 March, 2017.

National Development and Reform Commission of China. (2006). Construction Project Economic Evaluation Approaches and Parameters. Beijing: Jihua Press.

National Development and Reform Commission of China. (2012). The Overall Planning of Accelerating to Developing the Yunnan Bridgehead to the Southeast.

National Development and Reform Commission of China. (2013). National Road Network Plan (2013-2030).

National Development and Reform Commission of China. (2014). Administrative Measures for the Government Confirmation of Investment Projects(End). [Online]. Available at: http://www.sdpc.gov.cn/zcfb/zcfbl/201405/w020140526539381444296.pdf. Accessed on: 7 January, 2017.

National Development and Reform Commission of China. (2016). Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China.

National Research Council. (2009). Sustainable Critical Infrastructure Systems: A Framework for Meeting 21st Century Imperatives: Report of a Workshop. Washington, D.C. US: National Academies Press.

Nie, S. K. (2002). The Indicator Weight Methods Comparison. South China J Prev. Med, 28(6), pp. 46-51.

Nie, X. T. and Chen, Y. H. (2008). Building Business Management Performance Assessment Indicator System. Journal of North China Institute of Water Resources and Hydropower, 29(2), pp.83-86.

Niu, W. Y. (2012a). Theory and Practice of China’s Sustainable Development. Bulletin of Chinese Academy of Sciences, 26(3), p. 78

Niu, W. Y. (2012b). The Cognition of Sustainable Development Content. China Population,

Resources and Environment, 2(5), pp. 55-56
O'flaherty, C. A. (2001). Highways: The Location, Design, Construction and Maintenance of Road Pavements. 4th ed. Routledge.
Ofori, G. (1998). Sustainable Construction: Principles and a Framework for Attainment-Comment. Construction Management & Economics, 16(2), pp.141-145.
Oltean-Dumbrava, C., Watts, G. and Miah, A. (2016). Towards a More Sustainable Surface Transport Infrastructure: A Case Study of Applying Multi Criteria Analysis Techniques to Assess the Sustainability of Transport Noise Reducing Devices. Journal of Cleaner Production, 112(4), pp.2922-2934.
Pan, J. (2015). Expressway Construction Cost Control in Mountainous Area：Optimizing the Large Temporary Engineering and Design Program to Save Construction Cost. Value Engineering, 16, pp.124-126
Pan, H. Z., Chen, M. J., Miao, W. and He, J. (2016). Comparison and Analysis on LEED in the United States and Green Building Evaluation Standard in China. Construciton Economy, 37(1), pp.87-92.
Parahoo, K. (2006). Nursing Research: Principles, Process and Issues. New York: Palgrave Macmillan.
Parker, J. (2012). The Value of BREEAM: A Bsria Report. BSRIA.
Patton, M. Q. (2002). Qualitative Research and Evaluation Methods. 3rd ed. Thousand Oaks, CA: Sage Publications Inc.
Pawłowski, A. (2008). How Many Dimensions Does Sustainable Development Have? Sustainable Development, 16(2), pp.81-90.
Pearce, D., Markandya, A. and Barbier, E. B. (1989). Blueprint for a Green Economy, a Report Prepared for the UK Department of Environment. London: Earthscan Publishers Ltd.
Peng, J. (2011). Establishment of Highway Engineering Sustainability Assessment Index System. Technology of Highway and Transport, 4, pp.32-36.
Peng, L. (2010). Establishment of Evaluation Index System for Sustainability of Highway Construction Projects. Technology of Highway and Transport, (4), pp.144-148.
People’s Government of Yunnan Province. (2015). Province Overview. [Online]. Available at: http://www.yn.gov.cn/index.html. Accessed on: 12 October, 2016.
People’s Government of Yunnan Province. (2016). Government Work Report 2016 of Yunnan. [Online]. Available at:

http://www.yn.gov.cn/yn_zwlanmu/qy/gzbg/201601/t20160130_23680.html. Accessed on: 3 February, 2017.

Piątek, Z. (2008). Ecophilosophy as a Philosophical Underpinning of Sustainable Development. Sustainable Development, 16(2), pp.91-99.

Picciotto, R., Van Wicklin, W., Rice E (eds) (2001). Involuntary Resettlement: Comparative Perspectives Volume 2 of World Bank Series on Evaluation and Development, Vol 2. Transaction Publishers

Pierantoni, I. (2004). A Few Remarks on Methodological Aspects Related to Sustainable Development. In: Measuring Sustainable Development: Integrated Economic, Environmental and Social Frameworks, 2004, OECD, pp.63-90.

Pieterse, J. N. (2009). Development Theory: Deconstructions/Reconstructions. 2nd ed. London: SAGE Publication.

Pinto, J. K. (2014). Project Management, Governance, and the Normalization of Deviance. International Journal of Project Management, 32(3), pp.376-387.

Podsakoff, P. M., Mackenzie, S. B., Lee, J.-Y. and Podsakoff, N. P. (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. Journal of Applied Psychology, 88(5), pp.879-903.

Polit, D. F. and Hungler, B. P. (1995). Nursing Research: Principles and Methods. 5th ed. Philadelphia PA: JB Lippincott.

Punch, K. F. (2009). Introduction to Research Methods in Education. London: Sage

Ragin, C. C. (1994). Introduction to Qualitative Comparative Anlaysis. In: Janoski, T.and Hicks, A. M., eds. The Comparative Political Economy of the Welfare State. New York: Cambridge University Press.

Rodríguez López, F. and Fernández Sánchez, G. (2011). Challenges for Sustainability Assessment by Indicators. Leadership and Management in Engineering, 11(4), pp.321-325.

Rogers, M. and Enright, B. (2016). Highway Engineering. 3rd ed. London: John Wiley & Sons.

Rogers, P. P., Jalal, K. F. and Boyd, J. A. (2006). An Introduction to Sustainable Development. Harvard University Press.

Rose, K. H. (2013). A Guide to the Project Management Body of Knowledge (Pmbok® Guide). 5th ed. Project Management Institute.

Rosnow, R. L. and Rosenthal, R. (2013). Beginning Behavioral Research: A Conceptual Primer. 5th ed. Prentice-Hall, Inc.

