

13

CHOICES MODEL FOR SUSTAINABLE PORTFOLIOS OF  
INFRASTRUCTURE FACILITIES

By

Roger H. Evje

B. S. In Civil Engineering  
Northern Arizona University (1996)

Submitted to the Department of Civil and Environmental Engineering  
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE  
in Civil and Environmental Engineering  
at the

Massachusetts Institute of Technology

December 1997

[February 1998]

© 1997 Massachusetts Institute of Technology. All rights reserved.

Signature of Author.....  
Department of Civil and Environmental Engineering  
December 17, 1997

Certified by.....  
John B. Miller  
Professor of Civil and Environmental Engineering

Accepted by.....  
Joseph M. Sussman  
Chairman, Department Committee on Graduate Studies

FEB 18 1998



# **Choices Model for Sustainable Portfolios of Infrastructure Facilities**

by

Roger H. Evje

Submitted to the Department of Civil and Environmental Engineering  
on December 17, 1997, in partial fulfillment of the  
requirements for the degree of  
Master of Science  
in Civil and Environmental Engineering

## **Abstract**

In the United States, public entities have hit a spending wall in their ability to finance infrastructure repair and creation. Privatization, or public-private procurement, is being considered as an option to traditional tax-supported work. CHOICES II is a spreadsheet based computer program written to support this transition. It is a strategic tool meant to be employed at the preliminary design stage to test projects and portfolios for financial feasibility. CHOICES II uses Discounted Cash Flow, the option of different delivery procurement methods, and the concept of Life Cycle Costs to adjust project parameters and leverage public funds. Implicit is the willingness to incorporate new technologies, construction techniques, and financial considerations as design parameters.

Thesis supervisor: John B. Miller

Title: Assistant Professor of Civil and Environmental Engineering

## BIOGRAPHICAL NOTE

Roger H. Evje earned his undergraduate degree in Civil Engineering from Northern Arizona University in May, 1996. Prior to this, he worked twenty five years in the construction industry. Seventeen of those he ran his own business as a licensed General Contractor. Mixing business and pleasure, he has also found employment as a whiterwater guide, a roped rescue instructor, and a ranch hand. His hobbies include mountain biking, rock climbing, and detective novels. He is married to Kay Evje, an acupuncturist and artist, and has two children, Vanessa Evje, a Russian history scholar, and Audrey Julia Evje, an attorney.

## DEDICATION

To John B. Miller,  
who suggested this thesis and has guided me through it

To Kay Evje,  
who continues to amaze me with her perceptions

To Vanessa and Audrey Evje,  
whose presence in school convinced me that I could do it too

To SAR,  
whose friendship and support made the journey possible

and

To my parents, though deceased,  
thank you for raising me,  
thank you for your love

## TABLE OF CONTENTS

INTRODUCTION-----	page 6
CHAPTER ONE-GENERAL DISCUSSION-----	page 8
CHAPTER TWO-PRIVATIZATION-----	page 12
CHAPTER THREE-A TOOL BOX OF NEEDS-----	page 17
CHAPTER FOUR-THE CHOICES II MODEL-----	page 21
CHAPTER FIVE-CHOICES II AT WORK-----	page 44
CHAPTER SIX-CRITIQUE OF CHOICES II -----	page 46
CONCLUSIONS-----	page 49
FURTHER WORK-----	page 52
BIBLIOGRAPHY -----	page 60
APPENDIX I-INSTRUCTIONS FOR USE -----	page 64
APPENDIX II-INTERMODAL TRANSIT CONNECTOR DATA-----	page 84
APPENDIX III-SENSITIVITY ANALYSIS-----	page 92

## INTRODUCTION

Public infrastructure is that part of the built environment dedicated to the movement of people, goods and supplies. It encompasses roads and airports, pipelines and telecommunications, water and wastewater treatment plants. Infrastructure is the structure that supports the economic growth of a region. The shortfall between public infrastructure needs and public infrastructure budgets has made the procurement of public infrastructure center stage in the construction world. Some love it; some hate it. Most do not understand it.

This thesis will start with a general discussion of financial constraints on infrastructure procurement and the move towards privatization as a solution. It will then note that in the United States, privatization is not new, just being revisited. A sector model of infrastructure delivery systems will be shown. The need for a tool box of techniques will be urged. Chief amongst these is a financial model to be applied as a design parameter during the planning stage. CHOICES II is such a model.

CHOICES II allows the analyst to leverage inadequate public funding sources through a matrix of procurement delivery methods to achieve more societally beneficial infrastructure goals than might otherwise be possible. CHOICES II is an Excel based set of spreadsheet pro formas linked to a summary sheet, called the CHOOSER, that presents myriad data in a coherent form. In its current version, developed using data from the Logan Airport, CHOICES II represents infrastructure procurement from the public point of

view. Plans are suggested for a program rewrite that is more general in nature. Experiments are proposed that might yield some analysis heuristics. The thesis closes with the instruction set for CHOICES II.

If a picture is worth a thousand words, a program is worth more than words and pictures about it. Description is fine but limited. Application and use are where the appreciation lies. The next step in the development of CHOICES II is its use in the design and planning workplace where it can be shaken out further.

## CHAPTER ONE-GENERAL DISCUSSION

The three traditional issues of project management are "that a project should finish under budget, on time, and within scope." Once the contract sum is determined and the initial budget battles are over, time and performance have been viewed as the construction project drivers. In today's climate of public construction financing shortfall, however, several more drivers need to be considered. They include technical feasibility, financing, the governmental permitting process, Life Cycle Costs, social benefits and the political process.

Feasibility is, in the narrow sense, technical possibility; in a broader sense it covers all the variables of a project. Financing can be public bonds and taxation or private loans, concession fees and equity investment. Governmental rules and regulations, permits, and environmental considerations impact the success of a project. Life Cycle Cost analysis augments the typical planning, design, and construction factors by adding land acquisition costs, short- and long-term financing costs, permitting fees, maintenance and operating costs as well as the cost of eventual demolition and disposal to the equation. Social benefits and political concerns evade quantification, are highly subjective, vary over time and can be the success or death of a project. These factors apply to both public and private projects.

This thesis is about a financial tool, a computer program called CHOICES II, which has been written with these variables and the public side in mind.

Government at all levels-national, state, and local-is running out of money to adequately maintain, renew and create infrastructure. The purpose of CHOICES II is to tackle part of the increasing public difficulty in meeting infrastructure needs. It is designed to be invoked at the planning stage as a strategic tool. It is used to provide early cost estimates and alternatives for the portfolio of projects at hand by looking at the cost effects of design, delivery method, finance, construction, maintenance and operations. CHOICES II is designed to work in the governmental paradigm shift towards infrastructure provision and procurement that is now occurring.

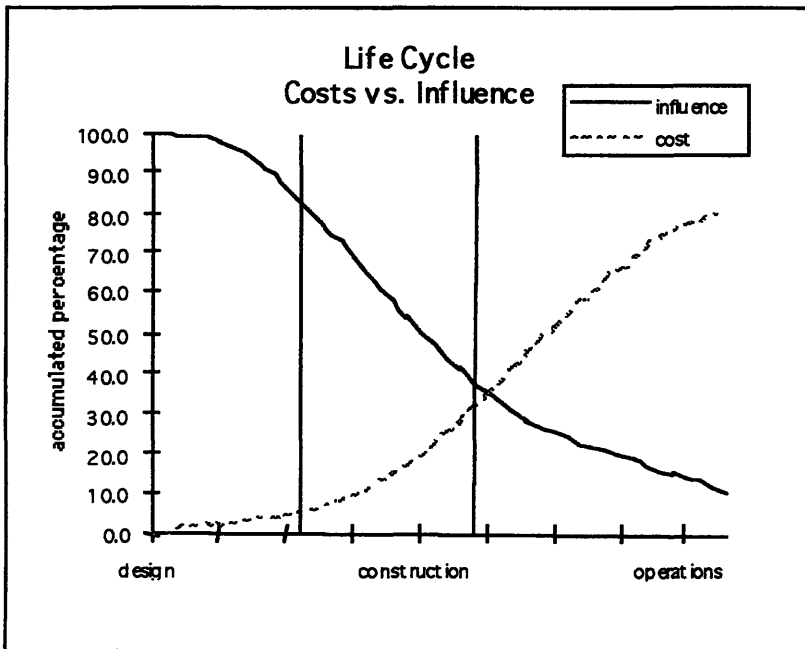
This shift has come about because the public infrastructure planning process, as currently practiced, is flawed. One problem is the local rather than regional outlook that prevails. Since most agencies plan at the local level without reference to one other, the result is often competition for and the inefficient use of existing funds and resources. In spite of mounting evidence to the contrary, many agencies, in the United States at least, cling fondly to the remembered, not so distant days, of seemingly limitless federal funding for every project. These days are gone, lost to taxpayer revolts and a demand for tax reduction. Perversely, in this time of tax and user fee shortfalls, private, non-traditional funding sources may exist but remain untapped due to insular planning views, to legislative restrictions, or to unfamiliarity with the funding sources themselves.

A second problem is that the governmental approach to infrastructure is less a strategic one which seeks to satisfy societal goals than an administrative

approach tactically concerned with the rules of procurement (Lowi 1978). This micromanagement view misses the big picture while swamping itself in the minutiae of detail. Likewise, planning experts churn out forecasts based on an unrealistic confidence and precision in regards to the input data. Forgotten is the larger perspective of input uncertainty and the hindsight that forecasts historically are wrong. This myopia can lead to extensive master plans that generate over- or undercapacity design. These plans then spawn project bids that typically are higher than predicted. The result is projects that do not go forward. Money and time are wasted by the government advancing fully developed plans that cannot be built and by members of the private Architects/Engineers/Contracting professions who bid on them. The public need remains unsatisfied. CHOICES II has been written to alleviate this inefficiency through the early evaluation of project practicality.

Currently in the United States there is a legal environment prejudicial to the success of infrastructure projects. For example, the Brooks Act (Congress 1972) prevents the joint development of construction plans by designers and constructors. Constructibility, innovation, and new technology possibilities are missed at the design stage. In Massachusetts, by law, subcontractors are chosen for public projects two weeks ahead of the general contractor. In the guise of fairness to the public in the form of the lowest bid, unintentional adversarial bad marriages are often created between these important players. The efficiency of proven team work relations is lost. The public suffers the outcome.

Privatization is being hailed as a possible savior for public infrastructure. However, the public side has yet to learn that private capital will not participate in a climate that is punitive, unsophisticated and unwilling to accept efficiency. Private capital is liquid and can easily go where conditions are favorable. CHOICES II is structured to look at the investing climate from the most restrictive to the most liberal. The analyst working in CHOICES II is



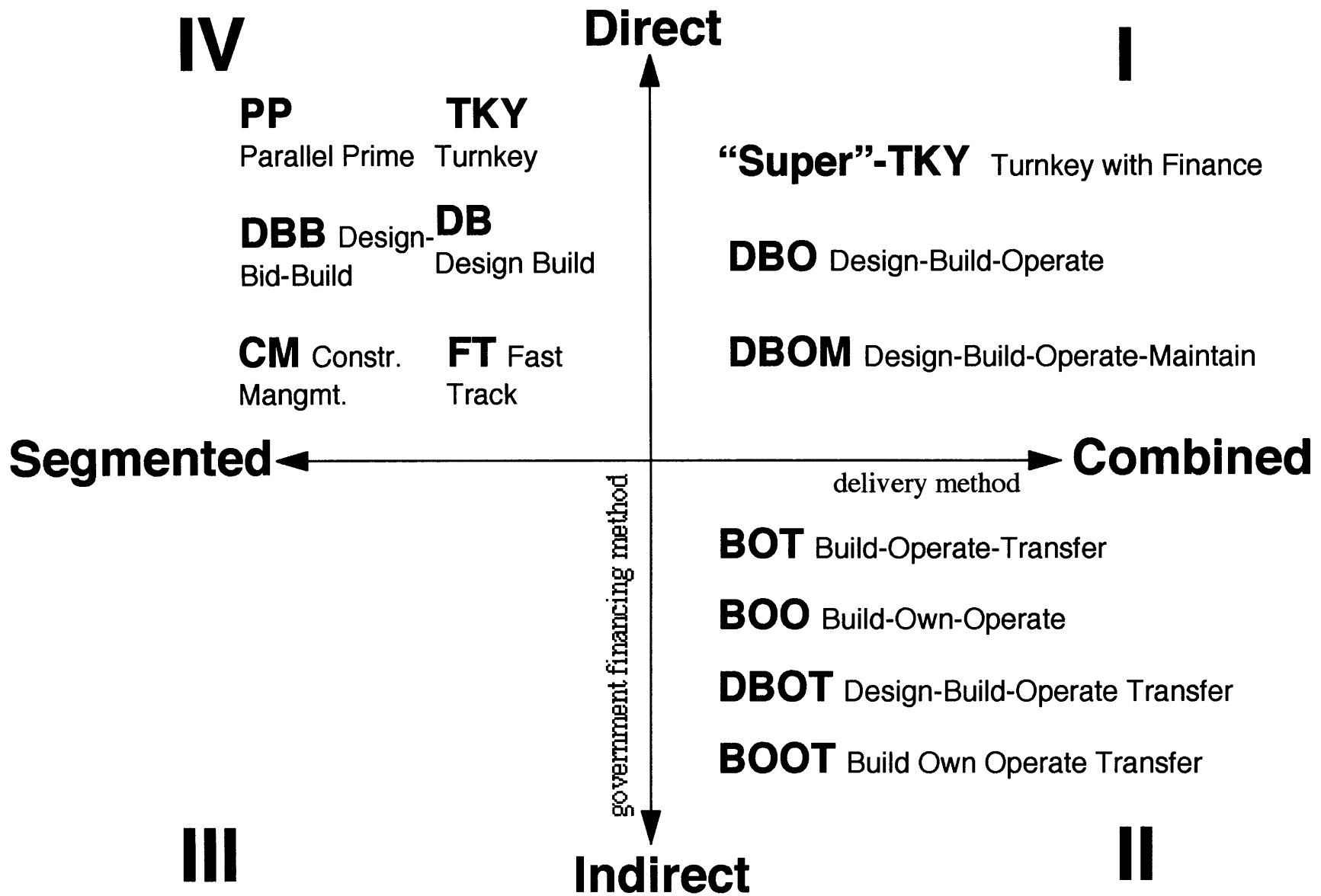
encouraged to look beyond the hurdles and to suggest measures to overcome them. CHOICES II looks beyond the lowest construction bid to Life Cycle Costing since land, financing, design, operation and

maintenance costs can dwarf the contribution of construction.

## CHAPTER TWO-PRIVATIZATION

Privatization is a term that describes the participation of the private sector in projects or enterprises that are under the control of the state. This may include any combination of design, construction, maintenance, operation, and financing. Similar terms gaining currency are: public-private partnership; contracting out; procurement strategies. No matter the terminology, what is meant is that the private sector provides facilities and/or services in lieu of the government. Privatization is being applied to transportation needs such as roads, seaports and airports; municipal needs such as water or wastewater plants, prisons or schools; telecommunications, power and pipelines; and "pure" public services such as fire departments, medical services, and road maintenance.

The move to privatization in the United States is a response to the past fifty years of "traditional" Design/Bid/Build procurement mentality. In Design-Bid-Build, the government creates a preliminary design program to an approximately five percent design state. Design firms compete in a professional qualification competition to see who will bring the plans to 100%. These plans are then put out to a lowest bid competition. Most often the winning bid does not represent the completed price but is the entry ticket to build the project. Supplemental change orders and court time complete the "as built" price. While there are legitimate uses of Design-Bid-Build, there are definite drawbacks (Gorton 1991). Design-Bid-Build works well for standard,



recurring projects. On unique projects it tends to be higher priced and longer in delivery than some of the options shown in the Miller sector diagram.

The alphabet soup of the this diagram can be reduced to five categories: Design-Bid-Build; Design-Build; Design-Build-Operate; Build-Operate-Transfer; Maintenance-Operation. Design-Build joins the design and construction operations in one firm or joint venture. Advantages usually include a shorter duration from planning through completion, a lesser total price due to innovation and constructability considerations and the lack of adversity between the designer and the contractor. There is a certain loss of fiduciary representation to the client using this method. Design-Build-Operate moves further than Design-Build in combining players by adding the responsibility of project operation and maintenance to the mix. Advantages often include a higher quality project and the use of state of the art technology since the concessionaire will be operating the facility at his or her cost. Design-Build-Operate requires a revenue stream in the form of user fees or government subsidy paid to the operator. Case studies in the water treatment field, for example, indicate that the private side is able to run the plants more efficiently than the public side and at the same time is able to charge water users less in fees (Miller 1997a). Maintenance-Operations, also known as contracting out, is already in use in older, extant projects. Maintenance-Operations can be considered Design-Build-Operate minus the construction. The same comments apply. These four delivery methods are above the horizontal line in the sector diagram since funding flows from and/or is

guaranteed by the government. Build-Operate-Transfer occurs below the line. A Build-Operate-Transfer is much like a Design-Build-Operate except that the private sector provides the construction equity and financing. Like a Design-Build-Operate it counts on a revenue stream or a subsidy for operations, but the risk of this revenue stream is on the developer, not the state. Toll roads with their uncertainty of revenue are an often seen example.

Privatization is just being relearned in this country after being ignored for the past fifty years (Miller 1995). We can look to Hong Kong for a success model of how delivery method variability and privatization are used to achieve strategic societal goals. In Hong Kong, every year, the government generates a wish list of desired projects. Since this list invariably exceeds the capital publicly available, Hong Kong separates the list into revenue generating projects and non-generators and actively encourages the private sector to compete for concession rights to the former. Private interest is keen to bid on these projects as the Hong Kong government provides a transparent, stable environment, fair treatment to all competitors, regulation and rate control for its citizens. By mixing contracting delivery methods, Hong Kong leverages its capital to create more infrastructure than Design-Bid-Build alone could provide. The private side develops those projects that have associated income streams while Hong Kong builds those that have no return but that are important for the city.

Privatization needs a proper environment for success. Drawing on the example of Hong Kong, a government body should choose from its

underfunded infrastructure list those strategic projects which might be considered by the private side. It should then develop them through the preliminary design stage of approximately five percent. This would demonstrate the government's good faith and strategic intention. It should then issue a Request for Proposals that invite interested parties to participate. Teams consisting of designers, engineers, constructors, financiers and operators would proceed through design development to the thirty percent design stage at their own cost. At this point a selection would be made that focuses on financial proposals, innovations, and design achievements. The proposal which best serves the public goals would be chosen. The winning team would then design to 100%, proceed to build the project, and go on to operate it over a time period long enough to paydown the debt and equity. Typically this is fifteen to thirty years.

Both sides in the process will benefit and the public's goals will be achieved. The government invests a small amount defining the scope of the project before knowing its feasibility. The private side understands the intent of the government and is able to propose possible solutions relatively inexpensively in a schematic way. The winning team undertakes the substantial costs of full development as part of its project bid. The public gains a project that otherwise would not have been built. The government, having leveraged its funds in this manner, uses the remainder to proceed with other projects or services.

## CHAPTER THREE-A TOOL BOX OF NEEDS

The use, in the United States, of Sector I and II non-segmented procurement methods, Design-Build-Operate and Build-Operate-Transfer, is currently at the beginning of a learning curve. Tools, time and successes will be necessary for acceptance. Worldwide, to date, some privatization has succeeded, as in the case of the Northumberland Bridge and the Hong Tunnels; some has failed, as in the case of the Mexican toll roads and the Dulles Greenway; some is ambiguous, as in the case of the English Channel "Chunnel" which has bankrupted once and has been restructured to try to create success (Miller 1997a). The passage of time and the occurrence of more privatized projects will create an example base from which to evaluate successes and failure.

Anticipating this base it is necessary to create a tool box of evaluation techniques. The first of these needs to be a financial model which will enable infrastructure analysts to see the effect over time of delivery choices and funding sources on the host agency. It should allow sensitivity studies and delivery option considerations. It needs to be usable in a hierarchical manner by a local agency (say the water department or the road department of a township), by a higher consolidating authority (say the city government looking at public services, roads and schools) or by a yet higher regional authority (say an area transit coordinating authority.) The model must be able

to study infrastructure whether segregated as projects or aggregated as portfolios. CHOICES II is written to be such a tool.

Another tool should be a publicly accessible Moody-type project rating system. This could be a central clearinghouse in which government agencies would file proposed project specifics for independent evaluation and to which the private sector would be subscribers. Good evaluation coupled with private interest will indicate a viable project. A poor rating or a lack of interest and response will indicate the need to rethink the offering. Both sides will gain from the efficient use of their funds, time and effort pursuing mutually worthwhile projects. CHOICES II is a logical tool for this service.

A third needed tool is an easy, early way to weave project cost numbers into the planning process. Too often an elegant solution is fully planned that, when put out to bid, is found to be too expensive to be built. The result is wasted time, energy, expenses and hope. There is a disdain that must be overcome amongst the design profession that when a price is tied onto a project too early the design intent is hampered. Similarly, in the academic world, the importance of pricing is often disregarded when seeking an analytic solution that fits theory. In the real world of construction and financing, costs determine project viability. Incorporated from the start as part of the design process, cost considerations permit early revision and encourage innovation in design, construction, and technology. CHOICES II has been written to be used at this early stage.

Finance needs to be considered a design element. Currently projects are planned in terms of an architectural program or a social need with finance deferred to afterthought status. In the proposed tool box, the availability of and conditions for the use of money are key to the viability of the project. Financial considerations, brought early into the project, can be used to see the project differently. Perhaps it is possible to re-envision the project and identify revenue producing parts that can be put out to the private side. Perhaps the relocation of a project in time can make it feasible. Thinking strategically parallel with designing technically is wise use of money and resources. CHOICES II allows the designer/analyst to easily work financial concerns into the design process.

There is a need for the government to have a better understanding of private side requirements as regards the project's viability and technical feasibility. For example, water systems with established or predictable revenue streams are proving very salable while toll roads with their uncertainty of fare are not. Plans constrained by old technology or allowed only one delivery method do not seem salable. An openness on the part of government to new, efficient technology, to issues of constructability, to new engineering and management tools, and to alternate delivery methods can make the project very desirable to the private point of view. This openness shows the government not only free of hide-bound convention but desirous of the best solution to the problem. CHOICES II, in the hands of the progressive analyst, works in this freer milieu.

There is a need for that integrating discipline called systems engineering in its original sense. This was a team based effort that looked at the bigger picture as well as focused on detailed aspects of it. An example is the NASA effort that put a man on the moon. The maintenance, repair and creation of infrastructure today requires a return to this discipline. Especially in the privatized world, a project that is going to be built needs designers, engineers, constructors, financiers, operators, and attorneys involved in the effort. The regulatory framework needs to be open to this spirit of cooperation. The bigger picture concept means working at a unifying project portfolio level. Interagency cooperation and a true public-private partnership become necessary.

Finally there is a need to develop a body of knowledge, a logic, through which science and engineering can be funneled towards the creation of new infrastructure. One approach is to develop case studies of the privatized work that exists. Analysis needs to be done of the occasioning circumstances, the environment of competition, the awarding mechanism, and the results to date. From these studies, perhaps some "rules of thumb" can be generated that will prove useful when looking at the feasibility of proposed offerings. CHOICES II will prove to be useful as a consolidating tool when developing this logic.

