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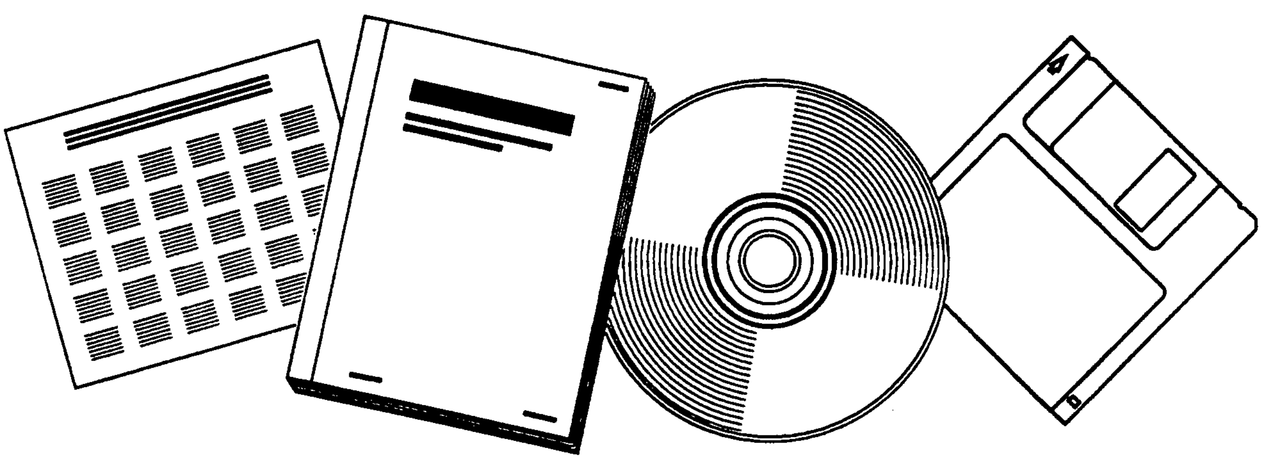

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TIMING OF MAJOR TRANSPORTATION INVESTMENTS

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TIMING OF MAJOR TRANSPORTATION INVESTMENTS

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16. Abstract

This report offers a broad overview of timing research as it applies to major transportation investments. Specific emphasis is given to major public transit investments. The report is designed to provide planners and decision-makers with a better understanding of timing research. The report emphasizes basic economic principles of investment timing rather than detailed techniques. The purpose of this particular report is to describe the kind of investment timing rules most useful in making investment decisions so that transportation investments are made most efficiently. The report is divided into nine chapters. Chapter 1 is an introduction. Chapter 2 reviews basic concepts related to economic analysis of investment timing. Chapter 3 discusses the perceptions and attitudes of the planning profession toward investment timing. Chapter 4 shows with examples both quantitative and qualitative significance of timing. Chapter 5 describes conditions under which waiting can create a value to invest. Chapter 6 discusses timing rules under different scenarios, including traditional rules, rules with certainty, and rules with uncertainty. Chapter 7 presents two approaches to time subsequent analysis of a project following an initial build-later decision. Chapter 8 identifies what type of data economic principles require, what federal regulations on investment analysis require, and what is inadequate in current practice. Chapter 9 provides a number of recommendations regarding what needs to be done in order to use these economic principles of investment timing in practice. References are included along with a technical appendix on models of investment timing.

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Chapter 1

INTRODUCTION

Purpose and Scope

This report discusses perceptions and attitudes toward investment timing, presents economic principles of optimal timing, and offers practical consideration of the timing of major transportation investments. The report addresses a number of issues, including: 1) The inadequate consideration of timing in the current planning process; 2) The significance of timing, both qualitatively and quantitatively; 3) General conditions under which it may be worthwhile to postpone an investment; 4) Rules for determining the optimal timing of investment projects under both certainty and uncertainty; 5) Criteria for subsequent steps following a postponed investment under uncertainty; 6) Data requirements for investment timing analysis; 7) Procedures recommended by federal regulations on investment analysis; and 8) The state of current practice of investment analysis. The report provides a number of recommendations for better analysis and decision-making regarding the timing of major transportation investments.

This report addresses one of three basic questions involved in making major transportation investments: 1) Should any project be built? 2) What particular project should be built? And 3) When should the project be built? Properly answering these questions is important partially because these investments are often the single largest public works projects in a given area.

This report is limited in three ways. First, the timing of investments may be addressed under different perspectives ranging from economic to environmental to political. This report focuses on timing of investments only in terms of their economic worth, which presumes that projects be built when their net present value is positive and maximal. In reality, the decision to invest depends not only on economic worth but also on social and environmental considerations that are beyond the scope of this report.

Second, timing rules can differ, depending on whether individual projects are being considered in isolation or whether there are budgetary constraints. Procedures for timing projects vary according to the presence and nature of budget limitations and the mutual exclusivity of projects or alternatives. In all cases, projects can be timed through a linear or dynamic program that takes into account such budget constraints and project interdependence (Marglin, 1963). This report deals with the simplest case where one single project is being evaluated against the "do-nothing" alternative.

Third, the timing rules under uncertainty are derived under a particular form of uncertainty. Specifically, today's annual benefits are known with certainty, and future annual benefits are uncertain and lognormally distributed with a constant variance. This form of uncertainty is used only for analytical convenience. Regardless of the form of uncertainty, however, the basic result holds: there is a value of waiting to invest under uncertainty.

The issue of investment timing is conceptually not unique to transit investments. The principles of investment timing presented in the report apply to major transportation investments across many modes. However, it may be more relevant for transit given empirical data on the performance of transit investments relative to their roadway counterparts. If one believes the numerous needs estimates for roadway investment and looks at project histories, it is apparent that in the vast majority of cases we are building roadway capacity to meet historic or existing demands. Indeed, the highway engineer is often accused of building roadways that are immediately or very soon self fulfilling prophesies. That is, they are utilized at or near capacity soon after they are completed. Thus, the issue of investment timing may be less critical for roadway investments where the project is far less likely to depend on growth in the demand. Other modes, particularly transit, perhaps ITS investments, air, and water port investments, might be strong candidates for investment timing analysis. These modes are more frequently dependent on future demand to be economically justified. Furthermore, the degree of uncertainty about the future demand for these modes is likely to be higher than that for highways.

Fundamental Flaw in Existing Process

The interest in investment timing is motivated by a concern that the current planning process for major transit investments does not adequately consider investment timing. A brief review of the current process reveals this problem (UMTA, 1984; USDOT 1993). The initial consideration of most major capital investments occurs as part of the long-range plan development. Many major capital projects, especially transit guideway projects, are often conceived by staff or decision-makers and are usually first explored as a scenario in the development of the long-range plan. In practice, projects moving from the long-range plan toward implementation are those perceived to be of the highest priority. However, there is seldom a systematic or analytical method of determining whether the "highest" priority in the long-range plan is the highest priority for immediate implementation. Often, major projects pass into the phase of major investment studies (MIS) based on their ranking in the long-range planning process.

The Build-Later Alternative

While a project may be very promising for meeting long-range needs, it may not be best that the project should be implemented immediately. The MIS stage of planning typically looks at performance in the context of a 15- to 25-year time frame. It is implicitly assumed, by virtue of the fact that evaluation focuses on design year performance measures, that if the project performs well in the design year, then implementation now is an appropriate action. This creates strong process biases toward early implementation and can result in erroneous decisions by favoring a build-now alternative in the absence of build-later alternatives as an option in the choice set.

Consideration of build-later alternatives is particularly important in light of the strong decision-making preference for a build-now alternative. Even if there are no obvious transportation needs, seldom will a decision-maker favor a do-nothing alternative. Low-cost options can be part of major investment studies; however, these options often under perform build options and, evaluation in the context of design-year performance does not fully reflect the prospect that a low-cost option could be coupled with build-later options. This composite scenario may offer a superior overall alternative; however, it is usually not in the choice set in a major investment study. One way to address this potentially significant option is to include the issue of investment timing in major investment studies.

The ultimate objective is to encourage more explicit consideration of investment timing. The analytical approaches presented in this report provide possible methods of addressing the optimality of investment timing. While the concept of investment timing is not new, only recently has an analytical framework for evaluating this concept for public transit investments been explored. This report summarizes efforts to develop analytically the concept of explicitly evaluating investment timing, i.e., considering build-later alternatives. However, simply recognizing the issue of investment timing and reflecting on it as one carries out major investment studies is a very important first step.

A Debate about Build-Later

A great deal of concern exists regarding the effectiveness and efficiency of major transit investments, especially light rail systems, in some of the rapidly growing urban areas in the US. The significance of these projects is heightened because they represent an alternative to the historical pattern of addressing transportation capacity problems by building additional roadways. Thus, transit guideway options represent not only major investments but provide an important test of fundamentally different transportation investment strategies. In some cases the investment also provides a test of a significantly different urban vision and urban lifestyle. Thus, there is strong interest in evaluating the performance of these investments.

New guideway investments have frequently been characterized by serious local debate regarding project merit and the investment worthiness of the projects. These debates can become polarized discussions with participants being quickly labeled as pro or anti transit, or at least pro or anti rail transit. This polarization of discussion suggests that some aspects of project worthiness or some considerations in the evaluation of projects are not being adequately captured in traditional evaluations. Even the nomenclature of traditional alternatives in the Alternatives Analysis process, now the MIS process, highlights the polarization as we have the "do-nothing" alternative and a variety of "build" alternatives.

In at least some instances, the critics of a project were not necessarily against transit or even rail transit but rather concerned that the necessary market to support the investment was not adequate. A potential strategy that can capture the fact that the market may not yet be sufficient for a particular project to operate cost-effectively is the introduction of the "do something later" alternative, or investment timing analysis.

Timing Decisions are Common

Investment timing decisions are common in households and businesses. Newlyweds, for example, may decide to buy a large house with the attitude that they will grow into it. Those having lived through the housing price inflation of the seventies and early eighties may look back with pride at how shrewd they were to invest in the large home. On the other hand, a couple may not choose to afford the initial cost (taxes, mortgage, insurance, maintenance, etc.) of the large house or their situation might change so many times that the buy-now decision might result in very negative consequences. They might be relocated, might not like the neighborhood as it changes, never have children and the need for the space, wish they had bought a modest home and reserved resources for a second vacation home, or any number of other possibilities that might make them favor an incremental approach to housing investment. Business analogies abound as well and range from the shrewd decision to make an investment that stretches resource now with the opportunity of a big payoff, to the overextended firm going under in a mild downturn because everything did not go just right and it was too leveraged to survive in any but the most optimistic conditions.

Literature

This report builds on four streams of literature. The first is the limited transportation literature on investment timing. Georgi (1973) argued for the necessity of dynamic investment planning and showed a simple timing rule due to Marglin (1963): the annual benefits of an investment should exceed the interest costs for the first year for the project to be worthwhile. Szymanski (1991) investigated how differences in public and private sector incentives lead to differences in the optimal timing of infrastructure investment. Polzin (1992) suggested that build-later be considered in alternatives analysis in a workshop on alternatives analysis sponsored by the Urban Mass Transit Administration. Lewis (1992) and FHWA (1996) suggested that major transportation investments should be subject to the simple timing rule derived by Georgi and Marglin. Chu and Polzin (1996) extended the model by Szymanski to address three questions: Under what conditions build-later might be optimal? How do changes in the parameters of an investment affect its optimal timing? How significantly do differences in the stream of annual benefits affect optimal timing? These authors do not provide a systematic treatment to timing rules, nor do they address the issue of uncertainty.

The second stream of literature is a growing one in the field of economics about the timing of irreversible investments under uncertainty (McDonald and Siegel, 1986; Crousillat and Martzoukos, 1991; Martzoukos and Teplitz-Sembitzky, 1992; and Dixit and Pindyck, 1994). The central argument is that there is a value of waiting to invest when the project is irreversible and its profile of impacts is uncertain. This value of waiting exists because waiting maintains the option to invest and makes it possible to adopt a better decision when new information arrives.

The third stream is the transportation literature on uncertainty. The general role of uncertainty in the planning and decision-making for major transportation investments has been widely recognized in the transportation literature (Pearman, 1977; Ashley, 1980; Pell and Meyburg, 1985; Gifford et al., 1993; Khisty, 1993; Lewis, 1995; FHWA, 1996; and Mierzejewski, 1996). Traditional approaches to addressing uncertainty include sensitivity analysis, scenario analysis, and risk analysis. Sensitivity analysis evaluates how sensitive numerically the initial investment timing and the corresponding net present value are to changes in one of the many assumptions in an analysis. Scenario analysis, on the other hand, evaluates this sensitivity with respect to a set of assumptions that represent likely future scenarios. Unlike sensitivity analysis or scenario analysis, risk analysis assigns a distribution on each assumption and produces distributions for investment timing and net present value, respectively (Pouliquen, 1970; Lewis, 1995). These traditional approaches do not lead to timing rules, nor do they account for the value of waiting to invest under conditions of uncertainty.

The report is also related to the general literature on public infrastructure planning and the literature on evaluating the planning process for major transit investment projects. The strong interest in public infrastructure planning is evidenced in the two recent special issues in the *Annals of Regional Science* (Snickars, 1989; Rietveld, 1995). A number of authors, including Deen et al. (1976), Stowers (1983), Johnston et al. (1988), Johnston and Deluchi (1989), UMTA (1989), Euritt et al. (1990), Hirschman et al. (1991), and FTA (1994), have evaluated the planning process in the United States for major transit investment projects from a variety of perspectives. None of these authors, however, considered the timing issue.