Saaty, T. L. (2008). Decision-making with the Analytic Hierarchy Process. International Journal of Services Sciences, 1(1), pp.83-98.

Sachs, J. D. (2012). From Millennium Development Goals to Sustainable Development Goals. The Lancet, 379(9832), pp.2206-2211.

Santos, J. R. A. (1999). Cronbach's Alpha: A Tool for Assessing the Reliability of Scales. Journal of Extension, 37(2), pp.1-5.

Saunders, M., Lewis, P. and Thornhill, A. (2009). Research Methods for Business Students. 5th ed. England: Pearson Education Limited.

Saurat, M., Ritthoff, M. and Smith, L. (2015). SAMT Deliverable 1.1. Overview of Existing Sustainability Assessment Methods and Tools, and of Relevant Standards. SAMT Project. Grant Agreement No. 636727

Shao, Q., Li, Y. J. and Tian, Q. W. (2004). Method for Building Comprehensive Indicator System. Journal of Daqing Petroleum Institute, 28(3), pp.74-78.

Sharrard, A.L., Matthews S., and Roth M., (2007). Envrionmental Implications of Construction Site Energy Use and Electricity Generaltion. Journal of Construction Engineering and Management. 133(11). pp.846-854

Shen, L.Y., Tam, V. W., Tam, L. and Ji, Y.B. (2010). Project Feasibility Study: The Key to Successful Implementation of Sustainable and Socially Responsible Construction Management Practice. Journal of Cleaner Production, 18(3), pp.254-259.

Shen, L., Wu, Y. and Zhang, X. (2011). Key Assessment Indicators for the Sustainability of Infrastructure Projects. Journal of Construction Engineering and Management, 137(6), pp.441-451.

Shen, M. Z. (2013). Sustainable Development Principles and Golobal Climate Changing. Shandong Social Seiences, 1(209), pp.164-168.

Shi, Q. (2007). Engineer Project Sustainable Construction and Management. Nanjing: Tongji University Press.

Shi, Q. (2016). Establishment and Operation of Resettlement Monitoring Organization for Expressway Project. China Science and Technology Information, (1), pp.83-84.

Shi, Z. and Huang, Z. (2015). The Economic Evaluation for the Large-Scale Construction Project. Statistics & Decision, 10, pp.183-185.

Shi, H., X., Li D., and Liu , S. (2011). A Brieft Discussion of Highway Route Selection in Yunnan Moutain areas. Journal of Highway Communication Technology, 79 (7), pp. 89-92.

Shi, Q., Liu, Y., Zuo, J., Pan, N., Ma, G.(2014). On the Management of Social Risks of

Hydraulic Infrastructure Projects in China: A Case Study. International Journal of Project Management, 33(3), Pp.483-496.
Silvius, A. G. and Schipper, R. P. (2014). Sustainability in Project Management Competencies: Analyzing the Competence Gap of Project Managers. Journal of Human Resource and Sustainability Studies, 2(02), pp.40-58.
Silvius, G., Schipper, R. and Van Den Brink, J. (2012). Incorporating Sustainability in Project Management. Silvius, Schipper, Planko, van den Brink, & Köhler (Ed.), Sustainability in Project Management. Franham, UK: Gower Publishing.
Söderqvist, T., Brinkhoff, P., Norberg, T., Rosén, L., Back, P.-E. and Norrman, J. (2015). Cost-Benefit Analysis as a Part of Sustainability Assessment of Remediation Alternatives for Contaminated Land. Journal of Environmental Management, 157, pp.267-278.
Soleri, P. (1973). The Bridge between Matter & Spirit Is Matter Becoming Spirit: The Arcology of Paolo Soleri. In: The Arcology of Paolo Soleri, Garden City. N.Y: Anchor Books, p.876.
Song, L. and Gong, W. (2016). Green Building Development Situation and Problem in China. Construction Science and Technology, 5.
Song, L., Ma, X. and Gong, W. (2014). The Study of Implementing Mandatory Policy for Green Building Evaluation in China. Construction Technology, 6, pp.45-48.
Stevens, B., Schieb, P., Andrieu, M., Bohlin, E., Forge, S., Blackman, C., Morgan, T., Stambrook, D., Ashley, R. and Cashman, A. (2006). Infrastructure to 2030-Telecom, Land Transport, Water and Electricity. Paris: Organization For Economic Co-Operation and Development.
Streubert, H. J. and Carpenter, D. R. (1999). Qualitative Research in Nursing: Advancing the Humanistic Imperative. 2nd ed. Philadephia: Philadephia.
Stripple, H. and Erlandsson, M. (2004). Methods and Possibilities for Application of Life Cycle Assessment in Strategic Environmental Assessment of Transport Infrastructures. Building Environmental Assessment Consensus on the Transeuropean Transport Network (BEACON). ISER Institute.
Stripple, H. and Uppenberg, S. (2010). Life Cycle Assessment of Railways and Rail Transports. Appplication in environmental product declarations (EPDs) for the Bothnia Line. Göteborg, Sweden: IVL, Swedish Environmental Research Institute Ltd. [Online]. Available at: http://www.ivl.se/download/18.343dc99d14e8bb0f58b75d4/1445517456715/b194