## CHAPTER FOUR-THE CHOICES II MODEL

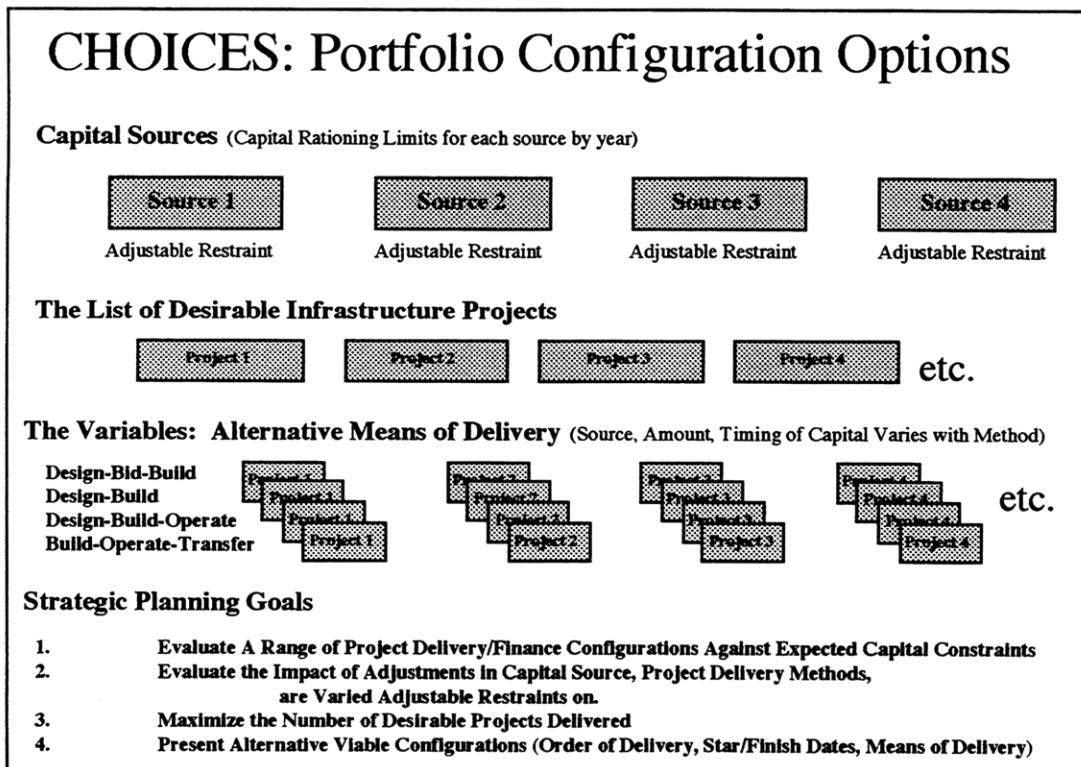
The most central and immediately useful item in the toolbox above is a financial model such as CHOICES II. Such a tool makes it possible to move between the local and the regional points of view to test strategies. It allows the analyst to assume scenarios based on changes in the law regarding allowable procurement methods. It demonstrates the benefits of cooperation between agencies and the need for umbrella authorities.

CHOICES II brings to one place all the financial budgeting data that goes into a privatization inquiry. It incorporates variables such as the time horizon, delivery method options, the costs of planning, design, construction, operations, maintenance, bonding interest, inflation, overruns, and revenue sources. It uses a thirty year span (120 quarters) deemed necessary to handle the typical privatized offering. It incorporates the five available delivery methods-Design-Bid-Build, Design-Build, Design-Build-Operate, Build-Operate-Transfer, Maintenance-Operations-and the variable of timing for starting dates and duration. It considers revenue sources from the point of view of a government agency. Bonding is therefore the norm rather than loans. Federal and state funds may be available. Unlike the private side, costs inputs do not include concerns of tax consequence planning nor depreciation. Since local funding such as the tax base is assumed to be constrained, the authority is looking for other funding. The model assumes unlimited private funding, not unreasonable in today's economy, for quality projects. CHOICES

at funding constraints by period and in total. It is interactive; data entry is possible at any time. It is executable on a PC or a Mac.

The first attempt at CHOICES was made in the Spring of 1997 by an MIT graduate student, Nolan Ryan. Thinking that an optimization program was desired, Ryan made the decision to use MS Excel for its Solver function. He chose a simplified pro forma format to contain and display the data. This first programming effort, as so many initial versions, was clumsy, hard to open, slow to use, and did not perform well. The current version, CHOICES II, while drawing on this legacy version is an entirely new version written during the Fall of 1997.

CHOICES II has been designed to address this problem statement from the

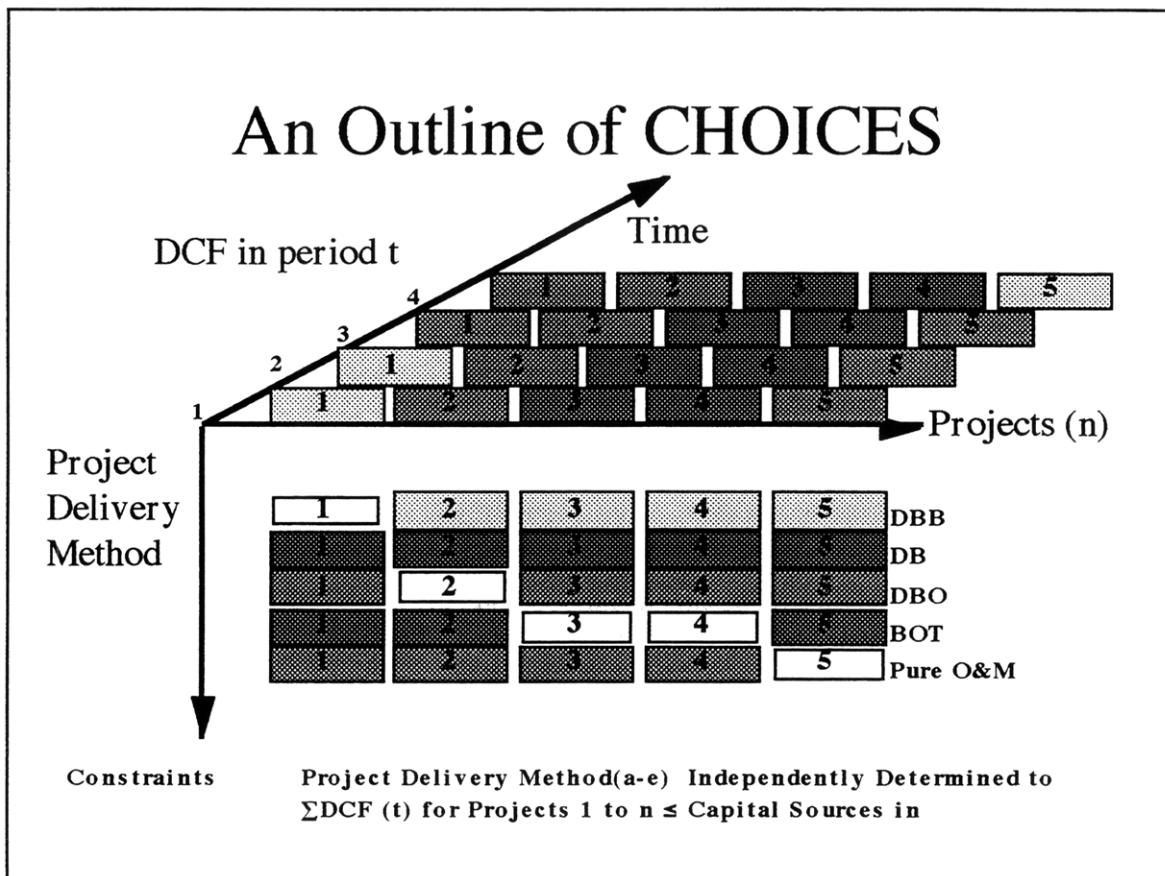


procurement strategy work of John B. Miller (Miller 1997b).

In the first row there are a certain amount of funding sources available. They may be federal, state or local; they may be private. They are subject to constraints and restrictions such as matching requirements, valid use of funds, or designated business entitlements. In the second row there is a wish list of projects that range from massive building projects such as Boston's Central Artery to the more mundane such as pothole repair of the local streets. Significantly, in today's climate, there is insufficient traditional funding to cover all these. The third line suggests an open-minded examination of each and every project to see if there are delivery options available that may serve as an inducement to the private sector to participate.

This problem statement has been refined graphically on page 23. Each column represents a project. Each rectangle in the column marks a delivery method option that may be available for the project. In fact, some projects may only support one kind of method while other projects support several. The skewed line represents the time continuum. A physical analogy may be useful. Let each project represent a many drawer file cabinet. Let the portfolio of projects be many file cabinets banked together. Let there be the restriction that only one drawer per file cabinet may be open at a time. Within each drawer there are time sequential files that represent financial information quarter by quarter for the particular project for the particular delivery method chosen. CHOICES II functions as if the analyst stands to the side and, quarter by quarter, looks across all the open drawers. The sum of this glance is the

# An Outline of CHOICES



delivered results of CHOICES II. By opening and closing different drawers, the analyst discovers the full range of possibilities of the project portfolio.

CHOICES II is an Excel based linkage of pro formas which addresses this problem statement in a dynamic planning environment. It has been written using Excel 5.0 from the Microsoft Office Suite on a Power Macintosh (6100/60). It opens on newer and older Macs as well as IBM PC compatibles. It is currently in a beta version that is being tested in MIT's Construction Management Program. Input is being gathered against a future revision to be called CHOICES III. This revised version is discussed schematically later.

CHOICES II is entirely different than the Spring 1997 CHOICES effort for three reasons. First, the Spring version had huge memory requirements

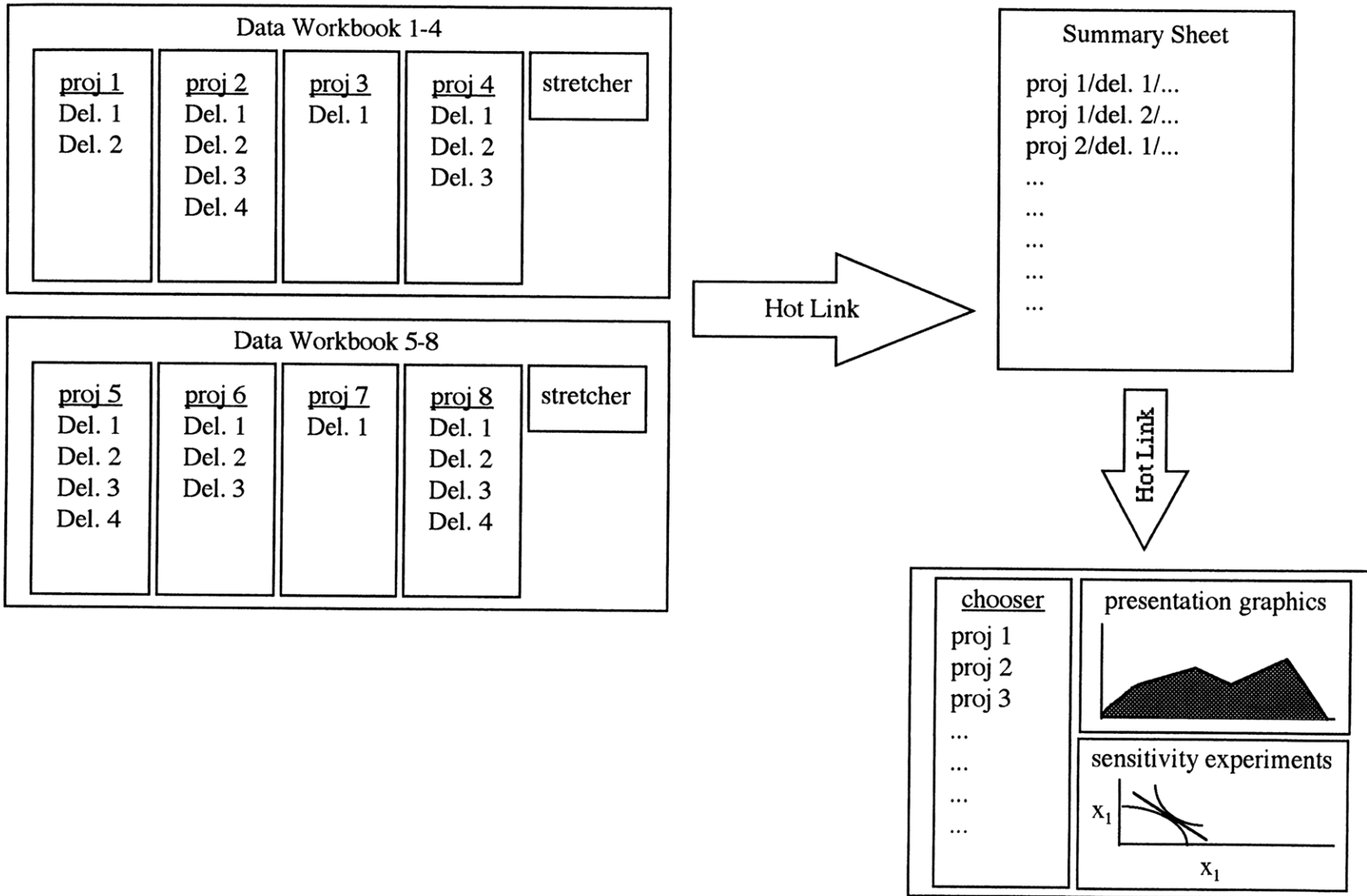
which caused the program to open, operate, and save very slowly. This seems more a function of Excel's Linkage function than computer RAM or processor. Second, little developmental data was left behind that described the logic, intent and assumptions of the program. As there was very little to work with and refine, CHOICES II is essentially written from scratch. Third, it was finally deduced that the Spring version had a top down point of view.

CHOICES II is written instead more from the bottom up.

The top down point of view seems to be the operative norm in government bureaucracies. This point of view contends that, since there are limited financial resources to draw upon, projected capital improvements can only be a function of funding availability. Going to Washington and lobbying for funds seems typical of this mentality. CHOICES II adopts the more optimistic, bottom up point of view. This is the working premise that only quality, worthwhile projects have been placed in the development portfolio. Granted that funding restrictions do exist, the analyst will explore different delivery options, deadlines, delays, and funding sources seeking to achieve a larger, more varied mix of capital. A creative, open-minded, proactive stance characterizes the bottom up approach. By analogy, this is like the old saw of the optimist and pessimist looking at the half full (half empty) cup.

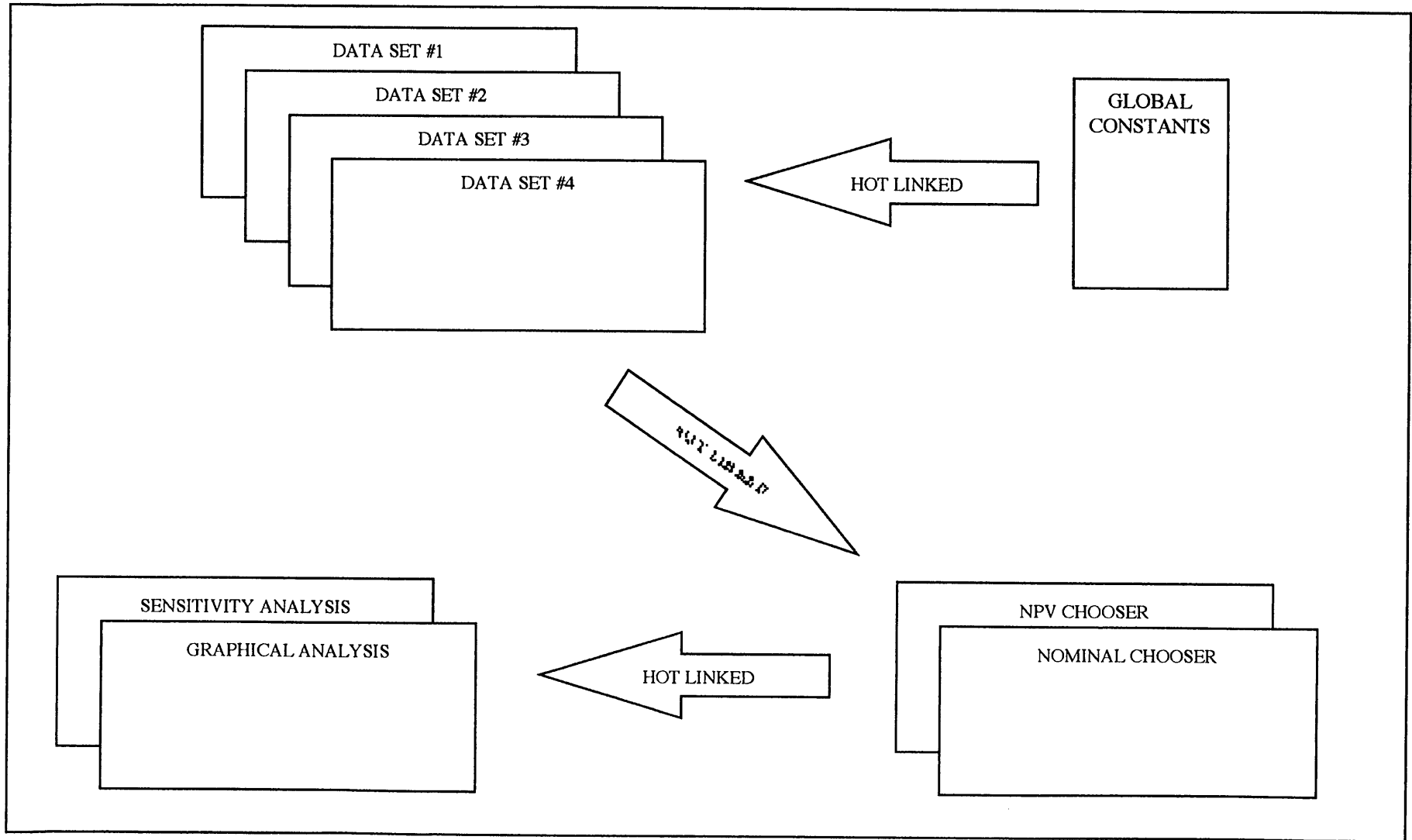
# Use of Excel Spreadsheets to Analyze Project Delivery Methods

(This was the original configuration)

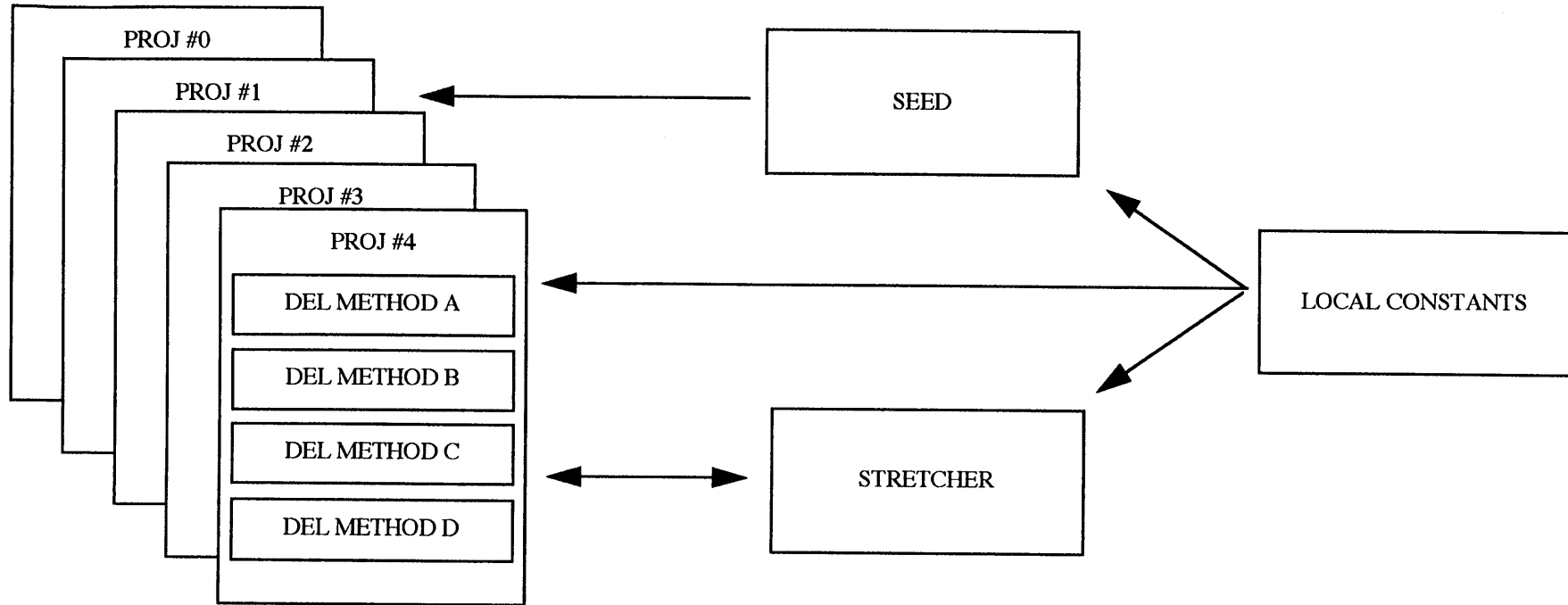


# DETAIL OF INFRASTRUCTURE PACKET

(Global constants added/chooser split for better operation)

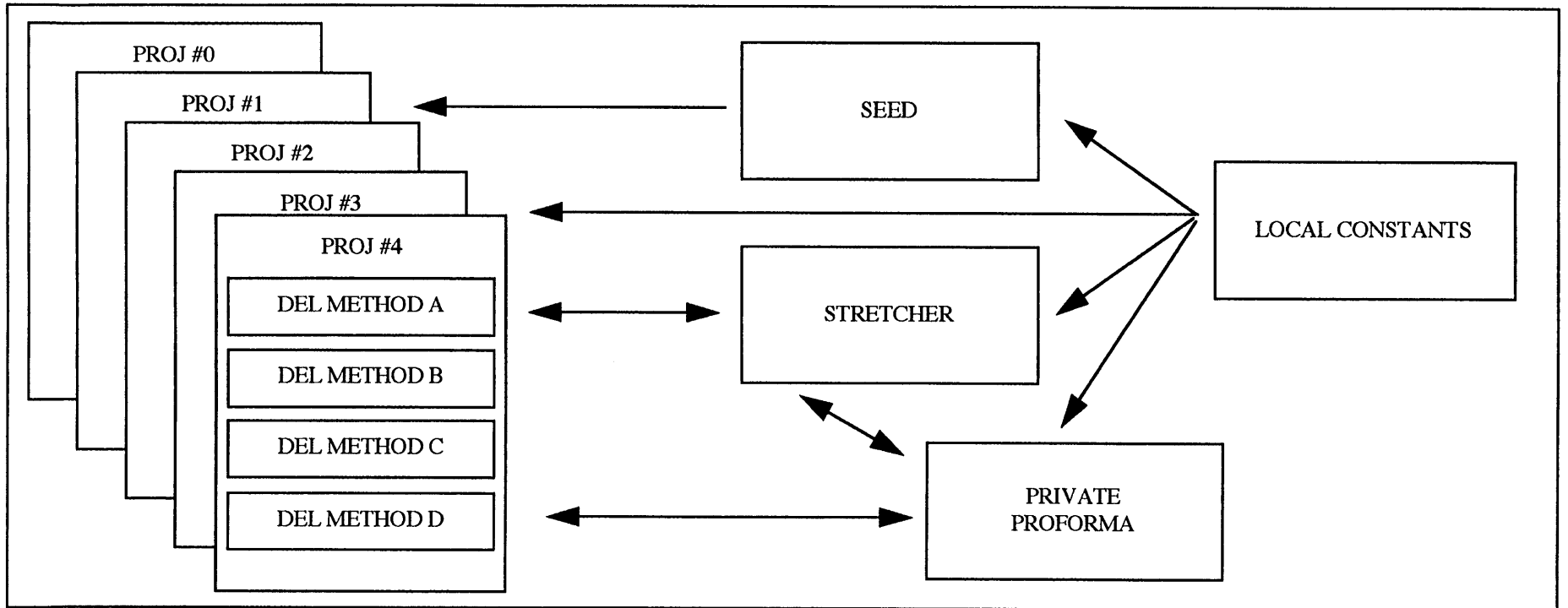


# DETAIL OF DATA SET DS/A (typical)



# DETAIL OF DATA SET

(Provision made for private sector use)



The early versions of the CHOICES II rewrite, influenced as they were by the original Spring version, tried to enter project data in one huge file (~7500+ KB) for its presumed convenience. Consistent out-of-memory problems occurred on all the computers involved independent of RAM size, virtual memory, or the dedicated memory settings of Excel. Consequently a decision was made to spread the project portfolio over four data folders, not the more logical one, to achieve a better running program. These four folders, labeled as DATA SETs in the illustration on page 26, are hot linked as sources to the display program named CHOOSER. While there is a small loss of user friendliness from this arrangement, this is offset by a more robust, stable program.

