

Springer Texts in Business and Economics

Uwe Götze
Deryl Northcott
Peter Schuster

Investment Appraisal

Methods and Models

Second Edition

 Springer

Springer Texts in Business and Economics

More information about this series at
<http://www.springer.com/series/10099>

Uwe Götze • Deryl Northcott •
Peter Schuster

Investment Appraisal

Methods and Models

Second Edition

 Springer

Uwe Götze
Faculty of Economics and Business
Administration
Technische Universität Chemnitz
Chemnitz
Germany

Deryl Northcott
Faculty of Business
The Auckland University of Technology
Auckland
New Zealand

Peter Schuster
Faculty of Business and Economics
Schmalkalden University of Applied Sciences
Schmalkalden
Germany

ISSN 2192-4333 ISSN 2192-4341 (electronic)
Springer Texts in Business and Economics
ISBN 978-3-662-45850-1 ISBN 978-3-662-45851-8 (eBook)
DOI 10.1007/978-3-662-45851-8

Library of Congress Control Number: 2015935651

Springer Heidelberg New York Dordrecht London
© Springer-Verlag Berlin Heidelberg 2008, 2015

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

Springer-Verlag GmbH Berlin Heidelberg is part of Springer Science+Business Media
(www.springer.com)

Preface

Investment decisions are of vital importance to all companies, since they determine both their potential to succeed and their ultimate cost structure. Investments usually entail high initial cash outflows and thus tie up substantial funds. Sound investment decisions are therefore important. Yet, due to a highly complex and rapidly changing business environment, they remain a challenging management task.

Effective appraisal methods are valuable tools to support investment decisions. They have been the subject of discussion for several decades, particularly in the 1960s and 1970s. During this period, different approaches were examined, developed and refined to support aspects of investment appraisal such as multi-criteria or simultaneous decision-making and the consideration of uncertainty. In the last decade, these methods have been advanced further by insights from capital market theory, such as options pricing and risk-return models.

A number of methods are included in this book, some of which—while examined in research journals—are not widely known or at least not widely described in other textbooks. Investment appraisal methods are an important part of an academic management accounting education, yet they are sometimes neglected in books and university curricula. Due to its growing importance for companies, however, this rapidly developing area of expertise has become increasingly relevant for potential management accountants.

This book derives from a long-standing tradition in Germany and builds on a successful German textbook by one of the authors (Götze, U. 2014. *Investitionsrechnung*. 7 ed. Berlin, Heidelberg: Springer). It describes a wide range of investment appraisal methods to support capital budgeting decisions and evaluates their use, assumptions and limitations using illustrative examples and calculations.

The authors would like to express their gratitude to the following people who made valuable contributions to this book: Prof. Jürgen Bloech for his substantial input on investments and their assessment and Dr. Fadi Alkaraan (Aleppo University) for his contribution to the discussion of strategic analysis tools in Chap. 1.

We hope that readers will find this new edition of the book helpful and to be a valuable source in classroom use and in company practice.

Chemnitz, Germany
Auckland, New Zealand
Schmalkalden, Germany
January 2015

Uwe Götze
Deryl Northcott
Peter Schuster

Guided Tour of the Book

This book is split into five main parts organised into nine chapters. After an introductory part about capital budgeting and investment decisions, Part II describes the basic methods of investment appraisal. They can be classified into *static methods* (analysing an average period) and the most widely used *discounted cash flow methods*. Part III then moves beyond the basic techniques to introduce *compounded cash flow methods* and illustrates *specific applications* of discounted and compounded cash flow methods.

Part IV deals with *multi-criteria methods* and the application of *selected methods for simultaneous investment and financing or production decisions*. Methods and models for the consideration of uncertainty form the concluding Part V of the book. These are divided between methods and models applied to single investment projects and those useful for investment programmes.

Each of the sections is organised in the same way, with a sequence consisting of the *Description* of the model or method, an *Example* providing ample illustration and practice in performing the investment appraisal calculation and the *Assessment* of the model or method. Additionally, *Key Concepts* are highlighted throughout the text. Finally, end-of-chapter *Exercises* are provided to reinforce and extend relevant concepts, with *Solutions* to the exercises given at the end of the book. The suggested *Further Readings* offer additional sources for readers who wish to research a topic in greater depth.

The main target audience for this book is students of management, business and, specifically, management accounting. However, the book will also interest business practitioners concerned with investment decision-making and students engaged in higher professional education. The instructional approach of the book combines the delivery of overviews, as bases of understanding, with a detailed description and discussion of relevant models and techniques, supported by extensive examples and exercises. This combination of features aims to meet the needs of university students around the world and provide all readers with a thorough insight into the different investment appraisal methods, their uses, assumptions and limitations.

Contents

Part I Introduction

1 Capital Budgeting and Investment Decisions	3
1.1 Characteristics and Classification of Investment Projects	3
1.2 Investment Planning and Investment Decisions	6
1.2.1 Investment Planning as Part of the Management Process	6
1.2.2 Investment Planning as Part of the Capital Investment Decision-Making Process	8
1.2.3 Strategic Analysis Tools Supporting the Capital Investment Decision-Making Process	19
1.3 Investment Appraisal Methods as Tools for Investment Planning	23
Further Reading – Part I	25

Part II Basic Methods of Investment Appraisal

2 Static Methods	29
2.1 Cost Comparison Method	31
2.2 Profit Comparison Method	37
2.3 Average Rate of Return Method	39
2.4 Static Payback Period Method	42
Assessment Material	44
3 Discounted Cash Flow Methods	47
3.1 Introduction	47
3.2 Net Present Value Method	50
3.3 Annuity Method	61
3.4 Internal Rate of Return Method	63
3.5 Dynamic Payback Period Method	71
3.6 Data Collection	73
Assessment Material	79
Further Reading – Part II	81

Part III Advanced Methods and Applications of Investment Appraisal

4	Compounded Cash Flow Methods	87
4.1	Compound Value Method	87
4.2	Critical Debt Interest Rate Method	92
4.3	Visualisation of Financial Implications (VoFI) Method	94
	Assessment Material	102
5	Selected Further Applications of Investment Appraisal Methods	105
5.1	Income Taxes and Investment Decisions	105
5.1.1	Taxes and the Net Present Value Method	105
5.1.2	Taxes and the Visualisation of Financial Implications (VoFI) Method	110
5.2	The Assessment of Foreign Direct Investments	112
5.2.1	Special Characteristics of Foreign Direct Investments	112
5.2.2	Net Present Value Model and the Assessment of Foreign Direct Investments	115
5.2.3	The Visualisation of Financial Implications (VoFI) Method and the Assessment of Foreign Investments	121
5.3	Models for Economic Life and Replacement Time Decisions	125
5.3.1	Overview	125
5.3.2	Optimum Economic Life Without Subsequent Projects	127
5.3.3	Optimum Economic Life with a Limited Number of Identical Subsequent Projects	130
5.3.4	Optimum Economic Life with an Unlimited Number of Identical Subsequent Projects	133
5.3.5	Optimum Replacement Time with an Unlimited Number of Identical Subsequent Projects	137
5.3.6	Optimum Replacement Time with a Limited Number of Non-identical Subsequent Projects	140
5.4	Models to Determine Optimum Investment Timing	143
	Assessment Material	152
	Further Reading – Part III	158