3.pdf. Accessed on: 11 February, 2016.
Strong, M. (1992). Required Global Changes: Close Linkages between Environment and Development. In: U. Kirdar (ed). Change: Threat or Opportunity for Human Progress. Ecological Change.New York: United Nations
Su, B., Ren, B. X., Teng, H., Duan, X., Lan, Y. and Pu, M. (2015). The Application of Questionnaire Survey in Environmental Management. Journal of Educational Institute of Jilin Province, 31(11), p.395.
Sun, H. and Li, X. (2013). Establishing the Sustainability Assessment Indicator System for Large-Scale Infrastructure Project. Statistics & Decision, 388(15), pp.28-33.
Sun, H. L. (2010). Large Infrastructure and Sustainable Development. Future and Development, 20(6), p.5.
Sun, M. (2016). Green Building Design Based on the Idea of Sustainable Development : Take Suzhou Phoenix International Bookstore Project as an Example. Chinese & Overseas Architecture, 8, pp.110-115.
Sustainableni. (2012). Principles of Sustainable Development. [Online]. Available at: http://www.sustainableni.org/sustainable-development/sustainability-principles/index.php. Accessed on: 15 March, 2014.
Tan, J. and Yang, J. (2013). Infrastructure Development and Economic Growth: Theories and Policies. China: Wuhan University Press.
Tang, Z. (2016). Study on the Existing Problems in Technical Assessment of Construction Project Environmental Impacts Reports. Journal of Green Science and Technology, 8, pp.98-97.
Tavakol, M. and Dennick, R. (2011). Making Sense of Cronbach's Alpha. International Journal of Medical Education, 2, p.53.
Teng, M., Han, C. and Liu, X. (2014). Indicator System of Social Impacts Assessment of Large-Scale Infrastructure Project in China. China Population, Resources and Environment, 24(9), pp.170-176.
The Law Library of Congress. (2015). National Funding of Road Infrastructure [Online]. Available at: https://www.loc.gov/law/help/infrastructure-funding/infrastructure-funding.pdf. Accessed on: 12 February, 2017.
The Port Authority of New York and New Jersey. (2011). Sustainable Infrastructure Guidelines. [Online]. Available at: https://www.panynj.gov/. Accessed on: 19 February, 2015.
Thomopoulos, N. and Grant-Muller, S. (2013). Incorporating Equity as Part of the Wider

Impacts in Transport Infrastructure Assessment: An Application of the Sumini Approach. Transportation, 40(2), pp.315-345.

Thomopoulos, N., Grant-Muller, S. and Tight, M. (2009). Incorporating Equity Considerations in Transport Infrastructure Evaluation: Current Practice and a Proposed Methodology. Evaluation and Program Planning, 32(4), pp.351-359.

Thorn, M. J., Kraus, J. L. and Parker, D. R. (2011). Life‐Cycle Assessment as a Sustainability Management Tool: Strengths, Weaknesses, and Other Considerations. Environmental Quality Management, 20(3), pp.1-10.

Thorne, J. H., Huber, P. R., O'donoghue, E. and Santos, M. J. (2014). The Use of Regional Advance Mitigation Planning (Ramp) to Integrate Transportation Infrastructure Impacts with Sustainability; a Perspective from the USA. Environmental Research Letters, 9(6), p.65.

Titscher, S., Meyer, M., Wodak, R., & Vetter, E. (2000). Methods of Text and Discourse Analysis. London: Sage.

Tong, G. (2014). Evaluation Index and Evaluation Methods on Sustainable Development of Highway Traffic. Transportation Standardization, 42(2), pp.97-100

Tong, T. (2016). Application of Concept Based on Safety ＆ Environmental Protection and Land Saving in Comparison and Selection of Yunnan Puli - Xuanwei Expressway. Technology of Highway and Transport, 32(1), pp.32-36.

Transport Department of Yunnan. (2014). Yunnan Province Highway Assets Management Programme, Ethnic Groups Development Plan. [Online]. Available at: http://www.ynsglj.com/item/4881.aspx. Accessed on: 28 October, 2016.

Transport Department of Yunnan. (2016a). The Long-Term Plan of Highway Network. (2016-2030) [Online]. Available at: http://www.ynjtt.com/item/43879.aspx. Accessed on: 5 October, 2016.

Transport Department of Yunnan. (2016b). The Summarize Report of Transportation Industry 12th Five-Year Plan. [Online]. Available at: http://zizhan.mot.gov.cn/st2010/yunnan/yn_fazhangh/201601/t20160107_1973133.html. Accessed on: 5 October, 2016.

Transport Department of Yunnan. (2017). The Investment in Fixed Assessts of Transporation in Yunnan Province from January to December, 2016. [Online]. Available at: http://www.ynjtt.gov.cn/Item/86326.aspx. Accessed on: 13 May 2017

Transport Deparment of Yunnan. (2017). The Investment in Fixed Assessts of Transporation in Yunnan Province from January to March, 2017. [Online]. Available at: http://www.ynjtt.gov.cn/Item/173424.aspx. Accessed on: 7 May, 2017

Treloar, G. J., Love, P. E. and Crawford, R. H. (2004). Hybrid Lifecycle Inventory for Road Construction and Use. Journal of Construction Engineering and Management, 130(1), pp.43-49.

Tricker, R. C. (2007). Assessing Cumulative Environmental Effects from Major Public Transport Projects. Transport Policy, 14(4), pp.293-305.

Trinius, W. and Borg, M. (1999). Influence of Life Cycle Allocation and Valuation on Lca Results, Int. Journal of Low Energy and Sustainable Buildings, Stockholm 1999.

Tsai, C. Y. and Chang, A. S. (2012). Framework for Developing Construction Sustainability Items: The Example of Highway Design. Journal of Cleaner Production, 20(1), pp.127-136.

Ugwu, O., Kumaraswamy, M., Wong, A. and Ng, S. (2006). Sustainability Appraisal in Infrastructure Projects (Susaip): Part 1. Development of Indicators and Computational Methods. Automation in construction, 15(2), pp.239-251.

United Nations. (2006). A Comprehensive Guide for Social Impact Assessment. [Online]. Available at: http://unpan1.un.org/intradoc/groups/public/documents/cgg/unpan026197.pdf. Accessed on: 12 January, 2017.

United Nations. (2011a). Guidelines for Developing Eco-Efficient and Socially Inclusive Infrastructure. [Online]. Available at: http://unpan1.un.org/intradoc/groups/public/documents/cgg/unpan026197.pdf. Accessed on: 15 March, 2015.

United Nations. (2011b). The History of Sustainable Development in the United Nations. [Online]. Available at: http://www.uncsd2012.org/history.html. Accessed on: 16 March, 2015.

United Nations. (2012). Un General Assembly Creates Key Group on Rio+20 Follow-up Group to Work on Design of New Sustainable Development Goals. In: Rio+ 20 United Nations Conference on Sustainable Development, June, 2012.

United Nations Conference on Environment and Development. (1992). United Nations Conference on Environment & Development Rio De Janerio, Brazil, 3 - 14 June 1992. Agenda 21. [Online]. Available at: https://sustainabledevelopment.un.org/content/documents/agenda21.pdf. Accessed on: 21 June. 2014.