CHOICES II has been developed and proofed using data generated last year from Prof. John B. Miller's 1.961 seminar, " The People Mover Project at Logan Airport." By the conclusion of the seminar the title had changed to the "Intermodal Transit Connector" and the findings had become regional reflecting the possibility of tying work at Logan Airport into the greater Boston transit network. As an aside, this change to a more global consideration is typical of systems engineering and a program being developed as Engineering Systems Investigation in the MIT Construction Management Program. CHOICES II is being used in this development.

The proofing Intermodal Transit Connector data includes sixteen major projects varying from one to four delivery methods each. All other variables held constant, these sixteen projects represent approximately five hundred

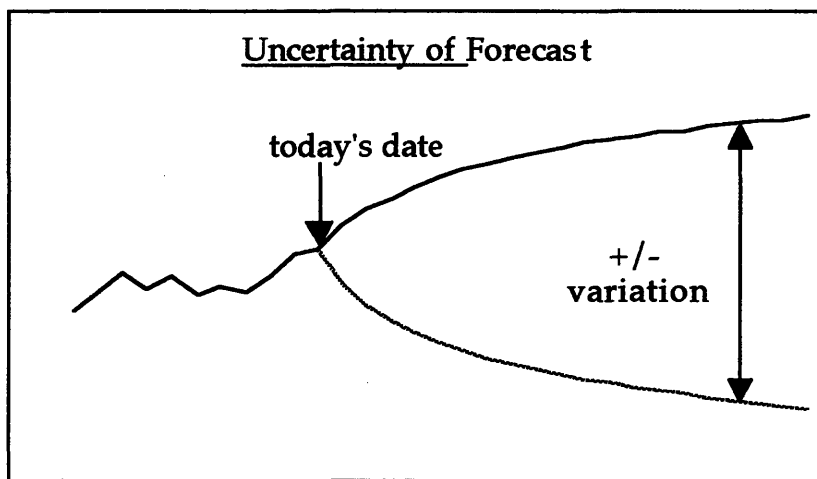
<p><u>Intermodal Transportation Connector Arithmetic</u></p> <p>(1st project @ 1 delivery method) x (2nd project @ 4 delivery methods) x  (3rd project @ 4 delivery methods) x (...@ 2 delivery methods) x (...@ 1 ...) x  (...@ 1...) x (...@ 2 ...) x (...@ 4 ...) x (...@ 1 ...) x (...@ 4 ...) x (...@ 2 ...) x (...@ 4 ...)  x (...@ 2 ...) x (...@ 2 ...) x (...@ 4) x (...@ 4 ...) = 524,288 combinations.</p>
---

thousand possible financial combinations. For any project this number can be compounded by the option of not proceeding, by the adjustment of the construction duration or starting date, and by changing the interest rates, growth rates or user fees. Since this can be done for each project, the number of financial combinations becomes astronomical. CHOICES II tracks this array of data graphically leaving it to the analyst to pick, choose and refine as experience and inclination dictate. The interactive nature allows the analyst to see and act upon the decisions immediately.

The Spring CHOICES model tried for a solution premised on optimization. If optimization were to be desirable, the problem of huge numbers is solvable by modern computers and enumeration. Objective functions and restraint conditions can be written. There is a larger question of the validity of optimization applied so early in the design sequence. All of the input data-construction costs and duration, maintenance an operations costs, interest rates and inflation over thirty years-is guesswork Highly uncertain

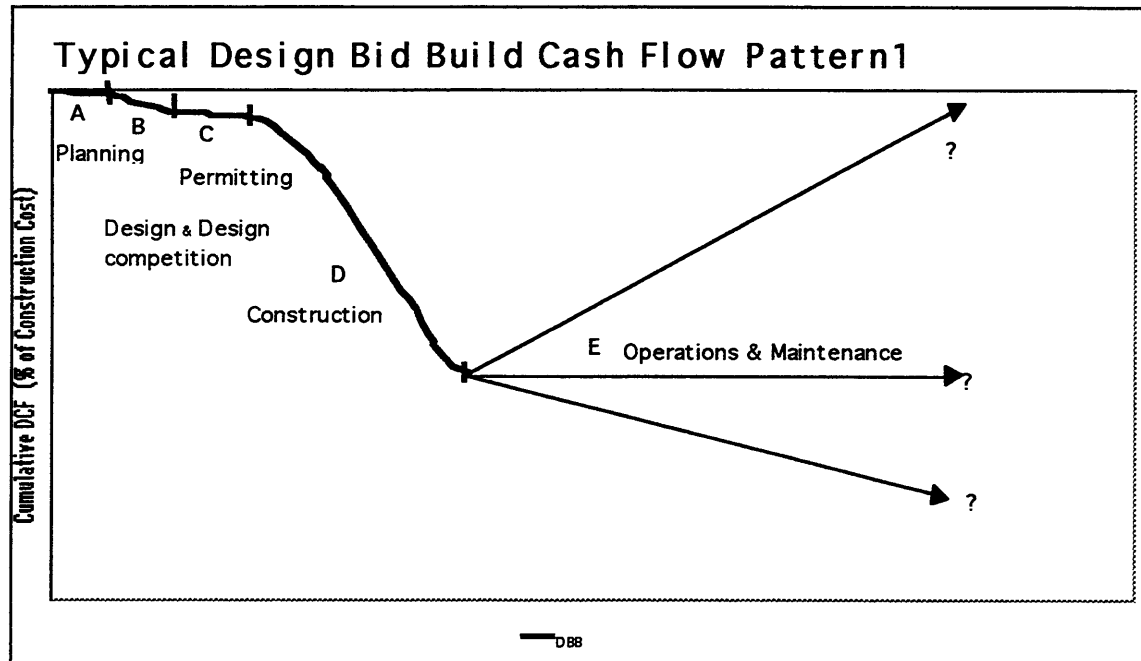
guesswork. In addition to this, the infrastructure portfolio exists in a social, cultural, political context that is not quantifiable. While optimization may suggest a solution when applied to the financials, that solution may be unacceptable otherwise. For example, an optimized financial solution might reject proposed school projects in favor of prison spending when the wishes of the electorate are just the opposite. Allowing that pro formas at best are guesswork

predictions of revenue streams and costs, growth trends, inflation, interest rates and discount factors



over time, there may be merit in looking for near-optimal, good enough, solutions. At the budget stage, optimization implies a precision that is not present and may instill false confidence. For example, in Boston we have the experience of the Central Artery Project which was originally priced at \$2.5 billion currently costing at \$10.8 + billion (Air Travel Journal 1997). Presumably a very detailed analysis preceded the commitment to begin. While some inflation is reflected in the current price, a good deal of uncertainty and real world cost is there also.

CHOICES II is budgeting tool with which to examine "what if" scenarios. It can function as the back of an envelope estimator for a single project or as the



integrator of a portfolio of projects. Different delivery methods can be tried and evaluated. Viable options can be retained and pursued; less viable ones can be discarded. It allows the analyst examining a project to wonder what the next step should be. CHOICES II is written in Excel spreadsheets which, due to the popularity of Excel, makes them understandable and useable to the army of users. CHOICES II uses operator entered data cells, automated "cut and paste," Visual Basic macros and buttons, and hot linkage to intake source data and display it as presentation summaries and graphics.

CHOICES II is written from the point of view of a public entity. Since the public does not pay a tax on its activities, the private side issues of net income before taxes and depreciation are not incorporated. There is the option of a

compensating balance feature that is provided to balance shortfalls and surpluses in each and every period if desired. Since this program was developed using Logan Airport data, bonds rather than loans have been considered the primary source of construction financing. Quarterly periods, rather monthly or annual, are assumed and incorporated into cell formulas. Constants used for interest, growth, discount rate, et cetera need to be entered at a per annum rate. There are one hundred twenty quarters built into this model. Modifications are easily made by a relatively fluent Excel user.

Excel's Linkage function has proved to be troublesome developing this program. Early efforts at consolidated data packets consumed time and were disappointing. Crashes were frequent; opening and saving were slow; things did not feel robust. Consequently four DATA SETs of up to ~2500+ KB are used in lieu of one large one of ~7500+ KB in CHOICES II . Two CHOOSERs, one for Nominal Value calculations, one for Net Present Value, replace the original one. There seems to be a problem with long file names and the Linking function. A folder within a folder within a folder generates a lengthy pathway name. It has been found best to keep the portfolio folder at or near the desktop as this lessens the pathway name. The pathway name should be less than thirty one characters and spaces total. It has also been observed that in transmission over some networks, file names become corrupted. If this happens, correction can be achieved by the skilled use of the Edit:Replace function.

Within a DATA SET, the CONSTANT SHEET is linked as a source to each of the PROJECT SHEETS, the SEED SHEET, and the STRETCHER. All four DATA SETs are linked as sources to the CHOOSERS. In the proposed revision, tentatively named CHOICES III, CHOOSERS from various DATA SETs will be linked as source sheets to a SUPER CHOOSER. A pyramid of data is envisioned from the local on the bottom to the regional on the top. Per the illustrations, the current CHOOSER has already been used for some preliminary sensitivity analysis, experimentation graphics, and custom summaries.

DATA SETs are the workhorses of CHOICES II. They contain information such as : the name and cost of the project; delivery type, duration and start; source and percentages of funding sources; a Nominal Valued pro forma; a net Present Value pro forma; and modifiers such as bond interest, inflation, and construction growth overruns. See Appendix II for a more specific discussion of the working cells of the program.

CHOICES II has an initial data entry block used for the existing obligations of the public entity that takes only one delivery method. There are eighteen additional data entry blocks for the portfolio projects that can take up to four delivery methods each. In the interest of memory conservation, these are generated sequentially as needed. There is a built in sorting function at the DATA SET level that allows the delivery methods within a project to be ranked in ascending or descending order. This ordering enables the analyst, when operating in the CHOOSER, to increase or decrease the portfolio value.

CHOICES II has a STRETCHER function that contains templates for the four delivery methods-Design-Bid-Build, Design-Build, Design-Build-Operate, Build-Operate-Transfer-and the ability to override. The template values have been generated from the People Mover project data and from conversation with private contractors involved in public-private work. The base planning and construction duration values for the templates are as follows:

<b>Delivery Method</b>	<b><u>Planning Phase</u></b>	<b><u>Construction Phase</u></b>	<b><u>Total</u></b>
<b>Design-Bid-Build</b>	<b>16 periods</b>	<b>16 periods</b>	<b>32 periods</b>
<b>Design-Build</b>	<b>15 periods</b>	<b>13 periods</b>	<b>28 periods</b>
<b>Design-Build-Operate</b>	<b>11 periods</b>	<b>13 periods</b>	<b>24 periods</b>
<b>Build-Operate-Transfer</b>	<b>11 periods</b>	<b>13 periods</b>	<b>24 periods</b>

Maintenance-Operations, also called contracting out, can be represented by zeroing out the construction part of any of the templates. Illustrations of the four templates follow. The STRETCHER works as if the template is on a rubber sheet and can be lengthened or shortened. The effects of duration change for Design-Bid-Build, as an example, are illustrated graphically on page 41. With the aid of macro buttons, a delivery template can be entered anywhere within the 120 quarters of the model. The STRETCHER paste line is two hundred forty cells in length to accommodate any template paste need; it is truncated at one hundred twenty cells when being transferred to a DATA SET.

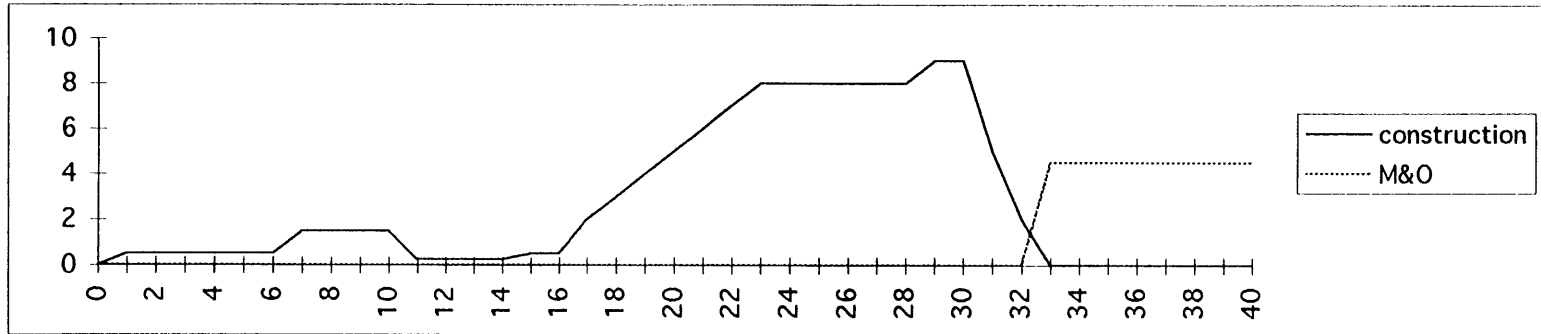
DBB

Project #	xxx
Description	
Delivery Method	1.0
DBB = 1; M&O percent at	18.0
DB = 2; M&O percent at	16.2
DBO = 3; M&O percent at	15.5
BOT = 4; M&O percent at	0.0
Construction starts in period	17
Construction duration (periods)	16.0
Construction ends	32
Paste design zero at this number	0

design period	0	1	2	3	4
construction	0	0.5	0.5	0.5	0.5
M&O	0				

Vary this number from 1-40 to change above values. Template set up at 32

DBB



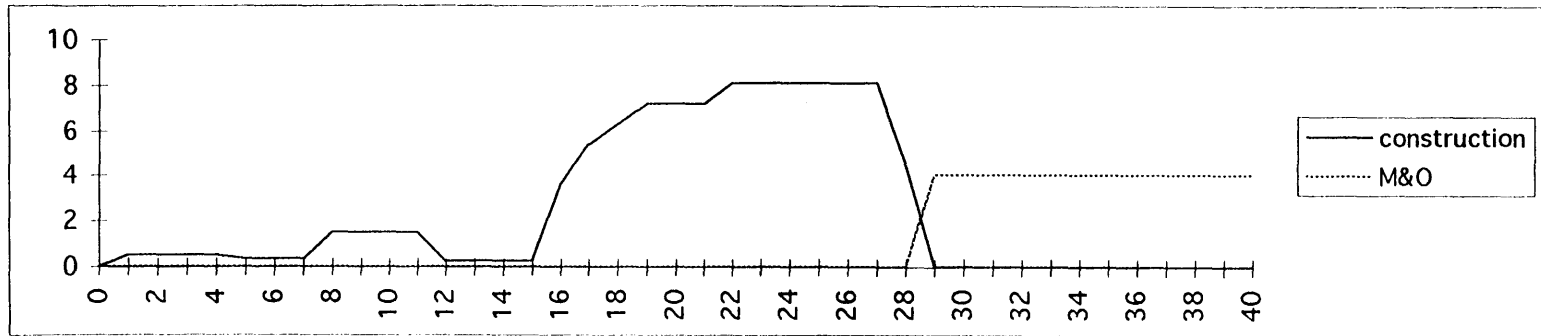
DB

Project #	xxx
Description	
Delivery Method	2.0
DBB = 1; M&O percent at	18.0
DB = 2; M&O percent at	16.2
DBO = 3; M&O percent at	15.5
BOT = 4; M&O percent at	0.0
Construction starts in period	16
Construction duration (periods)	13.0
Construction ends	28
Paste design zero at this number	0

design period	0	1	2	3	4
construction	0	0.5	0.5	0.5	0.5
M&O	0				

Vary this number from 1-40 to change above values. Template set up at 32.

DB



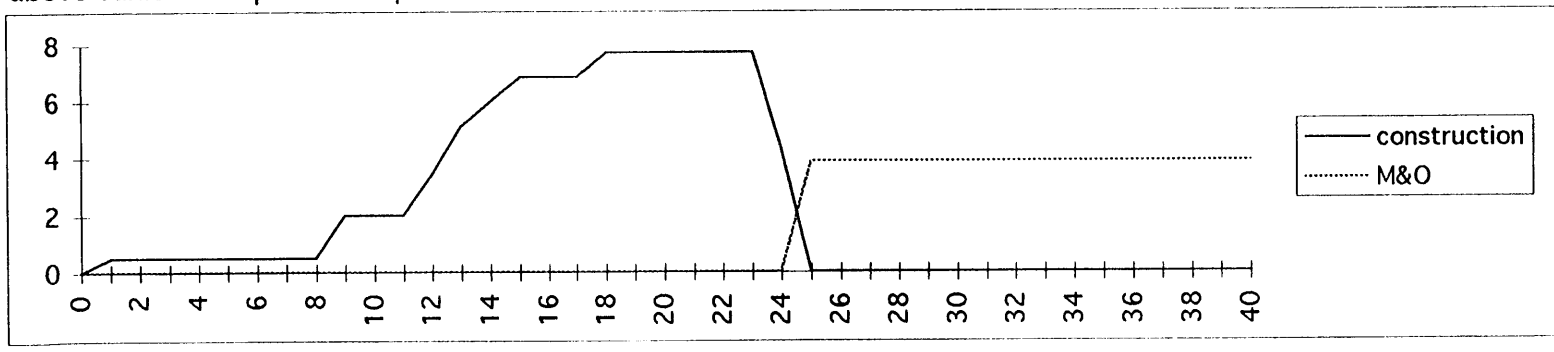
DBO

Project #	xxx
Description	
Delivery Method	3.0
DBB = 1; M&O percent at	18.0
DB = 2; M&O percent at	16.2
DBO = 3; M&O percent at	15.5
BOT = 4; M&O percent at	0.0
Construction starts in period	12
Construction duration (periods)	13.0
Construction ends	24
Paste design zero at this number	0

design period	0	1	2	3	4
construction	0	0.5	0.5	0.5	0.5
M&O	0				

Vary this number from 1-40 to change above values. Template set up at 32

DBO



BOT

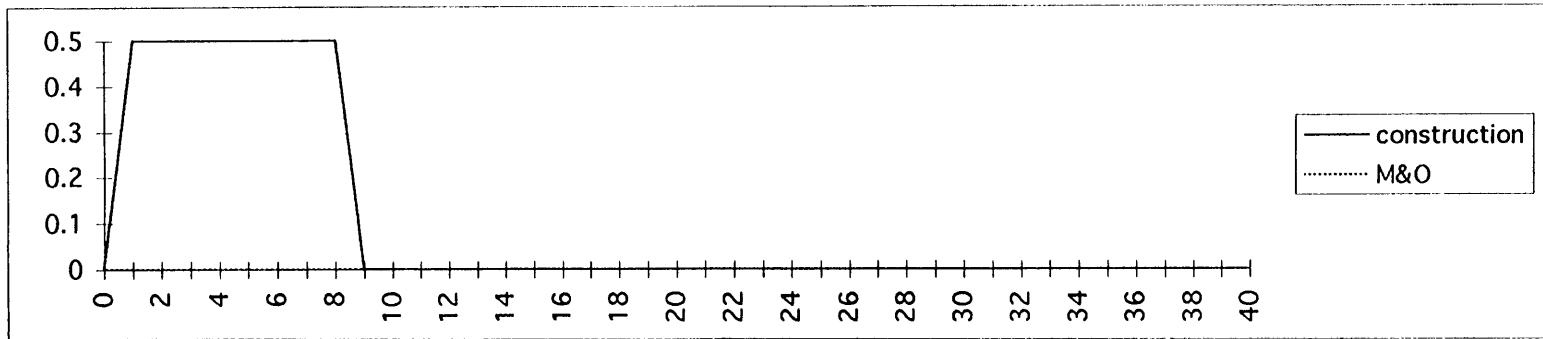
Project #	xxx
Description	
Delivery Method	4.0
DBB = 1; M&O percent at	18.0
DB = 2; M&O percent at	16.2
DBO = 3; M&O percent at	15.5
BOT = 4; M&O percent at	0.0
Construction starts in period	12
Construction duration (periods)	13.0
Construction ends	24
Paste design zero at this number	0