Part IV Multi-Criteria Methods and Simultaneous Decision-Making

6	Multi-criteria Methods	163
6.1	Introduction	163
6.2	Utility Value Analysis	167
6.3	Analytic Hierarchy Process	171
6.4	Multi-attribute Utility Theory	184
6.5	PROMETHEE	193
	Assessment Material	204

7	Simultaneous Decision-Making Models	209
7.1	Static Model for Simultaneous Investment and Financing Decisions (DEAN Model)	209
7.2	Multi-tier Model of Simultaneous Investment and Financing Decisions (HAX and WEINGARTNER Model)	216
7.3	Multi-tier Model of Simultaneous Investment and Production Decisions (Extended FÖRSTNER and HENN Model)	226
	Assessment Material	234
	Further Reading – Part IV	240
 Part V Methods and Models that Incorporate Uncertainty		
8	Methods and Models for Appraising Investment Projects Under Uncertainty	247
8.1	Decision Theory	248
8.2	Risk-Adjusted Analysis	253
8.3	Sensitivity Analysis	259
8.4	Risk Analysis	265
8.5	Decision-Tree Method	270
8.6	Options Pricing Models	280
	Assessment Material	290
9	Analysing Investment Programmes Under Uncertainty	299
9.1	Overview	299
9.2	Portfolio Selection	302
9.3	Flexible Planning	310
	Further Reading – Part V	318
	Solutions	323
	References	355
	Index	363

List of Figures

Fig. 1.1	Classification of investments	4
Fig. 1.2	Phases of the management process in companies	7
Fig. 1.3	The capital investment decision-making process	9
Fig. 1.4	Characteristics of decision models	24
Fig. 1.5	Structure of the book	25
Fig. 2.1	Capital tie-up for investment project A (with zero liquidation value)	34
Fig. 2.2	Capital tie-up for investment project B (with positive liquidation value)	34
Fig. 3.1	Dynamic investment appraisal methods	50
Fig. 3.2	Discounting net cash flows for the net present value method ...	51
Fig. 3.3	The NPV of isolated investment projects as a function of the uniform discount rate	65
Fig. 3.4	Interpolation to determine the internal rate of return	67
Fig. 4.1	Dynamic investment appraisal methods	88
Fig. 4.2	The VoFI table	96
Fig. 4.3	VoFI plan for investment project A	98
Fig. 4.4	VoFI plan for investment project B	99
Fig. 5.1	VoFI plan for investment project A considering taxes	111
Fig. 5.2	Separate calculations to determine the tax effects of investment project A	112
Fig. 5.3	VoFI table of a daughter company	122
Fig. 5.4	VoFI table of a mother company	123
Fig. 5.5	Number and types of subsequent projects in economic life and replacement time models	126
Fig. 5.6	Temporal linkage between projects in a two-project investment chain	131
Fig. 5.7	Annuities for a chain of identical investment projects as a function of economic life	135
Fig. 5.8	Marginal profit criterion and the optimum economic life	136
Fig. 5.9	Replacement criterion for an unlimited chain of identical projects	139

Fig. 6.1	MADM methods according to the type of information	166
Fig. 6.2	Hierarchy of targets	169
Fig. 6.3	Transformation function for the criterion 'size of land'	170
Fig. 6.4	SAATY's nine-point scale for pair comparisons	172
Fig. 6.5	Average values of indices of consistency	176
Fig. 6.6	Decision hierarchy	179
Fig. 6.7	Pair comparison assessments for the alternatives and their evaluation	181
Fig. 6.8	Pair comparison assessments for the target criteria and sub-targets, and their evaluation	182
Fig. 6.9	Utility measurement by attribute comparison	186
Fig. 6.10	Determination of an individual utility function	187
Fig. 6.11	Indifference curves	188
Fig. 6.12	Individual utility function for the attribute 'size of land'	190
Fig. 6.13	Generalised criteria with PROMETHEE	196
Fig. 6.14	Generalised criteria and preference functions in the example ...	200
Fig. 6.15	The outranking relationship	201
Fig. 6.16	The partial pre-order	202
Fig. 6.17	Graphical presentation of the partial pre-order	202
Fig. 7.1	Graphical solution using the DEAN model	214
Fig. 7.2	Relationships between the model endogenous compounding factors and the model endogenous interest rates	222
Fig. 7.3	Production structure in the basic model for a production programme decision	227
Fig. 7.4	Temporal structure of the liquidity, capacity and sales restrictions and the objective function	232
Fig. 8.1	Decision matrix	248
Fig. 8.2	Changes in the net present value with variations in individual input measures	261
Fig. 8.3	Critical values of individual input measures	262
Fig. 8.4	Net present value relative to variations in sales prices and volumes	263
Fig. 8.5	Critical sales and production volumes for two investment alternatives	264
Fig. 8.6	Distribution function of the net present value of investment project A	267
Fig. 8.7	Distribution function of the net present values of investment projects A and B	269
Fig. 8.8	Formal structure of a decision-tree	271
Fig. 8.9	Decision-tree of Example 8.3	273
Fig. 8.10	Decision-tree for a decision about investment timing	276
Fig. 8.11	Differentiated expectations about future developments	279
Fig. 8.12	Share prices, option values and value of the duplication portfolio in the binomial model	283
Fig. 8.13	Cash flows and share prices during the investment period	286

Fig. 9.1	Linear membership function for a sales restriction	301
Fig. 9.2	Expected profit and risk measures of portfolios	303
Fig. 9.3	Development of share returns	304
Fig. 9.4	Distribution of security returns	305
Fig. 9.5	Iso-variance-ellipses	307
Fig. 9.6	Iso-variance-ellipses, expected returns and efficient portfolios	308
Fig. 9.7	Efficient portfolios in the return-variance diagram	309
Fig. 9.8	Stochastic tree	311
Fig. 9.9	Stochastic tree for the example model	314

Part I

Introduction

1.1 Characteristics and Classification of Investment Projects

Investments can be considered from different points of view. According to the cash flow oriented perspective an investment project can be characterised by a stream of cash flows starting with an initial investment outlay—a cash outflow. The basic task for investment decision-making then will be to ascertain whether the future benefits from the investment will make the initial outlay worthwhile.

Key Concept

An investment project is a series of cash inflows and outflows, typically starting with a cash outflow (the initial investment outlay) followed by cash inflows and/or cash outflows in later periods (years).

This approach on the one hand leads to relatively easy solutions through the use of calculations that allow the stream of cash flows to be converted into (one or more) measures of the investment project's profitability. On the other hand, it limits the analysis of benefits and returns to the effects of cash flows. At this point it is crucial to remember that investment projects often show important effects other than those easily measurable in cash flows (e.g. research and development activities). Non-monetary effects are considered and described later in Chap. 6.