Summary

This chapter covers the purpose and scope of the report, discusses limitations of current practice, describes the concept of build-later alternatives, and reviews the related literature.

Chapter 2 reviews a number of basic concepts of planning for major transportation investments. These concepts are separated into three groups: those related to general cost-benefit analysis, those related to investment timing, and those related to uncertainty.

Chapter 3 discusses the perceptions and attitudes of the planning profession, particularly transit planning, toward investment timing. It focuses on those factors that may be responsible for failing to consider investment timing in current practice. For example, election cycles, discretionary project funding, and politicians' desire for action now tend to create a bias toward early implementation of major transportation projects.

Chapter 4 illustrates the importance of investment timing both quantitatively and qualitatively through three examples. In one example, where the annual net benefits from a $1,200 investment are assumed to increase from $100 to $114 by waiting for one year, the net present value would increase by almost 40 percent by waiting. In another example, alternative growth patterns in annual net benefits result in dramatically different optimal timing and net present values. The second example also indicates that there can be a wide window of opportunity for later implementation that would result in higher net present values than immediate implementation.

Chapter 5 presents conditions for waiting to invest. Generally, either growth in benefits or uncertainty can create a value to waiting. Waiting saves interest costs but at the same time may preclude realizing some benefits. When benefits are relatively small today and grow over time, the savings in interest costs will more than offset the losses in benefits. As a result, waiting creates a value. Four forms of growth in benefits are illustrated. Under uncertainty, on the other hand, there is an opportunity cost of making an irreversible investment now by giving up the option of waiting for new information. It is true that waiting in general does not resolve uncertainty. However, waiting could increase the value of an investment. Two examples are used to illustrate the value of waiting under uncertainty.

Chapter 6 presents three types of timing rules that are applicable under different conditions, depending on whether the objective is to maximize the net present value of an investment and whether annual benefits of the investment are uncertain. Traditional rules apply if the objective is simply to get a positive net present value. Certainty rules apply if net benefits are known with certainty and the objective is to maximize net present value. Uncertainty rules apply if future net benefits are uncertain and the objective is to maximize expected net present value.

Each type of timing rule is stated in three forms. The first is as a ratio of project value and capital costs of an investment. The project value of an investment measures the total value of its stream of annual benefits discounted to various years of implementation. This form is an extension of the traditional benefit-cost ratio. The second form is in terms of annual benefits, which is net of annual variable costs of an investment, including operating, maintenance, and other societal costs. The third form is in terms of the year of implementation.

The timing rules are compared analytically and illustrated with an example. The analytical results indicate that maximizing net present value would delay investments beyond what achieving a positive net present value would suggest; and that uncertainty in annual benefits would delay investments longer than what certainty would suggest. This is true regardless the direction of uncertainty in annual net benefits. The numerical results show that the different sets of conditions are quantitatively significant.

These timing rules may serve three purposes: 1) to determine whether an investment being proposed for implementation in a particular year is premature or overdue; 2) to determine the optimal timing for implementation under conditions of certainty; and 3) to determine an appropriate time for reevaluation of a project after it is postponed.

Chapter 7 offers two approaches to determining subsequent steps that might be followed under uncertainty when a project is postponed. The discussion focuses on a choice between time planning, in which subsequent steps are taken on a fixed schedule, and event planning, in which subsequent steps may be triggered by particular events.

Chapter 8 discusses data requirements for investment timing analysis, procedures recommended by federal regulations on investment analysis, and the state of current practices of investment analysis as revealed in a survey of 35 transportation projects throughout the country. It appears that the procedures in current regulations are poorly followed in practice.

Chapter 9 makes recommendations for incorporating timing into the current planning and decision-making processes for major transportation investments. The recommendations are in three groups: those on improving general cost-benefit analysis; those on considering timing in investment analysis and decision-making; and those on dealing with uncertainty. In an era of increasingly scarce resources, it is important to improve the economic worth of our investments through better timing.

Appendices A and B contain models of investment timing and references, respectively. The models are used to derive the conditions for waiting in Chapter 5 and the timing rules in Chapter 6.

Chapter 2
BASIC CONCEPTS

This chapter describes a number of basic concepts related to investment analysis. These concepts are organized into three groups: those related to general cost-benefit analysis, those related to investment timing, and those related to uncertainty. Most of the definitions related to general cost-benefit analysis are adopted from "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements" (AASHTO, 1977) and Circular NO. A-94, "Guidelines and Discount Rates for Cost-Benefit Ana ysis of Federal Programs" (OMB, 1992). Most of the definitions related to uncertainty are adopted from "Guidelines for Risk and Uncertainty Analysis in Water Resources Planning" (USACE, 1992).

Cost-Benefit Analysis

Annual Net Benefits

Annual net benefits are the difference between annual benefits and annual costs (including mainly operating, maintenance costs, and other societal costs but excluding initial capital costs) of an investment. Annual net benefits may be affected by project age as well as investment timing. A project's stream of net benefits is the series of annual net benefits over its lifetime. The three terms, annual net benefits, net benefits, and annual benefits, may be used interchangeably throughout this report.

Discount Rate

The discount rate represents the rate of interest which money can be assumed to earn over the period of time under analysis. Benefits and costs are worth more if they are experienced sooner. The higher the discount rate, the lower the present value of future cash flows. For typical investments, with construction costs concentrated in early periods and net benefits following in later periods, raising the discount rate tends to reduce the net present value. The proper discount rate depends on whether the construction costs and annual net benefits are measured in real or nominal terms. A real discount rate has been adjusted to eliminate the effect of expected inflation and should be used to discount constant-dollar or real benefits and costs. A nominal discount rate reflects expected inflation and should be used to discount nominal benefits and costs. A real discount rate can be approximated by subtracting expected inflation from a nominal discount rate. A real discount rate of 7 percent is required for federal projects (OMB, 1992).

Net Present Value

Net present value is a common criterion for deciding whether a program can be justified on economic principles. Net present value is computed by assigning monetary values to benefits and costs, discounting future investment costs and net benefits using an appropriate discount rate, and subtracting the discounted investment costs from the sum total of discounted net benefits. An investment with a positive net present value is likely to be worthwhile in that it is likely to contribute to productivity and economic growth in an economy. Net present values of different projects can be used to reflect their relative contributions.

Real Values

Economic analysis is often most readily accomplished using real or constant-dollar values, i.e., by measuring benefits and costs in units of stable purchasing power. Nominal benefits and costs are measured in terms of the future purchasing power of the dollar. Analysis should be done in constant dollars.

Study Years

Study years are selected from the analysis period at which benefits and costs are estimated. Benefits or costs are estimated preferably for each year of the analysis period. Since calculations of year-by-year values is laborious, many analysts choose only one, two, or three years of the project life for detailed study and extrapolate or interpolate for the other years. The suggested practice in selecting study years is to choose the minimum number of years that allow reasonably accurate interpolation or extrapolation of benefits or costs in other years.

Investment Timing

First-Year Net Benefits

First-year net benefits are the annual net benefits in the first year after an investment is made. Annual net benefits are annual benefits net of annual costs including operating, maintenance, and other societal costs; initial capital costs are excluded. First-year net benefits for a given project can vary with investment timing. First-year net benefits may be used in relation to initial capital costs to decide whether a proposed investment is premature, overdue, or optimal in timing for realizing maximum net present value.

Project Age

The project age is the number of years after the construction of a project. It has a range of one through the lifetime of the project. Annual net benefits of a project can vary with project age. Net benefits may change with changes in the economy or age-induced operation and maintenance costs. For example, growth in the economy may increase the net benefits of a project for a given level-of-service. A rail project may carry more passengers as the population and employment in the service area increases. Also, physical deterioration may require expensive maintenance and replacement to maintain a given level-of-service and, as a result, reduce annual net benefits.

Project Value

Project value is the total value of a project's stream of annual net benefits discounted to a particular year of implementation. For a given project, there is a project value for every potential implementation year. Project value differs from the present value of a project's stream of annual net benefits in the base of discounting. Annual net benefits are discounted to the current year in calculating present value, while they are discounted to potential implementation years in computing project values. Project value may be used in timing rules to help decide whether a proposed investment is premature, overdue, or optimal in timing for realizing maximum net present value.

Uncertainty

Uncertainty is broadly defined here to include both risk and uncertainty as conventionally defined (USACE, 1992). Under conditions of risk, we know the outcomes and we can estimate the probabilities of their occurrence. As a result, we can do risk analysis (Lewis, 1992) and compute expected values. Under conditions of uncertainty, on the other hand, we may not be able to identify outcomes and cannot estimate the probabilities of their occurrence.

Sources of uncertainty can be many in making decisions for major transportation investments. Investment costs can be uncertain because of delays in construction, increases in general construction costs and in right-of-way costs, and technological changes. Operating and maintenance costs can be uncertain because of increases in energy costs and labor costs. Potential benefits can be uncertain because of changes in demand and a lack of knowledge as to whether alternative transportation projects will be built.

Chapter 3
WHY TIMING IS NOT CONSIDERED

This chapter discusses the issue of investment timing in the context of the decision-making environment for major transportation investments. It attempts to capture the perceptions and attitudes at work in these decision-making environments and reflect on the prospects for a more comprehensive, explicit consideration of investment timing in decision-making for major transportation projects. Specifically, this chapter addresses several of the considerations that appear to have a significant impact on the decision-making process for major investments. The arguments and factors that have resulted in resistance to considering build-later options or other treatments of the issue of investment timing are many. These arguments are legitimate and in some cases powerful motivators and are no doubt part of the reason that investment timing has received little attention in the mainstream of MIS policy development and process specification. Each of these factors is discussed briefly in the narrative below.

Transit is a Long-Term Investment

Transit investments are perceived differently from roadway investments in many situations. Often transit investments are made with the intention of meeting future demand and in fact creating future demand. Throughout the seventies and eighties the issue of major transit investments not realizing the benefits and serving the levels of demand forecast was a major point of contention within the transportation planning community. These disputes boiled over into the mainstream press as new systems opened and various parties reflected on whether or not they were meeting their objectives. Where a project did not meet expectations, discussions often erupted regarding the true project goals and expectations. Advocates reflected on the fact that guideway investments are 50 to 100 year investments and one should not be attempting to evaluate the contribution of recently implemented projects. Another argument has been to discuss benefits of the investment that go beyond the impacts that one might try to measure by reflecting on the near-term success in attracting riders. Comments like

"This is a long term investment, we did not expect to realize the benefits for years. This is an investment in our children's future..." are among the types of dialogue that followed. If there are no near term expectations then it is difficulty to argue nonoptimal investment timing.

The Chicken or Egg Dilemma

Another perception is that a major transit investment is not an independent event in the development of urban areas and the shaping of travel behavior. Rather, a major transit investment is very much a factor in the subsequent development of an area and in the subsequent travel behaviors, specifically mode choice that will result. This perception has influenced the attitudes toward quantitative analysis of the costs and benefits of transit investments.

Transit investments are often perceived to be the catalyst for significant changes in urban land use. These changes will ultimately create the market and demand levels that will enable transit to deliver the transportation benefits that it was originally intended to deliver. A typical argument is that we need to make the major transit investment now in order to begin influencing the land use patterns to ultimately make transit work. The logic continues, "... If we do not make this early investment the densities needed to make guideway transit effective will never materialize. Hence, if we delay investment we will never grow the market that we seek." This logic is generally considered sound, and, with the exception of those markets that matured at high densities because they were built before the dominance of the auto, it is often believed that an exclusive auto/bus based market will never increase density to the point at which guideway will operate effectively absent of some exclusive guideway transit investments.

The dilemma of this assumption is the fact that there is little assurance that the market will mature or become denser even if we build the transit investment. And, even if the market does materialize over time, is it a sound investment? If the payoff is so far in the future do we ever capture enough benefits to compensate for the early investment and carrying costs of the investment and service provided in the early years when the system operates below economically effective conditions? With several new rail systems implemented in the past three decades in this country, the verdict is still out regarding how effective rail investments can be in building transit markets.

We'll Grow Into It

Many urban areas have ignored investment timing by reliance on the "We will grow into it" argument. Increasingly, smaller urban areas are looking to transit investments as a means to help them shape urban growth and help solve or prevent transportation congestion and sprawl from materializing. Scarce resources have historically restricted consideration of guideway projects to our largest urban areas, most often with significant existing transit markets that would form the principle market for a future guideway investment. Increasingly, urban areas with modest existing transit use and smaller overall markets are considering guideway transit as an investment. While the desired expectations from these investments can be lower as a result of some opportunities to reduce the right-of-way and other costs of the investment, the ultimate ability of these systems to serve a market large enough to have desired impacts may be highly uncertain.

Most existing light-rail investments were made in urban areas with central business district employment levels near 100,000 jobs and with existing daily transit ridership levels of more than 100,000 when the planning was taking place. Increasingly, urban areas with far lower central business district employment levels and far lower existing transit-use levels are considering transit investments. In these markets, investment timing is a very important consideration.

We'll Lose the Opportunity

Another factor in the arguments regarding investment timing, or a reason for ignoring this issue, is that many planners and decision-makers believe that one must strike when the iron is hot, i.e., one must take action when the possibility for action exists. Several things have been mentioned as inevitable constraints if one does not act now.

