THE DETERMINATION OF EQUIVALENT VALUE IN LIFE-COST STUDIES:

An Intergenerational Approach

A Thesis Submitted to
the University of Technology, Sydney
in Candidacy for the Degree of
Doctor of Philosophy

by

Craig A. Langston

Sydney, Australia
April, 1994

"I apply my perspective not merely to space but also to time. In time the world will cool and everything will die; but that is a long time off still, and its present value at compound interest is almost nothing."

Ramsey (1931, p. 12)

TABLE OF CONTENTS

Page

LIST OF TABLES ix

LIST OF FIGURES xi

ABSTRACT xiii

CHAPTER ONE INTRODUCTION:

1.1 BACKGROUND TO THE RESEARCH 1

1.2 HYPOTHESIS 5

1.3 AIMS AND OBJECTIVES 5

1.4 RESEARCH METHODOLOGY 6

1.5 STRUCTURE OF THE THESIS 8

1.6 APPLICATION OF THE RESEARCH 11

Page

CHAPTER TWO DISCOUNTING: The Underlying Theory

2.1 PURPOSE AND APPROACH 12

2.2 THE TIME VALUE OF MONEY 14

2.2.1 Compound Interest 14
2.2.2 Inflation 14
2.2.3 The Discounting Process 17
2.2.4 Discount Rate 19

2.3 DISCOUNTED CASH FLOW ANALYSIS 22

2.3.1 Cash Inflows and Outflows 22
2.3.2 Capital Budgeting Techniques 24
2.3.3 Cost-Benefit Analysis 28
2.3.4 Taxation 29

2.4 DISCOUNTING PHILOSOPHY 31

2.4.1 The Rationale for Discounting 31
2.4.2 Time Preference 34
2.4.3 Capital Productivity 34
2.4.4 Further Considerations 37
2.4.5 Time, Discounting and Value 38

2.5 COMPOSITION OF THE DISCOUNT RATE 43

2.5.1 Interest Receipts and Payments 43
2.5.2 Accounting for Inflation 48
2.5.3 The Taxation Issue 52
2.5.4 Profit Expectations 53
2.5.5 Risk Contingencies 55
2.5.6 Discount Rate Determination 63

2.6 CONCLUSIONS 65

CHAPTER THREE LIFE-COST STUDIES: A Review of Current Practice

3.1 PURPOSE AND APPROACH 68

3.2 THE TOTAL COST APPROACH 70

3.2.1 The Concept of Value 70
3.2.2 The Importance of Total Costs 72
3.2.3 Terminology 73

Page

CHAPTER THREE LIFE-COST STUDIES *continued*

3.3 LIFE-COST PLANNING 76

3.3.1 The Purpose of Cost Planning 76
3.3.2 Types of Life-Costs 78
3.3.3 Study Period 80
3.3.4 Residual Value 86
3.3.5 Problems with Traditional Techniques 88
3.3.6 Subjective Considerations 91

3.4 LIFE-COST ANALYSIS 92

3.4.1 The Purpose of Cost Analysis 92
3.4.2 Monitoring and Management 93
3.4.3 Data Collection 93
3.4.4 Classification System 96

3.5 LIFE-COSTING IN PRACTICE 100

3.5.1 New Challenges for Life-Cost Studies 100
3.5.2 The Cost Control Process 103
3.5.3 Investment Appraisal and Cost Control 107
3.5.4 Capital Budgeting Versus Life-Cost Studies 111
3.5.5 The Future of Life-Cost Studies 112

3.6 DECISION THEORY 114

3.6.1 Making Decisions 114
3.6.2 Human Judgement 116
3.6.3 Human Limitations 117
3.6.4 The Structure of Judgemental Tasks 118
3.6.5 Judgement Bias 120
3.6.6 Forecasting Future Events 122

3.7 CONCLUSIONS 125

CHAPTER FOUR SUSTAINABILITY:
Intergenerational Equity and the Environment

4.1 PURPOSE AND APPROACH 128

4.2 SUSTAINABLE DEVELOPMENT 130

4.2.1 The Environmental Crisis 130
4.2.2 Concept of Sustainability 138
4.2.3 Capital and Environmental Wealth 139
4.2.4 Interaction Model 141

Page

CHAPTER FOUR SUSTAINABILITY *continued*

4.3 ENVIRONMENTAL CONSIDERATIONS 143

4.3.1 Valuing the Environment 143
4.3.2 Sustainability Constraint 144
4.3.3 Energy Auditing 147

4.4 SOCIAL CONSIDERATIONS 149

4.4.1 Welfare Economics 149
4.4.2 Equity and Justice 151
4.4.3 Distributional Effects 153

4.5 ECONOMIC APPRAISAL 153

4.5.1 Intangible Costs and Benefits 153
4.5.2 Sustainability Constraint Revised 155
4.5.3 Equivalent Value and Equity Assessment 157