Other ways of looking at investments exist. Connecting investments to the company's balance sheet (since investments transform capital into assets) emphasises the tying-up of capital. This capital budgeting perspective implies a systematic approach to evaluating an investment as a long-term (or capital) asset. The benefit of an investment project is then seen as the monetary value gained by the company through acquiring a long-term asset in the form of increased future profits and cash flows attributable to that long-term asset.

The cash flow oriented concept that is used throughout most of the chapters of this book has the key advantage that anything that can be measured in cash flow(s) can be transformed and combined into target measures for deciding about a project's profitability. In accordance with the definition used, an investment project requires a long-term perspective and a long-term capital commitment. The investment appraisal methods mainly differ in the way they transform cash flows from different years, the target measure(s) they use as the decision criterion, and the assumptions they make.

Following the same line of argument, a financing alternative can be regarded in a similar way, i.e. it is a project that starts with an inflow typically followed by outflows and/or inflows. This reflects the close connection between investment and financing alternatives and the methods used for appraising each of them.

Investment projects can take many forms. One way to classify them is according to the *type* of investment. Financial investments can be either speculative or non-speculative and include, for example, shareholder deposits, the purchase of investment certificates and real-estate funds. Investments in assets can be subdivided into those concerning physical assets (e.g. goods, machines, equipment) and those concerning 'intangible' assets (e.g. education, advertising, research and development).

Figure 1.1 (adapted from Kern 1974, p. 14) shows a differentiation of physical investment projects, classifying them according to *possible causes for investments*.

The distinction between foundational, current and supplementary investments refers to the different phases of products or companies. Foundational investments are linked with a start-up and they can be either investments in a new company, or in an existing company's new branch at a new location. Current investments are replacement, major repair or general overhaul investments: a simple replacement investment is characterised by the substitution of equipment without a change in its characteristics. Frequently, however, the substitute is an improved, non-identical asset. In this case the substitution might also be viewed as a rationalisation and/or expansion investment, making its classification potentially ambiguous.

Supplementary investments refer to investments in equipment in existing locations and they can be classified as expansion, change, or certainty investments. The first type (expansion) leads to a rise in either the capacity or the potential of a company. Change investments are characterised by the modification of certain features of the company for varying reasons. Within this category, rationalisation

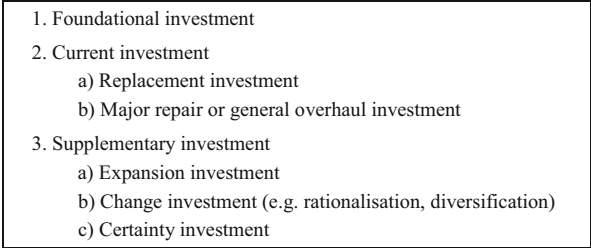
- 
1. Foundational investment
 2. Current investment
 - a) Replacement investment
 - b) Major repair or general overhaul investment
 3. Supplementary investment
 - a) Expansion investment
 - b) Change investment (e.g. rationalisation, diversification)
 - c) Certainty investment

Fig. 1.1 Classification of investments

investments are primarily driven by a requirement to reduce costs (e.g. caused by changed volumes of sales of existing products), while diversification investments arise from the need to prepare for changing production programmes. The demarcation between expansion and change investments can be problematical, since an increase in capacity is often accompanied by a change in the company's characteristic features.

Finally, certainty investments are those that aim to reduce risk in a wider sense. Examples might include buying shares in suppliers of raw material or in research and development companies.

Another possible classification criterion is the *operational area* that drives the investment. For example, investments can be categorised as being for procurement, production, sales, administration, or research and development. This can be a helpful classification when investment projects are isolated within one operational area and have little or no impact on other areas. However, many investments that are instigated by one operational area affect other parts and other decisions of a company, especially in regard to the availability of internal financial funds.

To illustrate, consider investments in a production plant. The procurement of these long-term assets is primarily decided based upon assumptions about future production. However, an expansion investment carried out to manufacture a new product type (for example) is an interdependent investment project, requiring considerable co-ordination of decisions from areas like sales, production, financing, human resources and research and development. Since the investment links to the company's environment in many ways, it is not just a production-related decision. In such instances, companies should be regarded as open systems and investment decisions should pay attention to the diverse effects that an investment can have. Sometimes, classifying investment projects by operational area can be counterproductive in this regard.

The final, very important, classification criterion is the *level of uncertainty* an investment entails. A situation of perfect certainty in regard to the effects of investments rarely exists, since investments generally show long-term future effects. However, uncertainty can vary substantially and it is possible to differentiate between relatively certain or uncertain investment projects. For example, a financial investment in fixed-yield bonds can be regarded as entailing little uncertainty. In contrast, investments to manufacture brand-new products usually involve considerable uncertainty in regard to sales potential, market success, and production processes that are not yet well established. Another example is investments in research and development, for which future resource requirements and outcomes (in terms of usable results) are extremely uncertain. For such investments, the necessary forecasting of uncertain cash flows is both difficult and inexact.

Although it is common to categorise investment projects as outlined above (based on cause, operational area, or level of uncertainty), some *other project characteristics* may be relevant to how they should be appraised. The first of these relates to whether the outcomes of the investment are readily quantifiable. The investment appraisal methods described in Part II assume that all effects of an investment can be measured in monetary terms (e.g. cash flows or costs and profits)

and attributed to both certain periods and certain projects. But, qualitative differences can exist between competing projects and therefore need to be considered. Projects with substantial qualitative outcomes require different appraisal methods to those with exclusively quantitative/financial outcomes.

Also, time-related differences may exist. A project could involve either a limited or an unlimited time horizon (e.g. for a financial investment), which will affect how it should be appraised. Other differences can result from whether a project is a stand-alone investment or links into subsequent projects. Investment projects can have no subsequent projects, a limited number, or an unlimited number of subsequent projects. These different forms may affect the profitability of the initial project (they are described in Chap. 5, Sect. 5.3).

In summary, investments exist in multiple forms: single or multi-purpose; certain or uncertain; isolated or interdependent; with limited or unlimited time horizons; stand-alone or connected with subsequent projects. All must be considered using appropriate investment appraisal methods. These are applied within a decision-making and control approach that primarily focuses on projects or programmes, i.e. makes decisions about a single investment project or a set of interrelated projects. The decision process usually is called *capital budgeting* and relates to long-term capital investment programmes and projects that must be assessed by investment appraisal.

Key Concept

Investment projects can be categorised in many different ways. As they have substantially different characteristics, investment projects may require different investment appraisal methods to appropriately assess their impact, value and profitability.

1.2 Investment Planning and Investment Decisions

The life cycle of an investment can be regarded as consisting of specific phases. The main phases of this life cycle are: planning, implementation and utilisation. Since the appraisal of investment projects is part of the planning phase, this book focuses on planning rather than issues related to project implementation and utilisation.

In the following discussion, investment planning will be considered from different perspectives, first as part of the management process and second, in more detail, as part of the specific capital investment decision-making process.