design period	0	1	2	3	4
construction	0	0.5	0.5	0.5	0.5
M&O	0				

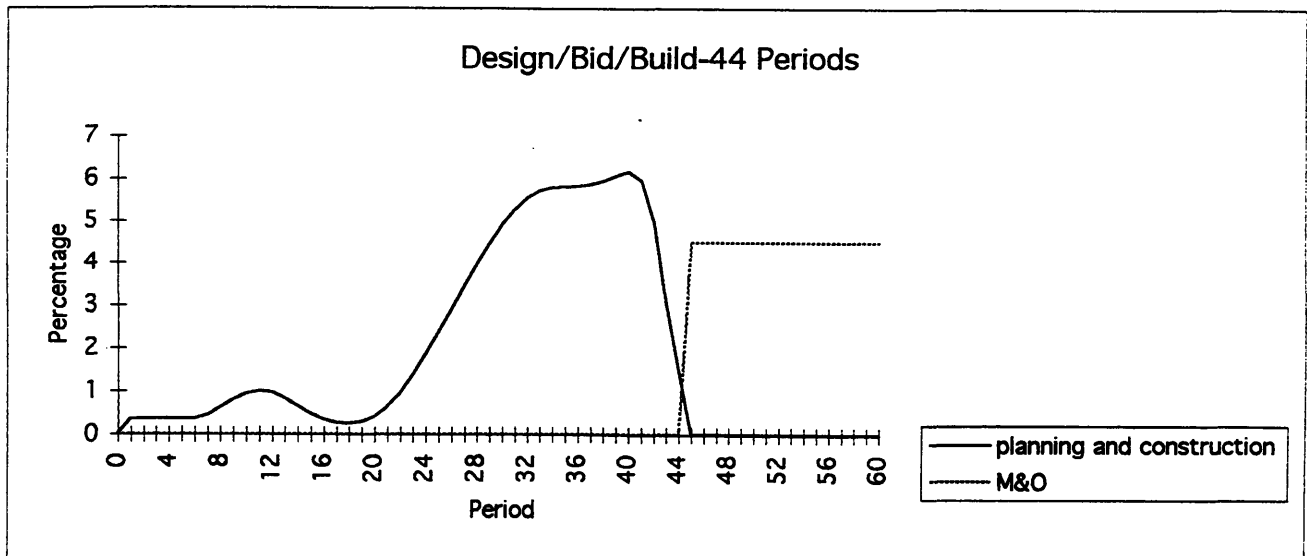
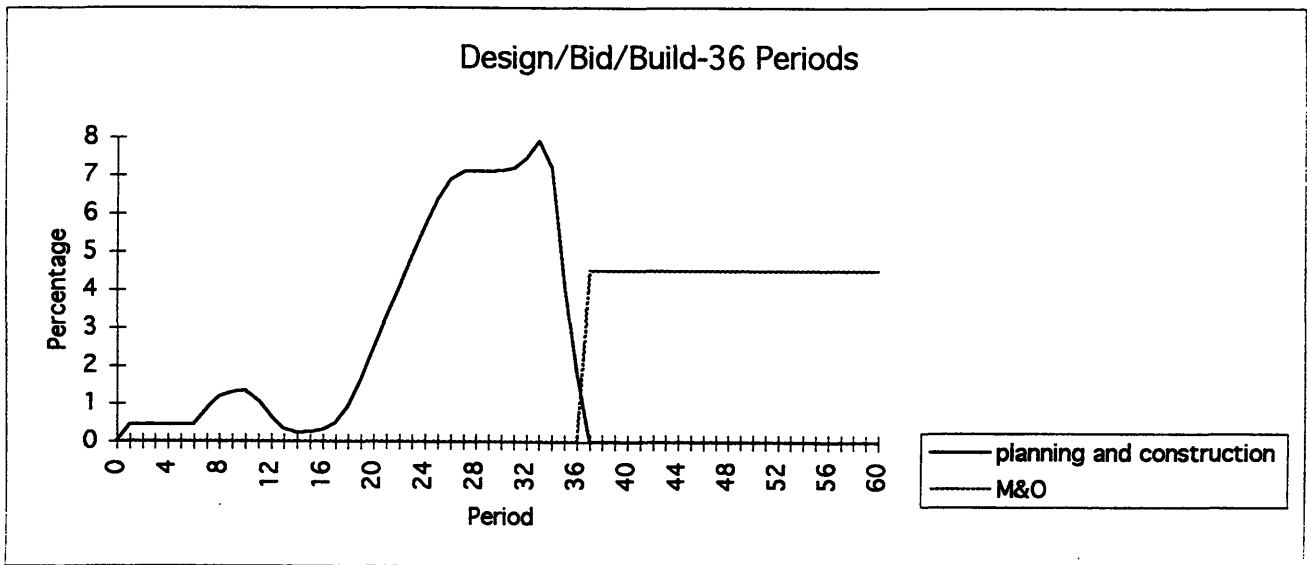
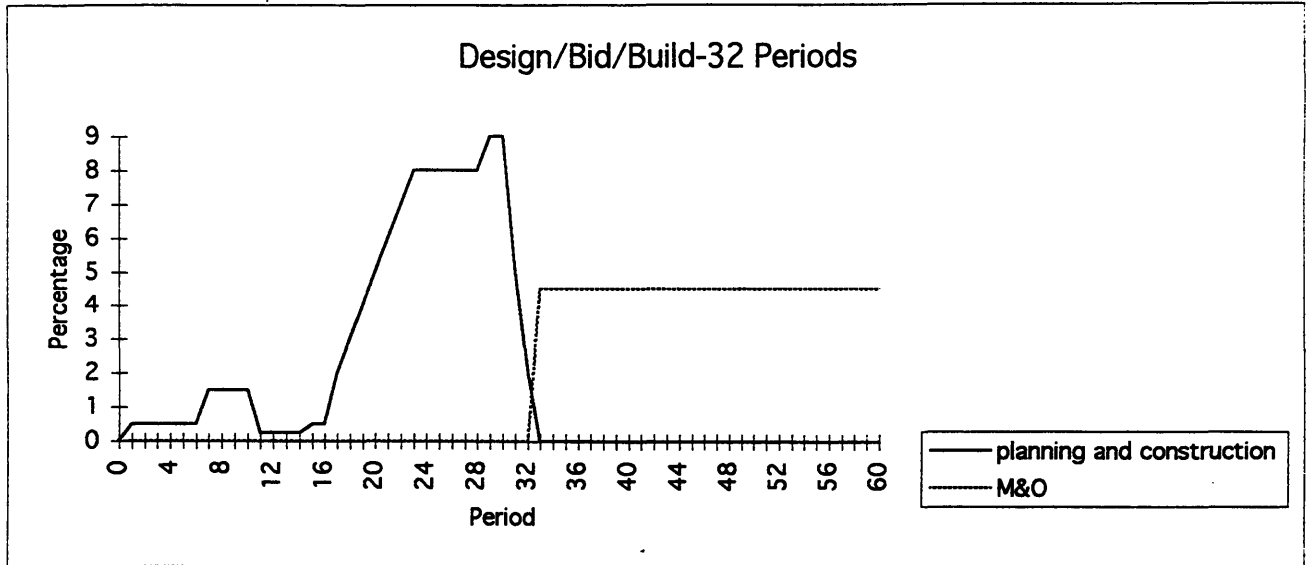
Vary this number from 1-40 to change above values. Template set up at 32.

32

BOT



## Comparison of Design/Bid/Build Over Three Intervals



The CONSTANT SHEET of a workbook supplies local values to the PROJECT SHEETs within the workbook but not those of another DATA SET workbook. Currently a global change of a constant must be entered in all four workbooks. The CONSTANT SHEET allows four Maintenance and Operation inputs associated with Design-Bid-Build, Design-Bid, Design-Bid-Operate, Build-Operate-Transfer, seven revenue funding sources, and four cost categories. The Maintenance-Operations values are displayed in the STRETCHER as suggestions only that are easily overridden by the analyst. The other values are automatically inserted in the DATA SETs. See the Instruction Set in the appendix for more detail.

There are two CHOOSERS wherein all the DATA SET information is summarized. One displays Nominally Valued Cash Flows; the other Discounted Cash Flows (or Net Present Value). They are separate both for convenience reasons and due to memory difficulties. The CHOOSERS have switching mechanisms that allow for the sequential display of the various delivery methods of each project. The analyst cycles through the delivery methods to explore portfolio options. The sorting function referred to in the DATA SETs supports a qualitative a high/low correspondence between the switching mechanism and the information displayed. Data in the CHOOSER is represented graphically and quantitatively. The upper left hand graphics is a columnar display of revenues versus costs. The upper central graphics is a modified area display of revenues versus costs on a quarter by quarter basis. Revenues and costs are broken out as a further refinement. The Excel Filter

function is installed on the main body of imported data to allow the analyst to pick, choose and consolidate as desired.

## CHAPTER FIVE-CHOICES II AT WORK

CHOICES II is currently being tested in the MIT Construction Management Program. Graduate student David Fanon Toney is working with it on his thesis developing five funding scenarios for the MassPort Logan Airport. Graduate student Matt Dieterich is using it on his thesis which compares MassPort's Logan Airport to the San Juan Tren Urbano Project. Professor John B. Miller is trying it on financing structures and delivery methods for the Winchester, Massachusetts, school district. In addition he has incorporated CHOICES II as a chapter in his recently written textbook on infrastructure procurement methods and featured it in a paper that he presented in Singapore in Fall, 1997 (Miller 1997c).

The three users have received tutoring in CHOICES II. A proficient Excel user needs about two hours of coaching to be up and running. The first hour is used to demonstrate and convey the major features. The cumulative second answers specific questions that occur from use. Feedback and recurring difficulties have been incorporated into the Instructional Appendix.

The selection of Excel for the development of CHOICES II has been a fortuitous one as it allows for easy modification. For example, Toney needed to examine the impact of a flat passenger facility charge of \$3.00 as a possible funding mechanism for the proposed Intermodal Transit Connector. This fee would be put into a sinking fund for the future major expansion of the transit system. However the current incarnation of CHOICES II has no budgeted

space for this kind of item. After some initial, unsuccessful jury-rigging was attempted, a more elegant and satisfactory solution was found. A second worksheet was opened in the CHOOSER, data was transferred from the first worksheet, the proposed passenger facilities charge was added to this, and a graph incorporating the sinking fund was created. Similarly, the sensitivity studies included in the appendix were created in the CHOOSER worksheet using the Excel Table function. Since CHOICES II is an Excel spreadsheet, it is easily modified by anyone with spreadsheet abilities.

A minor anomaly of using Discounted Cash Flow has been noted. A project performed as a Design-Build rather than a Design-Bid-Build, for example, can appear to cost more since it is delivered sooner. This is consistent with the Discounted Cash Flow concept that discounting over time places more weight on the early use funds than later expenditures. The analyst,

when encountering this apparent contradiction, should rationalize that the user benefits of a completed project received early are superior to those of a later delivery.

			DBB				Nominal Value	DCF Value
80.0	80.0	80.0	80.0	80.0	80.0	480.0		
80.0	72.7	66.1	60.1	54.6	49.7		383.3	
			DB					
120.0	120.0	120.0	120.0	0.0	0.0	480.0		
120.0	109.1	99.2	90.2	0.0	0.0		418.4	

## CHAPTER SIX-CRITIQUE OF CHOICES II

Linkage is both the strength and weakness of CHOICES II. The strength derives from its interactive nature, the weakness from the large memory requirement and attendant slowness. During development, a non-interactive, Visual Basic CHOOSER was prototyped, tried and discarded. Although it was smaller and quicker, the lack of interactive feedback was a negative. Another Linkage weakness is the consistency required when naming folders and files since idiosyncrasies such as capitalization, spelling and spacing are crucial. Also some electronic transfers have been observed to play havoc with names. Finally, there is a certain amount of skill required when opening linked files and responding to the Excel:Update Linkage messages. While suggestions are offered in the Appendix Instructions, only experience will help the analyst.

A second weakness is the inability of the private side to use the current model. Since CHOICES II was written from the public point of view, allowance was not made in the pro formas for depreciation and tax consequences. A side worksheet, functioning as a subroutine, can be written to overcome this. However the proposed revision, CHOICES III, will be more general, more flexible and thus more useful for different inputs. It is planned that this version will handle both the public and private sides by being less limiting in the lines of input allowed.

CHOICES II can be written a little more efficiently. More Visual Basic macros can be used. Some bulkiness in the formula cells can be removed. The

DATA SET worksheets can be set up to ease the transfer of data to the CHOOSER. During this, the developmental stage of CHOICES II, the use of Excel spreadsheets seems a wise choice. Excel is user friendly and allows the experienced analyst to write his or her own modifications, as required, onto the basic program. The transparency and openness of the program invites creative interplay. Eventually these user generated changes can be integrated via an appropriate programming language into a model that has a more commercial appearance and vitality.

Finally there are a few minor but persistent idiosyncrasies in the current version. The first is a nagging problem in the Project Start Up data block in the STRETCHER. Depending on the numbers used for the starting date and the project duration, the Paste Zero cell can return a nonsense, negative number. Adjustments made to the cell algorithm have not solved the problem; more work is required. A constant annoyance is the necessity to place the active cell in particular locations for macro operation. This has been overcome in project worksheets restricted to a single delivery method using a tightly specified Macro. However the space saving feature of generating delivery data blocks as needed requires a more general Macro. This generality is responsible for the active cell placement requirement. In the STRETCHER, pasting data is taken from templates which are currently locked from view. While an analyst can overwrite the data in the pasting line quite easily, this proves a nuisance if different template values are regularly desired. There is

**an easy correction to this problem that can be incorporated into the planned revision.**

## CONCLUSIONS

CHOICES II has been written to facilitate the move to a more rational infrastructure procurement system. Currently there is an insufficiency of public funds and an unwillingness of the public to support more taxes. At the same time there is a need to repair and maintain old infrastructure as well as create new for the support of our economy and the quality of our lives. Privatization, with the implication of user fees in lieu of taxes, is being rediscovered as a possible solution.

In England, privatization has transformed inefficient water plants into modern, cost efficient operations. In Argentina, privatization is credited with controlling inflation. In Hong Kong, privatization has leveraged limited public funds into economically beneficial infrastructure. The United States, after fifty years of non-use, is again learning the power of privatization. Perhaps it is more appropriate to say that it is learning the benefits of a mixed approach to contracting methods. Five realms of delivery are possible: Design-Bid-Build; Design-Build; Design-Build-Operate; Build-Operate-Transfer; and Maintenance-Operate. These are defined by the degree of unity amongst all the players as well as the details of revenue streams. The move away from the current Design-Bid-Build requires that the government revise laws and create a transparent, fair environment to entice the private side to participate.

There is the need for a tool box of techniques to accompany this shift. The foremost one is a financial model such as CHOICES II. Another, a Moody-type

rating system will prove efficient for both the public and private side. In spite of a reluctance by designers and planners, there is the need to incorporate financial planning as a design element. There is the need that the government open its mind to other procurement strategies in order to receive the benefit of new technologies, better constructability, and financial resources. There is also the need to view the creation of infrastructure from a portfolio point of view, that is as a system, rather than an insular point of view.

The problem statement of limited resources filtered through a matrix of delivery options to fund a list of desired infrastructure was introduced. CHOICES II is the response to the statement. It is an Excel based set of pro forma spreadsheets hot linked to a consolidating worksheet called the CHOOSER. The analyst, using CHOICES II, is able to aggregate or separate projects, to specify a range of delivery options, and to control variable such as project duration, inflation, user fees, overruns, growths, et cetera. Optimization has been considered and rejected as inappropriate at the design level of study for which CHOICES II has been written as there are too many fluid variables to have any meaning. Rather the analyst is looking for feasibility in light of restraints that are financial, social, and political.

CHOICES II has been developed around MassPort's Logan 2000 Intermodal Transportation Connector data. This thesis used the information to "prove out" the program. Other researchers in MIT's Construction Management program are working with CHOICES II in part as a shake down. Feedback has

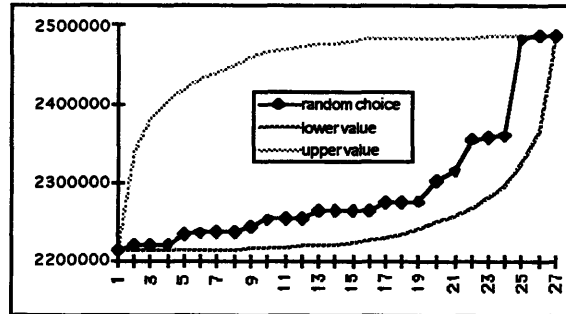
been incorporated into the current version, into the instruction set, and is being considered for a future rewrite. The choice of Excel has proven useful as the program is both visible to the user and is easily modified. There have been some consistent problems centered on memory requirements, size and linkage which are more or less in control. There is a bias in that the current version has been constructed with the public side in mind; this is easily corrected in a future version.

Following this conclusion are some recommendations for possible experiments to further the tool box idea. Perhaps it will be possible to develop some heuristics to enable the analyst to narrow the number of choices possible. There is a schematic suggestion for a rewrite. There is an instruction set now in its third version.

CHOICES II is not the be all, end all but is a useful start on the path to better understanding of the infrastructure delivery system.

## CHAPTER NINE-FURTHER WORK

As discussed above, CHOICES II can be used in the development of a procurement toolbox. A number of experiments are envisioned to pursue that goal. One of these is a mapping of the upper and lower



financial bounds of the portfolio. In the figure, the left side of the graph is rich with alternative delivery methods while the right is more traditional Design-Bid-Build. The area between the curves represents all the possible outcomes. By drawing a horizontal line that represents a spending limit and noting the intersection with the financial curves, the analyst may be able to narrow the selection criteria for the portfolio delivery method from the hundreds of thousands to a few thousand. Preliminary trials of this experiment have indicated that hoped for monotonic concavity and convexity may not be possible due in part to switching properties in the CHOOSER. Nonetheless, some winnowing of the many possibilities seems possible.

Another experiment might try a random number generator on the switching function of the CHOOSER to produce a Monte Carlo type simulation. The hope again is to investigate a way to winnow the huge number of possibilities. This experiment could be extended down to the pro forma level varying inflation, interest, user fees and overruns. Duration,

startup and fee mixtures will not lend themselves to automatic random shuffling. There may be an efficient way for the analyst to run a side random number and place the indicated results by hand.

A third experiment might look at constraining the funding sources or cost of funding. Given the discussion against optimization, there might nonetheless be a way to use Excel's Solver function to investigate the portfolio. This does not seem very promising due to the large number of quarters involved. For example, CHOICES II has one hundred twenty quarters each of which would need a constraint equation for each variable. How the Solver will function with one hundred twenty constraints or two hundred forty or.....is an unknown.

A fourth experiment might be to use CHOICES II in segments of a decision tree analysis or real world option valuation. This investigation would extend the current Discounted Cash Flow analysis by incorporating the uncertainties of variables and forecasting expressed in a decision tree matrix and by adding the option of abandonment as considerations. The outcome desired is a more favorable valuation that is nonetheless steeped in real world feasibility (de Neufville 1997).

These experiments are proposed to generate data, to look for patterns and to become more involved with the financial forecasting of alternative methods of delivery. Possibly the data generated may prove useful to argue for and market alternative delivery methods. Possibly some kind of heuristics

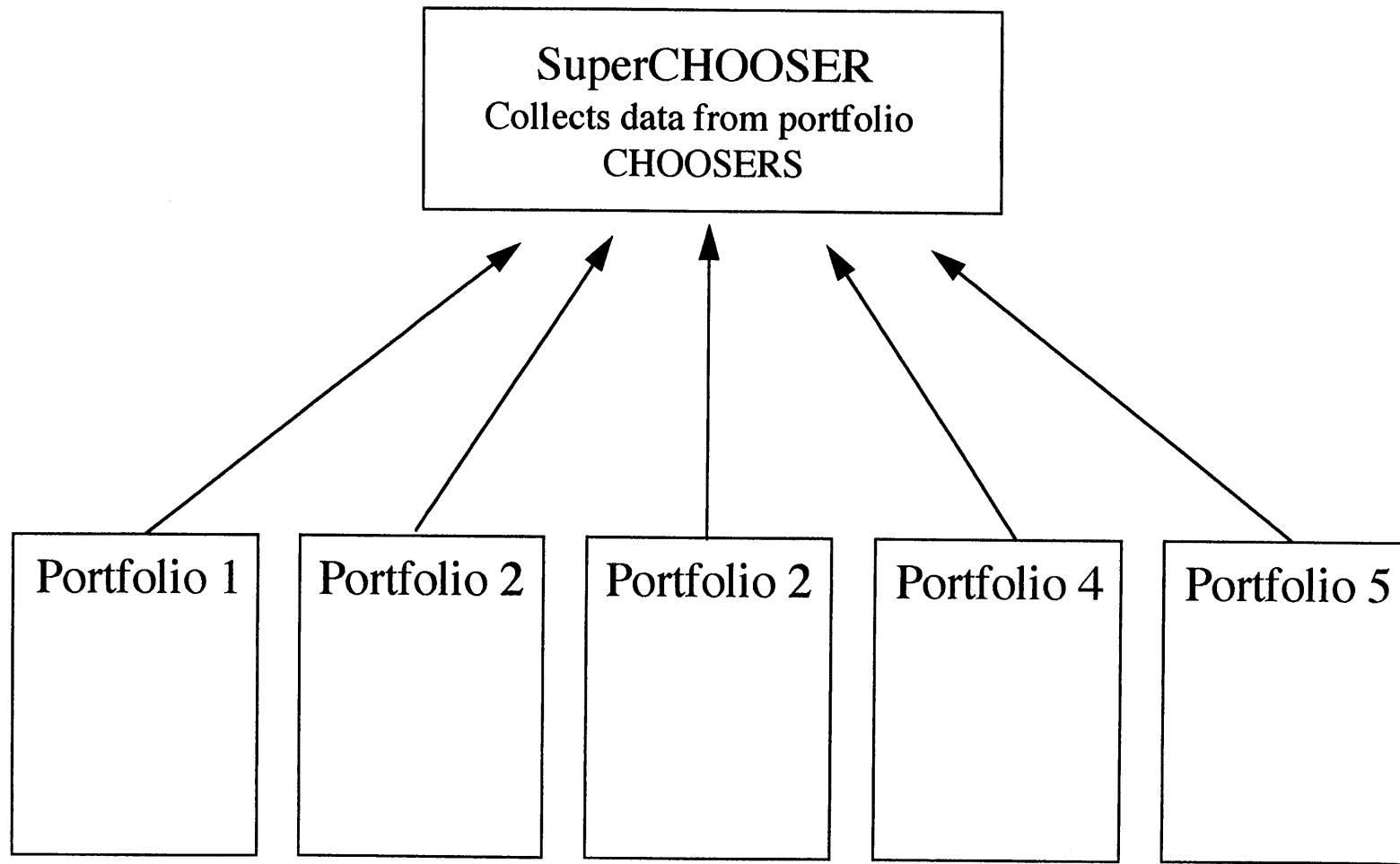
may be developed. At the very least there will be better understanding of the process.

CHOICES II can be used historically as an analysis tool to evaluate case study data. It may also be used contemporarily as a synthesis tool in the design process to investigate alternative strategies. Professor John B. Miller, of the Construction Management Program, has received inquiry from organizations such as MassPort's Logan Airport, the Dalles Airport, and the Cranston, RI, water department which are seeking to privatize parts of their operations. CHOICES II will be brought to these studies.

Finally, CHOICES II can be written yet again as CHOICES III. The first change envisioned is a SuperCHOOSEr which would function to collect the information of several sub-CHOOSErS in a hierarchical pyramid. The second change would be to place all the PROJECT SHEETs as workbooks within a folder rather than the worksheet within a workbook arrangement currently at hand. Worksheets could then be reserved for variations on a project. Since a PROJECT SHEET is smaller than a DATA SET, the speed of opening and saving should be improved. Global Constants will more easily be applied to all the projects. Within a PROJECT SHEET, this default may be overridden by a local choice; while at the delivery level the constant can be overridden again. Delivery blocks can be written a little cleaner to facilitate the transfer of data to the CHOOSEr and to allow the analyst a more custom slate on which to write his or her own code. The purpose of a CHOICES III is a more general, more responsive strategy tool. Schematics follow.