Right-of-way Availability

One of the most frequent fears is the prospect of diminishing right-of-way availability. More highly urbanized areas typically have much lower right-of-way availability and proponents of early investment argue that if we do not build now the opportunity to build will pass as critical right-of-way is developed into other uses. At a minimum, delays in commitment might result in far higher costs for right-of-way as land prices are bid up, the need to buy and demolish existing development increases, the cost of utility and maintenance of traffic increases, and the prospects of needing to build elevated or subway systems increases. While these sound logical, even the oldest urban areas have found ways to implement systems and it presumes that it is not possible or economical to preserve the right-of-way now for future system development when the market is more mature. Unfortunately, the logic of these arguments is very hard to evaluate in a given context as conjectures about future costs and availability are highly uncertain.

Inflation

Another fear, most probably born in the inflation heyday of the 70's and 80's, is that rising costs will preclude the investment at a later date. Implicit in this argument is the assumption that costs will inflate faster than will the revenues from the funding sources. This was in fact the case in the era of high inflation in construction costs and may still be a valid concern in situations where right-of-way or other cost components are rapidly increasing. The source of funding may also play a role in this fear as those funding sources that are not indexed to economic growth and/or inflation may not keep up with inflation costs. However, in many instances, the growth in revenues due to economic growth and inflation exceed the pace of inflation in construction costs. Some legitimate concerns regarding the rates of cost increases for land, maintenance of traffic, or the prospect that new requirements such as broader citizen participation, increased expectations for impact mitigation or other system elements will increase faster than general inflation, merit consideration. In most instances, these arguments still deserve consideration but may not be as valid in today's planning environment where inflation costs are lower.

Opportunity Knocks

It is sometimes perceived that the congruence of factors that may enable a build-decision or a positive decision on funding may not be assured in the future. Often decision-makers change regularly and one cannot be assured that a favorable response to a proposal will be received in the future regardless of economic or logical arguments regarding investment timing. The presence of a supportive city council, a strong local legislative delegation at the state level, or the presence of the right person in the right committee position at the federal level is seen as a compelling justification for a build-now decision. The election cycles bring opportunities that may not be duplicated in the future when the analytically optimal time arrives. The discretionary nature of project funding perpetuates this sensitivity to decision-makers.

Time to Quit Planning and Start Building

Another factor biasing decision-making to build-now decisions is the strong emotional appeal of a do-something mentality. Frustrations with congestion, a cynical attitude toward government, a disdain of bureaucracy and process, and perception that we plan projects to death often results in a strong predisposition to an action-oriented decision. This creates a populist sense of action, and evidences serious efforts to actually solve problems. It implies decisiveness and leadership that can be very appealing for decision-makers. On a more pragmatic note, it also increases the chances that some of the benefits of the project will be reaped within a political time-frame that is relevant to the decision-makers. That might only mean consultant contracts for planning and design or initial efforts to buy right-of-way as opposed to ribbon-cutting ceremonies, yet these actions can provide a strong constituency for decision-makers.

It is a Build-Later Decision

Others would argue that the time frames that are currently required to plan, design, and implement major projects are such that a decision today is in actuality a decision to build later given the reality of how long it takes to implement major urban infrastructure projects today. Not only has the time for decision-making expanded with the broadening of the players and funding agencies in complex major projects, but the legal hurdles, cash flow constraints, and other factors result in most projects taking more than a decade to advance from the concept to concrete stage. Light rail new start projects are typically taking more than ten years to implement the first approximate 20 mile stage of a system. The first stage often costs between one-half and one billion dollars and carries fifteen to twenty-five thousand passengers on an average weekday in the early years of operation. Often these projects are part of larger system plans and the total system implementation time may be measured in decades. Thus, there is a strong desire to get started, knowing that the start of service may be many years away.

Don't Forget the Non-Economic Benefits

Over the past several years the goal set for public transportation investments has gradually shifted from a simple focus on cost effectiveness, capacity, and safety to a much broader set of goals as far ranging as contributing to economic development, to aiding in the reduction of the balance of trade deficit by reducing the need for petroleum imports, to contributing to the sense of community and social understanding facilitated by the interpersonal opportunities afforded by the "mass" in mass transit and the urban environment that guideway transit facilitates. This diverse set of goals, specifically the contribution that guideway transit is expected to make on influencing land-use patterns, has resulted in transit advocates often arguing that traditional cost/benefit or other economic impact assessments of guideway investments do not fully capture the range of impacts of transit investments and, hence, understate the benefits. Thus, the logic goes, the assessment of timing is not analytically sound since we are unable to fully capture the positive impacts and quantify them in a technical analysis.

This large and sometimes abstract set of objectives does not render the consideration of investment timing irrelevant nor assure that the broadly defined cost-benefit assessment always produces a positive number. It does make the analytical assessments alluded to in this report more difficult or may result in them being only a single piece of information in the decision-making information base. However, it should not invalidate the merits of reflecting on or analyzing the issue of investment timing.

We Need Balanced Transportation

Occasionally the logic for build-now decisions reverts to emotional appeals rather than attempts to analytically or theoretically rationalize a position. This can result in turning to arguments favoring balanced transportation or critiquing the social cost or hidden subsidies of auto reliance. After all, who would want an unbalanced transportation system? We are supposed to have a balanced diet, a balance between work and play, and a well-balanced disposition. Budgets should be balanced and, of course, we need a balanced transportation system.

Balanced transportation seems to mean spending a lot more money on public transportation and at least some more money on pedestrian and bicycle facilities. The transit industry would like 20 percent of any new revenues in the transportation trust fund dedicated to public transit. The appeal to a balanced system or an intermodal system is emotionally compelling regardless of whether or not its merits can be substantiated with empirical data or other facts. Nonetheless, these types of positions are common in discussions about transportation investment.

Summary

This chapter attempted to capture the perceptions and attitudes that surround the existing major investment study process and identified those factors that may have resulted in a reluctance to consider alternatives that might delay implementation of major investments. These arguments are not without merit and clearly have a basis in logic as well as strong appeal to advocacy-oriented entities that might be involved in the MIS process. Among the factors discussed, only two are beyond being incorporated into economic analysis of investment timing. These two are election cycles and politicians' desire for action now. These two factors are related because short election cycles can create an incentive to politicians for action now.

The fundamental shortcoming of the current practices and the opportunities for revisiting current practice merit serious consideration. At a minimum, planners should reflect on the issue of optimal investment timing. Preferably, there would be efforts to analytically evaluate the time stream of costs and benefits for build-later alternatives or to utilizing the information in the remainder of this report to evaluate the consequence of delayed implementation. In an era of scarce resources, this is an opportunity to improve the economic worth of investments. This report presents a rationale for doing this and analytic tools to help in carrying it out.

Chapter 4
TIMING CAN BE SIGNIFICANT

Waiting can add a value to an investment by improving the net present value of a project. Two examples are used to illustrate qualitatively the importance of timing. In addition, timing can be quantitatively significant. Optimal timing can mean substantial postponement of a project and at the same time dramatic improvement in its net present value. One example from Chu and Polzin (1996) is used to illustrate the quantitative significance of timing.

Waiting Can be Valuable

Waiting can increase the economic worth of an investment project. The objective of economic analysis of transportation investments is to help select and time investments so that their net present values are maximized. The net present value of an investment project can be sensitive to its start-date. This is especially true for investments that draw progressively greater benefits as traffic grows. A project with an estimated economic loss from an immediate implementation can be timed to yield a positive economic worth. A project with an estimated economic worth in the positive range now can often be scheduled to yield an even greater worth through adjustments to the timing of the project. This is also true for investments in which future construction costs and annual net benefits are uncertain. Two examples are used to illustrate the value that waiting to invest can create.

Under Certainty

Consider a community that is trying to decide whether to make a major transportation investment. To keep the example as simple as possible, we will assume that the project can be built instantly at a cost of $1,200. Also, a discount rate of 7 percent is assumed. If built now, annual net benefits are constant at $100; annual benefits will change to $114 if built next year. Annual net benefits will then remain at this new level forever. Should this community invest now, or would it be better to wait a year? If it decides to invest now, the project value would be $1,529 and the net present value would be $329. The net present value would increase to $450, however, if the investment is made next year. The value of waiting in this case is $121. This is an increase of almost 40 percent in net present value by waiting.

Under Uncertainty

Now suppose that annual net benefits are uncertain for next year. If built now, annual net benefits are $100; annual benefits will change if built next year. With probability 0.5, net benefits will rise to $150, and with probability 0.5, annual benefits will fall to $50. Annual net benefits will then remain at this new level forever. Should this community invest now, or would it be better to wait a year and see whether net benefits go up or down? Again, if it decides to invest now, the project value would be $1,529 and the net present value would be $329. It seems that the community should go ahead with the investment because net present value is positive now. The conclusion is incorrect, however, because it ignores the opportunity cost of investing now, rather than waiting and keeping open the possibility of not investing should annual net benefits fall. In fact, the net present value would be $511 if the community waits a year and decides to invest only if annual net benefits go up. An increase in the net present value by over 50 percent would be realized by waiting for an increase in annual net benefits.

The Value Can Be Significant

The quantitative significance of investment timing is illustrated with an example adopted from Chu and Polzin (1996). The purpose is to see how much optimal timing and net present value of a project are affected by variations in its stream of net benefits.

The lifetime of the project is 40 years and the project costs $1,000,000 if built now. Construction costs grow at an annual exponential rate of one percent. The cost to acquire the right-of-way is $100,000. These values are shown at the bottom of Table 1. In addition, Table 1 shows the example streams of net benefits. They are convex

Table 1. Quantitative Significance of Timing [a]

	Streams of Net Benefits			
	Convex	Linear	Concave	Horizontal
Net benefit function: $B(t)$	$b_1(t+1)^{1.5}$	$b_2(t+1)$	$b_3(t+1)^{0.5}$	b_4
Net benefits at time 0: $B(0)$	2,321	10,000	38,520	127,000
Optimal timing (years): t^*	13	9	3	0
Improvement in NPV	92%	44%	8%	0%

[a]NPV of investing at time t is computed as follows:

$$NPV(t) = \int_t^{t+T} B(s)e^{-rs}ds - K(t)e^{-rt} - M$$

$$K(t) = Ke^{bt}$$

where the parameters are set as follows:

Construction cost growth rate	Discount rate	Lifetime (years)	Right-of-way cost ($)	Initial capital cost ($)
$b = 0.01$	$r = 0.07$	$T = 40$	$M = 100{,}000$	$K = 1{,}000{,}000$

(growing at an increasing rate), linear (growing at a constant increment), and concave (growing at a decreasing rate). The horizontal stream is included for comparison. The constants in these functions, b_i (I = 1, 2, 3, 4), are determined as follows: the constant for the linear example is arbitrarily chosen to be $10,000; and the others are chosen such that these streams result in the same net present value if the project starts now. The resulting values are shown in Table 1 under "Net benefit at time 0." The three streams of net benefits are plotted in Figure 1 along with the horizontal.

Alternatively, these streams may be compared in terms of the cumulative distributions of their discounted values (Figure 2). The farther away a distribution is from the bottom right-hand corner, the larger is the proportion of benefits materializing in the early years. These cumulative distributions capture the differences among these streams of net benefits better than a simple plotting of them as shown in Figure 1.