1.2.1 Investment Planning as Part of the Management Process

The planning phase involves preparing to make decisions about one or more investments, including identifying the types of investment projects necessary to

achieve the company's objectives. These projects should be closely linked to the company's strategy. The search for alternative projects and the information acquisition that is required to define and assess them form an important part of the planning process, which is concluded by the selection of the investment project to be undertaken. During the implementation phase, detailed project planning is followed by the construction or acquisition of the asset. As soon as this is finalised, utilisation can start and the investment project can begin to earn returns for the company.

The capital budgeting process can be regarded as a specific kind of management process within a company. Figure 1.2 (GÖTZE 2014, p. 16, with further references) shows phases of the management process, which typically entails planning and control activities.

Planning requires many pieces of information and has multiple aims, including:

- Identifying risks and uncertainties
- Incorporating options and increasing flexibility
- Reducing complexity
- Identifying and exploiting synergistic effects
- Formulating targets
- Achieving early warning of problems

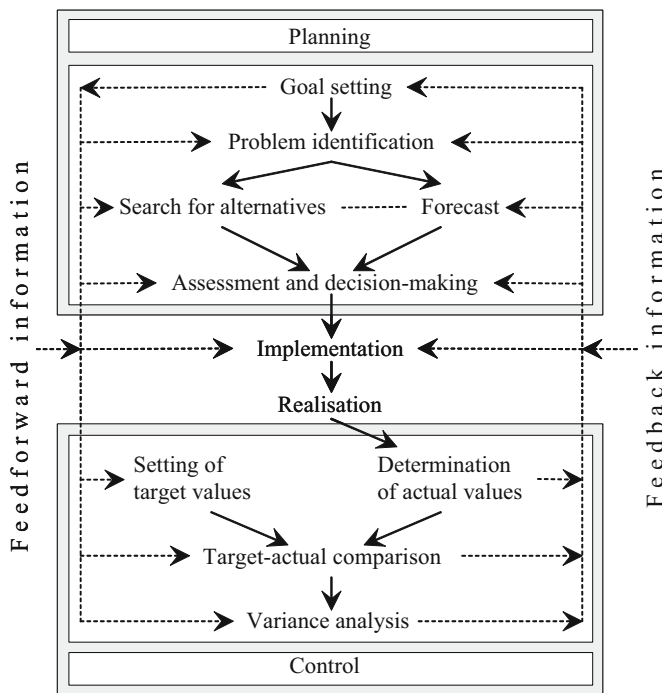


Fig. 1.2 Phases of the management process in companies

- Co-ordinating functional plans and sub-plans
- Enabling control processes
- Securing information
- Motivating employees and collaborators

Investment planning can be viewed as following the phases of the management process shown in Fig. 1.2. *Goal setting* will both influence awareness of the problems (and thus the search strategies for solutions) and provide a framework for the assessment of possible solutions. Different forms of goals exist. *Formal goals* (for instance to increase shareholder value, profits, or employment stability) provide the high-level criteria for assessing the consequences of investments. *Substantive goals* are derived from these formal goals and relate to the steps required to fulfil the formal goals (such as adaptations of the product types and qualities to be produced). After the operationalisation of the goals, uncertainty and risk, and especially risk attitudes, must be considered.

Problem identification and analysis forms the next part of the investment planning process. The aim here is to assess the present situation, anticipate the forecasted future development and identify the deviation between the two, so that the benefits of a potential investment can be anticipated. The third phase, the *search for alternatives*, identifies possible investment alternatives that might be suitable options to address current problems and future needs.

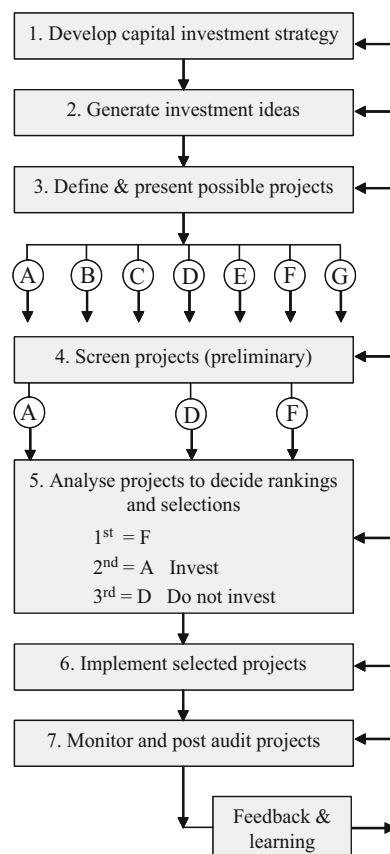
Forecasting and assessment and decision-making form the final phases of the planning process. They require that information is gathered to forecast the future impact of alternative investment projects and that suitable analyses (usually mainly financial) are carried out to select the best investment options.

1.2.2 Investment Planning as Part of the Capital Investment Decision-Making Process

This book will present detailed calculative analyses that can be used to support capital investment decision-making, and there is no doubt that these sorts of rigorous financial analysis tools are important for supporting well informed decisions. But, what else goes into capital investment decision-making in organisations? As noted in the introduction, there is more to planning capital investment projects than financial analysis alone.

A key theme of this chapter is the need for capital investment planning and analysis to be supported by an effective decision-making process that fits with, and enhances, organisational strategy. The capital investment choices that companies make are shaped by *current* strategy, but they also play a part in allocating substantial resources that will influence *future* strategy. This chapter will consider how investment analysis forms part of a broader, strategic decision-making activity. It describes how financial analyses fit into the overall decision-making process and what other activities are important in making well informed and effective capital investment decisions. In the next chapter, several emergent strategic analysis tools

Fig. 1.3 The capital investment decision-making process



are described that have been proposed as useful supplements to existing capital investment analysis techniques. The discussion of these topics is motivated by the importance of taking a balanced approach to capital investment decision-making in practice, synthesising rigorous financial appraisal with good decision-making processes and sound strategic analysis.

The analysis tools presented in this book are used to evaluate the profitability of capital investment opportunities. However, before such analysis tools can be applied, several other decision-making steps are necessary. Similarly, further steps are required *after* the financial analysis is undertaken, to ensure that a capital investment project has a successful outcome. Taking account of all of the necessary steps, investment decision-making can be represented as an ordered process, as shown in Fig. 1.3. The remainder of this section will describe each of the decision-making steps and show how financial appraisal methods fit into the overall process.

Developing the capital investment strategy

Capital investments should not be made on an ad hoc basis, but should link into the organisation's existing and planned investment programme. This investment

programme should in turn be driven by the company's long-term strategy. Strategy will dictate the kinds of products, markets and technologies the organisation wants to invest in, and so proposals to invest in projects outside these guidelines are unlikely to gain support and commitment or to be approved for funding. Throughout this book it will be assumed that the strategic objective of capital investment decision-making is to invest in projects that will maximise the company's wealth (an exception is presented in Chap. 6). However, for some organisations, or at some stages of an organisation's life-cycle, other objectives are more appropriate or similarly important, such as the continued survival of the company, the maximisation of sales, or the provision of services at the lowest cost (for example, in public sector organisations). Whatever the organisation's strategy, it should be translated into guidelines and limitations as to what sorts of investment projects are likely to be acceptable from a strategic standpoint. These guidelines should be clearly communicated to organisational personnel when capital investment policies are developed and disseminated.