United Nations Environment Programme (2014). The Emissions Gap Report a Unep Synthesis Report 2014. United Nations Environment Programme (UNEP). November 2014.

United Nations Environment Programme, KPMG, The Global Reporting Initiative and Unit for Corporate Governance in Africa. (2010). Carrots and Sticks - Promoting Transparency and Sustainability: An Update on Trends in Voluntary and Mandatory Approaches to Sustainability Reporting [Online]. Available at: http://www.integratedreportingsa.org/. Accessed on: 5 March, 2015.

United Nations Educational, Scientific and Cultural Organization. (2012). Culture: A Driver and an Enabler of Sustainable Development. In: UN System Task Team on the Post-2015 Un Development Agenda., May 2012.

United Nations Educational, Scientific and Cultural Organization. (2014). The Crucial Role of Science for Sustainable Development and the Post - 2015 Development Agenda. [Online]. Available at: http://en.unesco.org/un-sab/sites/un-sab/files/preliminary%20reflection%20by%20the%20un%20sg%20sab%20on%20the%20crucial%20role%20of%20science%20for%20the%20post-2015%20development%20agenda%20-%20july%202014.pdf. Accessed on: 23 June, 2014.

United Nations Economic and Social Commission for Asia and the Pacific. (2006). Sustainable Infrastructure in Asia. In: Overview and Proceedings Seoul Initiative Policy Forum on Sustainable Infrastructure Seoul, 6-8 September, 2006, Republic of Korea: United Nations ESCAP, 66, p.128.

United Nations Industrial Development Organization. (2011). Unido Green Industry Initiative for Sustainable Industrial Development. Vienna.

United States Environmental Protection Agency (2008). Reduce, Reuse, and Recycle Construction and Demolition Materials at Land Revitalization Projects. EPA-560-F-08-242.

Vaidya, B. C. (2003). Geography of Transport Development in India. New Delhi: Concept Publishing Company.

Van Teijlingen, E. and Hundley, V. (2002). The Importance of Pilot Studies. Nursing Standard, 16(40), pp.33-36.

Wainer, H. and Braun, H. I. (1988). Test Validity. Hilldale, NJ: Lawrence Erlbaum Associates, Inc.

Wang, G. (2013). Mountain Area Highway Construction Technology and Quality Control. China Building Materials Science and Technology, 22(3), pp.90-92.

Wang, H. (2011). On Validity in Qualitative Research - How Could I Know What I Judge Is Valid. Education Research Monthly, 2.

Wang, H. J., Li, B. X. and Li, S. T. (2000). Sustainable Development and Transportation. Beijing. China Railway Publishing House.

Wang, H. M. and Zhao, Y. Z. (2016). A Key Factor in Highway Construction Technology Management. Modern Industrial Economy and Informationizaion, 115(7), pp. 50-55.

Wang, J. (2000). The Indicator System of Regional Sustainable Development and the Evaluating Model. A Case Study of Changsha City Hunan Province. Chinese Journal of Management Science, 8(2).pp55-57

Wang, J., Zhao, G. and Sun, L. (2014a). Research on the Measures of Developing Low-Carbon Economy for Yunnan Province. Ecological Economy, 30(1), pp.101-104.

Wang, J., Shen, L., Zhang, Y. and Wu, M. (2005). The Study of Assessment Model for Sustainability in Construction Project. Construction Economic, 269(3), pp. 12-16.

Wang, L. M. (2014). Existing Problems and Suggestion on the Highway Construction Quality. Engineering Management, 8, pp.260-262.

Wang, R. and Zhu, C. (2015). Annual Report on the Development of the Indian Ocean Region (2015): 21st Century Maritime Silk Road. In: Current Chinese Economic Report Series. Springer.

Wang, X., Wu, W. and You, J. (2015). Effects of Project Governance Structures on Risk Management in Large Infrastructure Construction Projects. Journal of Engineering Management, 5, pp.56-60.

Wang, Y., Yi, H. and Fang, M. (2014b). Developing a Sustainability Performance Assessment Tool for Public Funded Projects According to Policies and Stakeholders' Perceptions. Open Construction and Building Technology Journal, 8, pp.52-62.

Wang, Z. and Shi, J. (2011). The Imbalanced Development of China's Regional Economy: Cause Analysis. Journal of Zhejiang University (Humanities and Social Sciences), 41(6), pp.93-103.

Wang, Z., Xin, Y. and Wan, Y. (2002). Strategic Environment Impact Assessment and Sustainable Development. Journal of Lanzhou Railway Institute, 2, pp.86-88.

Wang, Z., Sage, J., Goodchild, A., Jessup, E., Casavant, K. and Knutson, R. L. (2013). A Framework for Determining Highway Truck-Freight Benefits and Economic

Impacts. Journal of the Transportation Research Forum, 52(2), pp.27-43.

World Commission on Environment and Development. (1987). Our Common Future. New York: Oxford University Press.

Webb, E. J., Campbell, D. T., Schwartz, R. D. and Sechrest, L. (1966). Unobtrusive Measures: Nonreactive Research in the Social Sciences. Chicago, IL: Rand McNally.

White, L. and Lee, G. J. (2009). Operational Research and Sustainable Development: Tackling the Social Dimension. European Journal of Operational Research, 193(3), pp.683-692.

Wijnen, W., Wesemann, P. and De Blaeij, A. (2009). Valuation of Road Safety Effects in Cost–Benefit Analysis. Evaluation and Program Planning, 32(4), pp.326-331.

World Bank. (1997). Roads and the Environment. A Handbook. U.S.A.: The International Bank For Reconstruction and Development.

World Bank. (2004). Beyond Economic Growth: An Introduction to Sustainable Development. 2nd Ed. Washington, DC: The World Bank.

World Bank. (2008). World Bank Group Sustainable Infrastructure Action Plan (Siap). [Online]. Available at: http://siteresources.worldbank.org/. Accessed on: 15 March, 2015.

World Bank. (2012a). China: Improving Public Infrastructure and Services for 1.50 Million Small Town Residents [Online]. Available at: http://www.worldbank.org/en/news/press-release/2012/05/24/china-improving-public-infrastructure-and-services-for-1500000-small-town-residents. Accessed on: 2 May, 2016.