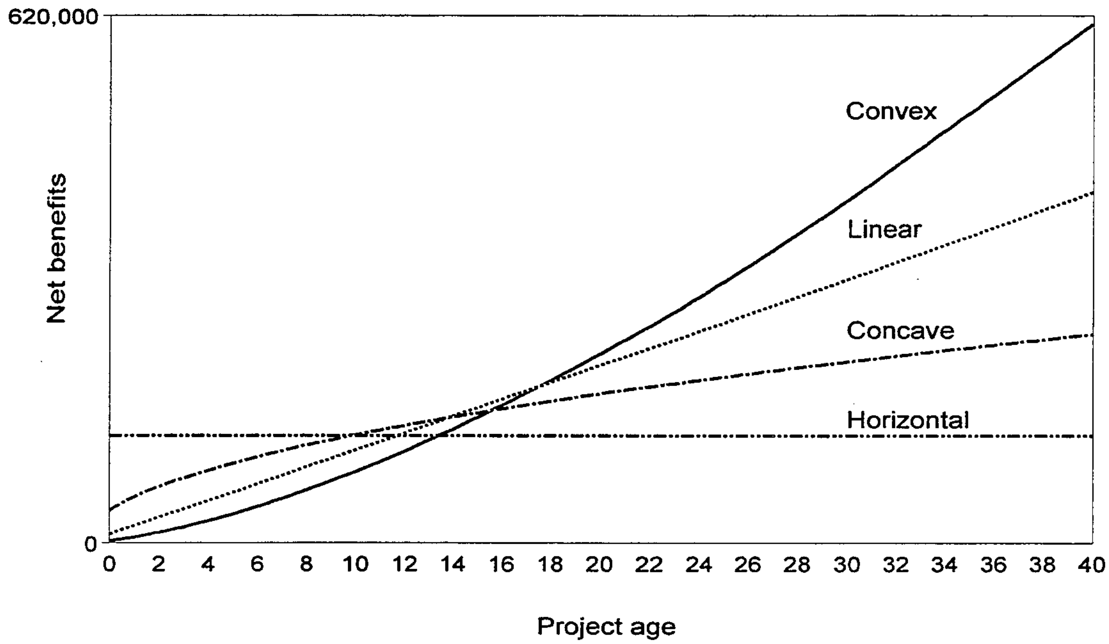

Figure 1. Alternative Streams of Net Benefits

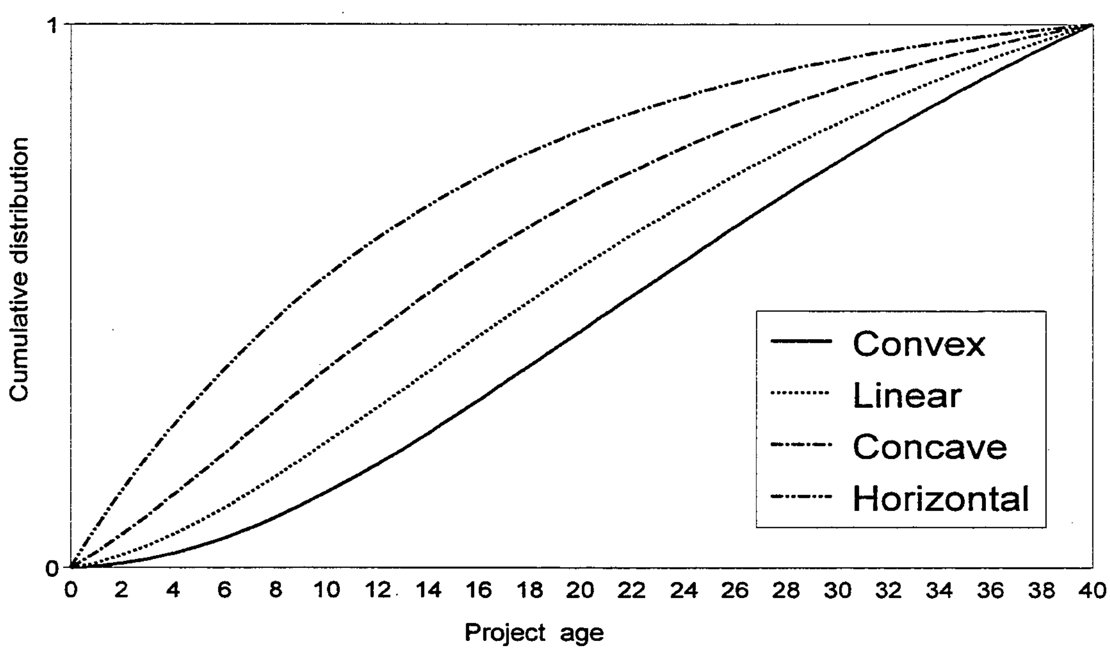

Figure 2. Cumulative Distribution of Discounted Net Benefits

The results are shown in Table 1. The optimal timing is 13, 9, 3, and 0 years from now for the convex, linear, concave, horizontal streams of net benefits, respectively. If the project is built now, these alternative streams would generate the same net present value of $603,400 because of a constraint imposed on the constants of the net benefit functions shown in Table 1. If the project is to be built at its optimal timing, however, the net present value would increase by 92 percent, 44 percent, 8 percent, and 0 percent for the four examples, respectively.

These differences in optimal timing and net present values are better reflected in Figure 3, which shows how net present value varies with investment timing for each of the example streams. First, these curves have the same value at time 0 because of the constraint mentioned above. Second, the net present value for the horizontal stream decreases over time, implying that build-now is better than build-later. Third, the other curves reach their maximum after time 0 (at years 13, 9, and 3, respectively), implying that build-later is better than build-now. Fourth, the curves for the non-horizontal cases are higher around optimal timing than they are at year zero, implying a window for later implementation that would result in higher net present values.

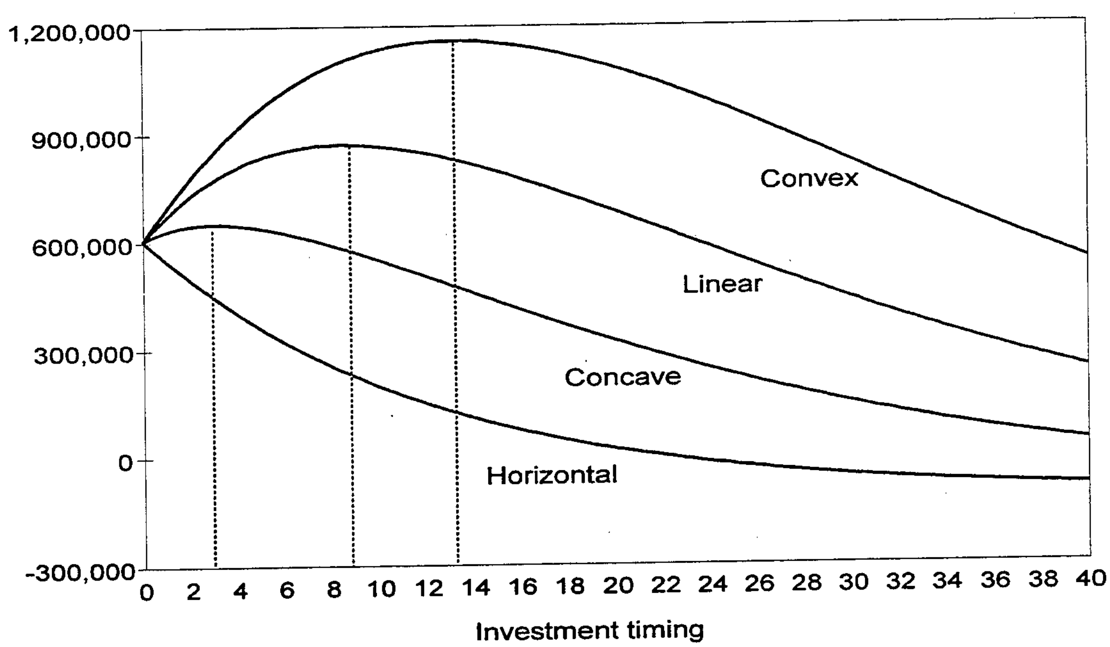

Figure 3. Net Present Value

Chapter 5

DETERMINING IF WAITING MAY BE WORTHWHILE

This chapter discusses some general conditions under which waiting to invest may be worthwhile. Both growth in project value and uncertainty can create a value to waiting. These two broad conditions are discussed separately below. Growth in project value is discussed under conditions of certainty, while uncertainty is discussed with examples that show how different types of uncertainty can create a value to waiting. Before proceeding, we discuss possible effects that time has on the net present value of investment projects.

Time Effects

Time affects a project's net present value at least in three ways. First, as a project ages, its net benefits may change with changes in the economy or age-induced operation and maintenance costs. For example, growth in the economy may increase the net benefits of a project for a given level-of-service. A rail project may carry more passengers as the population and employment in the service area increases. Also, physical deterioration may require expensive maintenance and replacement to maintain a given level-of-service and, as a result, drive down net benefits.

The second way that time affects net present value is through the timing of investment. Postponing an investment may require a different level of construction costs because of changes in real costs for construction. Postponing a project also may result in a different stream of net benefits because of changes in the demand for and supply of its services. Postponing also reduces the present values of a given amount of construction costs and a given stream of net benefits. The net result of postponing can be significant. It is possible to increase the net present value of a project by postponing it. It is even possible that postponing a project will change its net present value from a negative amount if constructed today to a positive amount if constructed later.

The third way that time can affect the economic value of a project is through uncertainty in its capital costs and annual benefits. There is a value in waiting to invest when the project can be delayed and its implementation is irreversible. This value of waiting exists because waiting maintains the option to invest and makes it possible to adopt a better decision when new information arrives.

Growth Conditions

Under certainty, waiting saves interest costs and at the same time preclude realizing some net benefits. When project value is relatively small today but grows over time, the savings in interest costs will more than offset the losses in net benefits. As a result, waiting creates a value. A number of conditions in terms of net benefits can result in growth in project value. Some of these conditions are based on the paper by the authors of this report, "Considering Build-Later as an Alternative in Major Investment Analyses" (Chu and Polzin, 1996). As discussed earlier, net benefits of a project may be affected by both project age as well as investment timing. The following conditions are some special cases of a general relationship between annual net benefits and project age and investment timing (see Appendix A).

Growth without Shift

Project value does not grow if the stream of annual net benefits does not shift with investment timing, and annual net benefits either remain constant or decline over time. When the stream of net benefits is independent of investment timing, the stream from investing at time t_2 is part of the longer stream from investing at t_1 (Figure 4). However, project value would grow if annual net benefits remains independent of investment timing, but grows over time. This is likely to be the case for many applications.

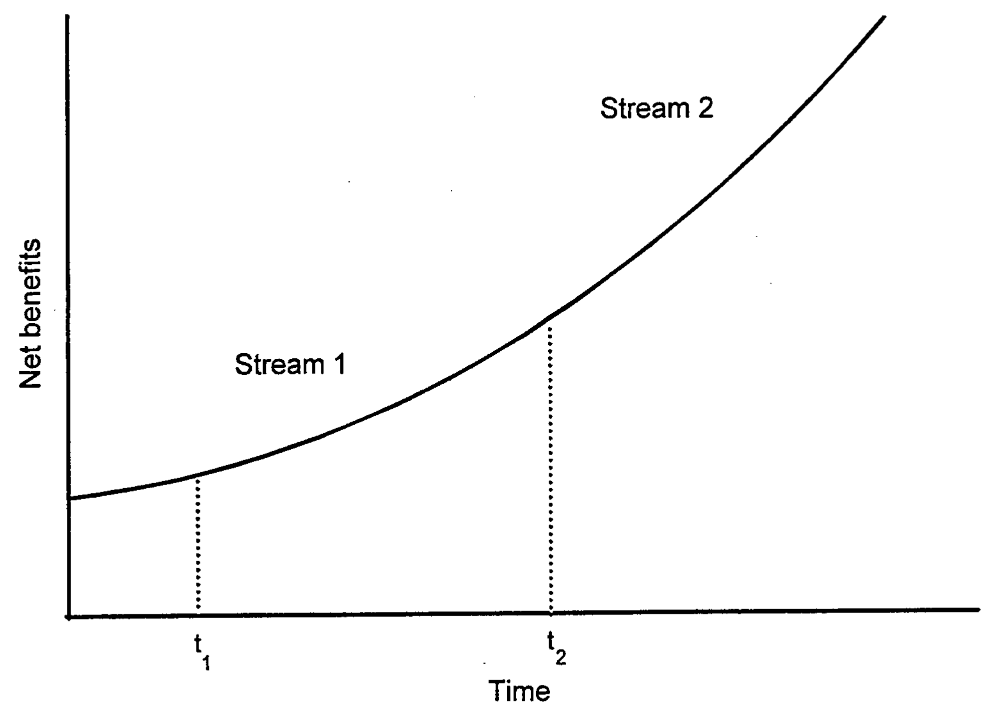

Figure 4. Growth Without Shift.

Upward Shift

Project value stays constant if the stream of annual net benefits repeats itself from investing at different times. In other words, one stream is a parallel shift of every other. In this case, the investment rule is to invest now or never. The intuition is that there is no advantage to invest later when the stream of net benefits repeats itself as investment timing changes. However, project value grows if the stream of annual net benefits shifts with an upward lift when investment timing changes. This result holds true regardless of whether annual net benefits grow or stay constant with project age (Figures 5-6).

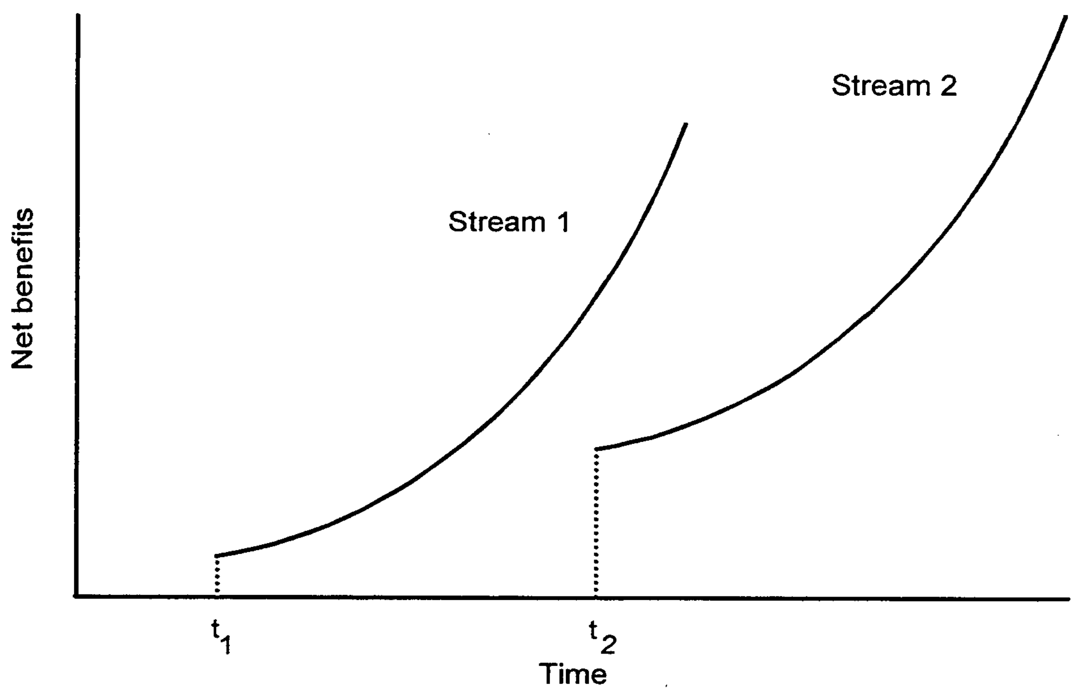

Figure 5. Upward Shift with Growth.