As part of integrating organisational strategy into the capital investment process, an investment budget should be planned for each year or preferably for several years to come (planning such a budget can be supported by the use of models for simultaneous decision-making, as described in Chap. 7). Project ideas should then be considered some time in advance of expected investment. For example, there may be a June deadline for proposing projects to commence in the year starting the following January. Projects that are eventually approved for investment are then included in the capital budget, which is a statement of spending intentions, and funds are earmarked to pay for budgeted projects. The advantages of this approach are that capital expenditure is planned according to agreed strategic aims, and decisions are based on direct comparisons between competing projects. Also, funding can be arranged in advance and there are fewer surprise expenditures to create cash flow problems for the organisation.

The disadvantage of this system, however, is that it is fairly inflexible and can reduce the organisation's ability to respond quickly to unplanned investment opportunities. If a project idea comes up that was not anticipated in the company's investment strategy or included in the capital budget, it may be delayed or even excluded. Indeed, it is often difficult to get funding for such last minute investments, since previously approved projects are usually given priority. To avoid this disadvantage, capital investment projects could be considered at any time of the year, without fixed deadlines for compiling a planned budget. However, this makes it difficult to compare projects that are competing for limited funds, since they are proposed at different times and decisions are made without knowledge of what opportunities might arise next. A balance between the first (planned) system and the second (ongoing) approach is usually best. Organisations should aim for a systematic approach that fits with strategic goals, while still retaining some flexibility and discretionary funds for unplanned investment opportunities that might arise during the year.

Generating investment ideas

Once the capital investment strategy is developed and budgetary processes are established, the rest of the process relies on the generation of good investment ideas (step 2 in Fig. 1.3). Projects do not just exist simply to be discovered—opportunities for investment need to be recognised or created and then exploited. In fact, the success of a company's capital investment programme often depends more on its ability to *create* profitable investment opportunities than on its ability to appraise them.

Ideas for capital investment may come from people throughout the organisation, from senior managers to people working in technical or production positions. For instance, a plant manager might be able to identify ways in which expanded capacity or updated machinery could increase the efficiency of a production process. It is important to encourage everyone to communicate their ideas for investment and to seek advice on proposed projects from people in relevant areas of expertise.

A two-stage decision approach can be a good way of encouraging investment ideas. First, all organisational personnel are encouraged to put forward any preliminary, undeveloped ideas they have. These ideas are then reviewed in the first stage and those which do not seem viable are screened out using relatively simple decision criteria (see the next decision-making step, described below). The more promising ideas continue to stage two, in which thorough financial and strategic appraisals are carried out. It is important to recognise that even projects that do not come to fruition may generate ideas and information that benefit future investments; so unsuccessful projects are not just a waste of time and effort.

Defining and presenting potential investment projects

An investment idea cannot be evaluated until it has been properly defined and presented (step 3 in Fig. 1.3). Consider an example where defective production output has been identified as a problem. Although an opportunity to invest in improving performance has been recognised, there is no real 'investment proposal' until possible solutions are identified, technical specifications collated, costs and time-scales ascertained, and likely benefits estimated.

At this definition stage of the decision-making process, the company must be clear about what information is required about a potential investment project and what format the proposal needs to take. The company's capital investment procedures manual should set out the requirements for project information and the format of the formal proposal. Preferred terminology must be specified and defined, and project appraisal methods and criteria should be made clear. Standardised proposal documentation should be used where possible to make project comparisons easier. However, since the nature and characteristics of projects can vary, project proposal forms need to allow for flexibility, for example in the life-span, costs and benefits of projects. Too much flexibility will reduce the comparability of proposals so a balance must be struck to suit the particular

organisation and the types of projects it considers. The design of these forms should draw on experiences with a range of recent projects.

The project proposal documentation must contain all the information required to carry out a full financial analysis of the project. It should also demonstrate how the project links to the organisation's strategic plans and identify any qualitative benefits it might have. Since project proposals may be reviewed by high level managers or board members whose expertise lies in areas other than those associated with a particular project, it is important that project technical details are summarised and presented in a clear and comprehensible way. All facts and figures included in a project proposal should be supported by reference to sources of information or investigations carried out. Attached working papers should record any calculations and assumptions made when putting together the project proposal. These supporting papers should be well organised and clear because they may need to be consulted when the project is being analysed. The project proposal should identify the 'critical variables' that will determine the success or failure of the project. For example, the success of an expansion project may depend on the price of additional raw materials and the market demand for increased output. Once critical variables have been identified, the project proposal should indicate worst-case, best-case and most-likely scenarios for these variables. These scenarios will form the focus of sensitivity analysis to examine the riskiness of the project (for a detailed description of sensitivity analysis, see Chap. 8, Sect. 8.3). Finally, the formal project proposal should be signed by the people initiating the project, and should indicate who would be responsible for commissioning, installing and running the project.

At the project definition and presentation stage, more than one option should be considered where possible. In the case of a project to reduce production defects, for instance, options might include:

- Modifying the existing production plant.
- Replacing the plant with similar technology.
- Completely overhauling the production technology.

Each option may have quite different costs and benefits, even though it is directed at solving the same problem. It is important that the company's capital expenditure proposal documentation requires the project initiator to identify options that have been considered, and to justify why a particular choice is recommended.

Projects are often divided into categories as part of the definition stage. In Sect. 1.1 it has been outlined how projects might be classified according to their purpose (see Fig. 1.1), their operational area (e.g. marketing, production, research and development etc.), or their level of uncertainty. Other categorisation options might focus on investment size, or the extent to which the investment is essential (e.g. for legal reasons, or to ensure business sustainability) or elective. In particular, the size of a capital project often dictates the organisational level at which it can be approved. Smaller projects may not have to be considered by a full capital

investment committee. For example an organisation may allow a divisional manager to authorise expenditure up to €50,000 and a regional manager up to €100,000. However, larger projects usually require systematic review by a capital investment committee with final approval granted at a senior level, such as by the chief financial officer, chief executive officer, managing director or board of directors.

The classification of investment types also has implications for the subsequent financial analyses and decision criteria that will be applied to each project. First, the emphasis of financial appraisal will differ between project types. For example, equipment replacement projects may focus simply on incremental savings expected from a new asset. Expansion and strategic projects will need to consider less certain information about markets, competition and capacity constraints. The analysis of legislatively required projects focuses on finding the least-cost alternative for achieving the desired (or required) outcomes. Second, the uniform interest rate used (i.e. the required rate of return) for project acceptance can be varied for different categories of projects (this may be interpreted as a risk-adjusted analysis, an approach that is described in Sect. 8.2). The main reason for this is the different risk profiles of investments. Replacement projects concern activities the organisation is familiar with, so they involve relatively little risk. Expansion projects are of higher risk, because the inputs, outputs and scale of the project might be hard to predict. Strategic projects may be even riskier, because they move away from familiar activities towards new areas where the organisation has less knowledge of costs and benefits. In many cases, it is demanded that the greater the risk the higher should be a project's expected return to compensate for that risk, so the preliminary categorisation of a project during the definition stage can have a big impact on how it is appraised.