World Bank. (2012b). Strategic Environmental Assessment in the World Bank : Learning from Recent Experience and Challenges (English) [Online]. Available at: http://documents.worldbank.org/curated/en/729811468331017746/strategic-environmental-assessment-in-the-world-bank-learning-from-recent-experience-and-challenges. Accessed on: 14 October, 2015.

World Economic Forum. (2014). Forum Document: Section Ii Infrastructure. [Online]. Available at: http://www3.weforum.org/docs/gcr2011-12/14.gcr2011-012dtiiinfrastructure.pdf. Accessed on: 3 May, 2016.

Wu, H. (2009). The Comparison of Quantities and Qualitative Research Methods. Journal of Chendu Aeronautic Vocational and Technical College, 3, pp. 33-36.

Wu, L. H. (2013). Risk Analysis of Highway Infrastructure Project Investment. China Venture Capital, 24, pp.19-20.

Wu, Q. (2006). Buidling Zhejiang High Technology Enterprises Research & Development Centre Performance Assessment Indicator. Modern Information, 26(7), pp.173-176.

Wuelser, G., Pohl, C. and Hadorn, G. H. (2012). Structuring Complexity for Tailoring Research Contributions to Sustainable Development: A Framework. Sustainability Science, 7(1), pp.81-93.

Xia, Y. and Zhang, P. P. (2015). The Analysis of Highway Construciton Proejct Sustainable Devleopment in Baohu, China. Modern Economic Information, 12, pp.420-421.

Xie, Y. (2012). Social Research Methods and Quantitively Methods. 2nd ed. Beijing: Social Science Academic Press.

Xinhua Net. (2013).Why Should Establish and Improve the Social Risk Assessment Mechanism of Major Decisions? Xinhua Net. 2013, Feb. 18th [Online]. Available at: http://news.xinhuanet.com/politics/2013-02/18/c_114706779.htm.

Xu, F. and Wang, Y. (2013). Prototype in Design: The Sustainable Design of Regional Architecture in Lijiang, Yunnan. New Construction, 3, pp.98-103.

Xu, Z. (2015). Highway Supply under the Local Government Completion: Comparison of Jiansu, Zhejiang, Shangdong and Guangdong. Construction Economy, 2 (340). pp.82-86

Xue, X., Wu, H., Zhang, X., Dai, J. and Su, S. (2014). Measureing Energy Consumption Efficiency of the Construction Industry: The Case of China. Journal of Cleaner Production, 107, pp.509-515.

Xue, Y. and Ren, M. (2010). Railway Sustainability Assessment Framework System. Academic Forum, 5, pp.35-39.

Yan, D. (2015). Poverty Eradication and Sustainable Development Pathways for Hydro-Electric Migrants. Gsdr Brief No. 22cn. [Online]. Available at: https://sustainabledevelopment.un.org/content/documents/6062gsdr%20brief%2022cn.pdf. Accessed on: 23 May, 2015.

Yan, G., Yu, J. and Gao, J. (2013). Study on Assessment Indicator and Assessment Indicator Weight Sustainability Assessment System of Large Public Building. Journal of Gansu Science, 25(2), pp.123-127.

Yan, H., Dong, K., Dong, X. C., Xu, T. and Guo, D. H. (2016). The Reflection and Discussion on the "Emission Standard for Industrial Enterprises Noise at Boundary". Environment and Sustainable Development, 1.

Yan, L. (2012). Research on Statues and Development of Public Project Governance. Soft Science, (12), pp.22-25.

Yan, L. W. (2016). Construction Quality Control on the Highway. Engineering Management, 395(17), pp.92-93.

Yang, F., Su, Z. and Yuan, Y. (2010). Evaluation Methods of Sustainable Development in the Construction Industry. Journal of Engineering Management, 24(3), pp.258-262.

Yang, F., Xin, L. and Liu, C. (2015). The Study of Sustainability Assessment on Urban Infrastructure Project Indicator System. Economic Tribune, 6, pp.49-53.

Yang, N., Liu, X., Zeng, Y. and Li, J. (2011). Methodology Innovations in Learning Sciences and a Synthesis of Its Research Methods. Open Education Research, 17(6), pp.20-29.

Yang, Q., Su, Z. and Jin, S. (2014). The Study of Approaches of Realizing Sustainability in Construction Engineering. Project Construction Economic. 380(6), pp.9-12.

Yang, S. (2016). Impacts of Highway to Economic Development. Modern Business Trade Industry, 11, p. 67.

Yang, Y. B. (2016). The Control Measure of Construction Environment Pollution. Jiangxi Building Materials, 187(10), pp.66-69

Yang, Y., He, K., Lu, Y. (2017). Research on the Temporal and Spatial Distribution of Water Environmental Sustainability in Yunnan Province Environment and Sustainabble Development, 4, 152-155

Ye, F. (2014). Building the Sustainable Construction Concept. Sichun Construction, 34(4), pp.100-101.

Yeung, Y. M. and Shen, J. (2004). Developing China's West: A Critical Path to Balanced National Development. The Chinese University of Hong Kong Press.

Yu, H. Y. (2014). The Approach of Reducing the Construction Cost of Highway in Mountainous Area. Highway Technology, 3, pp.317-319.

Yu, R. B. and Cha, N. (2011). Feature of Sustainable Development Theory in Different Subjects. China Population, Resources and Environment, 21(12), pp.447-450.

Yuan, J. B. (2007). Highway Economic Lessons. Beijing: The People's Communication Publishing Company.

Yunnan Highway Development & Investment Co. Ltd. (2016). The Report of Public Issuance of Corporate Bonds.

Yunnan Housing and Urban-Rural Development Bureau. (2011). Green Building Environment Assessment Standard of Yunnan Province. [Online]. Available at: www.ynjst.gov.cn:85/dew/editor/down.jsp?file=1336972552658.doc. Accessed on:

1 November, 2016.
Yunnan Provincial Bureau of Statistics. (2016). Statistical Bulletin. [Oline]. Avaiable from: http://www.stats.yn.gov.cn/TJJMH_Model/newslist.aspx?classid=133608. Accessed on: 17 May, 2017

Yunnan Provincial Department of Land and Resources. (2016). Yunnan Province Land Resources Statistics 2015. [Online]. Avaiable from: http://g.mlr.gov.cn/201701/t20170123_1429986.html. Accessed on: 23 November, 2016

Zabihi, H. and Habib, F. (2012). Sustainability in Building and Construction: Revising Definitions and Concepts. International Journal of Emerging Sciences, 2(4), pp.570-578.