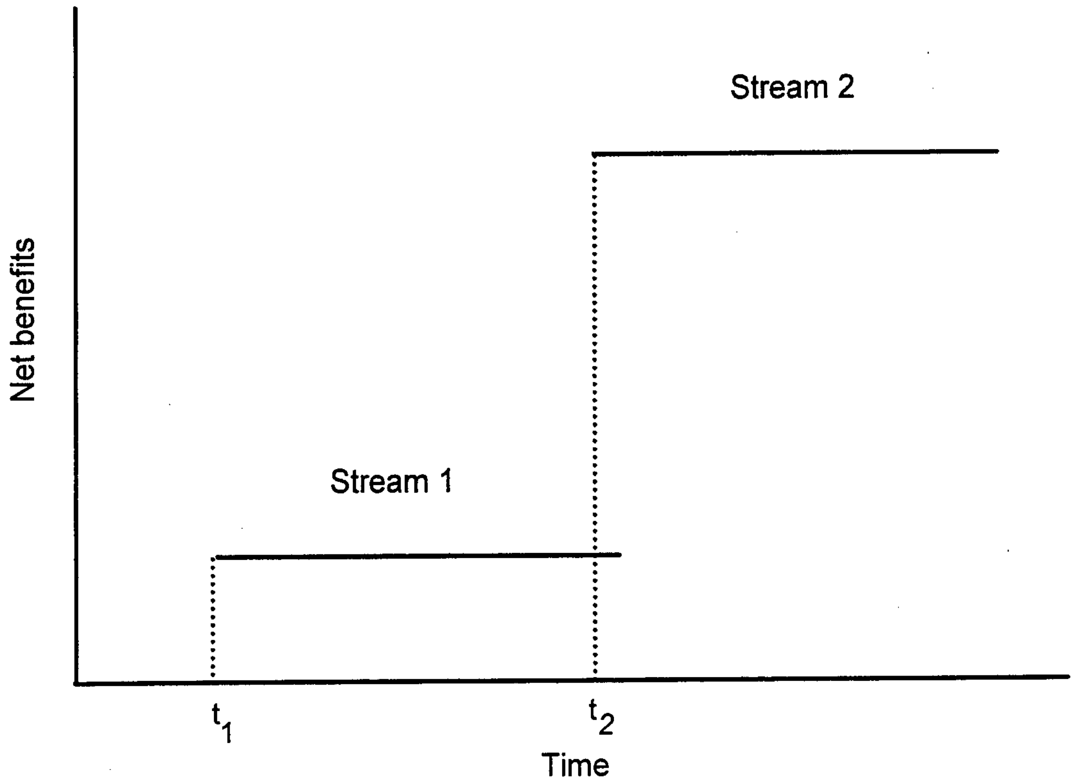

Figure 6. Upward Shift Without Growth.

Horizontal Shift

Project value stays constant if the stream of annual net benefits shifts parallel to itself when investment timing changes. That is, as investment timing changes, the first-year net benefits remain the same and, annual net benefits remain the same pattern over its lifetime. However, project value grows if the first-year net benefits remain the same, but annual net benefits grow faster over the lifetime when investment timing changes. Figure 7 illustrates this condition.

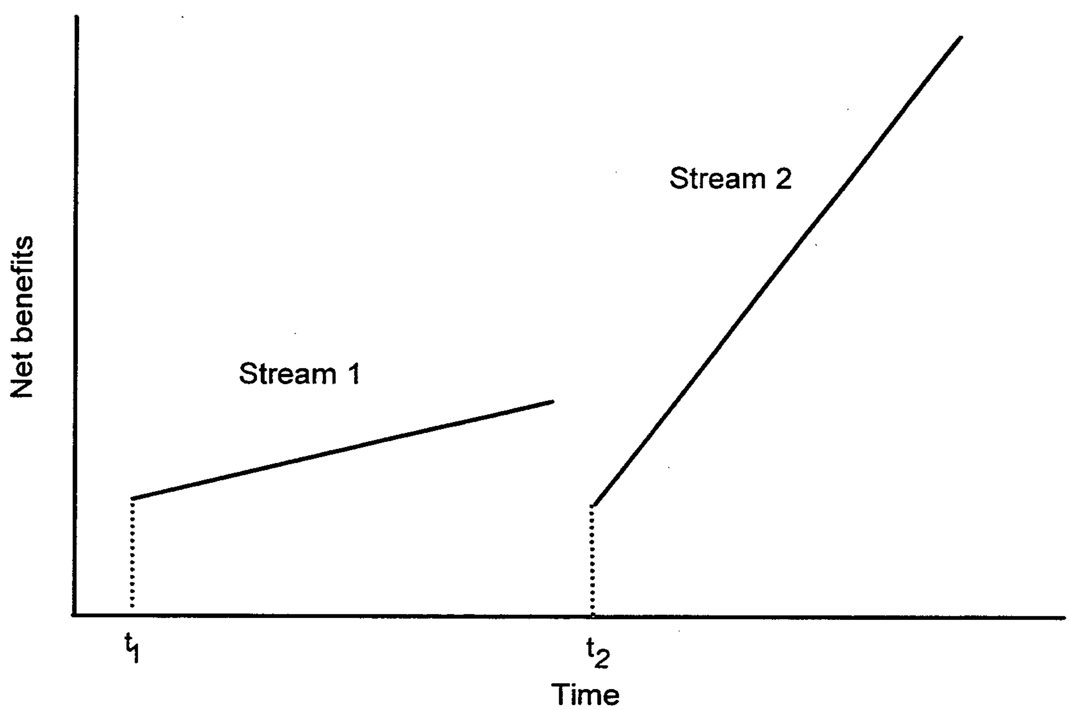

Figure 7. Horizontal Shift with Growth.

A precondition for waiting to be worthwhile under certainty is for today's project value to be small relative to the initial capital costs. This condition can also be stated in terms of annual net benefits for some special cases. Under the case of "Growth without Shift," for example, this condition is equivalent to the following: the first-year net benefits should be smaller than annual interest on the initial capital costs. That is, if the first-year net benefits are large because, for example, demand is already high today, the investment should be made immediately rather than delayed.

Uncertainty Conditions

Under conditions of uncertainty, there is an opportunity cost of making an irreversible investment now, and thereby giving up the option of waiting for new information. We already saw in Chapter 4 that uncertainty in annual net benefits can create a value to waiting. In what follows we examine two alternative sources of uncertainty. These examples are based on those by Dixit and Pindyck (1994). Under a narrow definition, these examples are really examples under conditions of risk.

Uncertainty over Cost

Continue with the example in Chapter 4, where a community is trying to decide whether to invest in a major transportation investment that is irreversible. Now suppose that investment costs are uncertain and the project costs, in real values, $1,200 today, but next year the cost will increase to $1,800 or decrease to $600, each with probability 0.5. As before, the discount rate is 7 percent and the project will generate annual net benefits of $100. Should this community invest today or should it wait to make a decision until next year? If it decides to invest today, the project value would be $1,529 and the project's net present value would be $329. This is positive, but once again it ignores an opportunity cost. To see this, let us recalculate the net present value, assuming the community waits until next year, in which case it will invest only if the investment cost falls to $600. In fact, the net present value in this case is $439. Thus, if the community waits a year before deciding whether to invest, the project's net present value can increase by $105, which is the value to waiting in this example.

Uncertainty over Discount Rate

Government agencies have guidelines for discount rates for transportation projects, but the discount rate can change. For example, a couple of years ago the Federal Transit Administration changed the discount rate for new starts from 7 percent for all projects to 4.9 percent for projects with a lifetime of at least 30 years and to a percentage between 4.2 to 4.9 percent for projects with a lifetime of less than 30 years and, recently, changed the discount rate back to 7 percent.

Suppose this time that the only uncertainty is over the discount rate. Today the discount rate is seven percent, but next year it will change. There is a 0.5 probability that it will increase to 10 percent, and a 0.5 probability that it will decrease to 5.4 percent. It will then remain at this new level. As before, the project cost is fixed at $1,200 and annual net benefits are $100. If the community invests today, the project value is again $1,529 and the net present value is $329. Suppose the community waits until next year before it decides whether to invest. If the discount rate rises to 10 percent, the project value will only be $1,100, which is less than the project cost of $1,200. Hence it will only invest if the discount rate falls to 5.4 percent. The net present value assuming that the community waits is $354. The value of waiting in this example is $25.

Chapter 6
DECIDE WHEN TO STOP WAITING

The conditions in the previous chapter allow determining whether waiting may be a better choice than investing today. This chapter presents rules of optimal timing that allow deciding when to stop waiting. Specifically, it presents three sets of timing rules, discusses their relationships, and illustrates their use and misuses with simple examples. Before proceeding with these timing rules, however, the basic rule is stated.

The Basic Rule

The basic rule for investment timing is that investments should be made when net present value is maximized with respect to different implementation years. This rule is based on a simple model of cost-benefit analysis:

Net Present Value =
Present Value of Net Benefits
minus
Present Value of Capital Costs

By investing in a major transportation project, society incurs costs to construct the project and enjoys a stream of net benefits over the project's lifetime. Net benefits here are net of operating, maintenance, and other societal costs. To calculate net present value, the stream of net benefits is first discounted and summed using an appropriate discount rate; this sum is then compared with discounted construction costs and, the difference gives net present value. Net present value can vary with investment timing because of changes in net benefits over time.

Optimal timing occurs when investment objectives are achieved. A common objective is simply to achieve a positive net present value. Another objective is to maximize the net present value of an investment under certainty or to maximize the expected net present value of an investment under uncertainty.

Derived Rules

The basic rule of maximizing net present value can be used to derive timing rules. This section presents three types of timing rules that are applicable under different conditions, depending on whether the objective is to maximize the net present value of an investment and whether annual benefits of the investment are uncertain. Traditional rules apply if the objective is simply to get a positive net present value. Certainty rules apply if future values of the investment are known with certainty and the objective is to maximize net present value. Uncertainty rules apply if future values of the investment are uncertain and the objective is to maximize expected net present value. Each type of timing rule is stated in three forms: the ratio of project value and capital costs of an investment (V/K); annual net benefits (B); and the year of action (t). These timing rules are shown in Table 2.

As stated in the introduction, these timing rules are derived with certain assumptions so that they are in algebraic forms. For example, we only consider the situation where a single transportation project is being evaluated against a "do-nothing" alternative. It is assumed that the cost of the investment, K, is known and fixed in constant dollars. Also, annual net benefits will change with investment timing at an annual rate of α. Furthermore, uncertainty takes a particular form: annual net benefits are lognormally distributed with constant variance.

Traditional Rules

Under rule (1), invest when project value exceeds capital costs or, when the ratio of project value and capital costs exceeds one. Rule (1) is widely used as the traditional benefit-cost ratio. Typically, this rule is used to decide whether a particular investment should be made now or never. This traditional use has been extended here to allow a project with a low benefit-cost ratio now to be worth investing in later. Under rule (2), invest when annual benefits exceed $B_T = (\rho-\alpha)K$ or, when annual benefits as a proportion of capital costs exceed the difference between the discount rate and growth rate of annual benefits. Under rule (3), invest when time reaches a critical year given by $T_T = \log[K/V(0)]/\alpha$.

Table 2. Timing Rules.

Type of Rule	Form of Rule: V / K		B		t	
Traditional	$V/K \geq C_T$	(1)	$B \geq B_T$	(2)	$t \geq T_T$	(3)
Certainty	$V/K \geq C_C$	(4)	$B \geq B_C$	(5)	$t \geq T_C$	(6)
Uncertainty	$V/K \geq C_U$	(7)	$B \geq B_U$	(8)	$t \geq T_U$	(9)

Notes to Table 2:

1. K is the construction costs in constant dollars.
2. V is the project value associated with a particular year of implementation.
3. B is the annual benefits associated with the year of implementation.
4. t is investment timing.
5. α is the expected annual rate of growth in annual net benefits.
6. ρ is the real discount rate for both construction costs and annual benefits.
7. σ is a measure of the uncertainty in annual benefits.
8. β is a parameter determined as follows:

$$\beta = 0.5 - \alpha/\sigma^2 + \sqrt{(\alpha/\sigma^2 - 0.5) + 2\rho/\sigma^2}$$

9. C_T, C_C, and C_U are critical values for the ratio, V / K. They are:

$$C_T = 1, \qquad C_C = \rho/(\rho - \alpha), \qquad C_U = \beta/(\beta - 1)$$

10. B_T, B_C, and B_U are critical values for annual benefits. They are:

$$B_T = (\rho - \alpha)K, \qquad B_C = \rho K, \qquad B_U = C_U(\rho - \alpha)K$$

11. T_T, T_C, and T_U are optimal timing. They are given by:

$$T_T = \log[C_T(K/V_0)]/\alpha, \qquad T_C = \log[C_C(K/V_0)]/\alpha, \qquad T_U = \log[C_U(K/V_0)]/\alpha$$

where V_0 is today's project value.

Rules under Certainty

Under rule (4), invest when the ratio of project value and capital costs exceeds a critical value, $C_C = \rho/(\rho-\alpha)$. Under rule (5), invest when annual benefits exceed annual interest costs given by $B_C = \rho K$. Rule (5) has been advocated by a number of authors (Marglin, 1963; Georgi, 1973; Lewis, 1992). A participant of an FHWA sponsored conference on benefit-cost applications indicated that the World Bank uses this method (FHWA, 1996, p. 17). Rule (5) is appealing because it is simple and easy to interpret. Under rule (6), invest when time reaches a critical year given by $T_C = \log[C_C(K/V(0))]/\alpha$.

Rules under Uncertainty

Rules (7)-(9) apply when future annual net benefits are uncertain in a particular way (Appendix A). Under rule (7), invest when the ratio of project value and capital costs exceed a critical value given by C_U. Under rule (8), invest when the first-year net benefits as a proportion of capital costs exceed the critical value multiplied by the difference between the discount rate and the growth rate of annual net benefits. Rule (7) has been advocated by a number of authors (Dixit and Pindyck, 1994; Martzoukos and Teplitz-Sembitzky, 1992; McDonald and Siegel, 1986). Rule (8) is cumbersome and does not appear often. Rule (9) gives the expected value of optimal timing.

Relationships

As shown in Appendix A, the critical values in the timing rules have the following relationships: $C_T < C_C < C_U$; $B_T < B_C < B_U$; and $T_T < T_C < T_U$. Thus, maximization of net present value under certainty defers investment so as to take advantage of the possibility that annual benefits and, hence, net present value of the project will grow later. Furthermore, uncertainty defers investment so as to receive more information about the future evolution of uncertain annual benefits and project value. In other words, rules (1)-(3) will result in earlier investment timing than rules (4)-(6), which, in turn, will result in earlier investment timing than rules (7)-(9).

It is important that rules (4)-(6) be used under conditions of certainty and rules (7)-(9) be used under conditions of uncertainty, while rules (1)-(3) may be used under conditions of certainty or uncertainty.

Application

Several steps may be involved in applying these timing rules. The first step of applying these timing rules is to determine which type of rule is the most appropriate for a given problem. Rules (1)-(3) are applicable if the objective is to achieve some positive net present value. Rules (4)-(6) are applicable to situations where there is no uncertainty and the objective is to maximize net present values. Rules (7)-(9) are applicable to situations where there is uncertainty in annual net benefits and the objective is to maximize expected net present values.

The second step is to determine the critical values for the rules. These critical values depend on the following parameters: growth rate of annual benefits, standard deviation of annual net benefits, capital costs, and today's annual net benefits.

The third step is to determine the type of applications. There are three general applications of these rules as follows:

1. The first type of application is for projects being proposed for implementation in a particular year under conditions of both certainty and uncertainty. The rules may be used in this application to check if a particular investment is premature, optimal, or overdue in timing. Consider rules (4)-(6) for example. An investment is optimal if rule (4) or (5) is satisfied with an equality in a particular year; premature if neither (4) or (5) is satisfied; and overdue if rule (4) or (5) is satisfied with an inequality. Rules (1)-(2) and (7)-(8) can be similarly used.

2. The second type of application is for projects being evaluated for timing re-evaluation under conditions of certainty. This application may be done in two ways. In one way, a particular project may be analyzed for a number of possible implementation years over an extended period. One then checks whether any of the rules stated in annual net benefits or the ratio of project value and capital costs are satisfied in each of these years. The optimal year of implementation is the earliest year in which one of the rules is satisfied. Another way is to calculate the critical year, which gives the optimal timing for implementation.

3. The third type of application is for projects being evaluated for timing re-evaluation under conditions of uncertainty. Rule (9) is based on the expected optimal timing, which is given by $T_U = \log[C_T (K/V(0))]/\alpha$. This expected value may be used as an approximation for timing re-evaluation of an investment after it is postponed. See more on the timing of re-evaluation in Chapter 7.

Example

This section specifies an example to illustrate the timing rules. This example extends those used in the earlier chapters, where a community is trying to determine the optimal timing of a $1,200 project. Results are shown separately for both correct uses and incorrect uses of the rules.

Specification

The example is specified so that all three types of rules can be illustrated. Suppose that a community is trying to decide in the base year 1997 when to make a major transportation investment. To keep the example as simple as possible, we assume that the project can be built instantly at a fixed cost of K=$1,200, with a discount rate of ρ=7 percent. If it decides to invest in the base year, the project value would be V(0)-K=$1,529 and a corresponding annual benefits of B(0)=$61. In addition, project value will be assumed to grow at an annual rate of 3 percent or $\alpha = 0.03$. For conditions of uncertainty, the standard deviation of annual benefits is assumed at 0.2 or $\sigma = 0.2$. These assumptions allow one to determine the critical values for the timing rules, which are shown in Table 3.

To illustrate the rules, future annual benefits and project values are estimated. With the assumptions described earlier, they can be determined, depending on whether future annual benefits are uncertain. They are shown for the period 1997-2017 in Table 4 for the case of certain annual benefits and in Table 5 for the case of uncertain annual benefits. Also shown in these tables are the ratio of project value to capital costs and

Table 3. Critical Values.

Type of Rule	Type of Critical Value		
	Project Value over Capital Costs	Annual Benefits	Timing
Traditional	$C_T = 1$	$B_T = 48$	$T_T = 0$
Certainty	$C_C = 1.75$	$B_C = 84$	$T_C = 11$
Uncertainty	$C_U = 2.57$	$B_U = 123$	$T_U = 23$

Table 4. Values of Variables under Certainty.

Year	Project Value ($)	Project Value / Capital Costs	Annual Benefits ($)	Net Present Value ($)	
1997	1,529	1.27	61	329	
1998	1,575	1.31	63	350	
1999	1,623	1.35	65	368	
2000	1,673	1.39	67	383	
2001	1,723	1.44	69	396	
2002	1,776	1.48	71	406	
2003	1,830	1.53	73	414	
2004	1,886	1.57	75	420	
2005	1,943	1.62	78	425	
2006	2,002	1.67	80	427	
2007	2,063	1.72	83	429	
2008	2,126	1.77	85	429	⇦
2009	2,191	1.83	88	428	
2010	2,258	1.88	90	426	
2011	2,326	1.94	93	423	
2012	2,397	2.00	96	419	
2013	2,470	2.06	99	414	
2014	2,546	2.12	102	409	
2015	2,623	2.19	105	404	
2016	2,703	2.25	108	397	
2017	2,785	2.32	111	391	

Table 5. Evolution of Variables under Uncertainty.

Year	Project Value ($)	Project Value / Capital Costs	Annual Benefits ($)	Net Present Value ($)
1997	1,529	1.27	61	329
1998	1,588	1.32	64	362
1999	1,809	1.51	72	529
2000	1,815	1.51	73	499
2001	1,777	1.48	71	436
2002	1,971	1.64	79	544
2003	1,537	1.28	61	221
2004	1,608	1.34	64	250
2005	1,784	1.49	71	334
2006	2,475	2.06	99	679
2007	2,554	2.13	102	672
2008	2,288	1.91	92	504
2009	1,929	1.61	77	315
2010	1,948	1.62	78	302
2011	1,725	1.44	69	197
2012	2,075	1.73	83	306
2013	2,450	2.04	98	408
2014	2,765	2.30	111	476
2015	3,747	3.12	150	722 ⇦
2016	3,608	3.01	144	637
2017	3,828	3.19	153	648

corresponding net present values. For example, annual benefits grow to $83 in year 2007 under certainty and the corresponding values for project values, the ratio of project value to capital costs, and net present values are $2,063, 1.72, and $429, respectively. Similarly, annual benefits grow to $102 in year 2007 under uncertainty and the corresponding values for project values, the ratio of project value to capital costs, and net present values are $2,554, 2.13, and $672, respectively. The two tables show the same values for the base year because today's annual benefits are known with certainty.

Correct Usage

The results in terms of timing and net present values from correctly applying the timing rules to this example are summarized in Table 6 below. Correct usage means that a particular type of rule is applied to the set of conditions that underlie this type of rule. For example, applying the certainty rules to Table 4 is correct. Results for different types of rule are discussed separately below.

Table 6. Summary Results of Correct Usage.

	Timing Rules		
	Traditional	Certainty	Uncertainty
Timing	1997	2008	2015
NPV ($)	329	429	722

<u>Traditional Rules</u>: Both Tables 4 and 5 can be used to illustrate the use of rules (1)-(3). In both cases, the optimal timing is 1997 and the corresponding net present value is $329. The results happen to be the same in this example because project value in the base year exceeds capital costs. In general, however, the results can be different if project value in the base year is less than capital costs.

For the traditional rules, the critical value is 1 for the ratio of project value and capital costs. The investment would be made in the base year under rule (1) because the actual ratio of project value and capital costs is 1.27. Rules (2)-(3) would result in the same conclusions because today's annual benefits are $61, which exceed the critical value of $48, and the critical timing is 0 years. If the critical ratio is below one, however, rule (1) may be used to find a better time when project value exceeds capital costs. This can be done by searching the earliest year when the actual ratio exceeds the critical value.

<u>Certainty Rules</u>: Table 4 can also be used to illustrate the use of rules (4)-(6). Annual interest costs are $84 as shown in Table 3 as B_C. Annual benefits do not exceed interest costs until 2008 when it becomes optimal to make the investment under rule (5). The corresponding net present value is $429. Using rules (4) or (6) would result in the

same conclusions. For example the ratio of project value and capital costs does not exceed the critical value C_C = 1.75 until the year 2008. Also, the critical time given by T_C is 11 years.

Uncertainty Rules: Table 5 can also be used to illustrate the use of rules (7)-(8) for determining whether a proposed investment in a particular year is premature, overdue, or optimal in timing. Using rule (7), the actual ratio of project value and capital costs does not exceed the critical ratio C_U = 2.57 until 2015. The corresponding net present value is $722. It would be premature to make the investment before 2015, while it would be overdue after 2016. Using rule (8) would result in the same conclusion. However, using rule (9) can result in a different result. In this case, T_U = 23. That is, the expected optimal timing is 23 years from the base year.

Incorrect Usage

The timing rules are incorrectly used if they are applied when conditions differ from those that what underlie the rules. For example, the certainty rules would be incorrectly used if they are applied to Table 5. Similarly, the uncertainty rules are incorrectly used if they are applied to Table 4. Also, the traditional rules are incorrectly used if the investment objective is to maximize net present value. The resultant timing and net present values from incorrectly using the timing rules are summarized in Table 7, along with the results of correct usage for comparison. For example, applying certainty rules to Table 5 would result in a wrong timing of 2006 and a wrong net present value of $679. Similarly, applying uncertainty rules to Table 4 would result in a wrong timing beyond 2017, the last year included in the table.

Table 7. Summary Results of Incorrect Usage.

Conditions	Certainty (data in Table 4)			Uncertainty (data in Table 5)		
Rules	Traditional	Certainty	Uncertainty	Traditional	Certainty	Uncertainty
Timing	1997	2008	2017	1997	2006	2015
NPV ($)	329	429	391	329	679	722

The errors from incorrect usage are shown in Table 8. It first shows the effects of incorrectly using the traditional rules. They are incorrectly used when the objective is to maximize net present value under certainty or expected net present value under uncertainty. Incorrectly applying the traditional rules to certainty conditions results in a bias toward early action for 11 years (from 2008 to 1997) and a reduction in net present values of over 23 percent (from $429 to $329), while incorrectly applying them to uncertainty conditions results in a bias toward early action for 18 years (from 2015 to 1997) and a reduction in net present values of over 119 percent (from $722 to $329).

Table 8. Errors from Incorrect Usage.

	Incorrectly Applying Traditional Rules to		Applying Certainty or Uncertainty Rules to Two Sets of Conditions		Applying Certainty and Uncertainty Rules to a Given Set of Conditions	
	Certainty Conditions	Uncertainty Conditions	Certainty Rules	Uncertainty Rules	Certainty Conditions	Uncertainty Conditions
Timing	-11 years	-18 years	-2 years	2 years	9 years	-9 years
NPV	-23%	-119%	58%	-46%	-9%	-6%

There are two ways to look at the effects of incorrectly using certainty and uncertainty rules. One way is to compare the results from applying the same type of rules to two sets of conditions. Let us look at certainty rules first. When they are applied correctly to certainty conditions (Table 4), the timing is 2008 and net present value is $429. When they are applied incorrectly to uncertainty conditions (Table 5), the timing is 2006 and net present value is $679. In this case, incorrect usage results in a timing two years earlier and an increase in net present value by 58 percent. Let us look at the uncertainty rules next. When they are applied correctly to uncertainty conditions (Table 5), the timing is 2015 and net present value is $722. When they are applied incorrectly to certainty conditions (Table 4), however, the timing is 2017 and net present value is $391. In this case, incorrect usage results in a delay of two years and a reduction of net present value by 46 percent.

The other way is to compare the results from applying two types of rules to the same set of conditions. Let us first look at both certainty and uncertainty rules being applied to certainty conditions (Table 4). While the certainty rules result in a timing of 2008 and net present value of $429, the uncertainty rules result in an incorrect timing of 2017 and an incorrect net present value of $391. In this case, incorrect usage results in a delay of nine years and reduces net present value by 9 percent. Now look at these two types of rules being applied to uncertainty conditions (Table 5). While the uncertainty rules result in a timing of 2015 and net present value of $722, the certainty rules result in an incorrect timing of 2006 and net present value of $679. In this case, incorrect usage results in a timing 9 years earlier and reduces net present value by 6 percent.

Two pattens emerge from the results in Table 8. One pattern relates to comparing the two ways to look at the effects of incorrectly using the certainty and uncertainty rules. If incorrect usage is examined from applying a given type of rules to two sets of conditions, errors in timing seem to be relatively small, while errors in net present value seem to be relative large. On the other hand, if incorrect usage is examined from applying two types of rules to a given set of conditions (certainty or uncertainty), errors in timing seem to be relatively large, while errors in net present value seem to be relatively small.