Once the definition and proposal-presentation phase of the decision-making process is complete, the company should have a good sense of what investment options exist, their scope and impact, and what likely costs and benefits they involve. However, they won't all be good investment prospects. So, the next stage is important to ensure that only promising projects, which fit with the company's strategy, proceed further to full financial appraisal.

Screening investment projects

The preliminary screening of capital investment proposals (step 4 in Fig. 1.3) weeds out projects which are clearly not viable and which do not warrant further investigation. It is useful, particularly in large organisations, to have a capital investment committee that screens all but the smallest capital projects. Members of this committee should represent a range of expertise in key areas (such as production, marketing, engineering, strategic planning and finance) and be headed by a senior financial manager, or perhaps the organisation's chief executive officer or managing director.

The screening stage is critical to a successful capital investment process, since it is here that a first decision is made about which projects will be given serious consideration. Although screening criteria can be simple, they should be applied

systematically to ensure that mistakes are minimised and promising investment opportunities are developed and exploited.

At its most simple level, screening can be based on a qualitative evaluation of a proposal. For example, a project idea might be eliminated at the screening stage if it is physically impractical, beyond the skills and experience of organisational personnel, or not in keeping with overall strategy. Qualitative screening relies on common sense and the experience of the capital investment committee. Simple financial analyses, such as the static payback period method (see Chap. 2) can be carried out in addition to qualitative screening, as a first test of the project's economic viability. Projects that take a long time to recoup their initial cost may be considered detrimental to the short to medium term liquidity of the organisation, so they may be screened out. Of course, it is dangerous to compare projects on the basis of their payback period if some projects are short lived (operating for say 2–5 years) while others are inherently very long-term in nature (running for say 10–20 years). Long-life projects are highly unlikely to pay back quickly, even though their eventual benefits might be substantial. In the screening stage, it is quite easy to spot unusually long-term projects and to ensure that they are not inappropriately ruled out.

Taking into account both qualitative and financial measures, the following questions should be asked when screening projects:

- Does the organisation have a choice about whether to invest in the project, or is it essential (perhaps for legislative or safety reasons)?
- Does the project fit within the organisational strategy?
- Is the idea technically feasible?
- Are the required resources (money, time and expertise) available to implement the project?
- Has this type of project been successful before, either for this organisation or for other organisations?
- Is the project considered too risky or uncertain?
- Does the project meet simple financial screening criteria?

After a project proposal has met preliminary requirements of feasibility and economic desirability (as for projects A, D and F in Fig. 1.3), it then moves on to a more rigorous assessment in the next stages of the capital investment process.

Formal analysis of projects

At this stage of the capital investment process (step 5 in Fig. 1.3), the company would employ a sophisticated financial and risk analysis using the methods outlined in this book to evaluate the economic viability of capital investment projects. Although accountants usually undertake this financial analysis, they should work in conjunction with the capital investment committee for all but the smallest projects, to draw on a wide range of expertise in areas such as production, marketing, engineering, strategic planning, and finance.

Before the financial analysis can be carried out, the capital investment committee must be satisfied that the formal project proposal contains sufficient information to complete a rigorous economic appraisal. Sometimes further information will be sought at this stage, or capital investment proposals may be sent back to the initiator for re-formulation. The committee should assess how realistic projected proposal cash flows are, and check that important variables are picked up in a project's sensitivity analysis. Of course, some types of proposals (for example those which are legislatively required) have less stringent information requirements at this stage, because the financial analysis results are less likely to determine the ultimate decision.

The various tools for financial and risk analysis are, of course, thoroughly reviewed in this book so are not discussed here. However, this analysis stage calls for a consideration of *both* financial and non-financial (or strategic) aspects of a project, so that a balanced evaluation of its overall costs and benefits can be made and it can be ranked against other competing projects. For some projects, for example low-risk replacements of existing assets, only financial results may be relevant. For projects where both financial and non-financial elements are important, there is no easy rule for weighing up these various factors. The final decision must be left to the judgment of the capital investment committee, since there are few hard-and-fast rules for how to incorporate qualitative aspects of a project into a capital investment appraisal (however, see Sect. 1.2.3 for some suggested approaches). Of course, intuition can be helpful at this stage of the decision-making process, particularly when it comes from experienced members of the organisation. People should be asked to justify and explain their intuitions, however, and intuition should complement the results of the financial analysis, not replace them.

To summarise, the analysis stage of the decision-making process does not begin and end with financial analysis. The capital investment committee must also:

- Review the organisation's capital investment strategy and how projects fit with it.
- Identify any constraints on the funds available for investment in the current period.
- Rank projects in order of desirability.
- Choose a portfolio of the best projects that can be afforded.
- For projects that have not been selected, check:
 - (a) Will there be unacceptable negative effects from rejecting these projects?
 - (b) Can any be delayed rather than rejected?
 - (c) Can any be modified to make them more acceptable?
- Make a final selection of projects to be funded.

Once the final project choices are decided upon, the planning phase of the capital investment activity is complete. However, further decisions and actions remain to

ensure that capital projects are effective and that the organisation gets the most it can from its decision-making efforts.

Implementing capital investment projects

Even the best capital investment decisions may be ineffective if project implementation (step 6 in Fig. 1.3) is poorly managed and executed.

It is the task of a designated project manager to oversee the physical construction or installation of a capital asset and to ensure that the project is adequately monitored (this is discussed next). The project manager should be someone technically skilled in the area, but who can consult with finance and accounting staff. Alternatively, some organisations may use implementation teams, where people with expertise in a variety of relevant areas contribute to the project's development.

Examples of specific tasks to be performed during implementation include: reviewing engineering specifications; finalising the contract price for equipment or construction requirements; ensuring that suppliers can meet the needs of the project; overseeing the development, commissioning and/or installation of the project; and arranging for any necessary re-training of employees. Project implementation also requires setting-up effective information systems that can provide feedback on progress, results and critical variables identified in the project proposal. It is useful at this stage to design any subsequent post audit of a project, taking into account the key variables the review will focus on, the responsibility of personnel for providing project information, and the timing of the audit. If post-audit requirements are considered from the start, it is much easier to identify and collect relevant information on the performance of a capital project. The post audit phase, which facilitates feedback and learning, is outlined next.

Project monitoring and post audit

Project monitoring and post audit provide information for the 'feedback loop' in the capital investment decision-making process. In some cases, this feedback can help to identify projects that are deviating from expectations so that problems can be rectified and poor financial outcomes avoided. In other cases, however, the feedback may come too late to help the current project, but it can still help the company to learn and improve future investment decisions and/or implementations.