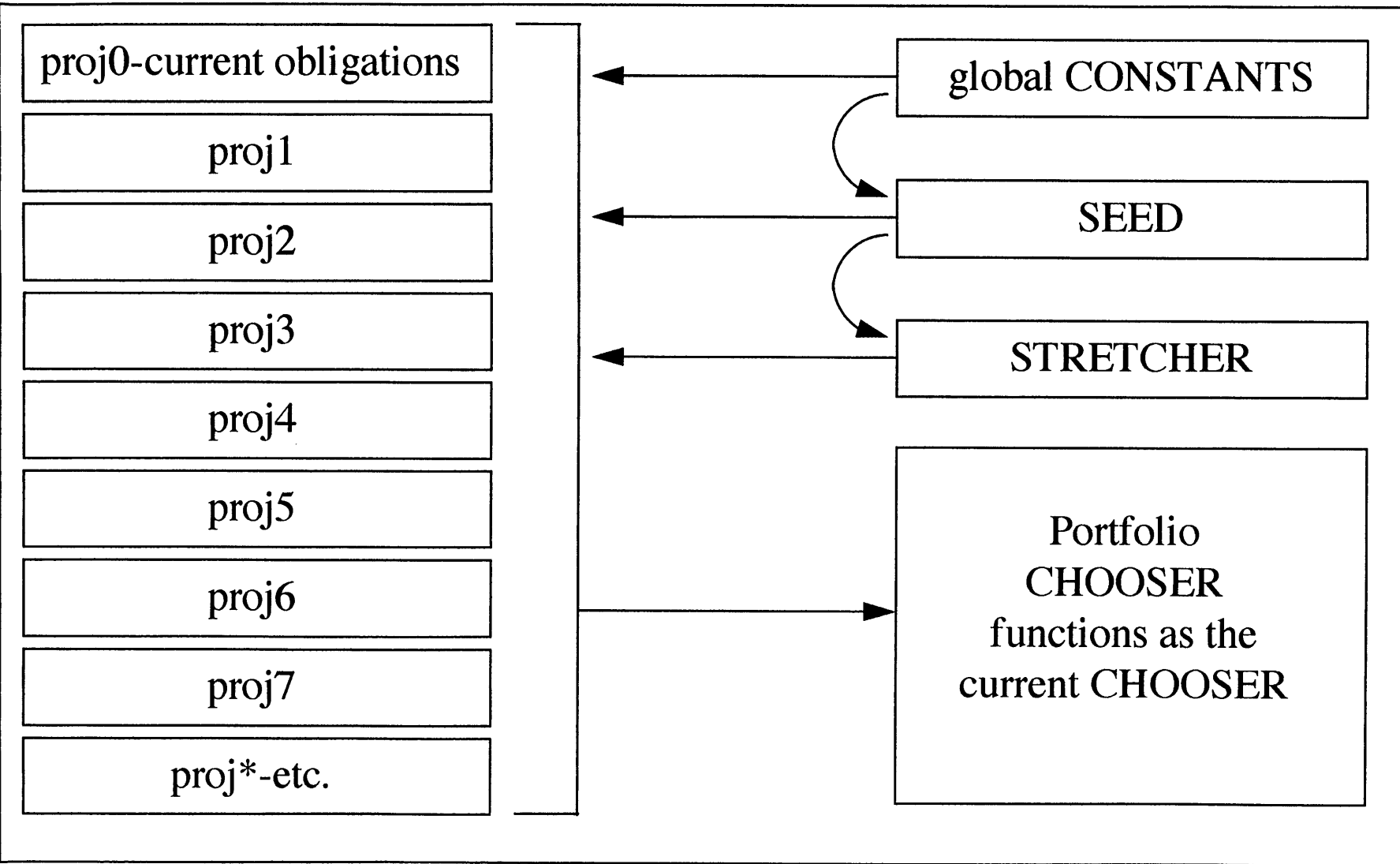
# CHOICES III

## Relationship of SuperCHOOSER to Portfolios



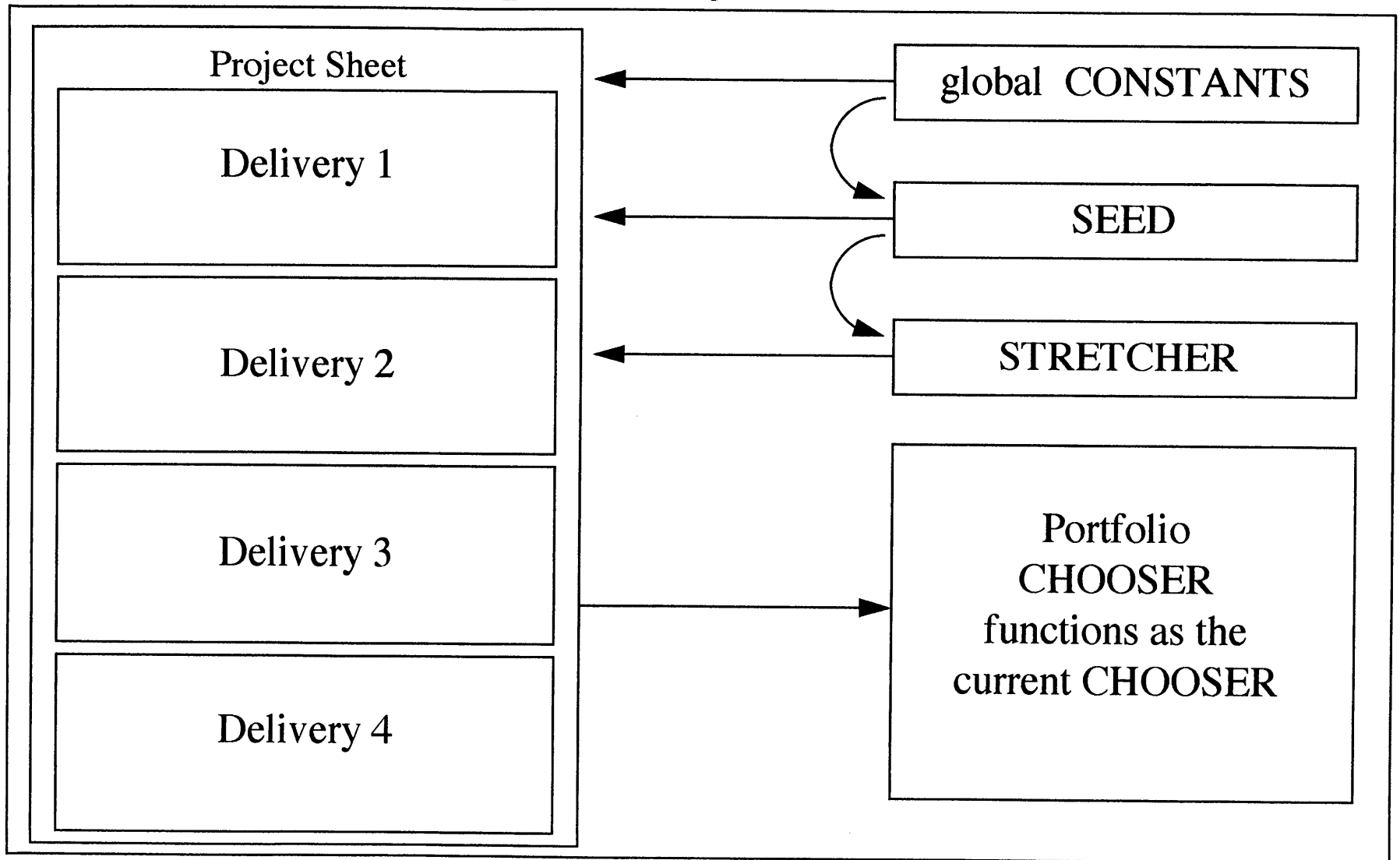
# CHOICES III

## Typical Portfolio



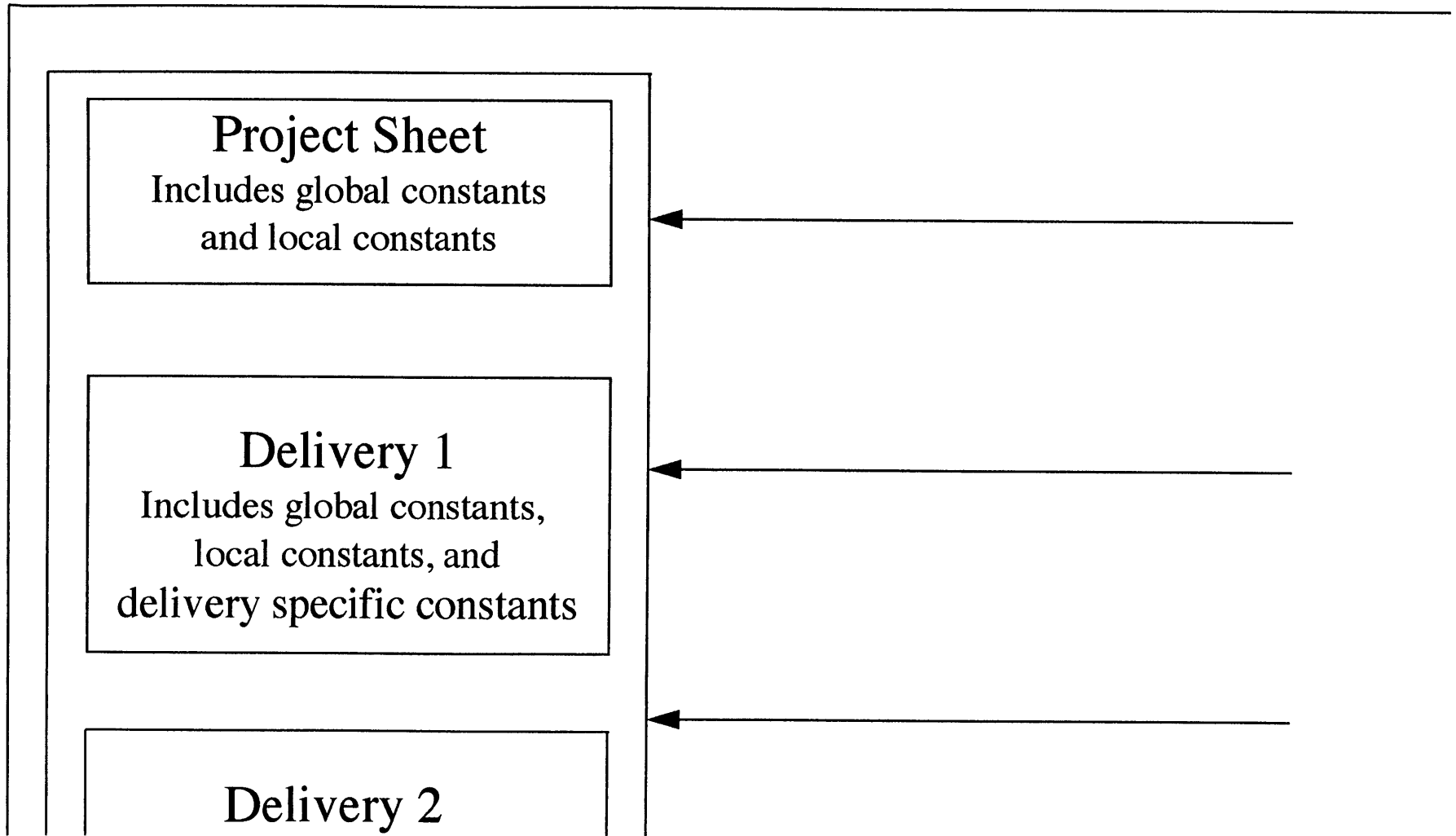
# CHOICES III

## Typical Project Sheet



# CHOICES III

## Close-up of Project Sheet & Delivery Block



# CHOICES III

## Close-up of Delivery Block

Description, price

STRETCHER info

CONSTANTS info

Revenue Assignments

Summary collections

Nominal periods  
40+ lines for revenues,  
costs, depreciation, taxes,  
etc.

NPV periods  
brought down  
from above

## BIBLIOGRAPHY

Angelo, William J. 1997. Booming Boston Raises Concerns. ENR, SEPT. 22, 1997, 8.

Ashford, Norman, and Stanton, H. P. Martin, and Moore, Clifton A. 1997. Airport Operations. NYC: McGraw Hill.

Brealey, Richard A., and Stewart C. Myers. 1996. Principles of Corporate Finance. New York: The McGraw-Hill Companies, Inc.

Byrns, Ralph T. and Stone, Gerald W. 1995. Microeconomics. NYC: HarperCollins College Publishers.

Congress, U.S. 1972. The Brooks Architect-Engineer Act. 86 St 1278.

de Neufville, Richard, and Marks, David. 1974. Systems Planning and Design: Case Studies in Modeling, Optimization and Evaluation. Englewood Cliffs, NJ: Prentice Hall.

de Neufville, Richard. 1990. Applied Systems Analysis: Engineering Planning and Technology Management. New York: McGraw Hill, Inc.

de Neufville, Richard. 1997. TPP-21: Dynamic Systems Planning-Course Notes. Boston.

Gordon, Christopher M. 1991. Compatibility of Construction Contracting Methods with Projects and Owners. Masters of Science, M.I.T.

Gordon, Chris M. 1997. 1.472: Innovative Project Delivery in the Public and Private Sectors-Course Notes. Boston.

Hanono, Alejandro V. 1995. Cost Model for Low Income Detached Houses, MIT.

Journal, Air Travel. 1997. Digging Deep. Air Travel Journal, Nov. 3-16, 1997, 1.

Krizan, William G. 1997. Design-Build Has Cost, Time Edge. ENR, Nov. 17, 1997, 16.

Legislature, Massachusetts. Massachusetts General Law, Chapter 149, §44, A-H.

Little, Jeffery B. and Rhodes, Lucien. 1991. Understanding Wall Street. NYC: Liberty Hall press/McGraw Hill.

Lowi, Theodore J. 1978. The End of Liberalism: The Second Republic of the United States. New York: W. W. Norton & Company.

Luehrman, Timothy. 1997. What's It Worth? General Managers Guide to Valuation. Harvard Business Review (May-June, 1997): 132-142.

Microsoft. 1990. Microsoft Excel Solver: User's Guide. Redmond, WA: Microsoft Corp.

Microsoft. 1991. Microsoft Excel: Function Reference. Redmond, WA: Microsoft Corp.

Microsoft. 1994a. Microsoft Excel: User's Guide. Redmond, WA: Microsoft Corp.

Microsoft. 1994b. Microsoft Excel: Visual Basic User's Guide. Redmond, WA: Microsoft Corp.

Miller, John B. 1995. Aligning Infrastructure Development Strategy to Meet Current Public Needs. Doctoral Thesis, Massachusetts Institute of Technology.

Miller, John B. 1996a. Massport Infrastructure Development Research Program. Cambridge, MA: MIT.

Miller, John B. 1996b. Using Competition to Stimulate Private Investment in Public Infrastructure. The Procurement Lawyer, Section of Public Contract Law, American Bar Association Volume 31, No. 3 (Spring, 1996): 1.

Miller, John B. 1997a. 1.441: Public Infrastructure Development Systems- Course Notes. Boston.

Miller, John B. 1997b. 1.961: Special Seminar on Logan International Airport- Course Notes. Boston.

Miller, John B. 1997c. Engineering Systems Integration for Civil Infrastructure Projects. Journal of Management in Engineering, ASCE 13 (No. 5 Sep/Oct).

Miller, John B. 1997d. The Fundamental Elements of Sustainable Procurement Strategies for Public Infrastructure. In First International Conference on Construction Industry Development. Singapore: National University of Singapore.

Miller, John B., and Evje, Roger H. 1997e. Life Cycle Discounted Project Cash Flows: The Common Denominator in Procurement Strategy. In First International Conference on Construction Industry Development. Singapore.

Miller, John B. 1997f. Procurement Strategies Which Encourage Innovation: The Fundamental Element of Sustainable Public Infrastructure Systems. Montreal, Quebec: CIB.

Morris, Kenneth M. and Siegel, Alan M. 1993. Guide to Understanding Money & Investing. NYC: Lightbulb Press/Simon & Schuster Inc.

Newman, Donald G. and Bruce Johnson. 1995. Engineering Economics Analysis. San Jose, California: Engineering Press, Inc.

Paulson, Jr., Boyd C. 1976. Designing to Reduce Construction Costs. Journal of the Construction Division, ASCE 102 (CO4): 588.

Stutely, Richard. 1993. The Economist Guide to Business Numeracy. NYC: John Wiley & Sons, Inc.

Webb, Jeff. 1996. Using Excel Visual Basic. Indianapolis, IN: Que.

Winston, Wayne L. and Albright, S. Christian. 1997. Practical Management Science: Spreadsheet Modeling and Applications. Belmont, CA: Duxbury Press.

## APPENDIX I-INSTRUCTIONS FOR USE

- CHOICES II is supplied in a folder containing : a CHOICES II MASTER

DATA SET (302 KB), a data

scratch sheet (14 KB), four

dummy DATA SETs (DS/A-D

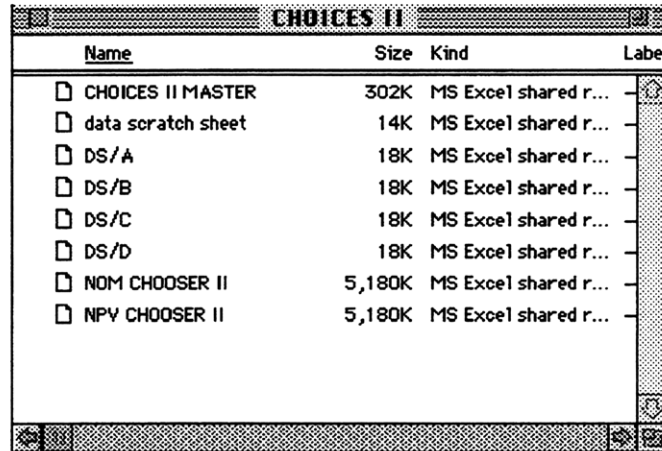
at 18 KB each), a NOM

CHOOSEER II (5180 KB), and a

NPV CHOOSEER II (5180 KB).

Make sure everything is

present before using.



Name	Size	Kind	Label
CHOICES II MASTER	302K	MS Excel shared r...	
data scratch sheet	14K	MS Excel shared r...	
DS/A	18K	MS Excel shared r...	
DS/B	18K	MS Excel shared r...	
DS/C	18K	MS Excel shared r...	
DS/D	18K	MS Excel shared r...	
NOM CHOOSEER II	5,180K	MS Excel shared r...	
NPV CHOOSEER II	5,180K	MS Excel shared r...	

- Make a copy! Use a small descriptive folder name of less than 31 characters. Keep the folder at or near the desk top when working in it ( This helps Excel's Linking function).

• Unless otherwise noted, keep things protected. This command is on the menu bar under "Tools:Protection".

• You will be doing most of your work in the DATA SETs. The CHOOSEER functions as a summary of that work.

- Open Excel.

100% [Navigation icons]

DS/A

	A	B	C	D	E	F	G
1	move to stretcher						
2							
3							
4	DBB = 1; M&O percent at	18%					
5	DB = 2; M&O percent at	16%					
6	DBO = 3; M&O percent at	15%					
7	BOT = 4; M&O percent at	0%					
8							
9	revenue source #1	MassPort Bond					
10	revenue source #2	MassPort Budget					
11	revenue source #3	Mass Hwy					
12	revenue source #4	MBTA					
13	revenue source #5	MA State Funding					
14	revenue source #6	NexTEA					
15	revenue source #7	User Fees					
16							
17	Bond Interest	6.0%					
18	Inflation	3.0%					
19	Discount Rate	8.0%					
20	2nd Discount Rate	10.0%					
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	OC	ED
1	Project #	xxx					1					Quarter	0	1	120	
2						Turn count flag on						MassPort Bond	(face value = no)	0	0.0	0.0
3						count equals	1					periodic paydown	(face value = nominal)	0	0.0	0.0
4	description											accumulated bor	(face value = no)	0	0.0	0.0
5						1. go to stretcher						MassPort Budget	(nominal)	0	0.0	0.0
6	Delivery Method	1.0	DEB									in trust	(nominal)	0	0.0	0.0
7						2. auto setup						balance sheet	(nominal)			
8	Price (x1000)	0.0										Mass Hwy	(nominal)	0	0.0	0.0
9												MBTA	(nominal)	0	0.0	0.0
10	Poste design zero at this number	0										MA State Funding	(nominal)	0	0.0	0.0
11	Planning Ends	16										NextEA	(nominal)	0	0.0	0.0
12	Construction starts in quarter	17										User Fees	(nominal)	0	0.0	0.0
13	Construction duration (quarters)	16										Subtotal revenues	(nominal)	0	0.0	0.0
14	Construction ends	<2				3. auto constant										
15																
16	DEB = 1; MAO percent at	18.0%														
17	DB = 1; MAO percent at	16.1%														
18	DEO = 1; MAO percent at	16.6%														
19	BOT = 4; MAO percent at	0.0%														
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																
34																
35																
36																
37																
38																
39																
40																
41																
42																
43																
44																
45																
46																
47																
48																
49																
50																
51																
52																
53																
54																
55																
56																
57																
58																
59																
60																
61																
62																
63																
64																
65																
66																
67																
68																
69																
70																
71																
72																
73																
74																
75																
76																
77																
78																
79																
80																
81																
82																
83																
84																
85																
86																
87																
88																
89																
90																
91																
92																
93																
94																
95																
96																
97																
98																
99																
100																

10000000

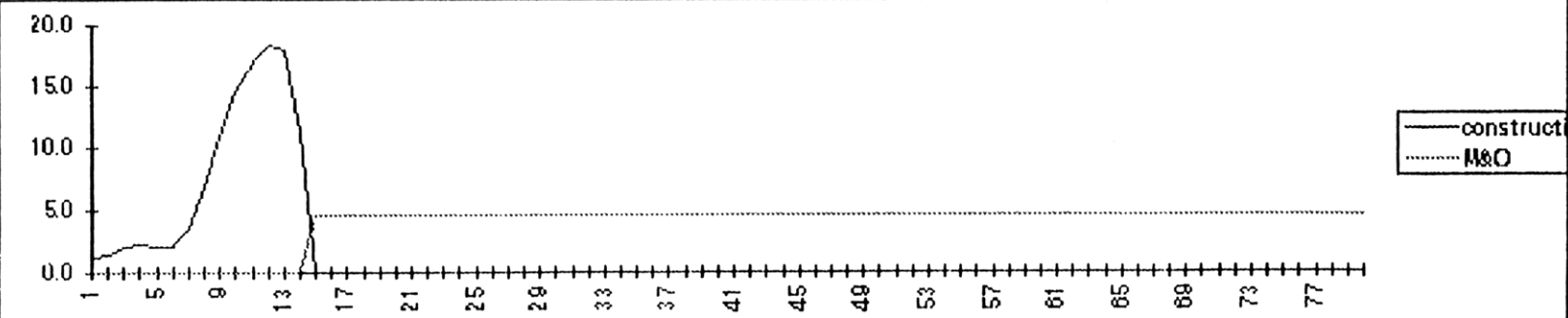
10000000

Project # xxx DEB npv to cost 0.0

Next Paste

choices data master b5.1

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Project #	xxx											
2				copy corner			8						
3	description												
4													
5	Delivery Method	1.0											
6				1	2	3	4		2nd copy				
7	Price (x1000)	0.0											
8	paste zero	44.0											
9	first planning period	45.0		5	6	7	8	design quarter	0	1	2	3	
10	planning duration	7.0						construction					
11	start construction	52.0	52					M&O					
12	construction duration	7.0	7	9	10	11	12		move zero		zero lin		
13	construction completion	58.0											
14	use stretcher #	14.0						111.0					
15	DBB = 1; M&O percent at	18.0%	18.0%	13	14	15		design quarter	0	1	2	3	
16	DB = 2; M&O percent at	16.2%	16.2%					construction	0	1.2	1.5	2.0	
17	DBO = 3; M&O percent at	15.5%	15.5%					14	M&O	0	0.0	0.0	0.0
18	BOT = 4; M&O percent at	0.0%	0.0%	16	17	18			1st copy				
19													
20							DBB						



69

- Open CHOICES II Master.

Click on the tab

"CONSTANTS." The colored cells are meant for data entry.

Tabbing will bounce the active cell through the allowable

ranges (if the worksheet is

protected). Data entered here

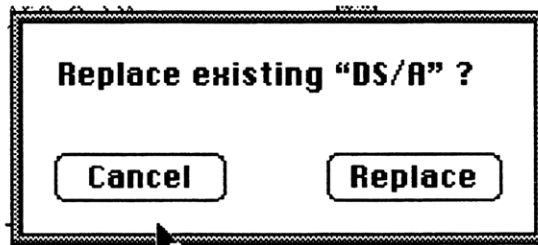
will be carried globally

throughout all the DATA SETs

you are about to generate.

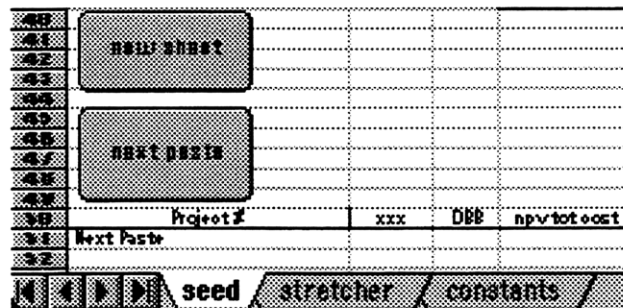
DBB = 1; M&O percent at	18%
DB = 2; M&O percent at	16%
DBO = 3; M&O percent at	15%
BOT = 4; M&O percent at	0%
revenue source # 1	MassPort Bond
revenue source # 2	MassPort Budget
revenue source # 3	Mass Hwy
revenue source # 4	MBTA
revenue source # 5	MA State Funding
revenue source # 6	NexTEA
revenue source # 7	User Fees
Bond Interest	6.0%
Inflation	0.0%
Discount Rate	8.0%
2nd Discount Rate	10.0%

- From the menu bar choose "Save As." Enter "DS/A." Note the capitalization. A message box will appear asking if you want to replace an existing folder. Agree.



- Go to the SEED worksheet.

- Use the "New Sheet" button on the SEED worksheet five times to generate five PROJECT SHEETS. Avoid the temptation to use the SEED



SHEET as one of the five as you may want to use it again to correct a mistake.



- Label the tabs as "proj#". No capitals, no space! This is required to use the macro buttons.

- PROJECT SHEET "proj0" is meant for current obligations. It takes only one delivery method data block. All other PROJECT SHEETs can take up to four delivery option blocks.

- Data entry starts with "proj1". Fill in the project # (cell B1), the description (cell A3),

the delivery method

number (cell B5: 1 =

Design-Bid-Build; 2 =

Design-Build; 3 =

Design-Build-Operate; 4 = Build-Operate-Transfer), and the price (cell B7:

divide price by 1000).

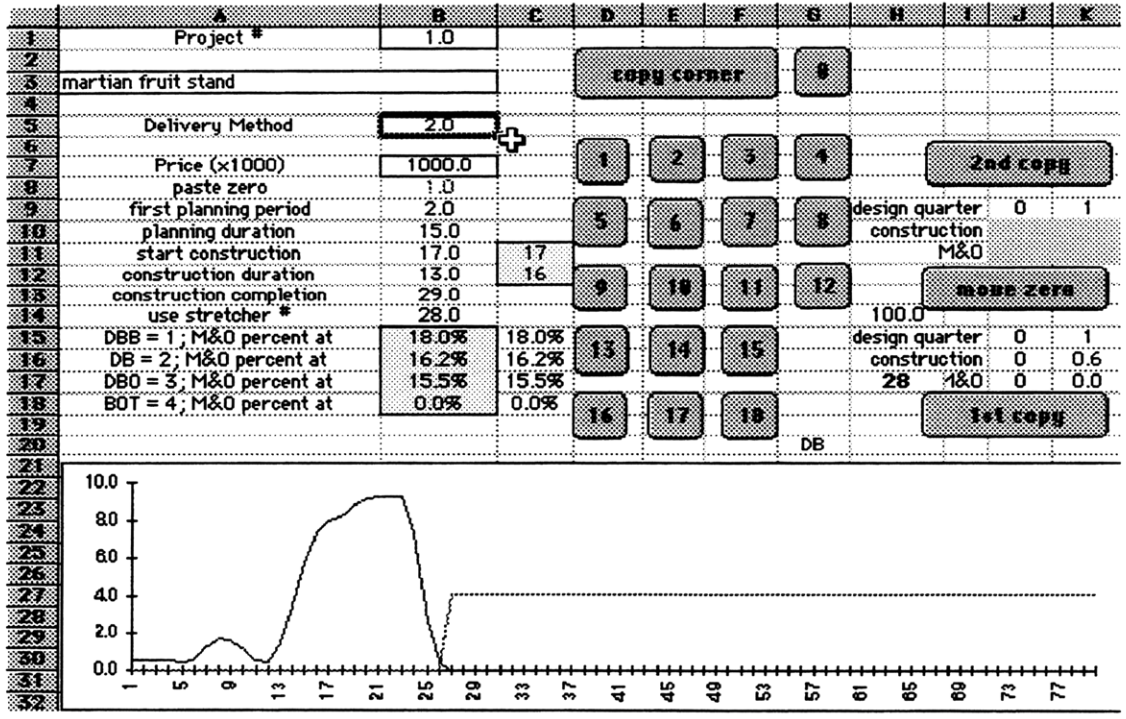
	B	C	D	E	F
1	Project #	xxx		Turn count flag on	
2				count equals	1
3	description		1. go to stretcher		
4					
5	Delivery Method	1.0	DBB		
6					
7	Price (x1000)	0.0	2. paste number		
8	paste zero	44			

- Click cell A1 to make it the active cell. Click "Go to STRETCHER Button".

- This will move you to the STRETCHER. Information from the PROJECT SHEET has automatically been entered.

- Set start construction (cell C11) and duration (cell C12). Verify duration profile in the graphical presentation and in cells J16-DZ17; adjust if necessary. The cells B8-B14 offer a suggestion of placement. To date there remains an

anomaly in the formula that sometimes indicates a negative start period. The planned rewrite will try to remedy this condition.



- Modify Maintenance-Operations percentages as necessary in cells B15-B19. The values in C15-C19 come from the CONSTANT SHEET and are included as the default reference.
- Use "Zero Line" button to clear the paste row. Use "1st Copy" button to pick up the STRETCHER information. Using the value suggested in cell B8 as a first guide, go to the blue "construction" line cells, J10 & J11 rightwards; the active cell is placed in row 10 under the desired period number. Hit the "Move Zero" button. Verify that paste up is what you desire. If not, run this instruction again choosing a different starting cell.
- At some point, some time, using this program you will generate a macro error. A dialogue box will appear on the screen. Accept the default ("End").

- Still in the STRETCHER worksheet, make cell A1 active. Use the "Copy Corner" button. Then use a number, 0-18, corresponding to the PROJECT SHEET you are working in, to return to the appropriate project.

- This will return you to the PROJECT SHEET you left before. Cell A1 should still be the active. Hit the "Paste Corner" button.

- Choose a funding source (sources)

by flagging the number "1" for each source in cells B21 through B26. For each flagged source of revenue enter a percentage in the adjacent C column cell. There are red flags under the two columns that serve as reminders.

Funding Data	on=1	%
Mass Port Bond		
Mass Port Budget		
Mass Hwy		
MBTA		
MA State Funding		
NextTEA		
Percent total	>=1	100% needed
User Fees	1	100%
Total revenues		

- Set a user fee percentage in cell C29.

- Check Bond interest, Inflation, and Discount Rate in cells F9-11. A global change can be effected in the CONSTANTS worksheet. A local change needs to have the Project Worksheet unprotected. Reset protection when done.

Bond Interest	6%
Inflation	0%
Discount Rate	8%
<b>MOVE TO CONSTANTS</b>	
Construction overrun	
M&O Growth	
User Fee Growth	

- Construction Overrun, Maintenance-Operations Overrun and User Fee Growth can be entered locally without removing the protection.

- Choose a "sort by" value by placing a single flag in the colored cells F21 through F26. A "1" will sort on the nominal value; a "2" will sort on the NV

value. Be consistent throughout all the projects. Default is "Total Costs/NPV".

- Make cell M16 the active cell. Use "Zero STRETCHER" button. Then use the

<b>4. paste stretcher</b>	Subtotal revenues (nominal)	0
	Paste line from str Quarter	0
<b>3. copy stretcher</b>	Construction (percentage)	
	M&O (percentage)	
	Construction (nominal)	0

"Copy STRETCHER" button.

- This will bounce you to STRETCHER. You may work here again if you wish. If so, hit "Second Copy" button. Then use numeric buttons to return to Project Worksheet.

<b>2nd copy</b>	gn quarter	0	1
	nstruction		
	M&O		
<b>MOVE ZERO</b>			
	00.0		

- Back from STRETCHER. Active Cell is M16. Hit the "Paste STRETCHER" button. Verify pasteup is as desired. If modification is desired you can return to STRETCHER and work there or manually enter data in the "Construction and/or Maintenance-Operations Percentage" lines.

- Do sensitivity studies as desired.
- Optional. If a bond paydown is desired it should be entered manually at this time in blue colored row below the bonding obligation.
- Optional. If a compensating balance is desired, make cell M7 active. Use the "Zero Compensating Balance" button. Hit the "Paste Comp" button. Cells D38 and E38 should turn to zero.

- If there are other delivery methods available, make the cell "Next Paste" (A51) active and use the "Next Paste" button. Directions are similar to the above except that the active cell is placed

44	
45	
46	<b>next paste</b>
47	
48	
49	
50	Project #
51	Next Paste

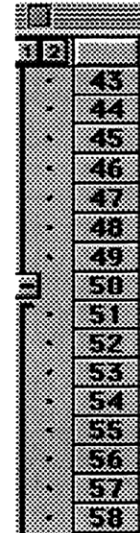
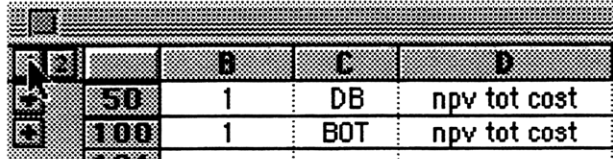
in the corresponding cell of the current delivery method. Rows 1-50 are for the first delivery entry. Rows 51-100 for the second. Rows 101-150 for the third. Rows 151-200 for the fourth. Thus, for example, cells A1, A51, A101, and A151 are corresponding cells. Other placements are similar. This requirement to locate the active cell is a property of relative cell referencing and macros. If the worksheet is protected, the worst outcome of misplacing the active cell might be erasing previously entered data (which you can easily reenter). A lesser consequence will be the "run time" error message (accept the default). An unprotected worksheet may require the regeneration of the PROJECT SHEET. A second point, you will have to zero out the pasted lines (pasted Construction and Maintenance-Operations percentages, Bond Paydown, and Compensating Balance) that have copied down. Set the active cell at the start of the line in question and use the appropriate "Zero" button.

- The next step, which is optional, is a sort on the Project Worksheet. An ordered sort will prove convenient but not necessary in the CHOOSER.

- Having been warned about an unprotected worksheet, the only way to sort is to unprotect the sheet.

- Use "Tools:Protection" to unprotect the worksheet. Show the outline bar on the left side of the worksheet (on the Mac: Command-8. PCs: see "Outline" in the "Help" function.). Collapse the outline to the first

level by clicking on "box 1". Highlight all the rows (up to four). Go to



"Data:Sort" choose column E5 ascending. Return to the outline side bar. Click "box 2" to return to all levels showing. Use Command-8 to put the sidebar away. Reprotect the sheet!

- Go to the next Project Worksheet and repeat these directions. Create a new DS/\* as necessary. Note the DATA SET/Project stipulation:

DS/*	PROJECT SHEETS Allowed
DS/A	proj0, proj1, proj2, proj3, proj4
DS/B	proj5, proj6, proj7, proj8, proj9
DS/C	proj10, proj11, proj12, proj13, proj14
DS/D	proj15, proj16, proj17, proj18

Also note the spelling and spacing are critical. Linking to the CHOOSER requires this form.

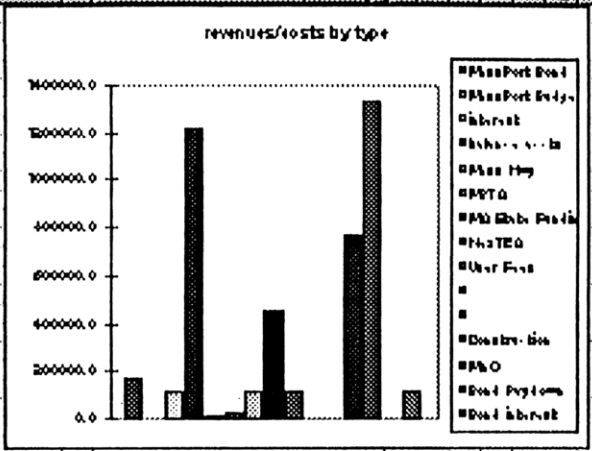
- When all the projects in all of the DATA SETs have been addressed, it is time to go to the CHOOSER.



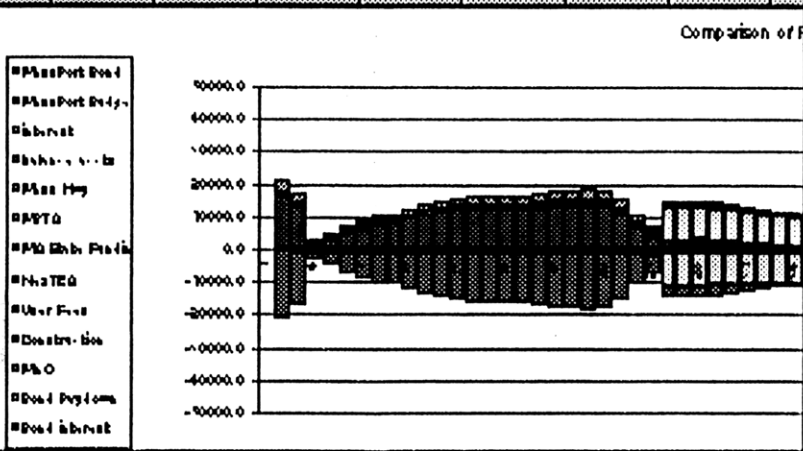
Navigation icons: Home, Back, Forward, Stop, Refresh, Print, Copy, Paste, Undo, Redo, Find, etc.

Zoom: 50%

### NPU CHOOSER 97 b.0

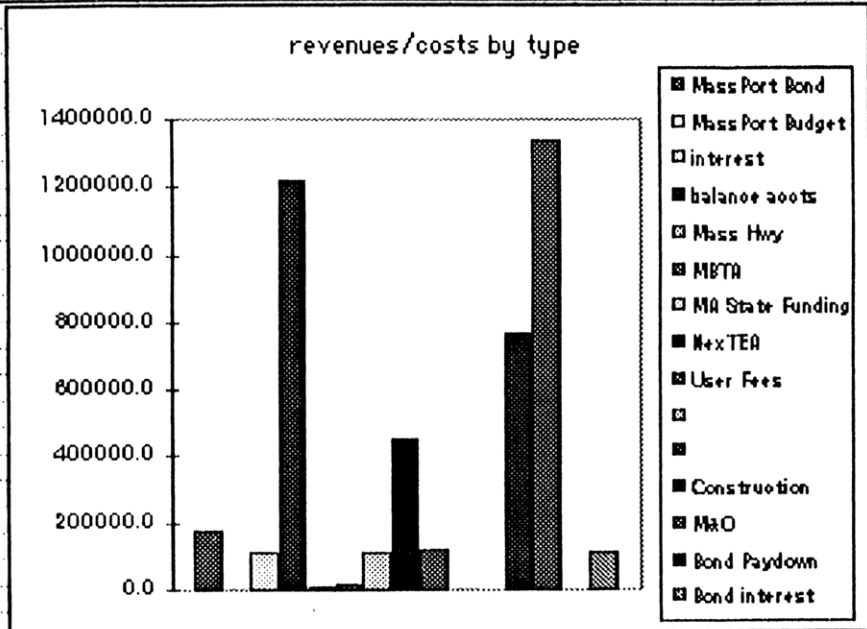


MassPort Pool	1760.16
MassPort Projct	0.0
Abstract	1070.7.2
MassPort Pool	121406.7
MassPort Pool	4044.0
MassPort Pool	1047.0
MassPort Pool	1267.0
MassPort Pool	4000.7.6
MassPort Pool	12006.1
MassPort Pool	227.07.2
MassPort Pool	227.07.2
MassPort Pool	1.750.4
MassPort Pool	0.0
MassPort Pool	1070.7.2
MassPort Pool	227.07.2



Proj	Item	Unit	Rate	Vol	Value	Yr	1	2	3	4	5	6	7
Proj 1.0	small abstract	DEP	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	small abstract	DEP	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	POT	from	1	to	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proj 1.0	large	DEP	from	1	to	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Navigation icons: Home, Back, Forward, Stop, Refresh, Print, Copy, Paste, Undo, Redo, Find, etc.



Class	Value	Legend	Value
MassPort Bond	174631.6	<input type="checkbox"/> MassPort Bond	
MassPort Budget	0.0	<input type="checkbox"/> MassPort Budget	50000.0
interest	107837.2	<input type="checkbox"/> interest	40000.0
balance accts	1221496.7	<input type="checkbox"/> balance accts	30000.0
Mass Hwy	80880.0	<input type="checkbox"/> Mass Hwy	20000.0
MBTA	19557.0	<input type="checkbox"/> MBTA	10000.0
MA State Funding	112673.0	<input type="checkbox"/> MA State Funding	0.0
NexTEA	452637.6	<input type="checkbox"/> NexTEA	-10000.0
User Fees	116096.1	<input type="checkbox"/> User Fees	-20000.0
Subtotal revenues	2213017.2	<input type="checkbox"/> Construction	-30000.0
Construction	767587.1	<input type="checkbox"/> MaO	-40000.0
MaO	1337592.8	<input type="checkbox"/> Bond Paydown	-50000.0
Bond Paydown	0.0	<input type="checkbox"/> Bond interest	
Bond interest	107837.2		
Subtotal Costs	221377.2		

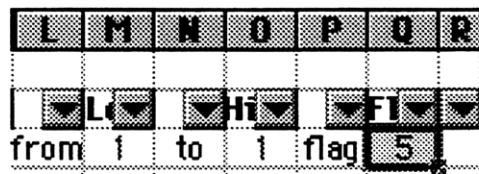
Project #	Description	Del	from	to	flag	Class	Totals	0	1	2
0	current obligations	DBB	from 1	to 1	flag	MassPort Bond	0.0	0	0.0	0.0
1	buses and operations	DBB	from 1	to 1	flag	MassPort Bond	865.8	0	865.8	0.0
2	displays	BOT	from 1	to 4	flag	MassPort Bond	12.0	0	12.0	0.0
3	bus maintenance facility	BOT	from 1	to 4	flag	MassPort Bond	39.5	0	20.5	13.0
4	D street ramp	DB	from 1	to 2	flag	MassPort Bond	0.0	0	0.0	0.0
5	transitway to D street	DBB	from 1	to 1	flag	MassPort Bond	57221.7	0	3300.0	3259.6
6	wood island station	DBB	from 1	to 1	flag	MassPort Bond	0.0	0	0.0	0.0
7	boyiston station	DBB	from 1	to 2	flag	MassPort Bond	0.0	0	0.0	0.0
8	rental car area	BOT	from 1	to 4	flag	MassPort Bond	95.6	0	0.0	0.0
9	rental car area	BOT	from 1	to 1	flag	MassPort Bond	95.6	0	0.0	0.0
10	terminal A/B	BOT	from 1	to 4	flag	MassPort Bond	95.6	0	0.0	0.0
11	terminal A/B	DB	from 1	to 2	flag	MassPort Bond	2861.9	0	0.0	0.0
12	terminal E above ground	BOT	from 1	to 4	flag	MassPort Bond	95.6	0	0.0	0.0
13	at A guideway above ground	DBB	from 1	to 2	flag	MassPort Bond	112278.5	0	0.0	0.0
14	harbor tube	DB	from 1	to 2	flag	MassPort Bond	0.0	0	0.0	0.0
15	at A guideway above ground	BOT	from 1	to 4	flag	MassPort Bond	0.0	0	0.0	0.0

- Close all of the open DATA SETs! Agree to the "Save" defaults.
- Open a CHOOSER (NOM or NPV. Only one at a time). Refuse the dialogue box asking to update links. Aside: There are four ways to "Update Links". The first is when opening the CHOOSER. This is very slow. The second is off the menu bar "Edit:Links" either "Update Now" (very slow) or "Change Sources" (better). The best is to open the CHOOSER and then sequentially open all the previously closed DATA SETs.

- Note that CHOOSER is an unprotected worksheet. Be careful! Save often. At the first sign of messing up, close the CHOOSER without a save. Close the open DATA SETs. Reiterate the opening sequence.

- The links in the CHOOSER recognize the DATA SETs and transfer the information. After this is done, the DATA SETs may be left open (if source adjustments are desired) or closed.

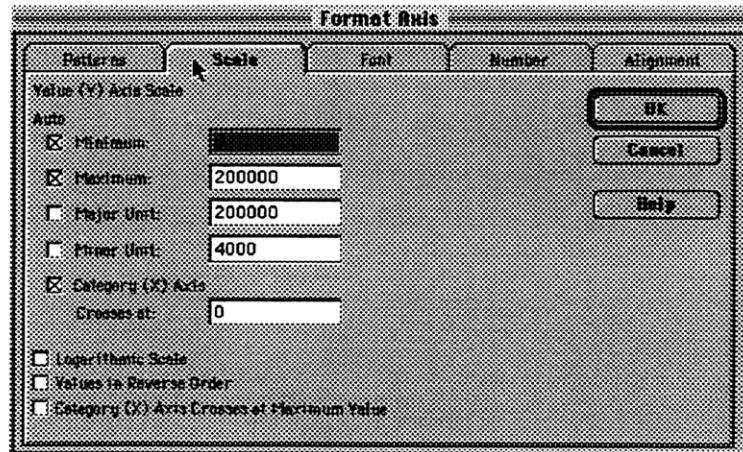
- CHOOSER comes with blue flag switches (Q27, Q42, Q57, ...) that can range in value from 1-4 depending on the number of delivery options available for



the project. The number 5 returns all zeros which is the same as turning off the project. If you have sorted previously, the number 1 will return the lowest valued delivery method. Value will increase as the flag value increases.

- Be careful in the CHOOSER. In order to use the filter function of Excel, the protection is turned off.
- The filter can be used to look at the imported information in several ways from all options to severely curtailed. Click on the arrowheads to see the options. Review "Filters" in the Excel Manual. The arrows in row B26-T26 are filter arrows.
- Summations can be done on filtered information, but do not use the "Summation" function of Excel as this can cause a freeze up of the screen. Rather click on the individual cells to do addition.
- There are two graphic displays in CHOOSER.
- The upper left columnar graph represents the totals in cells S3-T20. The vertical scale can be adjusted

by double clicking on the graph to activate it, then double clicking the axis itself to open a dialogue box. Click elsewhere on the worksheet to exit the graph.



- The graph on the right (second and third screens to the right) is a plot over 120 periods. Its generating DATA SET is underneath it. To view the data: click on the graph to generate the sizing handles which can be used to "size" the graph out of the way and expose the period summary data. On the graph the revenues are above the horizontal axis, costs below.

- Numerical work may be done interactively on opened DATA SETs as there is hot linkage.

- Excel suggests closing source documents first. Therefore, when done, close all open DATA SETs, then close the CHOOSER.

- While CHOICES II is pretty robust, it is possible to make serious mistakes.

- Save your work often!

- Keep worksheets in the protected mode as much as possible. Protection is found under "Tools:Protection". Do not use a password.

- If things seem messed up, quit without a save.

- Do not have the CHOOSER open when bumping the Dummy Worksheets (that is when creating the DS/\*s).

- Do not have the CHOOSER open when adding a second, third or fourth delivery block. In either case, CHOOSER loses the addressing needed for "Linking".

- When using the Macro buttons it is possible to generate an error message box. Choose the default button "End". Any other option will open a Visual Basic module. You do not want to go there.

- Observe the spelling, capitalization and spacing requirements for the "DS/\*" DATA SETs and the "proj\*" PROJECT SHEETs.

- Every DS/\* needs to have its full complement of PROJECT SHEET tabs even if they are not used. Dummy "Insert:Worksheets" may be brought down

from the menu bar if desired. The lack of a tab label will manifest in the CHOOSER as a "#REF!" error that will make the graphs inoperative. An alternative to dummy sheets is to make use of the "5" flag in the CHOOSER.

- Summation (command-shift-"T") in the CHOOSER may cause a screen freeze if any filters are being used. Find a desired total by "click-adding".

- Any constants supplied prior to bumping the dummy DATA SETs will be global. Within a DS/\* any changes to the CONSTANT SHEET will be local to that DS/\* only.

- Before entering any data, make sure that the folder contains the Data Master II, the dummy DS/\*s, and the CHOOSER(s) of choice. Everyone involved with shaking down the beta version has experienced trouble adding the CHOOSER later. It is possible to do so by assembling all the parts in a folder then using "Edit:Links:Change Sources" which is a very slow process.

- If you do not like the percentages for construction or Maintenance-Operations make the changes in the blue background rows. Do not unprotect the sheet and make changes to the formula cells.

- Use and enjoy!

- Comments, questions and/or access to CHOICES II, please contact:

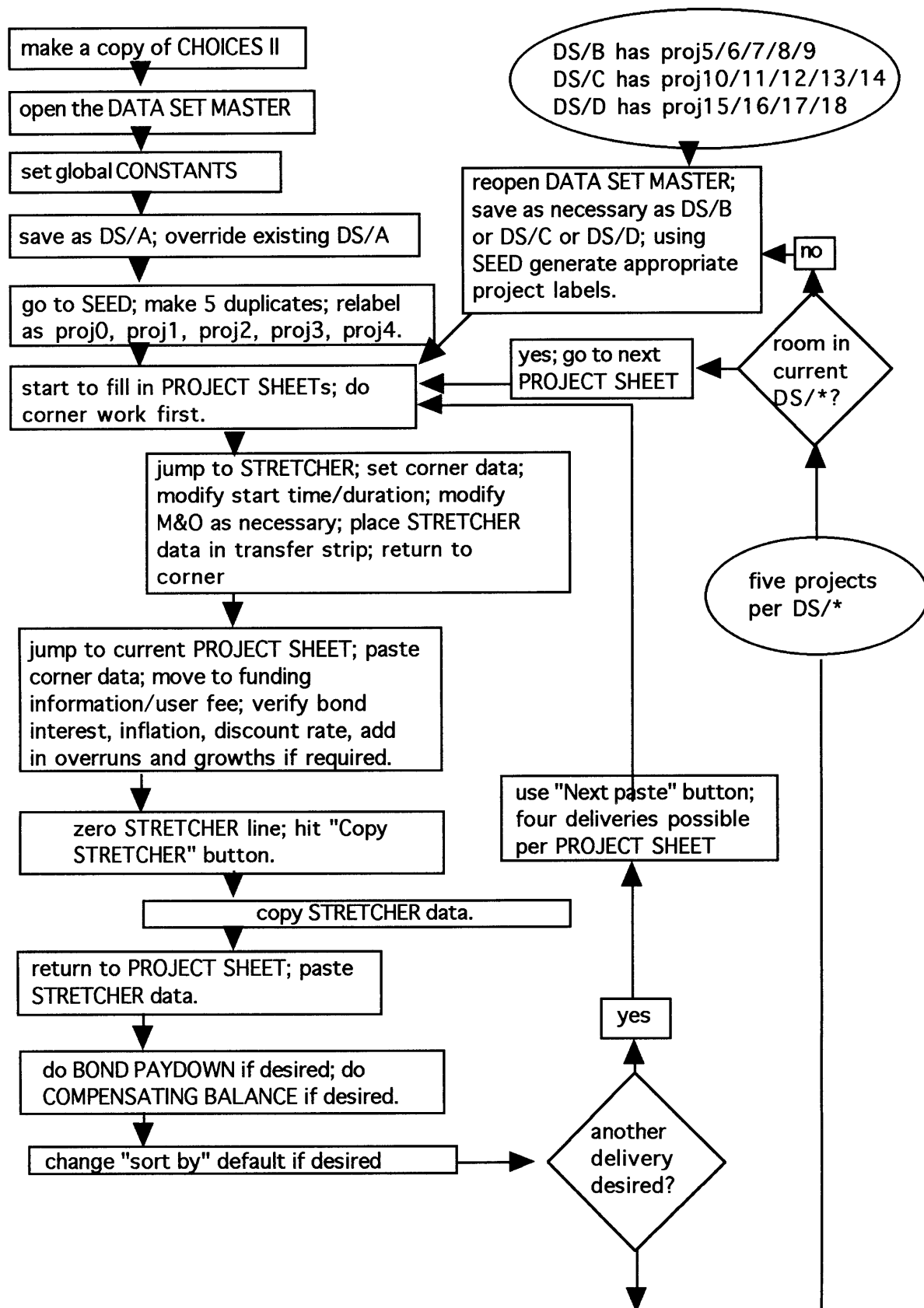
Roger H. Evje

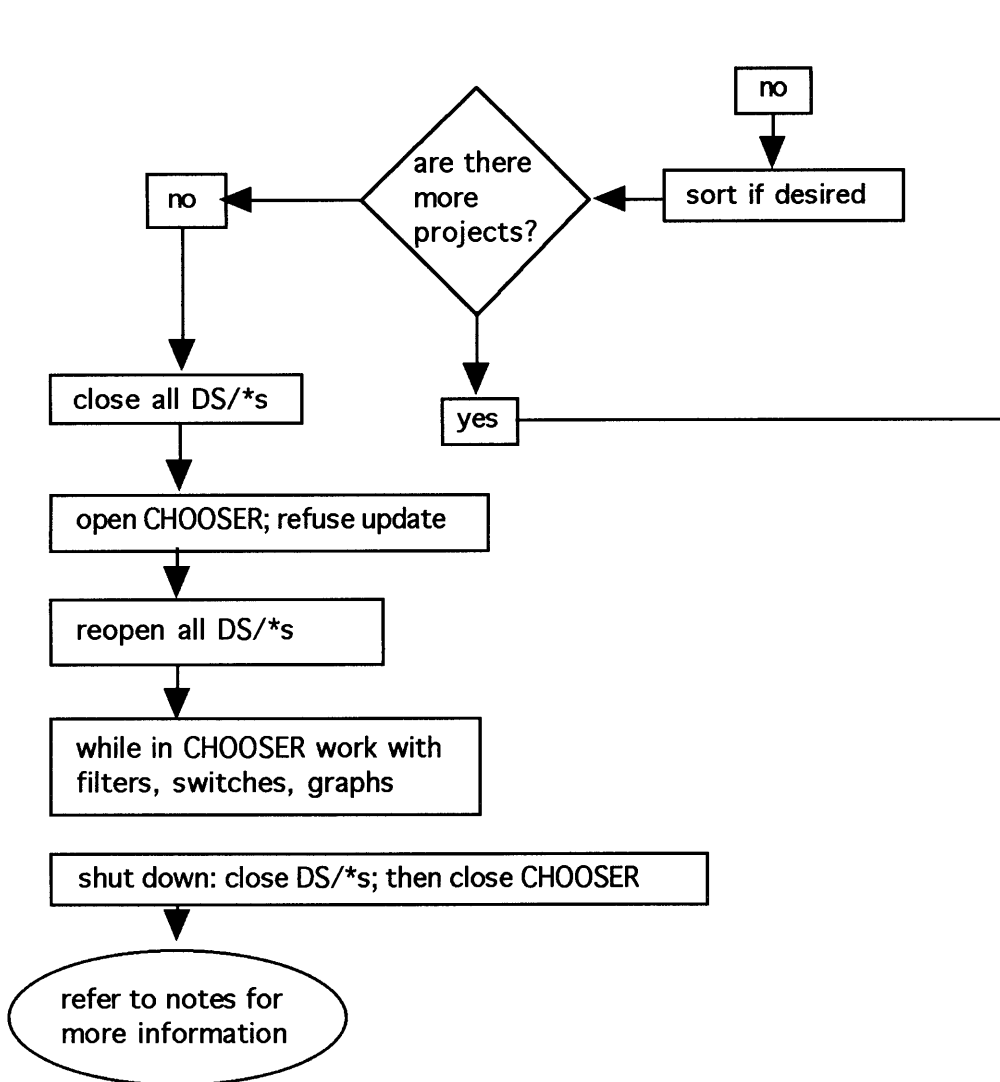
rhevje@mit.edu

-or-

Prof. John B. Miller

jbmiller@mit.edu





## APPENDIX II-INTERMODAL TRANSIT CONNECTOR DATA

CHOICES II has been developed using sample data collected last year in Course 1.961-Infrastructure Development Research: The People Mover Project as part of Logan 2000. The research was carried out as a seminar under the direction of Prof. John B. Miller. As the term progressed the seminar title was changed to reflect a larger regional picture that developed. This larger view is now called the Intermodal Transit Connector.

The goals of Infrastructure Development Research are to develop a competitive system of awarding project procurement, to increase the pace of technological development, to shorten the duration of delivery, and to foster creative planning of viable projects. Our team was given an initial directive by the Logan 2000 group to "find the money. We already have the plan" which was to be some version of a monorail-like sky train circulating about the airport grounds. Our team discovered, though, that there were many regional links being discussed and promoted, that the money and the effort of the Logan people could easily be incorporated into these greater plans, and that Logan and Boston could both benefit by this new integration.

Logan is the airport arm of the Massachusetts Port Authority (MassPort). It is both self funding as it turns a profit and well received by the Wall Street bond market. Seven revenue sources are collected in CHOICES II. They are: public utility bonding; MassPort charges against airport clients (airlines, car rental companies, taxi fees, food concessions, ground leases to companies like

UPS); Massachusetts Highway Department (especially Central Artery roadwork money); the MBTA (Boston public transportation); Massachusetts state government; ISTEA (Intermodal Surface Transportation Efficiency Act); and user fees charged against the traveling public. Four cost area are considered: construction including planning and design; maintenance and operations; bond paydown; and bond interest. Their inclusion in CHOICES II is discussed below:

ACCOUNT NAME	FORMULA/DEPENDENCY
UPPER BLOCK OF DATA	
MassPort Bond	Takes data from construction cost line if MassPort bond source is checked.
Periodic Paydown	Analyst data entry.
Accumulating Balance	Sum of incurred bond debt less paydown.
MassPort Budget	Takes data from construction cost line if MassPort source is checked.
Interest Payments	Takes its value from the interest cost line. Assumes that MassPort will pay out of operating funds
Compensating Balance	Zeros out shortfall or surplus. Assumes MassPort will pay out of operating funds.
Mass. Highway	Takes data from construction cost line if MassHwy source is checked.

MBTA	Takes data from construction cost line if MBTA source is checked.
ISTEA	Takes data from construction cost line if ISTEA source is checked.
User Fees	Takes data from the user fee assignment block, the user fee growth block (exponentiates), the Maintenance-Operations line.
SubTotal Revenues	SubTotal of above.
Construction Paste Line	Analyst data entry line. Can be placed automatically from the STRETCHER, or placed by hand.
Maintenance-Operations Paste Line	Analyst data entry line. Can be placed automatically from the STRETCHER, or placed by hand.
Construction Costs	Uses construction percentage from above, project price, inflation (exponentiated), and construction overrun (exponentiated).
Maintenance-Operations Costs	Uses Maintenance-Operations percentage from above, project price, inflation (exponentiated), and Maintenance-Operations growth

	(exponentiated).
<b>Bond Paydown</b>	Takes its value from bond paydown line above.
<b>Bond Interest</b>	Uses accumulated bond obligation and bond interest to figure simple interest owing. Assumption that interest is paid down each quarter, not capitalized.
<b>SubTotal Costs</b>	SubTotal of above four categories
<b>LOWER BLOCK OF DATA</b>	Corresponding values of upper block discounted per discount rate (exponentiated).

The data garnered from the Logan project follows:

Massport given data

proj #	1	2	2	2	2	3	3	3	3	4	4
description	buses and operations	displays	displays	displays	displays	bus maintenance facility-chelsea-----				D street ramp-----	
delivery method	DBB	DBB	DB	DBO	BOT	DBB	DB	DBO	BOT	DBB	DB
price (x1000)	3900	1500	1500	1500	1500	5000	5000	5000	5000	3500	3500
construction start	1	1	1	1	1	4	4	4	4	17	17
construction duration	1	1	1	1	1	4	4	4	4	7	7
M&O %	33	18	18	18	18	18	18	18	18	18	18
funding/%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MPA/20%	MHD/100%	MHD/100%
funding/%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%	NexTea/80%		
funding/%											
funding/%											
user fee %	33	0	0	0	0	0	0	0	0	0	0
bond interest	6	6	6	6	6	6	6	6	6	6	6
inflation %	3	3	3	3	3	3	3	3	3	3	3
discount rate	8	8	8	8	10	8	8	8	10	8	8
construction overrun	0	0	0	0	0	0	0	0	0	0	0
M&O growth	0	0	0	0	0	0	0	0	0	0	0
user fee growth	0	0	0	0	0	0	0	0	0	0	0
revs =? costs	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
npv total cost	24884	6082	5476	5232	67	18645	16820	16118	221	9849	8904

Massport given data

proj #	5	6	7	7	8	8	8	8	9	10	10
description	transitway to D street	wood island station	boylston str-----		rental car area-----				watershuttle stn	terminal A/B-----	
delivery method	DBB	DBB	DBB	DB	DBB	DB	DBO	BOT	BOT	DBB	DB
price (x1000)	300000	5000	153000	5370	5370	5370	5370	5370	5370	5370	5370
construction start	3	1	38	52	52	52	52	52	52	52	52
construction duration	23	7	20	7	7	7	7	7	7	7	7
M&O %	18	18	18	18	18	18	18	18	18	18	18
funding/%	MBTA/20%	MHD/100%	MBTA/20%	MBTA/20%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%
funding/%	NexTEA/80%		NexTEA/80%	NexTEA/80%							
funding/%											
user fee %	2	0	2	2	33	33	33	33	18	33	33
bond interest	6	6	6	6	6	6	6	6	6	6	6
inflation %	3	3	3	3	3	3	3	3	3	3	3
discount rate	8	8	8	8	8	8	8	10	10	8	8
construction overrun	0	0	0	0	0	0	0	0	0	0	0
M&O growth	0	0	0	0	0	0	0	0	0	0	0
user fee growth	0	0	0	0	0	0	0	0	0	0	0
revs =? costs	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
npv total cost	893246	17922	248050	255085	9970	9348	8954	145	145	9970	9348

Massport given data

proj #	10	10	11	11	12	12	12	12	13	13	17
description	-----		terminal C above ground		terminal E above ground-----				alt. A guideway above ground		harbor tube
delivery method	DBO	BOT	DBB	DB	DBB	DB	DBO	BOT	DBB	DB	DBB
price (x1000)	5370	5370	5370	5370	5370	5370	5370	5370	353000	353000	250000
construction start	52	52	52	52	52	52	52	52	38	38	46
construction duration	7	7	7	7	7	7	7	7	21	21	13
M&O %	18	18	18	18	18	18	18	18	18	18	18
funding/%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/100%	MPA/50%	MPA/50%	State/40%
funding/%									State/25%	State/25%	NexTEA/60%
funding/%									NesTEA/25%	NesTEA/25%	
user fee %	33	33	0	0	33	33	33	33	0	0	18
bond interest	6	6	6	6	6	6	6	6	6	6	6
Inflation %	3	3	3	3	3	3	3	3	3	3	3
discount rate	8	10	8	8	8	8	8	10	8	8	8
construction overrun	0	0	0	0	0	0	0	0	0	0	0
M&O growth	0	0	0	0	0	0	0	0	0	0	0
user fee growth	0	0	0	0	0	0	0	0	0	0	0
revs =? costs	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
npv total cost	8954	145	9970	9348	9970	9348	8954	145	629660	655931	377462

Massport given data

proj #	17	18	18	18	18	19	19	19	19
description	harbor tube	maintainence facility-Chelsea-----				vehicles and systems-----			
delivery method	DB	DBB	DB	DBO	BOT	DBB	DB	DBO	BOT
price (x1000)	250000	30000	30000	30000	30000	73000	73000	73000	73000
construction start	46	52	52	52	52	44	44	44	44
construction duration	13	7	7	7	7	15	15	15	15
M&O %	18	6	6	6	6	18	18	18	18
funding/%	State/40%	State/20%	State/20%	State/20%	State/20%	MPA/60%	MPA/60%	MPA/60%	MPA/60%
funding/%	NexTEA/60%	NexTEA/80%	NexTEA/80%	NexTEA/80%	NexTEA/80%	NexTEA/40%	NexTEA/40%	NexTEA/40%	NexTEA/40%
funding/%									
funding/%									
user fee %	18	15	15	15	15	30	30	30	30
bond interest	6	6	6	6	6	6	6	6	6
inflation %	3	3	3	3	3	3	3	3	3
discount rate	8	8	8	8	10	8	8	8	10
construction overrun	0	0	0	0	0	0	0	0	0
M&O growth	0	0	0	0	0	0	0	0	0
user fee growth	0	0	0	0	0	0	0	0	0
revs =? costs	yes	yes	yes	yes	yes	yes	yes	yes	yes
npv total cost	389824	46037	43114	41561	534	129841	129745	126252	2141

43

### APPENDIX III-SENSITIVITY ANALYSIS

There are no great surprises here. An engineering rule of thumb states that 80% of the cost of a project is committed in the first 20% of the job. Choices made from initial planning through design development factor heavily into the overall costs of the job. If Life Cycle Costs are viewed as planning, design, land acquisition, legal and permitting fees, financing costs, construction, Maintenance-Operations, and eventual demolition/disposal, this seems reasonable. Early choices affect the project throughout its life. Elements that occur early and are of a limited duration have a lesser effect overall than long running aspects that are affected by the uncertainties of inflation, overrun and user fees. By this view, construction even over a few years is less contributory than say Maintenance-Operations over thirty.

Inflation affects the bonding requirement in an exponential manner. Consequently MassPort's interest obligation is also exponential. Construction, while intense in cost for its period, is a fairly small aspect of the Life Cycle Costs. Its inflationary curve is very flat over its duration. Maintenance-Operations occurs for a long duration and throughout the later, more inflationary periods of the project. Its contribution to total costs is very sensitive to inflationary pressure.

The bonding requirement and construction costs show an inverse relation to the discount rate. This relation is less abrupt than that of interest cost, Maintenance-Operations, and the total job costs. This is because construction and its attendant bonding occur sooner rather than later in the job. Because

the discount rate, which is an exponential function of the period, is located in the denominator, earlier costs are discounted less severely than later costs.

Construction overrun is an exponential influence affecting the bonding requirement, the interest charges and the construction costs.

Maintenance-Operations growth has a very exponential affect on the total costs due to the long period that it runs. It is doubly vulnerable to inflationary pressures.

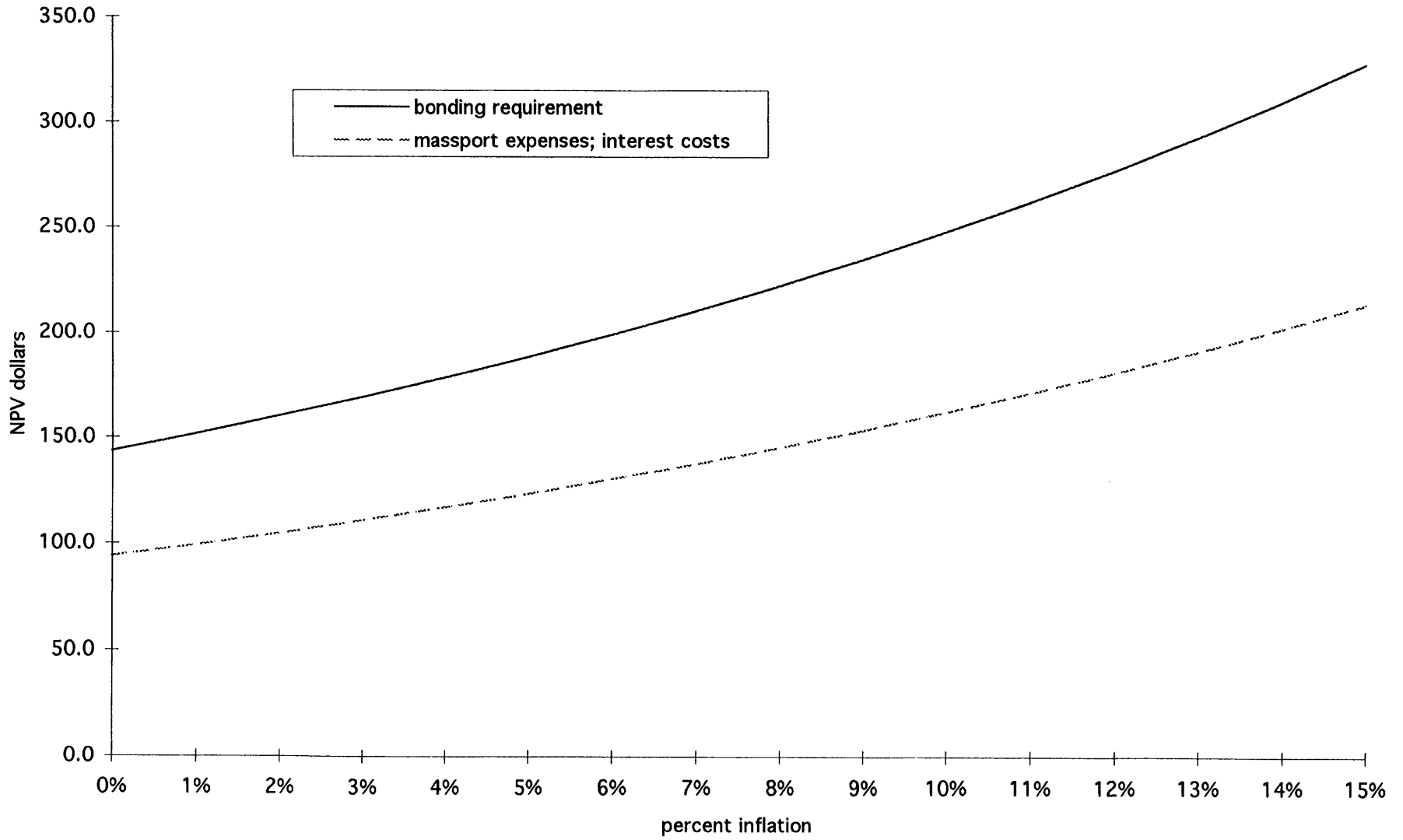
User fees have a linear influence on shortfall and surplus.

The bonding capacity has a linear effect on interest, bonding requirements and total costs.

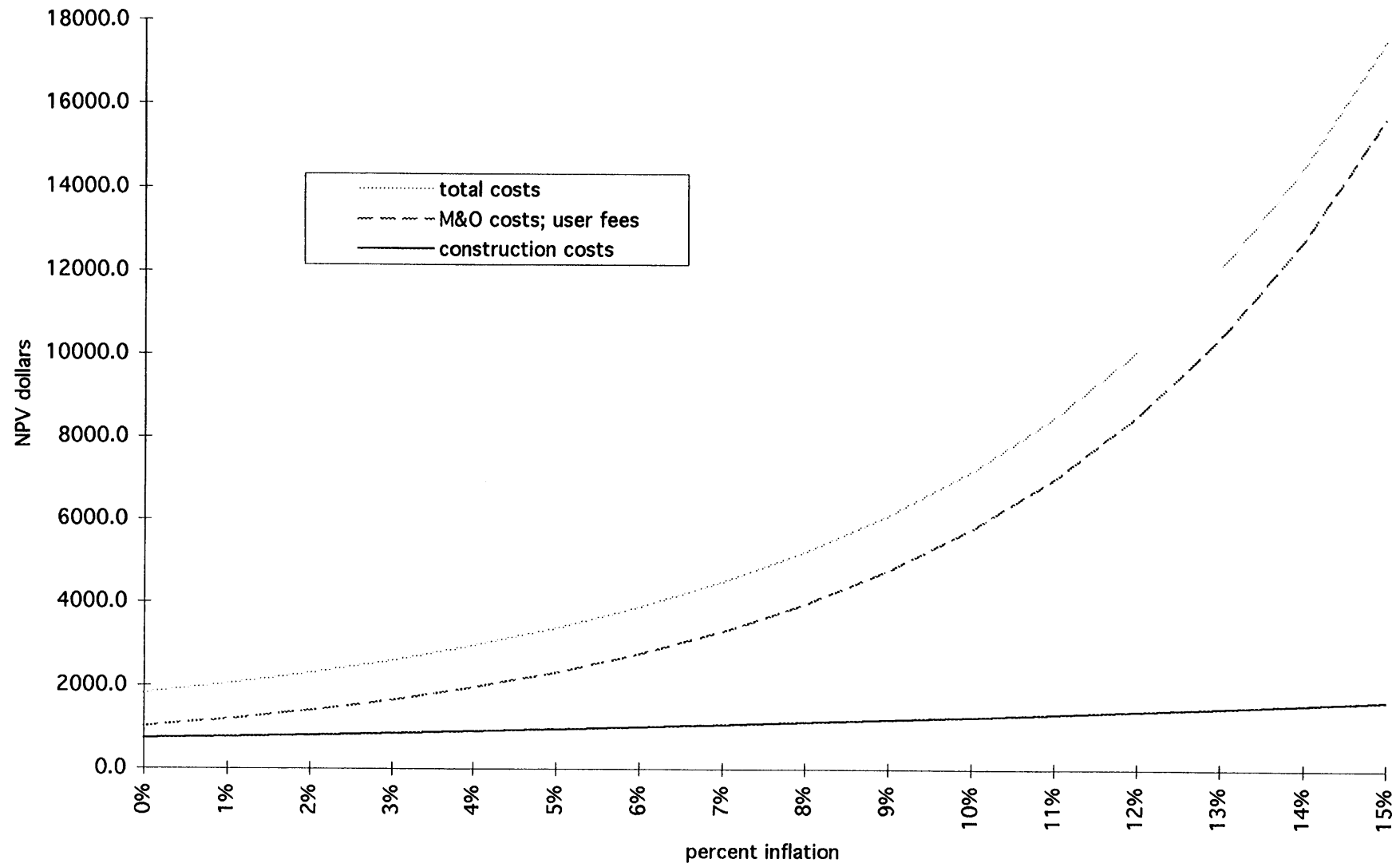
DBB Sensitivity Experiments  
(Base Case Values)

Unit Price equals	\$1,000
Start first planning period	1
Planning duration	16
Start construction	17
Construction duration	16
Construction completion	32
DBB: M&O percent set at	18%
Bond Interest	6%
Inflation	3%
Discount Rate	8%
Construction overrun	0%
M&O Growth	0%
User Fee Growth	0%

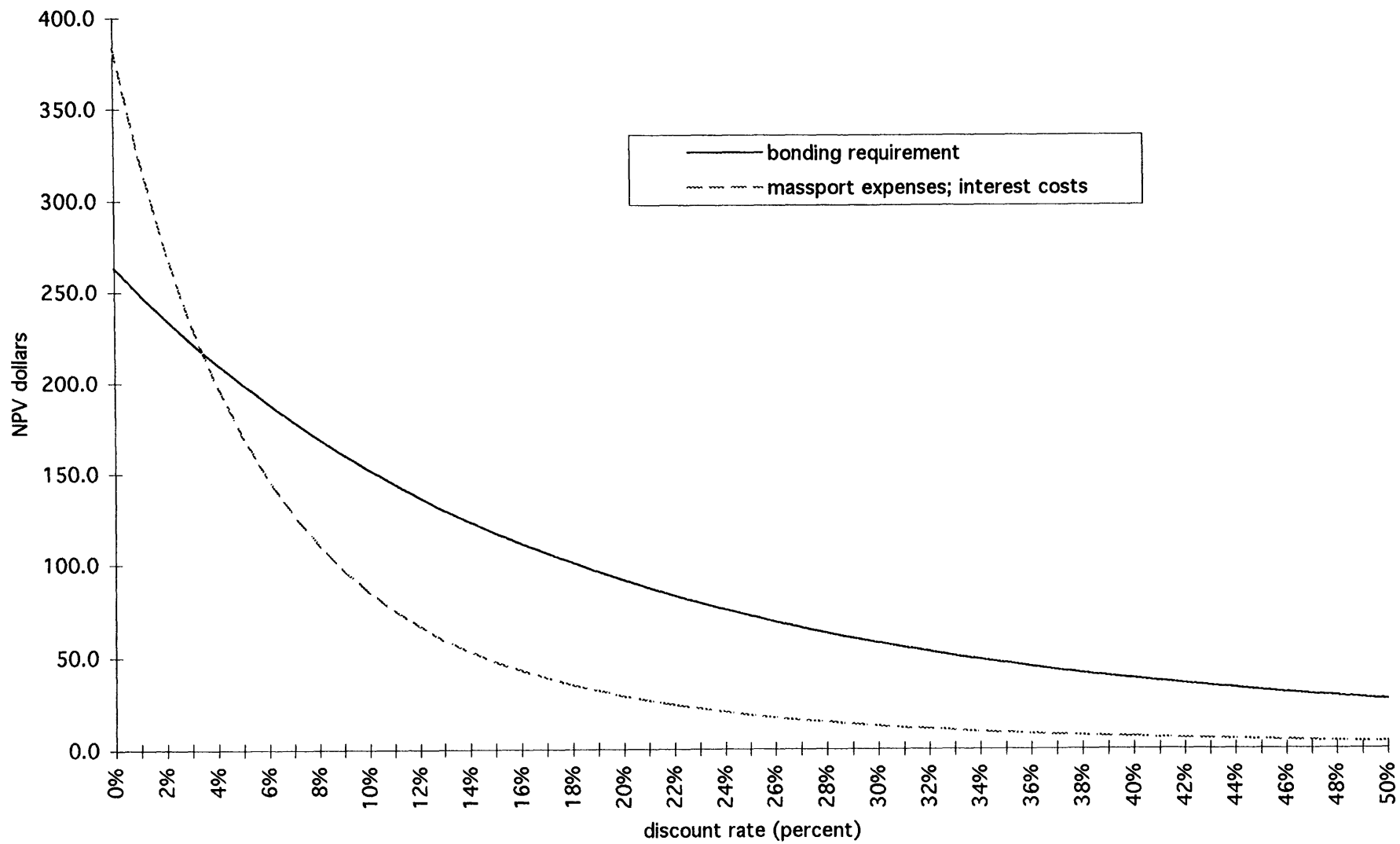
# NPV vs. Inflation



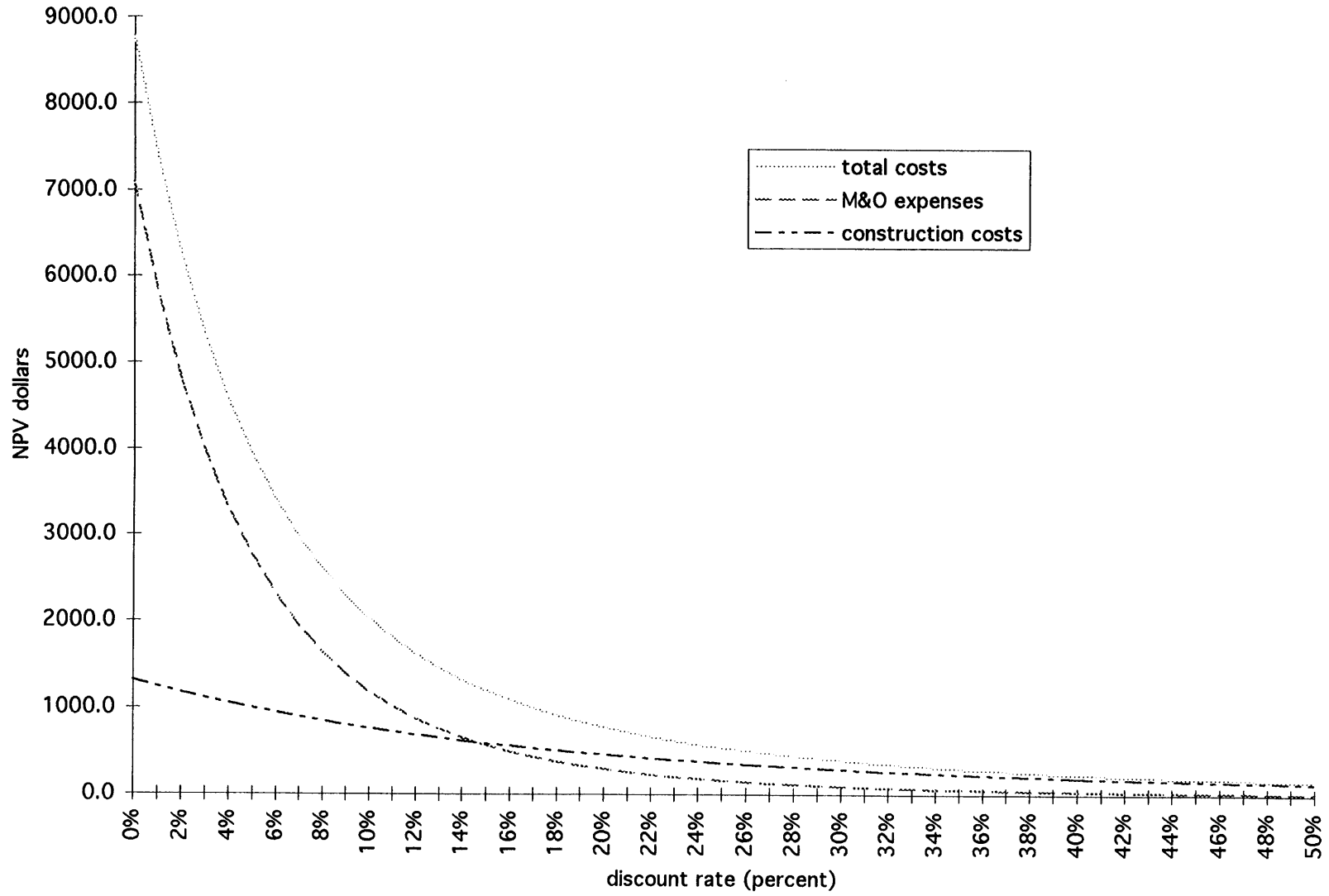
# NPV vs. Inflation



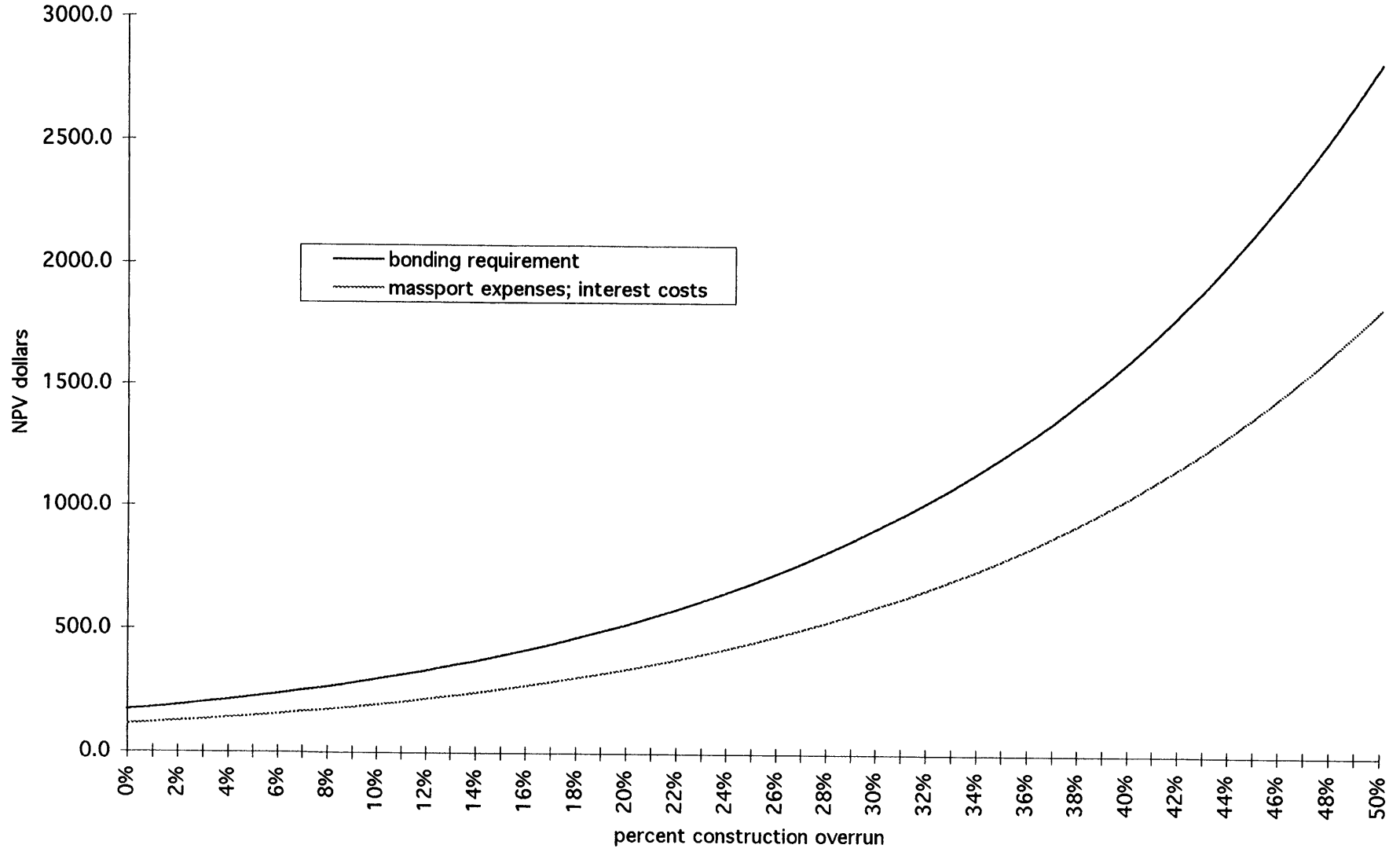
# NPV vs. Discount Rate



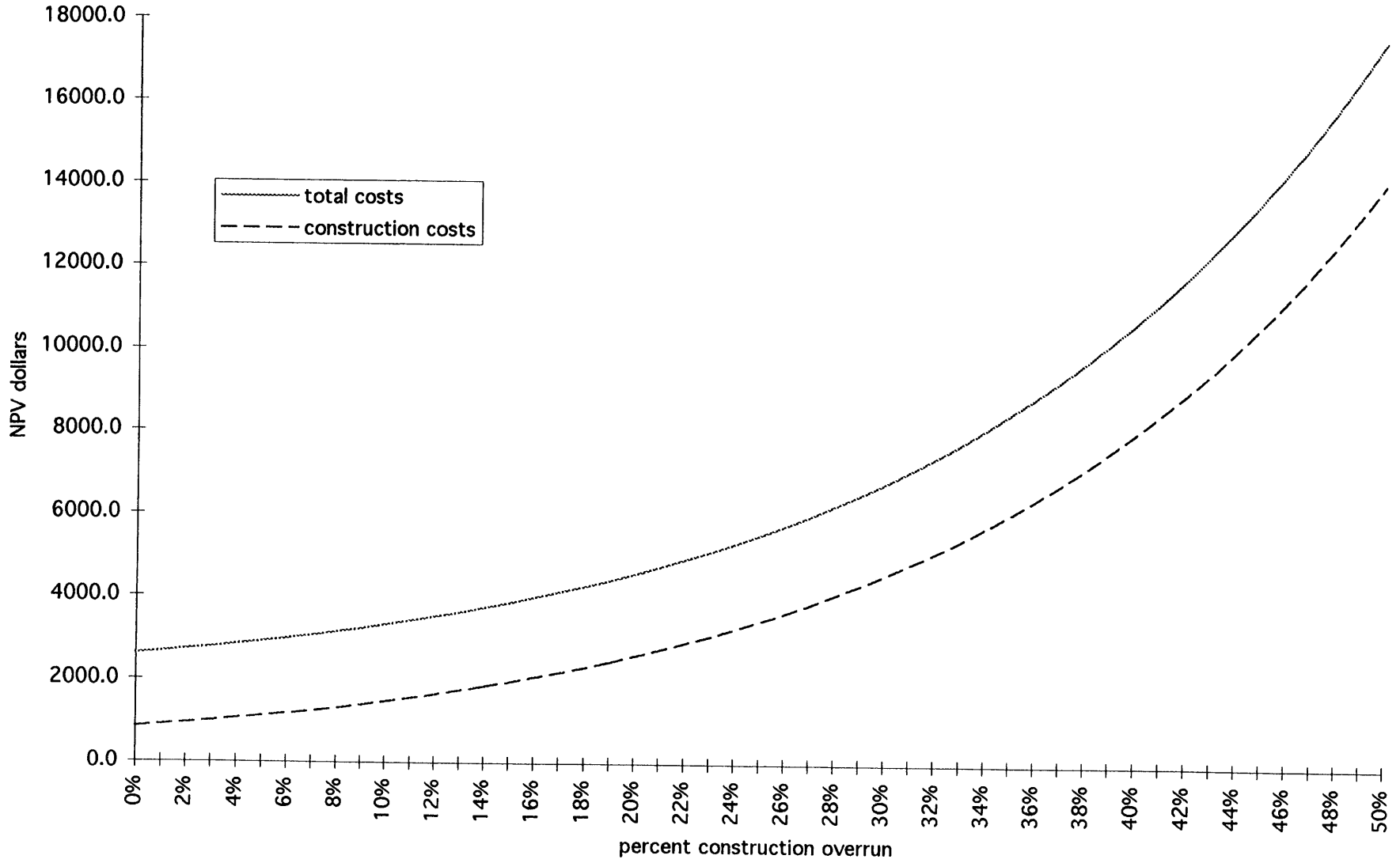
### NPV vs. Discount Rate



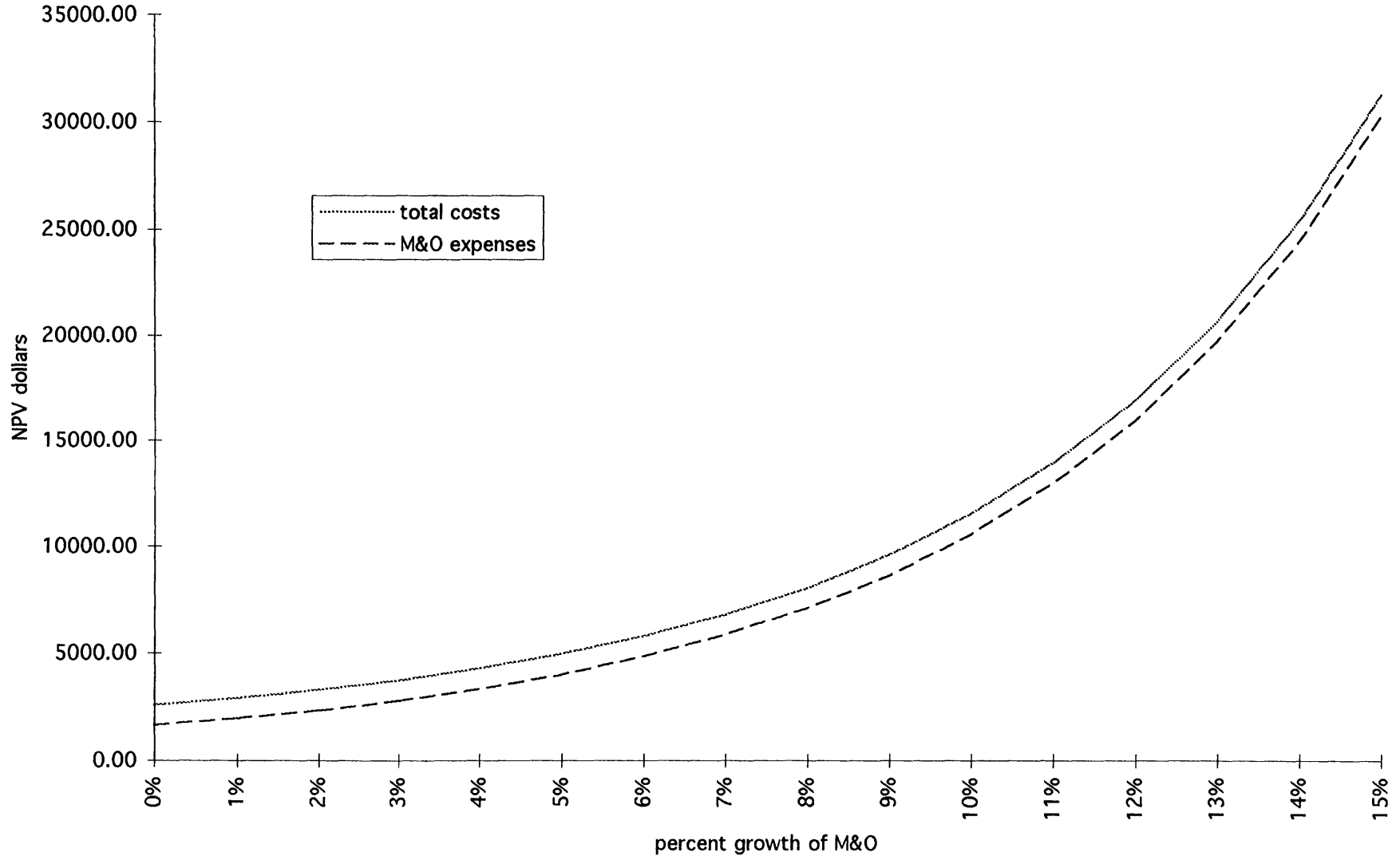
# NPV vs. Construction Overrun



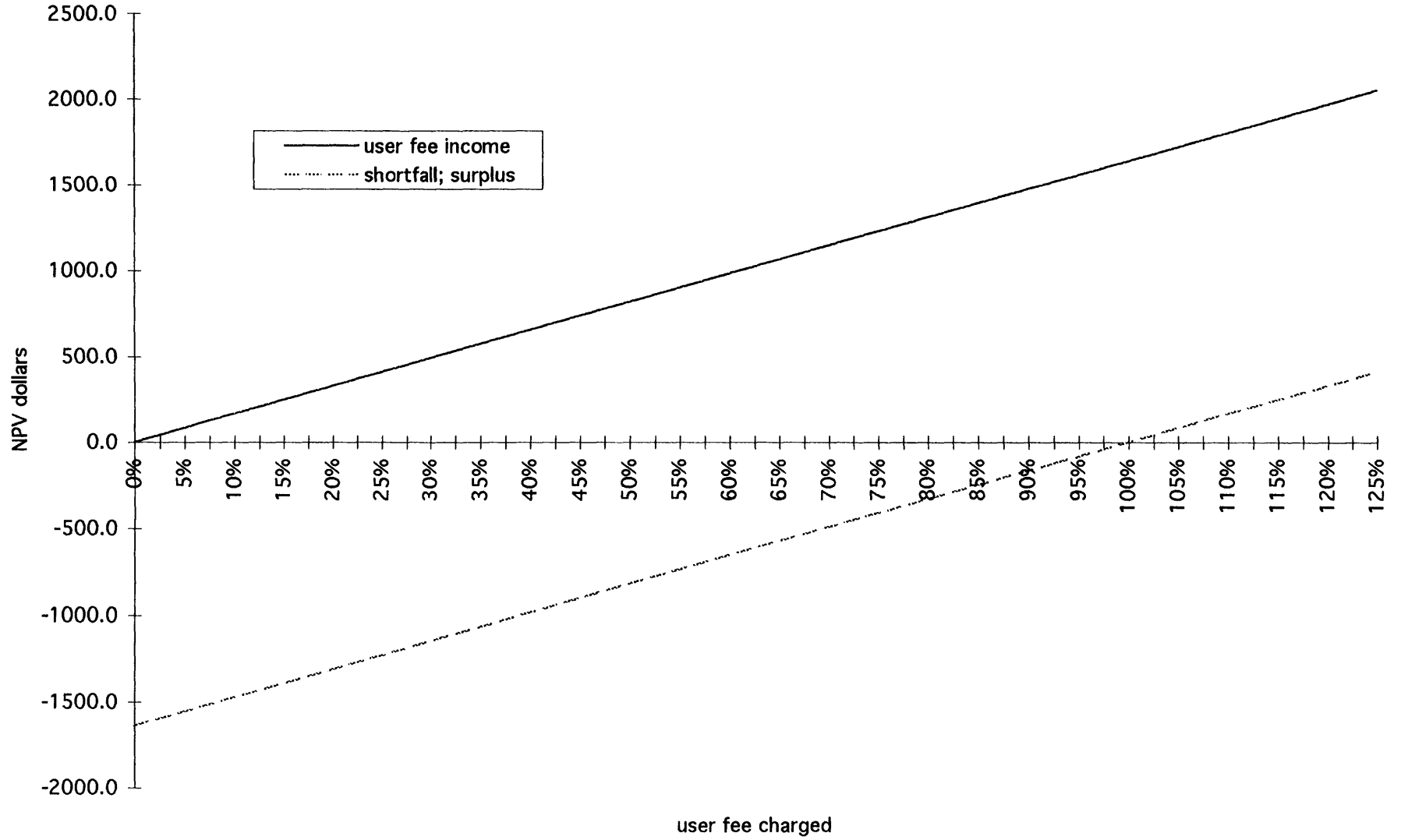
NPV vs. Construction Overrun



# NPV vs. M&O growth



NPV vs. User Fee Charged



# NPV vs. Bonding Capacity