The other pattern from the results in Table 8 relates to the errors from incorrectly using traditional rules. Errors in both timing and net present values can be significant when traditional rules are applied to cases where the objective is to maximize net present value.

Chapter 7

WHEN A PROJECT IS POSTPONED

The conditions and timing rules given in the previous two chapters help determine whether a project should be delayed under conditions of uncertainty. The next issue to address under conditions of uncertainty is to determine what follows when the current decision is build-later. That is, how should the timing of subsequent steps be determined when uncertainty exists? This chapter briefly discusses two approaches for addressing this issue. The discussion is adopted from Intriligator and Sheshinski (1986).

The basic choice is between the time approach, in which subsequent steps are taken on a fixed schedule, and the event approach, in which the timing of subsequent steps are triggered by particular events The time approach is the traditional method by which subsequent steps are being taken after a fixed time interval has elapsed. The event approach is an alternative method by which subsequent steps are being taken after a certain event or set of events occurs.

There is also the hybrid approach to following an initial decision of build-later. It combines the time and event approaches. In this approach, either time or some event or set of events can trigger subsequent steps. A subsequent step is taken if either a particular event occurs or a certain time interval has passed since the last decision of build-later. This approach has the desirable properties of both types of approach. It recognizes the existence of uncertainty by allowing events to trigger action. At the same time, it recognizes that a particular event cannot embody all relevant information concerning the transportation system.

What is the preferred approach to use? A simple theory of planning by Intriligator and Sheshinski (1986) seems to indicate that reanalysis on the basis of events is preferable to reanalysis only on the basis of time. Thus, if the impacts of the project are uncertain, then events should influence the timing of subsequent analysis. A major challenge of the event or hybrid approach, however, is to identify the particular event or set of events that would trigger subsequent analysis.

In the case of transportation projects, any number of logical events might be triggers. For example, if benefits were related to demand and demand grew over time with population and employment, one might be able to se target levels for demand or development as triggers for implementation or re-analysis.

In the transit industry, historically, some rules of thumb evolved that indicated an adequate market for consideration of guideway investments, such as central business district employment hitting certain levels, corridor travel volumes reaching certain volumes or existing bus ridership levels reaching certain levels, might be the trigger for re-analysis.

Chapter 8

THEORY, REGULATIONS, AND PRACTICE

This chapter discusses three issues related to timing considerations in the practice of investment analysis. One issue is what type of data the economic principles in Chapters 5 and 6 require for investment timing analysis. The second issue is what procedures federal regulations on the economic analysis of federal projects recommend. The third issue is the current practice of investment analysis for major transportation investments. It appears that the federal procedures are poorly followed in practice.

Data Required

Certain data and information are required to use the economic principles in Chapters 5-6 for analysis and decision-making on investment timing. Such data may not be readily available in current practice.

Net Present Value

Net present value is a common criterion for transportation investments. Net present value is the sum of net benefits discounted to the present day at a correct discount rate, minus the investment costs also discounted to their present value. Any project with a positive net present value may be regarded as acceptable in that it can be expected to yield productivity and growth-related benefits in excess of the investment costs. As an acceptance criterion, net present value rejects projects in which the value of any contribution to productivity and growth is less than the economic costs to be incurred in achieving that contribution.

Annual Benefits and Costs

One essential element of an economic analysis of investment timing is to identify and measure annual benefits and costs in constant dollars. Analysis should include comprehensive estimates of the expected benefits and costs to society. Social benefits and costs should be the basis for evaluating transportation investments. In order to calculate project value and net present value, one is required to estimate annual benefits and costs for each year of the life of a project. Annual net benefits are defined as annual gross benefits net of annual costs.

Discounting

In order to compute net present value from investment costs and annual net benefits, it is necessary to discount them. This discounting reflects the time value of money: benefits and costs are worth more if they are experienced sooner. This discounting also allows comparing benefits and costs occurring at different points of time in comparable terms. A failure to apply discounting techniques means that decision-makers cannot determine whether the capital resources would add greater economic welfare to the economy if directed to other uses. More generally, the absence of discounting will result in the improper allocation of investment resources for the objective of maximizing the economic contribution of public infrastructure.

It is important not only to discount benefits and costs but also to use the appropriate discount rate in discounting. If the rate is too high, we will wrongfully reject projects whose benefits are concentrated in the later years of its life-cycle. If the rate is too low, we will accept projects whose benefits are too far in the future to justify investment today.

Start-date

The economic worth of an investment can be sensitive to the start-date. Particularly, this sensitivity can result because of the timing of traffic growth, especially for investments that draw progressively greater benefits as traffic grows. This sensitivity can also result because downstream benefits are worth less than early benefits.

Maximizing net present value with respect to start-date requires that many of the variables be dependent on start-date. Specifically, the streams of net benefits over the life-cycle of a project be should calculated for every year over an extended period. Directly using the criterion of net present value requires calculating net present values for consecutive years of start-date over the extended period. Directly using the timing rules requires calculating the project value for every year over the extended period.

Regulations

Federal regulations on economic analyses of transportation investments require some of the elements necessary for an economic analysis of investment timing. Three such regulations are discussed below.

Executive Order No. 12893 (1994)

This document sets forth principles for Federal Infrastructure Investments. The order requires all Federal agencies with infrastructure responsibilities to conduct systematic analysis of expected benefits and costs for all infrastructure investments, including both quantitative and qualitative measures, in accordance with the following guidelines:

> (1) Benefits and costs should be quantified and monetized to the maximum extent practicable. All types of benefits and costs, both market and non-market, should be considered. To the extent that environmental and other non-market benefits and costs can be quantified, they shall be given the same weight as quantifiable market benefits and costs.
>
> (2) Benefits and costs should be measured and appropriately discounted over the full life cycle of each project. Such analysis will enable informed tradeoffs among capital outlays, operating and maintenance costs, and nonmonetary costs borne by the public.
>
> (3) When the amount and timing for important benefits and costs are uncertain, analyses shall recognize the uncertainty and address it through appropriate quantitative and qualitative assessments.

OMB Circular A-94 (OMB, 1992)

This circular gives guidelines for cost-benefit analysis of Federal programs. The Circular 1) recommends cost-benefit analysis as the technique to use in a formal economic analysis of government projects; 2) recognizes net present value as the standard criterion for making decisions on government projects on economic principles; 3) requires the use of a real discount rate of 7 percent in discounting future benefits and costs measured in constant dollars; and 4) requires that the effects of uncertainty be analyzed and reported. Restated below are three related sections from the Circular:

5a. The standard criterion for deciding whether a government program can be justified on economic principles is net present value -- the discounted monetized value of expected net benefits (i.e., benefits minus costs). Net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Programs with positive net present value increase social resources and are generally preferred. Programs with negative net present value should generally be avoided.

8b1. Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years.

9. Estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. Because such uncertainty is basic to many analyses, its effects should be analyzed and reported. Useful information in such a report would include the key sources of uncertainty; expected value estimates of outcomes; the sensitivity of results to importance sources of uncertainty; and where possible, the probability distributions of benefits, costs and net benefits.

Criteria for New Starts

The Federal criteria for new starts during the period 1976-1984 rely on cost-effectiveness measures with little attention devoted to the criterion of net present value (Johnston and DeLuchi, 1989). This is reflected in UMTA's policy statements (UMTA, 1976; 1984). Despite OMB Circular A-94 and Executive Order 12893, Federal Transit Administration continues to rely on cost-effectiveness measures (FTA, 1994). The FTA policy paper on selection criteria now describes cost-benefit analysis as the desirable basis for project evaluation. The agency, however, rejects the use of cost-benefit analysis in the actual evaluation because it believes that the problems of quantification are too great. Johnston and DeLuchi (1989) believe that FTA overestimates the problem of quantifying benefits and costs in conducting cost-benefit analysis for major transit investments.

Current Practice

Current practices of investment analysis for major transportation investments do poorly in meeting Federal regulations. These regulations recommend that:

- net present value be used as the evaluation criterion;

- annual benefits and costs be measured in constant dollars for the full life of a project;

- annual benefits and costs be discounted at a real discount rate of seven percent to calculate net present value; and

- uncertainty be analyzed.

However, a 1990 survey of 35 transportation projects conducted for NCHRP Project 2-17(1) (Lewis, 1992) indicates that:

- only about a third of the projects examined use net present value as a basis for evaluation;

- most projects fail to express costs and benefits on an annual basis over the life-cycle of the project;

- a large number of studies failed to use an appropriate analysis period;

- only about five percent use adequate discounting techniques and properly justified discount rates; and

- issues related to uncertainty were largely ignored.

The sample of 35 projects includes 10 airport and air traffic control-related projects, 10 highway projects, 6 public transit proposals, 2 high speed rail systems, five ports, and 2 inland waterway projects. The sample was drawn from a larger universe with a four-factor stratification: location and scale, mode, type, and point of approval. Location and scale covers national, regional and local projects, and project size; mode covers highway, public transit, rail, ports, airports, and inland waterways. Type covers construction, reconstruction, and repair. Point of approval covers appraisals in progress, projects rejected, and projects approved (including projects completed, projects in-progress, and those not started).

In addition, analysis is typically not undertaken in current practice to determine the most appropriate timing or start year of projects. This is not surprising. Federal regulations on investment analysis fail to recognize the importance of investment timing, though some federally-sponsored conferences and research projects do (Lewis, 1992; FHWA, 1996).

Chapter 9
RECOMMENDATIONS

This report has shown the importance of investment timing and presented theoretical principles for considering timing of major transportation investments. However, the report has also revealed a number of issues that need to be resolved in order to incorporate investment timing in evaluating and making decisions for major transportation investments. These issues include:

- Election cycles, discretionary project funding, and politicians' desire for action now create biases toward early implementation of major transportation projects.

- Federal regulations on investment analysis for major transportation investments fail to recognize the importance of investment timing and even cost-benefit analysis in the case of transit new starts.

- Current practices of investment analysis appear insufficient to meet Federal requirements for cost-benefit analysis, deal with uncertainty, and consider investment timing.

- Traditional rules reinforce the bias from election cycles, discretionary project funding, and politicians' desire for action now toward early implementation.

In an era of scarce resources, it is important to improve the economic worth of investments in transportation infrastructure. One approach is through better analysis and decision-making regarding the timing of these investments. To address these issues, the following are recommended:

Use Net Present Value as an Acceptance Criterion

Any project with a positive net present value may be regarded as acceptable under the objective of improving economic welfare and standard of living. A positive net present value means that a project contributes positively to both productivity and growth. As an acceptance criterion, net present value rejects projects in which the value of any contribution to productivity and growth is less than the economic costs to be incurred in achieving that contribution. The criterion of net present value may be supplemented by other criterion. However, it should be used for all major transportation investments.

Improve Cost-Benefit Analysis

The validity of the net present value criterion, however, hinges on an adequate cost-benefit analysis. As the survey for NCHRP 2-17(1) indicates, current practice of cost-benefit analysis needs improvements, particularly in the following three areas.

Annualize Benefits and Costs. A key requirement of any investment analysis under the net present value criterion is an accounting for annual benefits and costs realized over the life-cycle of a project.

Discount Benefits and Costs Appropriately. Because a dollar tomorrow is worth less than a dollar in hand today, future costs and benefits must be discounted to comparable worth today. The accepted approach is to calculate the present value of benefits and costs using a discount rate. The same rate should be used for both benefits and costs. The choice of the correct discount rate is also important. A rate of seven percent is recommended for all Federal projects when benefits and costs are in constant dollars. If the rate is too high, we will wrongfully reject projects whose benefits are concentrated in the long run. If the rate is too low, we will accept projects whose benefits are too far in the future to justify investment today.

Use An Appropriate Analysis Period. A properly done cost-benefit analysis requires using the life-cycle of a project as the analysis period. If an analysis period is too short, the project under consideration would in fact generate benefits well beyond the analysis period. As a result, these benefits would be excluded.

Consider Investment Timing in Decision-Making

Many factors may have contributed to a reluctance to consider timing in the current process of decision-making for major transportation investments. All but a few factors can be incorporated into a formal analysis of investment timing. It is often perceived that the election cycles bring opportunities that may not be duplicated in the future. Also, decision-makers tend to have a strong desire to do something and do it now. Both factors create a bias toward early implementation of investments. One effective approach to overcome these may be to require that all major transportation projects pass a test on the net present value criterion.

Consider Timing in Investment Analysis

For investment timing to enter the decision-making process for major transportation investments, a critical factor is to consider timing issues in investment analysis. The fundamental shortcoming of the current process and the opportunities for revisiting current practice merit serious consideration.

Reflect on Timing Issues

At a minimum, planners should seriously reflect on the issues of investment timing. These include the importance of investment timing in improving the economic worth of investments, barriers that prevent timing being considered in analysis and decision-making, and how investment timing may be incorporated into the current process of investment analysis for major transportation projects. Planners should be prepared to educate decision-makers on the issue of investment timing.

Use Economic Principles for Optimal Timing

Preferably, there would be efforts by planners to use economic principles of investment timing to find the optimal timing. This would include applying these principles to determine whether a proposed project should be delayed and how much it should be delayed. Chapters 5, 6, and Appendix A offer many of these principles under conditions of certainty.

Include Built-Later Alternatives

To find the optimal timing for an investment, one would need to estimate a series of net present values across an extended period of possible investment timing. The timing is optimal when net present value reaches its maximum. Doing this could mean an enormous efforts because, in order to estimate this series of net present values, one first needs to estimate a series of annual benefits and costs over the project's life-cycle for each net present value estimated.

One way to reduce these efforts is to only estimate net present values for a few years over an extended period. For example, net present value may be estimated for every five years over a period of 30 years. One can then choose the year that gives the largest net present value. This less extensive approach may not result in the optimal timing but will result in an improvement over what can be achieved if investment timing is ignored completely. These build-later alternatives can be analyzed along with those currently required for major transportation investments.

Use Proxy Variables to Time Implementation

As an approximation, proxy variables for net present value may be used to time investments after an initial decision of build-later. In the initial analysis, planners may evaluate the sensitivity of the project's net present value to variables that are closely related to market conditions and are readily measured. These could include population or employment in a given market area, roadway congestion, parking price, bus transit ridership levels or market share, and population density. The purpose is to determine the level of a particular proxy variable at which the project reaches its maximum net present value. Thus, rather than directly using net present value or time as the flag for implementation, one could establish performance or condition targets as triggers for implementation. This type of indicator might reinforce the logic of the delay, provide an incentive for policies designed to help build transit market and provide clear flags for decision makers and the public.

Deal with Uncertainty

Uncertainty prevails in project appraisal. The importance of uncertainty in transportation planning is increasingly being recognized (Mierzejewski, 1996).

Use Traditional Approaches

Traditional approaches to addressing uncertainty include sensitivity analysis, scenario analysis, and risk analysis. Sensitivity analysis evaluates how sensitive the initial investment timing and the corresponding net present value are to changes in one of the many assumptions in an analysis. Scenario analysis, on the other hand, evaluates this sensitivity with respect to a set of assumptions that represent likely future scenarios. Unlike sensitivity analysis or scenario analysis, risk analysis assigns a distribution on each assumption and produces distributions for investment timing and net present value, respectively (Pouliquen, 1970; Lewis, 1995).

Account for the Value of Waiting

None of the traditional approaches to dealing with uncertainty, however, account for the value to waiting. When a project can be delayed and is irreversible once built, this value can be large. There is an opportunity cost of making an investment today by giving up the option of waiting for new information. There is the possibility that new information is so unfavorable that the investment should never be built.

One way to capture the value of waiting is the option valuation approach (Dixit and Pindyck, 1994; Martzoukos and Teplitz-Sembitzky, 1992). The World Bank has studied it for power plant planning (Crousillat and Martzoukos, 1991). The results of a simple model under this approach are discussed in Chapter 6 and Appendix A.

The approach also offers a timing rule for determining whether a today's investment is premature, overdue, or optimal in timing. If the resulting decision is waiting, the timing rule is used again in the same way in a subsequent analysis of the investment. There are two basic approaches to determine when a subsequent analysis should be done: the time approach, in which subsequent analysis is done on a fixed schedule, and the event approach, in which the timing of subsequent analysis is triggered by particular events (Intriligator and Sheshinski, 1986). There is also the hybrid approach, in which either time or some event or set of events can trigger a subsequent analysis. Generally, it is preferable to have events influence the timing of subsequent analysis.

Sponsor National Forums

The Transportation Research Board should sponsor workshops, symposiums, or sessions in annual transportation meetings on issues related to investment timing. These could include theories, applications, decision-making, case studies, problems, and guidance.

Appendix A
MODELS

This appendix presents a basic model, derives the timing rules as shown in Chapter 6, compares these timing rules, and derives the growth conditions discussed in Chapter 5.

Basic Model

From investing in a major transportation project, society incurs capital costs to construct the project and enjoys a stream of *annual benefits* (net of operating, maintenance, and other societal costs) over the project's lifetime. To quantify these benefits, the stream of annual benefits is first discounted to the year of implementation and summed (the sum is called the value of the project, or simply *project value*). This sum is then compared with capital costs and, the difference is called *net project value.* Net project value becomes net present value if the discounting is to the current year. Timing decisions are based on either net project value or net present value, depending on investment objectives.

Time affects net project value or net present value in at least three ways. First, as a project ages, its annual benefits may change with changes in the economy or age-induced operation and maintenance costs. For example, growth in the economy may increase the annual benefits of a project for a given level-of-service. A rail project may carry more passengers as the population and employment in the service area increases. Also, physical deterioration may require expensive maintenance and replacement to maintain a given level-of-services and, as a result, drive down annual benefits.

The second way that time affects the economic value of a project is through the timing of investment. On one hand, postponing an investment may require a different level of construction cost because of changes in real costs for construction. Postponing a project also may result in a different stream of annual benefits because of changes in the demand for and supply of its services. To simplify matters, this paper focuses on annual benefits as the dominant source of change. Chu and Polzin (1996) consider both factors. On the other hand, postponing reduces the present values of a given amount of construction costs and a given stream of annual benefits. The net result of postponing can be significant. It is possible to increase the net present value of a project by postponing it. It is even possible that postponing a project will change its net present value from a negative amount if constructed today to a positive amount if constructed later.

The third way that time can affect the economic value of a project is through uncertainty in its capital costs and annual benefits. There is a value of waiting to invest when the project can be delayed and is irreversible. This value of waiting exists because waiting maintains the option to invest and makes it possible to adopt a better decision when new information arrives. To simplify matters, we focus on annual benefits as the dominant source of uncertainty. Crousillat and Martzoukos (1991) consider uncertainty for both costs and benefits.

The following model, adopted from Dixit and Pindyck, incorporates these effects of time on the economic value of a major transportation investment. The following are assumed:

1. Suppose that a community must decide when to invest in a single project, which has two important characteristics. First, the costs are at least partly irreversible; in other words, sunk costs that cannot be recovered. Second, the project can be delayed so that the community has the opportunity to wait for new information to arrive about market conditions before it commits resources. Major transportation investments typically show both characteristics.

2. Annual benefits of the investment, B(t), change over time with the following characteristics: a) the current value of annual benefits is known, but future values are lognormally distributed with a variance, σ^2; and b) annual benefits are expected to grow at an annual rate given by $\alpha > 0$. Both α and σ are fixed.

   Mathematically, annual benefits follow a geometric Brownian motion. Brownian motion is a continuous time Markov stochastic process, in which only the present state of the variable determines what may happen to the variable in the future. When the natural logarithm of a variable follows a Brownian motion, the variable is said to follow a geometric Brownian motion. One advantage of this particular form of uncertainty is that the problem of maximizing expected net present value has a closed solution.

3. The cost of the investment in today's dollars, K, is known and fixed. As mentioned earlier, we focus on annual benefits as the dominant source of changes and uncertainty.

4. The community determines a point at which it is optimal to invest. How the community determines this depends on its objective and whether uncertainty exists. Its objective may be simply to achieve a positive net present value, to maximize the net present value of the project under conditions of certainty, or to maximize the expected net present value under conditions of uncertainty.

The net present value of the project is given by

$$NPV(t) = (V(t) - K)e^{-\rho t} \tag{1}$$

where ρ is a discount rate and V(t) is the value of the project if the investment is made at time t. It can be shown that V(t) relates to B(t) in the following way (Dixit and Pindyck, 1994, p. 144):

$$V(t) = E\int_t^{\infty} B(s)e^{-\rho(s-t)}\,ds = \frac{B(t)}{\rho - \alpha} \tag{2}$$

where E denotes the expectation. For the problem to make sense, we must also assume that $\alpha < \rho$; otherwise waiting longer would always be a better policy.

The Case of Positive NPV

If the community's objective is to achieve a positive net present value, it will invest when NPV(t) > 0 or, the following is true:

$$V(t) > K \tag{3}$$

regardless of whether uncertainty exists. If today's project value V(0) > K, the community would invest now, even though project value will grow later. If V(0) < K, it would wait until project value exceeds capital costs. There is a value to waiting when V(0) < K because eventually V(t) will exceed K. The net present value of the project, W_T, at the time of investment T is:

$$W_T = (V(T) - K)e^{-\rho T} \tag{4}$$

Timing rule (1) is from equation (3), which extends the basic investment rule that invest if the net present value of a project is at least as large as its capital costs; never invest otherwise. Rule (2) can be derived from rule (1) using the relationship between project value and annual benefits in equation (2). Rules (1) and (2) apply under conditions of both certainty and uncertainty. Rule (3) can be derived from rule (1) and equation (6) below. Specifically, one can solve for t in rule (1) by first substituting V(t) in equation (6). Rule (3) is only applicable under certainty. Under uncertainty, one can only determine the expected length of the period at which the net present value is positive. This expected length can differ from T_T shown in Table 1. Rules (1) and (2) apply under both certainty and uncertainty.

The Case of Certainty and Maximizing NPV

When annual benefits are certain, the standard deviation, σ, becomes zero. It can be shown then that future values of annual benefits become (Dixit and Pindyck, 1994):

$$B(t) = B(0)e^{\alpha t} \tag{5}$$

where B(0) is today's annual benefits. That is, annual benefits grow at an annual constant rate of α. This is a common assumption in the literature of investment timing under certainty. Combining equations (2) and (5) gives the following equation for future project values:

$$V(t) = V(0)e^{\alpha t} \tag{6}$$

The community can determine a future time to invest from maximizing the net present value of the project given by equation (1). The net present value of the project will become positive at some point even if today's project value V(0) < K, because eventually V(t) will exceed K. One difference between this case and the case of positive NPV is that even if V(0) now exceeds K, it may be still better for the community to wait rather than invest now. The maximum net present value of the project, W_C, is V(0) - K if $V(0) > \rho K/(\rho-\alpha)$; it is the following otherwise:

$$W_C = \frac{\alpha K}{\rho - \alpha}\left[\frac{(\rho - \alpha)V(0)}{\rho K}\right]^{\rho/\alpha} \tag{7}$$

Timing rules (4)-(6) can be derived from maximizing net present value in equation (1) with future project values given in equation (6). Specifically, the first-order condition is

$$-[(\rho - \alpha)V(t) - \rho K]e^{-\rho t} = 0 \tag{8}$$

As long as today's project value V(0) is not too much larger than capital costs K, it is optimal to wait. Alternatively, as long as today's annual benefits B(0) are not too much larger than annual interest costs, it is optimal to wait. Rules (4) and (6) result from solving equation (8) for the ratio of V(t) and K and for timing t, respectively. Rule (5) can be obtained from rule (4) and the relationship between project value and annual benefits in equation (2).

The Case of Uncertainty and Maximizing Expected NPV

Under uncertainty, B(t) evolves stochastically. One will not be able to determine a future time for investment as it could from maximizing expected net present value. Rather, one can derive a critical value of project value, at which it is optimal for the community to invest.

Using methods of dynamic programming or contingent claims analysis, Dixit and Pindyck (1994) show that it is optimal to invest when the value of the project exceeds a critical value given by:

$$V^{*} = \frac{\beta}{\beta - 1} K, \tag{9}$$

where

$$\beta = 0.5 - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - 0.5\right) + 2\frac{\rho}{\sigma^2}} \tag{10}$$

Thus, rule (7) holds: invest when $V(t)/K \geq \beta/(\beta-1)$. Rule (8) results from rule (7) using the relationship between annual benefits and project value shown in equation (2). Unlike under certainty, where the critical value for timing is optimal, the critical value for timing in rule (9) is the expected value of optimal timing. As shown by Martzoukos and Templitz-Sembitzky (1992), the expected optimal timing is given by:

$$T_U = \frac{1}{\alpha} \log\left[\frac{\beta}{\beta - 1} \frac{K}{V(o)}\right] \tag{11}$$

The maximum expected net present value of the project is given by the following:

$$W_U = (V^{*} - K)\left[V(0)/V^{*}\right]^{\beta} \tag{12}$$

Comparisons

One way to compare these timing rules is through comparing the critical values. In fact, the following relationships are true: $C_T < C_C < C_U$; $B_T < B_C < B_U$; and $T_T < T_C < T_U$. The relationship among the critical values of timing follows that for the critical values of V/K. To see the other two relationships, notice first that $C_T < C_C$ and $B_T < B_C$ because $\rho > \alpha > 0$. To see $C_C < C_U$ and $B_C < B_U$, we use a relationship from Dixit and Pindyck (1994, p. 145):

$$\frac{\beta}{\beta-1} = \frac{\rho}{\rho-\alpha} + \frac{1}{2}\frac{\sigma^2\beta}{\rho-\alpha} \tag{13}$$

As a result, we have the following relationships between see C_C and C_U and B_C and B_U:

$$B_U = B_C + \frac{1}{2}\sigma^2\beta K > B_C \tag{14}$$

and

$$C_U = C_C + \frac{1}{2}\frac{\sigma^2\beta}{\rho-\alpha} > C_C \tag{15}$$

Thus, maximization of net present value under certainty defers investment so as to take advantage the possibility that annual benefits and hence net present value of the project will grow later. Furthermore, uncertainty defers investment so as to receive more information about the future evolution of uncertain annual benefits and project value.

Growth Conditions

To show the three growth conditions under certainty in Chapter 5, let s represent project age (or more precisely, s-t present project age) and B(s,t) be annual net benefits, depending on both investment timing and project age. The three specific growth conditions, growth without shift, upward shift, and horizontal shift, correspond to the following three special cases of annual net benefits:

$$B(s,t) = B(s) \tag{16}$$

$$B(s,t) = B(s-t)e^{at} \tag{17}$$

$$B(s,t) = B(s-t)e^{bs} \tag{18}$$

where both a and b are positive parameters. In each of these cases, project value grows with investment timing. Annual net benefits and project value relate as follows:

$$V(t) = \int_{t}^{\infty} B(s,t)e^{-\rho(s-t)}ds \tag{19}$$

assuming a very long life cycle for the project.

Appendix B

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