This review process comprises two main stages. The first, *project monitoring*, is more likely to identify a need for intervention in a current project since it is conducted while the project is in its early stages of implementation. Project monitoring should focus on a combination of physical measures (e.g. early indications of production volumes from a new manufacturing installation), and financial measures (e.g. how much has been spent). Monitoring systems must be able to quickly identify deviations from 'benchmark' performance variables or timing criteria, and should utilise regular expenditure reports to monitor costs against the original, approved investment plan.

The second stage, *project post audit*, occurs once a project is well established and operating to its expected capability, so that the actual outcomes of the project

can be assessed. For example, an investment to install a new production line might be reviewed after it has been in operation for an entire production cycle. That way, implementation costs and on-going performance can be observed and compared with initial estimates submitted in the project proposal. Because it occurs after a project is up and running, post audit has limited potential to correct problems in current projects. However, it does have four important benefits:

- To check that spending and specifications conform to the plan as approved.
- To increase the likelihood that capital expenditure proposals are realistic (since project initiators will know that the actual outcomes will be compared to their proposal).
- To identify factors that can lead to the success or failure of projects.
- To learn from past experiences and improve the capital investment process.

There are many possible sources of post-audit data, including: project files (for example: contractors' or engineers' reports, implementation log-books, warranty and service agreements, requests for specification or funding changes); organisational files (for example: accounting records, cost codes which trace expenditures to projects; legal/planning documentation); interviews with people involved with implementing and running the project; and customer feedback (for example about improvements achieved in quality or service).

While the overall aim of collecting this information is to facilitate feedback and learning, project post audit can also refer to particular stages of the capital investment decision-making process. For example, a *decision audit* reviews the effectiveness of the steps leading up to the decision to invest, i.e. project identification, screening, putting together the formal project proposal, the financial analysis, and the ranking and selection process. It checks that laid-down procedures were followed and notes any irregularities and their consequences. This type of audit can be very useful in improving the organisation's decision-making processes.

If, however, a company wishes to review the steps that occur *after* a decision is made to invest, it may choose to conduct an *implementation audit*. An implementation audit seeks to establish whether differences between planned and actual project outcomes are due to inaccurate planning or poor commissioning and implementation. The information generated can be a useful basis for assessing the performance of both the investment decision-makers and the project implementation team.

If a more general, strategic overview of a project's outcome is desired, a *final audit* may be appropriate. This considers how well the project supports the organisational strategy and identifies lessons for the future. It usually occurs a long time after the project is implemented so that the strategic impact of the project can be assessed. The success of the final audit depends on having a clear statement of organisational strategy and capital investment objectives, so that actual project outcomes can be compared with long-term plans. The sorts of questions that will be asked during a final audit include:

- Does the project fit within the organisational strategy (1) as it existed at the time of the investment decision and/or (2) as it exists now?
- Have strategic benefits (e.g. increased market share, improved price competitiveness, expansion into overseas markets) been obtained?
- How do qualitative outcomes (e.g. product quality, employee working conditions, reduced environmental impact) compare to what was expected?
- How have changes in the operating environment affected the project?
- Has top management commitment to the project been appropriate?
- Has responsibility for mistakes been allocated and actioned?

Many companies choose to employ a combination of decision, implementation and final project post audits, since each provides feedback about different aspects of the decision-making process and outcomes. However, since post audits are time-consuming and costly it is usually best to make a limited selection of projects to be post-audited, perhaps focusing on those that have experienced problems, required the greatest expenditure, or are perceived as particularly risky or strategically important. It is also helpful to post audit projects that are 'typical' for the company, since the lessons learnt can be applied to a good number of future projects.

In general, any post audit exercise should compare a project's actual financial results to the figures produced in the financial analysis stage of the capital investment process (e.g., the net present value that was calculated). It should focus on those aspects of an investment that were identified as critical to the success of the project, rather than necessarily being a comprehensive review of all aspects of the investment. For example, did the project really increase production output by 5 %, reduce labour costs by 10 % or increase market share by 15 %? If not, then why not? Was it because the project was not implemented properly, because changes in operating conditions were not adequately anticipated, or because the original project proposal was poorly thought out or over-optimistic? If any of these problems are identified, the organisation can learn from the post-audit and improve future decision-making and implementation.

Summary: the capital investment decision-making process

This section has outlined the various stages of the capital investment decision-making process. The financial analysis models reviewed in this book are crucial to the rigorous examination of projects in step 5 of Fig. 1.3 (analysis, ranking and selection of projects) and the less complex financial analysis methods (such as payback period calculations) are often employed at an earlier stage (step 4), when projects are screened so that only potentially viable projects are subjected to full appraisal.

The key message of this discussion, however, is that sound financial appraisal is not the only important part of investment decision-making. The success a company has in directing its capital expenditure towards projects that create wealth and promote organisational goals depends on the entire decision-making process. This means that the generation, definition and screening of project ideas have to be done

well *before* thorough financial analyses are completed. Also, project implementation has to be well managed so that the potential benefits of an investment are realised. Finally, the company needs to review its capital investment processes and outcomes so that it learns for the future and continues to improve its investment activities. All stages of this decision-making process must be well planned and executed, so that good investment ideas are identified, appropriately analysed and effectively implemented. Rigorous financial analysis will not help projects that are bad ideas to start with, nor does it mean that projects are successfully implemented to achieve their maximum contribution to the company.

The capital investment decision-making process presented here is tightly coupled with the company's strategic planning. Strategy will shape the choice of investment projects and, in turn, the choice of projects will dictate the company's future strategic direction. The decision-making process, from idea generation to project post audit, must reflect the strategic goals of the company if capital investment projects are to support the achievement of those goals. With this in mind, now some emergent analysis tools that can be used to supplement rigorous financial analysis with an evaluation of the strategic dimensions of capital investment projects will be reviewed.

1.2.3 Strategic Analysis Tools Supporting the Capital Investment Decision-Making Process

While important in themselves, even the most rigorous financial analysis tools cannot capture all of the strategic dimensions of capital investment projects, since many of them are not amenable to quantification. Consequently, researchers have looked for other analysis tools that *do* help decision-makers to incorporate these important aspects.

Broadly, two avenues have emerged for developing alternative strategic investment appraisal techniques. The first involves modifying established approaches to incorporate neglected 'strategic' project benefits. *Fuzzy set theory* and the *analytic hierarchy process* fit into this category (an approach using these methods will be explained later, various methods supporting multi-criteria decision-making are presented in Chap. 6). The second avenue involves drawing on analytical frameworks that are significant departures from conventional financial and risk analyses. These latter approaches are usually drawn from outside the traditional accounting or finance domains, having emerged in project management, strategy and technology fields, for example. Three such approaches that have been linked with strategic investment decision-making will be described now.

The balanced scorecard

KAPLAN and NORTON (2001) devised the popular 'balanced scorecard' as a framework for linking financial measures of performance with non-financial measures (focused on customers, internal business processes, and innovation and learning), to give managers an integrated framework for managing and evaluating their

businesses. They advocated the balanced scorecard as a strategic management and decision-making tool, which suggests that it may be a useful tool for capital investment decision-making, too (for a detailed description see KAPLAN and NORTON 2001).