Zai, W. G., Luo, A. D. and Yan, Z. L. (2016). Analysis of Techniques for Improvement of Highway Slope Landscapes Based on Ecological Protection. Technology of Highway and Transport, 32(1), pp.102-105

Zamagni, A., Masoni, P., Buttol, P., Raggi, A. and Buonamici, R. (2012). Finding Life Cycle Assessment Research Direction with the Aid of Meta‐Analysis. Journal of Industrial Ecology, 16(1), pp.39-52.

Zeng, W. and Huang, B. (2005). The Reliability and Validity Analysis in Survey Research. Statistics & Information Tribune, 5(13).pp.71-73

Zijp, M. C., Heijungs, R., van der Voet, E., van de Meent, D., Mark A. J. Huijbregts M., A., Hollander A. and Posthuma L. (2015). An Identification Key for Selecting Methods for Sustainability Assessments. Sustainability 2015, 7, 2490-2512; doi:10.3390/su7032490. [Online]. Availabe from: www.mdpi.com/journal/sustainability. Accessed on: 23, Novermber, 2016

Zhang, B. (2015). The Analysis of Investment Risks on Highway Infrstructures Projects and Avoidance Methods. Human Resources Management., 10, pp.240-241.

Zhang, C. (2011). The Sustainable Development Principles and Law. Seeker, 11, pp.165-168.

Zhang, D. Q. (2013). The Problems of Environmental Impact Law in China. Environment and Sustainable Development, 3, pp.87-89.

Zhang, Q., Jiang, Y., and Chen, X.(2006). Study on Expressway Related Environmental Destruction and Eco-restoration Assessment. Journal of Highway and Transporation Research and Dcvelopment, 23(5). pp.147-149.

Zhang, S., Shao, C. and Yan, H. (2005). Evaluation Indices and Model of Highway Transportation Sustainable Development. China Journal of Highway and Transport, 18(2), pp.74-78.

Zhang, W., Li, Y. and Yao, G. (2007). Public Participation in Enviornmental Impact Assessment on the Sustainable Development. Journal of Xi' An University of Arts & Science (Nat Sci Ed), 10(4), pp.89-91

Zhang, X., Shang, J., Zhao, D. and Guo, A. (2009). Sustainbility Assessment in Urban Land by Entropy Method with Case of Shijiazhuang. Territory & Natural Resources Study, 4, pp.35-37.

Zhang, Y. (2016a). The Analysis of Qualitative and Quantitative Methods in Rocicsl Rearch. Journal of Weifang Engineering Vocational Collegea, 29(3), pp.88-90.

Zhang, Y. (2016b). Quantitative and Qualitative Research Methods in Social Research. Jorunal of Weifang Engineering Vocational Collage, 3.

Zhao, H. Y. (2011). The Inherent Defect in the Urban Road Construction. Communications Science and Technology, 2, p. 145

Zhao, Y., Huang, Y., Liu, H. and Xie, Z. (2014). Research on the New Method of Project Social Impact Assessment: Based on Variable Analysis Method. Construction Economy, 35(11), pp.122-125.

Zheng, J. (2014). The Review of Questionnaire Survey. Theoretic Observation, 100(10), pp.102-103.

Zhou, H. (2010). The Discussion of Sustainable Development Principles. Science of Environmental Law, 1, pp.137-140.

Zhou, M. ((2012). A Comprehensive Method of Sustainability Assessment in Highway Construction Projects. Enterpriser World. 3. pp. 88-89

Zhou, J. and Liu, Y. (2015). The Method and Index of Sustainability Assessment of Infrastructure Projects Based on System Dynamics in China. Journal of Industrial Engineering and Management, 8(3), pp.1002-1019.

Zhou, K. and Wang, X. J. (2015). Decoupling Assessment from Administration: The Direction of China's Environmental Impact Appraisal System. Journal of Shenzhen University (Humanities & Social Sciences), 32(6), pp.62-67.

Zhou, S. L. (2016). The Discussion of Control on Highway Quality. Jiangxi Building Materials, 187(10), pp.182-184.

Zhu, G. P. (2015). Main Reasons of People Weak Awareness on Environmental Protection.

Theoretic Observation, 7(6), pp. 129-131

Zhu, H., Cai, D. and Zhang, Q. (2011). The Overview of Sustainable Development Concepts in China. Shangyeshidai, 7, pp.36-38

Zhu, D. (2012). The Methodology and Research Strategies of Mixed Methods Design and its Application: In a Case Study of Consumption Patterns. The Study of Sociology, 4, pp 146-166

Zhu, L. and Meng, X. (2013). The Comparison of Origin F Bibliometric Method and Content Analysis. Library Work and Study, 208(2), pp.64-66.

Zhu, W. and Yuan, C. X. (2002). Study on Sustainable Architecture and Its Design Method. Journal of NW Institute of Architecture and Engineering (Natural Science), 9(3), pp.37-39.

Zhu, X. (2014). The Discussion of Principles of Environment Law in China. Journal of East China University of Political Science and Law, 3, pp.121-122

Zhu, X., Zhou, Y., Wang, G. and Jiang, Y. (2014). The Development Situation and Prospects of Highway in Yunnan. . Journal of Highway Transpiration Science, 11(2).

Zhu, Z., Shi, X. and Gong, W. (2010). Review of Construction Engineering Project Sustainability Assessment. Journal of Engineering Management, 2, pp.23-26

Zou, L. (2009). The Analysis of Highway Construction and Impacts on Region Economic Development. Inquiry Into Economic Issues, 8, pp.162-168.

Zou, Y., Zhao, W. and Mason, R. (2014). Marketization of Collective-Owned Rural Land: A Breakthrough in Shenzhen, China. Sustainability, 6(12), pp.9114-9123.