4.6 CONCLUSIONS 157

CHAPTER FIVE EQUIVALENT VALUE: The Development of a New Concept

5.1 PURPOSE AND APPROACH 160

5.2 CHANGE IN WORTH 162

5.2.1 Determinants of Base Worth 162
5.2.2 Differential Price Level Changes 163
5.2.3 Diminishing Marginal Utility 169

5.3 DISCOUNTING REVISITED 174

5.3.1 A Further Look at Price 174
5.3.2 Future Value 178
5.3.3 Discounted Future Value 179
5.3.4 The Cost/Value Relationship 181
5.3.5 A Composite Discounting Philosophy 183

5.4 REAL AND EQUIVALENT VALUE 187

5.4.1 Conceptual Framework 187
5.4.2 Implications for Life-Cost Studies 190
5.4.3 Knowledge Gap 193

5.5 CONCLUSIONS 193

Page

CHAPTER SIX **AFFORDABILITY RESEARCH: Data Collection and Analysis**

6.1 PURPOSE AND APPROACH 196

6.2 RESEARCH STRATEGIES 198

6.2.1 Intergenerational Discounting Approaches 198
6.2.2 Affordability Measurement 202
6.2.3 Model Development 206
6.2.4 Data Requirements 208

6.3 ARCHIVAL RESEARCH 210

6.3.1 Population 210
6.3.2 Consumer Price Index 212
6.3.3 Gross Domestic Product 214
6.3.4 Private Final Consumption Expenditure 216
6.3.5 Household Sector Expenditure 218
6.3.6 Household Sector Income 220
6.3.7 Household Savings 222
6.3.8 Public Sector Expenditure 224
6.3.9 Public Sector Income 226
6.3.10 Corporate Sector Net Surplus 228

6.4 HOUSEHOLD SECTOR AFFORDABILITY 230

6.4.1 Expenditure Trends 230
6.4.2 Income Trends 234
6.4.3 Affordability Index 236

6.5 PUBLIC SECTOR AFFORDABILITY 240

6.5.1 Expenditure Trends 240
6.5.2 Income Trends 242
6.5.3 Affordability Index 244

6.6 CORPORATE SECTOR AFFORDABILITY 247

6.6.1 Net Surplus Trends 247
6.6.2 Affordability Index 247

6.7 OPINION RESEARCH 251

6.7.1 Consumer Survey 251
6.7.2 Analysis of Responses 254

6.8 AFFORDABILITY AND DISCOUNT RATE FORECASTS 256

6.9 CONCLUSIONS 260

Page

CHAPTER SEVEN CONCLUSIONS:

7.1 CONTRIBUTION TO KNOWLEDGE 262
7.2 REVIEW OF OBJECTIVES 264
7.3 RESOLUTIONS FOR FUTURE PRACTICE 267
7.4 POLICY INITIATIVES AND RECOMMENDATIONS 269
7.5 LIMITATIONS OF THE WORK 271
7.6 FURTHER RESEARCH 272

APPENDIX ONE LIFE-COST CASE STUDY 273

APPENDIX TWO LIFE-COST CALCULATIONS

A2.1 PURPOSE 291
A2.2 COMPARISON OF ALTERNATIVES 291
A2.3 MEASUREMENT OF LIFE-COSTS 298

APPENDIX THREE SURVEY ANALYSIS 300

APPENDIX FOUR GLOSSARY OF TERMS 309

REFERENCES AND BIBLIOGRAPHY 322

LIST OF TABLES

Table		Page
1.	The Discounting Philosophy	24
2.	Example of Discounted Cash Flow Analysis	27
3.	Example of Different Financing Methods	46
4.	Discounting with Real or Nominal Rates	51
5.	Discounted Cash Flow for Project A and Project B	57
6.	Conservative Benefit and Cost Estimating Technique	59
7.	Risk-Adjusted Discount Rate Technique	60
8.	Discount Rate Forecasts	64
9.	Value of $1,000 at Various Discount Rates	85
10.	NPWC List of Standard Elements	98
11.	NPWC List of Standard Sub-Elements for Roof Element	99
12.	Application of the Sustainability Constraint	146
13.	Escalation Rate Forecasts	167
14.	Australian Population Statistics 1950 - 1990	211
15.	Consumer Price Index 1950 - 1990	213
16.	Gross Domestic Product 1950 - 1990	215
17.	Private Final Consumption Expenditure 1950 - 1990	217
18.	Household Sector Expenditure 1950 - 1990	219
19.	Household Sector Income 1950 - 1990	221

Table		Page
20.	Household Savings 1950 - 1990	223
21.	Public Sector Expenditure 1950 - 1990	225
22.	Public Sector Income 1950 - 1990	227
23.	Corporate Sector Net Surplus 1950 - 1990	229
24.	Adjusted Household Sector Expenditure 1950 - 1990	231
25.	Adjusted Household Sector Income 1950 - 1990	235
26.	Household Sector Affordability 1950 - 1990	237
27.	Adjusted Public Sector Expenditure 1950 - 1990	241
28.	Adjusted Public Sector Income 1950 - 1990	243
29.	Public Sector Affordability 1950 - 1990	245
30.	Adjusted Corporate Sector Net Surplus 1950 - 1990	248
31.	Corporate Sector Affordability 1950 - 1990	249
32.	Affordability Rate Forecasts	257
33.	Discount Rate Ranges	259
34.	Comparison of Carpet and Parquetry	292
35.	Alternative Comparison of Carpet and Parquetry	297
36.	Measurement of Parquetry Life-Costs	298

LIST OF FIGURES

Figure		Page
1.	The Relationship of Equivalent Value and Affordability	6
2.	Thesis Structure and Logic	9
3.	Graphing the NPV and IRR Relationship	27
4.	Australian Interest Rates 1950 - 1990	49
5.	International Government Bond Rates 1950 - 1990	49
6.	Australian Inflation Rates 1950 - 1990	51
7.	Australian Taxation Receipts 1950 - 1990	52
8.	Costs and Benefits Sensitivity Testing	61
9.	Discount Rate Sensitivity Testing	61
10.	Cost Control Process for Buildings	104
11.	Value Management Study Evaluation Technique	110
12.	Environmental Interaction Model	142
13.	Escalation in Labour Costs	165
14.	Escalation in Material Costs	165
15.	Escalation in Labour and Material Costs	166
16.	Escalation in Energy Costs	166
17.	International Exchange Rate Fluctuations	169
18.	Housing Affordability Index	175
19.	Property Affordability Index	175

Figure		Page
20.	Relationship Between Cost and Value	184
21.	Conceptual Framework	188
22.	Household Expenditure Patterns 1950 - 1990	232
23.	Private Final Consumption Expenditure 1950 - 1990	233
24.	Changes in the Standard of Living 1950 - 1990	234
25.	Changes in Household Sector Affordability 1950 - 1990	238
26.	Real Household Savings 1950 - 1990	239
27.	Changes in Public Sector Affordability 1950 - 1990	246
28.	Changes in Corporate Sector Affordability 1950 - 1990	250
29.	Consumer Survey Questionnaire	253
30.	Consumer Survey Results	255
31.	Design Cost Summary	275
32.	Effect of Discounting on Operating Costs	290
33.	Discount Rate Sensitivity	297

ABSTRACT

Past analyses of design solutions for building projects have concentrated on initial capital costs, often to the extent where the effects of subsequent operating costs are completely ignored. However, even in cases where a wider view of cost has been adopted, the discounting process has commonly disadvantaged future expenditure so heavily as to make performance after the short term irrelevant to the outcome, resulting in projects which display low capital and high operating costs to be given favour. Thus design solutions that aim to avoid repetitive maintenance, reduce waste, save non-renewable energy resources or protect the environment through selection of better quality materials and systems, usually having a higher capital cost, are often rejected on the basis of the discounting process. Furthermore, the formulation of the discount rate has normally lacked rigour and has often resulted in an assumed rate that has implied profit and risk and has ignored taxation.

Discounted present value is a measure of equivalence for time-phased costs and benefits derived from consideration of the theoretical investment return, preferably after tax. As it takes account of the cost of money, discounting can be described as leading to the determination of equivalent value using an investment-based or capital productivity approach. It is hypothesized and verified that the value of future costs and benefits is additionally susceptible to fluctuations in their base worth over time as reflected by changes in incremental escalation and the affordability of goods and services between present and future generations. Making adjustments for changes in worth may thus be described as contributing to the determination of equivalent value using a prosperity-based or time preference approach.

The analysis of Australian sectorial income and expenditure data over a forty-year period shows that affordability changes can be measured and represented as an index. The discount rate is identified as a combination of the real weighted cost of capital, differential price level changes and diminishing marginal utility, where the latter is depicted by changes in the affordability of goods and services. This results in a composite discount rate that encompasses project-related, product-related and investor-related attributes. Tangible (financial) costs and benefits are discounted by this rate while intangible (environmental and social) costs and benefits are left as real value. Recommendations concerning the determination of equivalent value should ensure that the future operating performance of projects is more equitably assessed and that sustainable development remains an achievable objective in life-cost studies.

Keywords:

Discount rate, discounting, life-costs (life cycle costs), affordability, intergenerational equity, sustainable development, equivalent value.