The balanced scorecard provides a framework within which financial analysis tools (such as net present value (NPV), see Sect. 3.2) can be used alongside non-financial considerations of customer/user outcomes, internal business impacts and innovation and learning outcomes. Using this approach, established financial analysis techniques can be combined with other metrics that evaluate the project's strategic fit. This multi-dimensional appraisal usually requires significantly more input from top management than traditional capital investment analysis, thus compelling top management to take a broad, strategic view of investment projects rather than leaving their assessment to financial experts. This increased involvement of senior managers is, in itself, a useful side effect of using this strategic analysis tool.

To use a balanced scorecard approach in investment appraisal, it is necessary to weigh up various (quantitative and qualitative) aspects of a project and arrive at some final project 'score' (techniques for multi-criteria making that may be useful to calculate this score are described in Chap. 6). This is not an easy process and may require long periods of negotiation and deliberation about what the key aims and outcomes of a project might be. However, the process of negotiating through these issues has some benefits. It forces managers to consider how the capital budget aligns to strategic goals, and it requires consensus building that focuses on the entire organisation rather than departmental concerns.

As a framework for aligning financial and strategic project considerations, the balanced scorecard appears to have some potential, therefore. The challenge in applying it relates to the usual practical considerations of implementing balanced scorecards—how to select the key indicators and operationalise the 'balancing' that must be achieved between them.

Strategic cost management analysis

Noting the need to evaluate projects' strategic issues as well as their cash flows, SHANK and GOVINDARAJAN (1992) described strategic cost management (SCM) as an appropriate framework for giving strategic issues much more explicit attention in the investment decision-making process. SHANK and GOVINDARAJAN'S SCM framework comprises three related elements: value chain analysis, cost driver analysis and competitive advantage analysis. The first element, value chain analysis, is a useful tool for identifying strategically important, value-creating activities and developing appropriate competitive strategies. The 'value chain' is "the linked set of value-creating activities all the way from basic raw materials through to component suppliers, to the ultimate end-use product delivered into the final consumers' hands" (SHANK and GOVINDARAJAN 1992, p. 40). Its analysis focuses on finding opportunities, within the company's segment of the value chain, to enhance customer value or lower costs. Value chain analysis can produce quite different investment

decisions to those obtained using traditional financial analysis techniques, particularly where impacts on upstream and downstream value chain linkages are an important aspect of the decision.

Strategic cost management blends value chain analysis with cost driver and competitive advantage analyses. The first of these requires that cost drivers be carefully analysed so that their impact on the company's cost structure and competitive position are understood. In regard to capital investment decisions, *structural* cost drivers (i.e. those that relate to the company's explicit strategic choices) will flow from an investment decision, so their impact on future cash flows must be appropriately identified. Competitive advantage analysis completes the SCM picture with an evaluation of whether a project's achievable benefits are consistent with the company's competitive positioning strategy. Using an SCM approach to project appraisal requires that the project's ability to contribute to the chosen strategy (such as enhancing differentiation, or lowering costs) is explicitly considered. It offers a useful supplement to financial appraisal of investments, therefore.

Technology roadmapping

Since new technology projects comprise a substantial portion of strategic capital investments, developments in technology planning and appraisal offer insights for strategic project analysis. One such recent development is 'technology roadmapping', a planning process whereby a team of experts develops a framework for organising and presenting the information needed to make technology investment decisions. As part of the roadmapping process, this team attempts to project the needs of tomorrow's markets, and produces charts and graphs that identify the links between technology and business needs. This process can contribute to the definition of technology strategy by assisting managers to identify, select and develop technology alternatives to satisfy future service, product or operational needs.

The concept of technology roadmapping has gained widespread recognition, particularly in U.S. companies. According to its proponents, technology roadmapping: (1) helps an industry to predict the market's future technology and product needs, (2) defines the 'road' that industry must take to compete successfully in tomorrow's markets, (3) guides technology research and development decisions, (4) increases collaboration, shared knowledge and new partnerships, (5) reduces the risk of costly investment in technology, and (6) helps the industry seize future marketing opportunities.

Since a key aim of technology roadmapping is to look within and beyond the company to ensure that the right capabilities are in place to achieve strategic objectives, it has clear potential application to investment decision-making. The use of this approach for strategic investment analysis can help to balance long-term, strategic issues alongside near-term financial performance and to ensure that projects fit together well to enhance the company's value. However, the idea of using technology roadmapping to support capital investment decision-making is very new, so there is a lot to learn about how it works in practice.

Fuzzy set theory and the analytic hierarchy process

The three approaches outlined so far all avoid modifying the numerical calculations that support strategic project appraisal. ABDEL-KADER and DUGDALE's (2001) concept is very different. It is a mathematical approach that combines elements of the *analytic hierarchy process* (AHP) framework [which was developed by SAATY (1990a, b) and is described in detail in Sect. 6.3] with the mathematical concept of *fuzzy set theory* to propose a model for evaluating advanced manufacturing technology investments.

The AHP decision model has been proposed as a means of structuring and systematising the evaluation of non-quantifiable project attributes. This approach requires that decision-makers formulate a decision problem as a hierarchical structure, breaking down the overall objective (of the investment decision) into its key criteria and sub-criteria. They must then assign subjective weights to the various criteria. Finally, calculate an overall rating for each project alternative by adding up the weighted scores for each of the project's attributes. This approach allows decision-makers to focus on those project attributes most important to achieving the organisation's strategic goals. It cannot eliminate subjectivity from decision-making (it is inherent in the identification and weighting of project attributes), but it does promote the identification of both financial and non-financial project outcomes and provide a structured framework for evaluating and communicating their impact.

Fuzzy set theory allows ambiguous variables to be represented by a range of inexact, 'fuzzy' numbers (for a description see Sect. 9.1). Combining it with the AHP approach, ABDEL-KADER and DUGDALE propose a model for integrating the financial and non-financial elements of strategic project appraisal. A project's expected performance is evaluated in terms of three measures: financial return, intangible (strategic) benefits, and risk. While rigorous financial analyses (such as with the NPV) are still recommended as appropriate technique for determining financial returns, the model uses a *fuzzy* NPV to take into account that cash flow estimates are uncertain. Strategic and risk factors, which cannot be translated into cash flows, are given a similar treatment. This permits the assessment of non-financial and risk factors without the pressure or expectation of being precise. However, while the approach provides a mechanism for modelling and comparing the financial, strategic and risk attributes of investment projects, it does not provide a single measure of project desirability. Rather, the final accept-or-reject decision depends on decision-makers' preferences. So, despite the mathematical complexity of the method, subjective judgment remains critical to the decision-making process.

Summary: strategic analysis tools

The interpretation of investment planning as part of a (strategic) decision-making process, leads to the insight, that the strategic, non-financial aspects of capital investments need to be evaluated alongside financial factors. This book presents a range of rigorous financial analysis tools that can be used to evaluate a project's financial dimensions. This chapter has also pointed to some emergent strategic