Zuo, J., Zillante, G., Wilson, L., Davidson, K. and Pullen, S. (2012). Sustainability Policy of Construction Contractors: A Review. Renewable and Sustainable Energy Reviews, 16(6), pp.3910-3916.

Zuofa, T. and Ochieng, E. (2016). Sustainability in Construction Project Delivery: A Study of Experienced Project Managers in Nigeria. Project Management Journal, 47(6), pp.44-55.

APPENDIX I

Questionnaire related to the research of Build the Sustainability Assessment Model for the Highway Infrastructure Projects in Yunnan, China

关于构建云南省高速公路项目可持续性评价系统的问卷调查

This questionnaire helps to identify a set of the most important factors for assessing sustainability in the highway construction project, the information will be valuable to study on sustainable highway project, and will benefit the project planning. I would very much appreciate your participation in this research.

Notes: All personal information will be kept anonymous.

本问卷调查有助于识别评估公路建设项目可持续性的重要因素，。非常感谢您参与这项研究。

注：调查将以不记名的方式进行

Part one: This part provides your background information

第一部分： 个人基本信息

Q1. What is your profession? Please (✓)

Q1. 您的职业领域？ 请在（）里打"✓"

Academic profession ( ) Government decision-maker ( )

学术领域 （） 政府部门 （）

Construction engineer ( )

建筑工程师 （）

Q2. How many years have you worked on a highway project? Please (✓)

Q2. 关于高速公路建设的工作年限？请在（）里打"✓"

3 - 5 years ( ) 5 - 10 years ( ) 10 years and more ( )

3 - 5 年（） 5 - 10 年（） 10 年以上 （）

Q3. Have you ever involved in a part of a specific sustainability elements of highway project? Please (✓)

Q 3. 您是否参与过与高速公路可持续性相关的工作？Please (✓)

Yes ( ) No ( )

是（） 否（）

Part two：

第二部分：

Part two provides the chart on below which lists the optional sustainability assessment indicators emphasised by various institutions and studies. Please complete the chart, adding score for those indicators using the scale on the right: 通过对不同评估系统得到以下的评价指标，为了选出对高速公路项目可持续性影响最大的指标请您为以下指标打分：	0 = Not relevant 0 = 不相关
	1 = Low significance 1 = 基本相关
	3 = Average significance 3 = 重要
	5 = High significance 5 = 很重要
	7 = Very high significance 7 = 非常重要

Aspects **主要因素**	**Indicators** **指标**	**Score** **评分**
Economical aspect **经济因素**	Lifecycle cost 生命期成本	
	Project budget 项目预算	
	Project financing channel 项目融资渠道	
	Project investment planning 项目投资计划	
	Lifecycle profit 生命期收益	
	Financial risk 财务风险	
	Return on Investment (ROI) 投资回收率(ROI)	
	Net present Value (NPV) 净现值(NPV)	
	Payoff period 回收期	
	Internal rate of return (IRR) 内部收益率(IRR)	
	Cost/benefit ratio 成本/利润比	

Aspects **主要因素**	**Indicators** **指标**	**Score** **评分**
	Contribution to local economy 对地区经济的影响	
	Contribution to improvement of people's income and living standards 对地区人民收入和生活水平的影响	
Social aspect **社会因素**	Providing job opportunities 提供就业机会	
	Improvement on public health 改善公共健康	
	Effects on development of local education 对当地教育的影响	
	Protection of cultural and natural heritage which related to the project 与项目有关的文化自然遗产的保护	
	Resettlement work 移民安置工作	
	Suitable to different stakeholders 适用于不同利益相关人员	
	Coordination on various organisations 与其它组织的协调	
	Serviceability 适用性	
Environmental aspect **环境因素**	Effects on land (e.g. Land consumption and land pollution) 对土地的影响	
	Effects on ecological environment (changes on climate and local geology) 对生态环境的影响	
	Effects on air quality 对空气的影响	
	Effects on water quality（produced waste water, consumption of water resource, potential contamination) 对水资源的影响	
	Noise pollution 噪音影响	
	Waste disposal 废料处理	
	Use of green energy sources 绿色能源的使用	
	Energy saving 节能表现	
	Effects on natural landscape and historical sites 对自然景观和历史遗迹的影响	
Technological aspect **技术因素**	Advantage of project technologies 技术优势	
	Coordination with other transportation projects 与其它交通设施的协调	

Aspects **主要因素**	**Indicators** **指标**	**Score** **评分**
	Improvement on road network efficiency 对路网贡献率	
	Maintainability 可维护性	
	Extendibility 可扩展性	
	Disaster prevention capability 防灾应急能力	
Governance aspect **管理因素**	Rationality of project design and planning 项目设计的合理性	
	Rationality of organisational structure design 管理组组结构的合理性	
	Sound governance systems 良好的管理系统	

If you have correction or additions for the indicators, please give your comments here: 如您觉得需要增减的指标，请填写在空白栏中并说明您的意见:

APPENDIX II

Interview Survey Related to the Research of Build the Sustainability Assessment Model for the Highway Infrastructure Project in Yunnan Province, China

关于构建云南省高速公路项目可持续性评价模型的访谈调查

Purpose

The purpose of this interview is to obtain the individual's ideas of sustainable highway infrastructure project in Yunnan Province of China, through that aid the building and improvement of a sustainability assessment model for highway infrastructure.

Listed below are the open-ended questions about the sustainability in highway infrastructure project development in Yunnan province of China, and the developed sustainability assessment model. The questions are designed to extend the scope of explaining the main sustainability criteria which will help to refine the model. The participants will take 45 minutes to give answers through personal interviews or telephone surveys, during the research their participations are anonymous.

访谈目的：

本访谈的目的是为了获得关于中国云南省高速公路项目可持续发展的相关信息，通过访谈帮助完善和建立高速公路可持续性评价模型。

下面是关于中国云南省公路基础设施可持续发展的问题。目的旨在通过专家的知识和经验对当前高速公路项目的可持续性发展形势，以及已建立的评价模型提供建议。通过提供更广范围的解释帮助建立项目可持续性发展的标准并对已有模型进行完善。本次访谈可能通过面谈或电话的方式完成，不超过45分钟，所有参与者的信息都将是匿名的。

Questions

问题：

Part one: General information about the participant and highway infrastructure construction in Yunnan.

第一部份： 关于被访问者和云南省高速公路建设的基本信息

1. What is your job? what are the main duties of your job?
   您的职业是？主要从事的工作有哪些？

2. What experiences do you have on the highway project sustainability? Have you ever made suggestion that was implemented in this field?
   您在高速公路可持续发展方面有什么样的经验？
   您是否给这方面的工作提供过建议？

3. Please introduce the situation and the achievement in the highway infrastructure construction in Yunnan.
   请介绍一下当前云南省高速公路建设的情况和已取得的成就。

Part two: Information of how the participant understands the sustainability in highway infrastructure.

第二部分：关于高速公路项目可持续性的信息

4. How do you define the term of 'sustainability', and how do you assess or gauge progress toward sustainability?
   您怎么定义"可持续性"，您如何评价可持续发展的进展？

5. What are the benefits of sustainability in highway projects?
   公路项目可持续性的好处是什么？

6. Would you give a phrase or sentence to define sustainable highway?
   请定义什么是可持续的高速公路？

7. Please list a number, preferably between five and ten, of the most important priority factors that must be addressed to contribute to the achievement of sustainability in highway infrastructure.
   请列举 5 到 10 个您觉得最重要的关于高速公路可持续发展的因素。

8. Please describe the key factors that support the advancement of sustainability issues on highway in Yunnan? What factors do you think account for resistance to or lack of responsiveness to these concerns?
   请描述一下实现云南省高速公路可持续发展的主要因素。是什么原因阻碍了可持续性的实现？

9. Based on your experience what would be the key use of sustainability assessment highway project?
   根据您的经验高速公路可持续发展有什么样的评价方式？

Part three: comments on the developed sustainability assessment model.

第三部分：关于已建立模型的建议

10. To what extent did you understand the purpose/function of the highway sustainability assessment model?
    您怎么理解于高速公路可持续评价模型的作用？

11. If there was anything would like to add about the assessment model?
    对于新建的评价模型有什么内容需要增加吗？

12. Were any alternative sustainable assessment methods or tools considered?
    是否有其它评价模型可供选择？

13. Were there any significant gaps in the knowledge of the assessment model during in using it?
    在新建模型与已有知识之间有没有什么差异？

14. Were there any significant communication difficulties for using the model?
    这个模型沟通上有没有问题？

15. What extent could be working practices have been improved the sustainability after using the model?
    这个模型是否对可持续发展有所帮助?

16. How would you like to suggest a potential user wishing to use this model?
    您对于这个模型潜在的使用者有什么样的建议？

17. Any other comments on the model?
    是否有其它关于这个模型的意见？

APPENDIX III

LIKERT SCALE FOR SUSTAINABILITY ASSESSMENT OF KQ NO.4 PROJECT

关于 KQ No.4 可持续性评价的量表

Please rate the sustainable performance of the project based on the project feasibility report provided.

请根据所提供的项目可行性报告对该的可持续性进行打分。

Part one: This part provides your background information

第一部分： 个人基本信息

Q1. What is your profession? Please (✓)

Q1. 您的职业领域？ 请在（）里打“✓”

Academic profession ( )	Government decision-maker ( )	Construction engineer ( )
学术领域 （）	政府部门 （）	建筑工程师 （）

Q2. How many years have you worked on a highway project? Please (✓)

Q2. 关于高速公路建设的工作年限？请在（）里打“✓”

3 - 5 years ( ) 5 - 10 years ( ) 10 years and more ( )

3 - 5 年（） 5 - 10 年（） 10 年以上 （）

Part two: According to the right scale evaluate the sustainability of the KQ No.4 project. **第二部分：请根据表格右侧的评分标准对 KQ No.4 项目的可持续性进行打分。**	1= Weak 1 = 弱
	3 = Pass 3 = 合格
	5= Moderate 5= 中等
	7= Good 7 = 好
	9 = Excellent 9= 很好

Aspects **主要因素**	**Indicators** **指标**	**Score** **评分**
Economical aspect **经济因素**	Lifecycle cost 生命期成本	
	Project budget 项目预算	
	Project investment planning 项目投资计划	
	Financial risk 财务风险	
	Return on Investment (ROI) 投资回收率(ROI)	
	Net present Value (NPV) 净现值(NPV)	
	Payoff period 回收期	
	Internal rate of return (IRR) 内部收益率(IRR)	
	Cost/benefit ratio 成本/利润比	
	Contribution to local economy 对地区经济的影响	
	Contribution to improvement of people's income and living standards 对地区人民收入和生活水平的影响	
Social aspect **社会因素**	Providing job opportunities 提供就业机会	
	Improvement on public health 改善公共健康	
	Effects on development of local education 对当地教育的影响	
	Protection of cultural and natural heritage which related to the project 与项目有关的文化自然遗产的保护	
	Resettlement work 移民安置工作	
	Suitable to different stakeholders 适用于不同利益相关人员	
	Serviceability 适用性	
Environmental aspect **环境因素**	Effects on land (e.g. Land consumption and land pollution) 对土地的影响	
	Effects on ecological environment (changes on climate and local geology) 对生态环境的影响	

Aspects 主要因素	Indicators 指标	Score 评分
	Effects on air quality 对空气的影响	
	Effects on water quality (produced waste water, consumption of water resource, potential contamination) 对水资源的影响	
	Noise pollution 噪音影响	
	Waste disposal 废料处理	
	Use of green energy sources 绿色能源的使用	
	Energy saving 节能表现	
	Effects on natural landscape and historical sites 对自然景观和历史遗迹的影响	
Technological aspect **技术因素**	Advantage of project technologies 技术优势	
	Coordination with other transportation projects 与其它交通设施的协调	
	Improvement on road network efficiency 对路网贡献率	
	Maintainability 可维护性	
	Extendibility 可扩展性	
	Disaster prevention capability 防灾应急能力	
Governance aspect **管理因素**	Rationality of project design and planning 项目设计的合理性	
	Rationality of organisational structure design 管理组组结构的合理性	
	Sound governance systems 良好的管理系统	

Please give your comments here: 请填写在空白栏中并说明您的意见: