OPTIMIZING THE CAPITAL INVESTMENT PORTFOLIO

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ABSTRACT

As the telecommunications industry continues to become more competitive, telephone company investments exhibit greater risk and tend to be increasingly discretionary. To effectively meet the challenges created by this environment, new techniques are needed to evaluate the telephone company's "portfolio" of capital investment opportunities.

The articles in this seminar concentrate on a new approach to capital portfolio management being introduced at GTE. The approach will enhance our ability to understand alternative business strategies by helping management to evaluate tradeoffs between alternative capital portfolios that meet, to differing degrees, near term financial requirements and longer term objectives for shareholder wealth creation.

The first paper, "Evolving Capital Program Management Process," by Robert Glomski, provides an overview of the integrated business process for capital portfolio management and is designed to create the context for more in-depth discussion of the new optimization model used in the process.

Dr. Arthur Geoffrion's article entitled "Capital Portfolio Optimization: A Managerial Overview," explains the portfolio optimization problem and the essential features of the approach being used at GTE. He discusses the benefits of optimization by contrasting it with a conventional, albeit sophisticated, budgeting approach.

The paper entitled "Optimization of Capital Portfolios" by Dr. Gordon Bradley presents the optimization model's formulation but also discusses specific adaptations of the model to meet real world applications. These adaptations include the concept of "economic penalties" where the model recognizes that slight violations of some constraints can lead to significantly better capital portfolios and considers the economic tradeoffs.

Finally, Thomas Edwards' article "Capital Portfolio Optimization Results" discusses the benefits of this new process and modeling techniques by presenting some real results from their use at GTE. The paper focuses on the application of the process and tools presented in the preceding articles.

EVOLVING CAPITAL PROGRAM MANAGEMENT PROCESS

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Today's telecommunications business environment is unprecedented in its complexity, risks, variability, and in the magnitude of the challenges it presents. GTE is presently facing challenges, both internally and externally, of proportions never before experienced. Our external environment is characterized by increasing change and risk; large and rapid swings in the direction of the economy; increasing and vigorous competition; the continuing progression of technological advances; and many new market opportunities, each with its own demands and potential pitfalls. Internally, the corporate environment has entered a period of critical introspection, characterized by its Vision and Values philosophy and directed toward obtaining greater impact from fewer resources and dollars. These challenges affect all areas of our business but tend to have their most significant effect on the business process of "Provision of Plant" - the Corporate Capital Investment Program - because of the nature of our capital intensive industry.

The Capital Program Management System (CPMS) is a response to these challenges. It will aid in the effective and efficient management of the Capital Investment Program. Its direction is to provide a sound investment plan and the ability to answer:

- Why this much, why now, and why here?
- Did we do what we said we would do for the dollars budgeted in the time frame planned?

INTRODUCTION

CPMS is a business process that provides an overall framework for capital investment management, expressed through policy, management procedures and computer applications. While it is planned to support this business process with a considerable amount of mechanization, it should be recognized that CPMS uses the term "system" in its largest context; not merely to mean a computer system. GTE recognizes that not all aspects of the Provision of Plant can or should be mechanized, or even standardized, across our operating companies.

In addition to describing what CPMS is, it is important to note what it is not. While CPMS addresses the functions of Planning, Program Management, Engineering and Construction, it does not address the organizations that perform these functions. This is not to imply that organizational questions are not important, only that CPMS does not address them - the System is concerned with what is done, not who does it.

CPMS BUSINESS CONCEPTS

The environmental challenges highlighted above require significant changes in management philosophy for our business to remain successful. CPMS will facilitate implementation of a number of approaches to help GTE meet these challenges. Important business concepts are outlined below.

The objective of the investment process must be redirected from "the least costly alternative" philosophy of the past to the "maximize the market value of equity and stockholder returns" philosophy of the future. This redirection will promote the effective use of capital and correspond to a rational pricing policy that associates revenues with their true economic costs, thereby reducing the attractiveness of methods to bypass present and future network facilities. This will be supported by the CPMS Portfolio Management process which furnishes a view based on providing the service/products that are most profitable. Selection of this portfolio will consider various constraints (such as available capital, financial objectives and management objectives for market share). Executives will have information about the value of various capital portfolios; thus, enabling trade-off decisions to be made recognizing their consequences. CPMS will also require that these plans include an effective tracking mechanism for verification of the expected revenue and expense effects.

The CPMS computer applications will provide a mechanism to describe investments in terms of their business purpose and categories to assist management in high level business analysis.

Planning or market areas will be established as "business cost centers" for which all revenue, expenses, and investments can be analyzed. Procedures for identifying "discrete" investment opportunities within the cost center must be developed. A discrete investment opportunity or "Investment Cluster" focuses on the investment decision. The investment cluster concept "solves" the problem of joint costs by grouping programs that are supported by a common investment into a single decision. Then the total revenue impact from the various "dependent" programs and the total expense impact from the expense-affecting programs are evaluated along with the total investment required. As an example, the replacement of a particular central office (or group of related offices) will provide the capability to offer, at a small additional cost, call forwarding, call waiting, touch calling, usage sensitive service and other revenue affecting programs. This same investment in office replacement increases maintenance productivity and provides for customer growth. The Investment Cluster for this alternative will be analyzed considering total investment (including land, building, outside plant, etc.), total revenue and total expense cash flows. Revenue cash flows will show the effect of market demand forecasts. The expense cash flows will reflect the total expenses projected to support the services provided by the Investment Cluster. Another discrete investment cluster in the same planning area might be remote line test equipment. This investment decision is independent from the office replacement cluster and can be evaluated based on its own economics.

The new process must provide for integrated units, hours and dollars in the budget. The integrity of the capital program will be a primary concern of CPMS. As different constraints are applied to the capital program, all associated units and hours will be correspondingly adjusted. Additionally, the effect on revenue and expense estimates will be available to management.

Earned value analysis concepts for job progress control will be facilitated through retention of the elements of costing (e.g., units, labor rate components). These elements will be compared to actual results plus the construction supervisors' estimates to complete the work order to provide the budgeted cost of the work actually performed and other earned value measurements.

To become more competitive by lowering costs, new systems must estimate project milestone schedules based on forecasted requirements. Scheduling algorithms will be flexible to provide for individual variations, and these algorithms will consider such external factors as weather. Changes in the forecast will immediately be evaluated as to the impact on the capital program. Range forecasts will be used to perform contingency planning by indicating when decisions must be made to purchase equipment to allow for sufficient lead times.

CPMS will facilitate the adjustment of the capital program when vendor price changes or periodic changes in inflation assumptions and labor rates are recognized. This will provide the most up-to-date view of the capital program for contingency planning by management. "Bulk" recosting programs will provide reports indicating the impact that the price changes have on the present view of the capital program. When appropriate, a single supplement will be produced explaining the change and the affected projects and work orders will be automatically "flagged" with reference information to the single supplement. The mechanized system will assist costing of a work order based on advance units, piece parts or material codes. The system will return the extended cost and "lock this value in" as issue 1 of the project or work order. The cost can then be adjusted manually, but CPMS will maintain an audit trail to aid management in review and approval functions. CPMS tables will be Telco (and location within the Telco) specific allowing for variations in labor productivity factors and other cost factors.

Human resources load leveling will provide management with the increased capability to plan for force adjustments and training requirements. This process will allow for schedule adjustments early enough for management to take appropriate action. Detailed human resource scheduling will employ interactive sessions with supervisors to enable specific personnel to be assigned jobs because of unique requirements or on-the-job training considerations.

The CPMS process will provide a measurement of productivity. These measurements will be available at various levels, such as, company, location, work group and individual.

Support of an effective investment plan requires retrospective analysis of cost benefit assumptions. Future investment decisions must be based on the best available information pertaining to revenue and expense impacts. CPMS will provide the information that will enable management to evaluate their past investment decisions and accordingly adjust future decision making based on this data.

The concepts that are outlined above only highlight some of the important features that CPMS will provide. They are not an extensive list. In effect, these key concepts provide insight into CPMS's purpose and objectives. The System will allow us both to "do better things" via improved investment planning, and to "do things better" via improved operations management, plus to analyze the "things" we've done to ensure they <u>are</u> "better" via cost-benefit analysis and tracking.

Exhibit 1 reflects the structural and procedural aspects of CPMS and characterize the integrated nature of the process.

EXHIBIT I

CPMS FUNCTIONAL MODEL OVERVIEW

CPMS IS COMPOSED OF 13 MAJOR AREAS OF FUNCTIONALITY:

PLANNING

OPPORTUNITY ASSESSMENT

- Collect economic, technological, marketing and demographic data
- Review and analyze business plans and proposed investments
- Develop Opportunity Assessment Reports (OARs)

FUNDAMENTAL PLANNING

- Review OAR's
- Develop Proposals
- Generate expense, investment and revenue data associated with each proposal
- Evaluate investment alternatives for economic and service impact, feasibility and other considerations
- Select alternatives that will meet Telco and Corporate objectives
- Formulate network architecture alternatives to meet strategic opportunities for customer service.

PROGRAM MANAGEMENT

PORTFOLIO MANAGEMENT

- Use financial data developed by Fundamental Planning to generate portfolio alternatives
- Use Optimization program to determine most profitable combination of investment alternatives
- Develop recommendations for Capital Planning Committee

IMPLEMENTATION PLANNING

- Develop plan for implementing selection made by Capital Planning Committee
- Produce broad gauge pricing, sizing and milestone scheduling estimates for projects
- Develop Planning Area Profile site-specific plans for implementing the investment

PROGRAM CONTROL

- Maintain data base information
- Provide logistical support for other processes
- Distribute reports

BUDGET APPROVAL

- Approve recommended plans put forth by Portfolio Management

ENGINEERING

WORK ORDER ENGINEERING

- Develop work order specifications
- Identify material requirements
- Draft work orders
- Perform field engineering
- Schedule engineering activities

WORK ORDER PRICING

- Develop detailed material and labor prices
- Develop work order drawings and specifications
- Determine material and labor requirements and sources

WORK ORDER APPROVAL

- Perform on-site inspections
- Approve work order specifications
- Assemble work order documents

WORK ORDER MONITORING

- Identify work order changes
- Invoice material shipments
- Maintain engineering standards

CONSTRUCTION

PLANNING AND SCHEDULING

- Schedule work orders
- Perform manpower scheduling

PERFORMANCE

- Arrange for material delivery
- Record hours worked and materials used
- Track project schedule against actuals
- Report schedule variances

DOCUMENTATION

- Maintain work order documentation
- Update work order status
- Perform Quality Assurance and acceptance reviews
- Release completed work order documentation

CAPITAL PORTFOLIO OPTIMIZATION: A MANAGERIAL OVERVIEW

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ABSTRACT

Within the capital program management system discussed in the previous paper, an important new technique has been developed for optimizing capital portfolios. This technique has been designed with both near-term and long-term management objectives in mind. This paper explains the portfolio optimization problem and the essential features of the optimization approach, and illustrates it with a simple example. The example is also used to contrast the optimization approach with a more conventional approach, and to illustrate how the new approach can facilitate responding to new project opportunities regardless of when they happen to occur.

INTRODUCTION

As explained in the first session of this seminar, the central objective of the portfolio optimization part of CPMS was to develop a computer-based system capable of finding the best possible portfolio of capital projects. The system requirements include:

A) be clear about the assumptions and methods used to compute "optimal" portfolios,

B) be able to answer the "What If ...?" and sensitivity questions that management needs to address in the course of deciding on a capital portfolio,

C) be suitable for studying problems and opportunities as they occur throughout the year, as well as be able to support regularly scheduled strategic planning tasks,

D) clarify the inescapable managerial tradeoffs associated with capital management.

The general approach taken can be described in simplified terms as follows:

1. (Modeling) Study the general problem of designing capital portfolios for GTE operating companies, and formalize an idealized version of the capital portfolio optimization problem.

2. (Process Design) Determine how to incorporate portfolio optimization capability into the integrated capital program management process being developed under a broad, high-level charter.

3. (System Development) Develop the advanced optimization technology, modern data development/database software, and business practices and procedures needed to support capital portfolio optimization.

4. (Education) Develop complete documentation and give executive seminars and training sessions so that everyone concerned knows how to function effectively within the new approach.

5. (Implementation) Install the new computer software, business practices, and procedures.

6. (Support and Evolution) Provide for ongoing maintenance of all systems, training of new personnel, and evolution of systems and procedures as business requirements change.

This paper deals mainly with the modeling and education steps outlined above. The paper that follows entitled "Optimization of Capital Portfolios" by Dr. Gordon Bradley deals with the system development effort outlined in step 3 above and gives a more mathematical explanation of the optimization model. The last paper in this seminar deals with implementation by illustrating early results obtained during tests of the new system. The perpetual last step (support and evolution), although important, is not covered in this seminar.

FORMALIZING THE PORTFOLIO OPTIMIZATION PROBLEM

Only an optimization based approach can hope to achieve the central objective and associated system requirements.

In broad terms, the capital portfolio optimization problem is as follows:

> Given a list of candidate capital projects, select a subset which maximizes total net present value while making sure that the selected portfolio meets essential requirements and does not violate resource or financial constraints for a five year planning horizon.

This statement introduces several ideas that require further explanation.

The list of "candidate capital projects" can run into the thousands, and will include growth and modernization projects, bulk projects, and service and operating improvements. A given project can appear in several versions if there are alternative years in which to begin it, alternative funding profiles over time, alternative technologies or vendors, etc. Developing this list is, of course, a very important and time-consuming part of the problem, but will not be discussed further in this paper.

The choice of a five year "planning horizon" as a compromise between keeping data requirements reasonable and being able to support strategic planning requirements. Most data elements must be provided for each of the five years. The planning horizon rolls forward each year (year 2 becomes the new year 1, year 3 becomes the new year 2, etc.).

"Net present value" was chosen as the measure of merit because it is a well accepted measure of the wealth of the firm. The net present value of each candidate project is computed from data going well beyond the five year planning horizon.

The "essential requirements" referred to are partly technical (e.g., project B cannot be accepted unless project A is also accepted) and partly derived from managerial interpretation of what is necessary given the business environment (e.g., maintain necessary levels of service mandated by the public service commission).

"Resource constraints" refers, for example, to labor hour limits by labor category, to equipment delivery capacity, or to any other limitation an operating company may decide could be a limiting factor when designing the capital portfolio. These constraints, like all others, apply to each year of the planning horizon individually.

"Financial constraints" refers to three distinct conditions that must hold in each year of the planning horizon: (a) no more than a stipulated amount of capital can be used; (b) the percentage of internally generated funds must be above some stipulated lower limit; and (c) net income to common (that is, after covering preferred dividends) must be above some stipulated lower limit.

In order to deal with financial constraints (b) and (c), and to keep track properly of monies related to capital expenditures, it is necessary to formalize in some detail the standard financial statement known as the funds report. In particular, sufficient financial data is needed for each candidate project and for the operating company as a whole so that this statement can be calculated for any trial capital portfolio. This modeled funds statement is sufficiently detailed that, when properly calibrated by adding non-project expenditures, it yields pro forma financial predictions that correspond closely to those provided by the standard, regularly used GTE financial planning system.

THE OPTIMIZATION APPROACH

The optimization approach is quite different from the "conventional" approach to capital portfolio design. It does not accept or reject projects individually on the basis of any kind of "ranking". It does not view project selection as a sequential process that looks at projects solely in terms of their individual merits. Rather, it selects the entire portfolio of projects simultaneously based on how they all fit together.

It sometimes seems, even to experienced managers, that true optimization is not essential for designing capital project portfolios. This view is incorrect because it overlooks two important points.

The first is that the number of possible project combinations is so great that no intuitive or heuristic (trial-and-error) computational procedure could possibly come closer than a few percentage points to the true optimum. With literally billions of capital dollars at stake within GTE, this would leave a great deal of money on the table unnecessarily.

The second overlooked point is that true optimization is essential in order to answer "What If ...?" and sensitivity questions. Answering these questions involves measuring differences in best portfolio performance between data scenarios that are identical except for carefully controlled changes. The difference between two scenarios is the difference between the values of the respective optimal portfolios; the difference between the values of non-optimal portfolios will not be the correct value and may not even have the same sign.

The mathematical formulation of the portfolio optimization problem falls in a famous but difficult category of problems called "mixed integer linear programming". Not only is this general problem category difficult, but the problem instances that arise in most of GTE's operating companies are very large relative to the computational state-of-the-art. It was therefore infeasible to apply commercially available software. Instead, advanced (and, until recently, experimental) optimization software was adapted to the task.

ON-LINE TUTORIAL DEMONSTRATION

Capital portfolio optimization requires many levels of management to assimilate new ideas and perform some of their functions in new ways. How are these new ideas and job requirements to be communicated?

Generalities and words have their place. But concrete examples usually are more effective, especially if they are "live" rather than "canned".

That is why we use on-line computer demonstrations whenever possible. In particular, we have developed seminars with on-line examples of key concepts for vice-president level executives, for director level executives, and for less senior managers. A personal computer is ideal for most purposes, although a mainframe link is necessary if optimization is to be done on problems other than small demonstration prototypes.

This very session is, in fact, based on the on-line seminar that we give to vice-presidential level management of GTE's operating companies.

Obviously it is impossible to reproduce here the effect of a personal computer hooked to a large screen projector. We will have to be content with an outline of the on-line demonstration. Those who have seen the demonstration should find it a useful review, and those who did not may still find it worthwhile.

1. Introduce Demonstration Problem

A demonstration problem with only nine candidate projects suffices for most illustrative purposes. The projects are:

		NPV
A1	Convert C.O. A in 1990	80
A2	Convert C.O. A in 1991	60
B1	Convert C.O. B, nominal capacity	100
B2	Convert C.O. B, extra capacity	90
C1	Convert C.O. C in 1990	70
C2	Convert C.O. C in 1991	50
D1	Convert C.O. D in 1990	-10
D2	Convert C.O. D in 1992	-15
O	All other projects	1,000

NPV stands for total net present value. Note that the first eight projects are in pairs. At most one of each pair may be accepted. Project O stands for all of the many projects not listed explicitly in this simplified example; it is treated as a mandatory choice.

Several data elements (in addition to NPV) are required for each candidate project in each of the five years of the planning horizon, which in this example spans 1987-1991. The essential ones are: capital requirements, contribution to net income before interest on debt, impact on non-cash items (depreciation, etc.), and consumption of each resource.

Additionally, about 20 items of company financial data are required for each planning horizon year. These include such items as interest rate estimates for short term and long term debt, the debt retirement schedule, the desired proportions of new debt and equity capital, the effective income tax rate, and so on. Realistic data values were chosen based on the financial structure of an actual operating company.

2. Illustrate "Conventional" Portfolio Design

The new software for portfolio optimization can be used in non-optimizing mode to simulate a conventional approach to portfolio design. This sets the stage for contrasting the conventional and optimization approaches.

In our simulation of a conventional approach, the first trial portfolio is composed based on a single measure of merit, namely net present value. This leads to the portfolio [A1,B1,C1, D1,O] (remember that exactly one of each C.O. conversion pair must be accepted).

Unfortunately, this portfolio uses more capital in 1990 than is available. An examination of capital requirements data for the candidate projects suggests that C1 be changed to C2. This results in the second trial portfolio [A1,B1,C2, D1,O], which uses acceptable amounts of capital in all five years of the planning horizon.

This second trial portfolio must be sent to the budget department for detailed financial review. Such a review shows that the portfolio will lead to a smaller net income in 1991 than is desirable. Something must be done to remedy this deficiency. One possibility is to revise the capital portfolio further.

Examination of the data most pertinent to net income suggests changing A1 to A2. This is done and, as hoped, a second detailed financial review shows that the third trial portfolio [A2,B1, C2,D1,O] is feasible on all counts. This portfolio is dubbed the **Conventional Strategic Plan.** Its total NPV is 1200.

Remember that all of this trial-and-error and the associated financial evaluations are done "live" using a personal computer and large screen projector. The computer displays are designed for use by managers and are easy to follow.

3. Illustrate Optimization-Based Portfolio Design

An optimization-based approach eliminates most trial-and-error because the computer is programmed to anticipate not only when a trial portfolio will violate one of the straightforward requirements, like staying within a total capital budget every year, but also to anticipate when it will violate a hard-to-calculate requirement like meeting a floor on net income each year of the planning horizon. Moreover, the computer is programmed to do something equivalent to complete enumeration of all possible portfolios. (Actually, the computer program uses mathematical reasoning to avoid having to examine every possible portfolio.)

A push of the optimization button for this simple problem quickly reveals that the best possible portfolio is [A1,B2,C1,D1,O]. It has a total NPV of 1230, which is better than the total NPV of the conventional strategic plan. A (simulated) budget department review comes back clean, as it usually does with our optimization-based system since it incorporates a detailed financial model. The portfolio is dubbed the **Optimal Strategic Plan.**

What conclusions can one draw, from this simple example, about the relative nature of the conventional and optimization-based approaches to capital portfolio design? Some are obvious.

* The conventional approach selects projects sequentially and requires a lot of trial-and-error, while the optimization approach selects projects all at once and requires no trial-and-error in the usual sense.

* Because there are so many different possible portfolios, it is highly unlikely that the conventional approach will find the best possible one; optimization always constructs the best portfolio.

Perhaps less obvious is that the conventional approach does not really get down to the essence of portfolio design. It is "group" properties that distinguish a good portfolio from a bad one, not "individual" project properties. It is how the projects all fit together in terms of financial performance, resources, service, and so on, that matters. Some group properties are easy to calculate, such as the total amount of capital or other resources required. But other group properties, like a portfolio's impact on the income statement or funds statement, require complex calculations for which the conventional approach is hopelessly inadequate. These complex calculations require an elaborate financial model of the entire company.

This concludes our simplified illustration of portfolio optimization and how it compares to a conventional approach. We turn now to a hypothetical situation in which a new opportunity must be evaluated after the annual strategic plan has been completed.

4. Responding to a New Project Opportunity

New project opportunities can come along at any time. Suppose that an attractive marketing opportunity with high NPV (210) occurs just after the Optimal Strategic Plan has been agreed upon. What should be done?

One possibility would be simply to add the new project to the Optimal Strategic Plan: add the new project's data to our demonstration database, push the recalculation button, and observe that, although total NPV duly goes up by 210 to 1440, available capital is exceeded in 1989 and 1990.

It would be possible to make trial-and-error adjustments of this augmented portfolio in order order to make room for the new marketing project, but we would never know whether the best possible adjustment has been made. A better approach would be to reoptimize the portfolio using the enlarged list of candidate projects.

Reoptimization results in the portfolio [A2, B1,C1,D2,M,O], where "M" stands for the new marketing project. Total NPV is 1425. This portfolio meets all constraints (not just capital availability) and is an excellent solution except for one difficulty: project D2 is included. Unfortunately, upon close examination, D1 turns out to be a "must do" project for business reasons that transcend the pure numbers. Thus D2, the alternative to D1, is an unwelcome member of the new portfolio.

Lock D2 out of the portfolio? The numbers fall such that this would preclude the new marketing project, for D1 is financially incompatible with the marketing project. We can't have our cake and eat it too.

The logical thing to do in this situation is to augment the budget so that D1 and M are no longer mutually exclusive. An examination of the results for the Optimal Strategic Plan with the marketing project added on suggests a budget augmentation in 1990. A modest 1990 augmentation is therefore keyed into the computer. A push of the reoptimization button yields the portfolio [A2,B1,C1,D1,M,O] with total NPV 1430. Note that both D1 and M are included. It turns out that only a part of the extra capital made available is actually used.

5. Recap of Runs: Hard Managerial Decisions

Let us now recap the runs made as a consequence of the new marketing project opportunity. This will illustrate the point that even optimization capability does not make all managerial problems go away; hard decisions remain.

OPTION	NPV	FIVE-YEAR CAPITAL	D1
Original Strat Plan	1230	317,870	Yes
Original + Marketing	1440	364,400	Yes
Reoptimize (no extra $)	1425	359,860	No
Reoptimize with extra $	1430	360,700	Yes

The "5 Year Capital" column simply tallies (with no discounting) the capital dollars actually used by the portfolio over the entire five year planning horizon. This and the "NPV" column are in thousands of dollars.

It is important to note that a comparison of the last two options gives a precise answer to the inevitable question "How much value can be obtained in return for the extra capital?" GTE had never been able to answer this kind of question before, although it often came up, because true optimization is the only tool capable of answering it.

Consider now the tradeoffs implicit in the above recap of runs. There are three conflicting business objectives to be juggled in deciding which of the four portfolios to choose. The first, represented by the "NPV" column, is to maximize the long term wealth of the company. The second, represented by the "5 Yr. Capital" column, is to deal as well as possible with short term economic realities. The third, represented by the "D1" column, is to take account of important business considerations that have not been quantified. Each objective ranks the options differently. No option is best by all three objectives for this example, nor will it be in any realistic situation.

How to juggle these three conflicting objectives is a matter for business judgment, not for the computer. Such conflicts are inherent in all businesses. That's the bad news. The good news is that portfolio optimization is a nearly ideal tool for helping management cope with these conflicts. It quantifies the tradeoffs, calculates impacts of possible courses of action, and allows alternative capital portfolios to be evaluated quickly in depth.

SUMMARY

GTE presently is bringing on stream a comprehensive, computerized capital program management system of advanced design that includes the ability to calculate optimal project portfolios. Here "optimal" means that total net present value is maximized among all possible portfolios that satisfy technical and managerial constraints on available capital, other resources, and key financial measures. In addition to performing optimization, the system has the ability to perform a comprehensive evaluation of any proposed portfolio (or variant of the optimal portfolio) in detail. Of course, any candidate project can be locked in or out of the portfolio to help management quantify and evaluate its impact.

The managerial advantages of the computer-based optimization approach can be summarized as follows.

1. Optimization produces better capital portfolios than can be found by more conventional methods. This is so because all possible combinations are evaluated, and because provision is made to generate many more candidate projects than before.

2. Because it is fully computerized and perpetually maintained, the system is available to respond to problems and opportunities as they arise, in a timely way, regardless of when they happen to occur during or outside of the annual planning cycle.

3. Optimization permits quantifying the impact of changes in the limits and targets that management stipulates for such things as capital, other resources, and net income.

4. Optimization enables basic managerial tradeoffs to be clarified, including economic versus operational considerations, and long-term goals (like maximizing total net present value) versus short term objectives (like a net income target in the first year of the planning horizon).

Capturing these advantages requires an orderly transition to a new way of doing things for most of the managers and executives responsible for capital management. They must understand how to use the new tools effectively. The greatest challenges have not to do with systems, but rather with people.

OPTIMIZATION OF CAPITAL PORTFOLIOS

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ABSTRACT

Capital portfolio optimization for GTE is modeled as a mixed integer linear programming problem. The critical economic tradeoffs between maximizing the long-term market value of the firm's equity and satisfying shorter-term financial constraints, resource limitations and service objectives are incorporated into the model and into the software system that constructs optimal portfolios. The use of the model and the optimization software in the capital program management process is described.

INTRODUCTION

The goal of capital portfolio optimization is to maximize the long-term market value of the firm's equity while satisfying near-term financial constraints, resource limitations and service objectives. Facing an increasingly complex and competitive marketplace, GTE has developed a computer-based system to improve the quality of its capital decisions by using state-of-the-art decision technology to automate the quantifiable aspects of selecting optimal portfolios. This is part of the GTE Capital Program Management System (CPMS). The system allows the effective use of significantly more information at the highest levels of decision making. The additional information comes from requiring more information about capital investment opportunities and from requiring that several alternatives for implementing each be developed. Better decisions are achieved from the increased information by a process that includes using an optimization model to provide a conceptual framework for the problem and an extensive and innovative software system that coordinates the data gathering and constructs optimal portfolios. The automation of the quantifiable aspects of the problem allows management to focus on the critical non-quantifiable factors.

Improving the quality of capital decisions by making better use of information mandates that:

1. Design of portfolios must include an automatic means to guarantee that any selected portfolio meets corporate financial constraints. Manual evaluation of GTE's multi-billion dollar investment program is not feasible.

2. The system must automatically decide when it is justified to modify short-term restrictions in order to improve the long-term value of equity. This is a critical tradeoff between the short-term restrictions and long-term objectives. Because of the scale and complexity of GTE portfolio decision problems, the evaluation of these tradeoffs must be incorporated into the construction of optimal portfolios.

3. Using all the available quantifiable data, the system must be capable of automatically constructing the best possible (that is, the optimal) capital portfolio. GTE's capital program is so large that the dollar difference between the optimal portfolio and inferior portfolios is huge. The analysis of important non-quantifiable factors depends on the ability to produce optimal portfolios for "What if...?" questions. To decide whether strategy A is better than strategy B, it is necessary to compare the values of the optimal portfolio for each.

Item 1 is handled by incorporating a funds statement for the entire company into the model; this allows financial constraints for the portfolio to be imposed explicitly. Extending the model to allow "penalties" for constraint violations expresses the tradeoffs from 2 by assigning a dollar value to violating the near-term requirements. The mixed integer programming optimization system provides the capability required by 3 and it has demonstrated its ability to construct optimal portfolios in a cost effective and timely manner for GTE capital portfolio problems.

The project database, the model and the software to construct optimal portfolios are built to allow high-level management access to significantly more information about capital projects and their interactions than was previously possible. Studies to explore options, answer questions and investigate tradeoffs can be performed in a timely manner. The system can be used throughout the year as new opportunities and new problems require reconsideration of capital decisions. In a dynamic and demanding business environment the project database represents a valuable corporate asset; the system allows this information to be used effectively in the capital planning process.

A MODEL FOR PORTFOLIO DESIGN

Within GTE, each telephone operating company formulates its own capital portfolio problem. In capital portfolio optimization the candidate projects do not all fit the usual definition of "capital"; they include projects such as multi-year marketing plans. In a GTE telephone operating company the number of candidate projects ranges from many hundreds to several thousands. The candidate projects may begin in any of the first five years.

In the mixed integer linear programming model each candidate project is represented as a variable $x(p)$ where p ranges from 1 to the maximum number of projects. The value of each variable is the level of participation of the candidate project in the portfolio. Each variable must take on a value between 0 and 1:

$0 \leq x(p) \leq 1$ for all candidate projects p.

$x(p) = 0$ means the candidate project is not in the portfolio, $x(p) > 0$ means p is in the portfolio and $x(p) = 1$ means p is fully funded.

Most candidate projects are indivisible in that they must either be fully funded or not adopted at all:

$x(p) = 0$ or 1 for all p indivisible.

The remaining projects are divisible, they may take on any value between 0 and 1; $x(p)$ is the fraction of the project that will be funded. The term "mixed integer" denotes the presence in the model of both indivisible (=integer) and divisible variables.

Most capital investment opportunities are represented in the model by several candidate projects that are implementation alternatives. The alternatives may represent different timings (for example, accelerated, normal, stretched out), different funding levels (scaled back, normal, expanded), different technologies, different start years, etc. The indivisible alternatives are mutually exclusive, that is, at most one may be in any portfolio. For alternatives p1, p2,...,pk this is enforced with a "logical" constraint:

$$x(p1) + x(p2) + \dots + x(pk) \leq 1 .$$

There is one such constraint for each group of alternatives. For indivisible candidate projects this logical constraint means that either none or exactly one of the group can be in a portfolio. For divisible projects it is possible that several candidate projects in the group can have a positive fractional value; this represents a "blending" of the candidate projects.

Mutual exclusion among alternatives is one example of a "logical" restriction on the candidate projects that are allowed in a portfolio. Other possible logical restrictions include:

1. Choose at most one candidate project from a set of candidate projects (a generalization of mutual exclusion for alternatives).

2. Choose exactly one candidate project from a set of candidate projects.

3. A specified candidate project cannot be included in the portfolio unless another specified candidate project is also included.

4. Two candidate projects are either both in the portfolio or are both out of the portfolio.

The above description of logical constraints applies to indivisible projects; there is a slightly different interpretation for divisible projects.

The net present value (NPV) of a project is its discounted long-term cash flow. NPV is well accepted as a figure of merit for the long range market value of the firm's equity. Let NPV(p) denote the NPV of project p. The objective is to select the portfolio with the maximum NPV:

maximize sum-p NPV(p)*x(p)

where sum-p means "sum over all projects p".

In addition to the logical constraints discussed above, there are short-term (5-year) financial constraints, resource limitations and service objectives that limit the allowable portfolios. These constraints apply to each individual year of the five year short-term planning horizon. Let t be an index for the years 1,2,...,5.

One of the financial constraints is an upper limit UCAP(t) on the total company capital expenditure for each year t. The input data includes the company non-project capital expenditure OCAP(t). Part of the specification of each project is the capital expenditure (actually net plant requirement) of each project in each year CAP(p,t). The financial constraint for each t is:

OCAP(t) + sum-p CAP(p,t)*x(p) $\leq$ UCAP(t).

Another financial constraint is a lower limit LIGF(t) on the net funds from internal sources as a percent of the capital requirement. Let X be the vector of all the variables x(p). Let NFI(X,t) denote the net funds from internal sources for the portfolio X in year t and REQ(X,t) denote the capital requirement. The constraint for each t is:

NFI(X,t) / REQ(X,t) $\geq$ LIGF(t).

NFI(X,t) is calculated by computing the funds statement with the portfolio X. There is a complete funds statement for the company embedded in the portfolio optimization model. The funds statement is based on five years of financial data including information on sources to raise cash (short-term debt, long-term debt, preferred and common stock), various interest rates, corporate tax rates, etc.

There is financial data specified for each project, thus the impact of each project on the funds statement can be calculated. Although it is not practical to develop an explicit constraint for NFI(X,t) or REQ(X,t) in terms of the financial data items, it is possible via implicit calculation of the funds statement to obtain the numbers necessary to explicitly generate the above constraint as a linear function of the project variables x(p).

There is also a lower limit LNIC(t) on the net income to common. NIC(X,t) is the net income to common of portfolio X in year t. The financial constraint for each t is:

NIC(X,t) $\geq$ LNIC(t).

Again this constraint is explicitly constructed as a linear function of the project variables by means of an implicit computation of the funds statement and the relevant portion of the income statement.

The above three constraints are the financial restrictions on the portfolio. The embedded funds statement gives the model the potential to constrain the portfolios on any funds statement quantity of interest.

There are critical resources identified by each GTE telephone operating company that in the short term limit its freedom to select capital projects. These presently include upper bounds on labor hours in critical job skills, upper bounds on lines installed to mandate work force leveling over the five years, etc. Each telephone operating company may choose the resources that are most critical for it to control.

For each resource RES(t), a lower limit LRES(t) and/or an upper limit URES(t) may be specified. ORES(t) is the consumption of the resource by company non-project activities. For each project p and year t the consumption of resource r is specified as RES(r,p,t). For each resource r the constraint for each t is:

LRES(r,t) $\leq$ ORES(r,t) + sum-p RES(r,p,t) *x(p) $\leq$ URES(r,t).

Service criteria can be identified and objectives established for each criteria. For example, objectives could be set for toll call completion probability, trouble reports per 100 lines, etc. The portfolio can then be constrained to meet all the services objectives for the five years. Analogous to resource constraints, the constraints SER(s) for each t are:

$$LSER(s,t) \leq OSER(s,t) + \text{sum-p } SER(s,p,t) * x(p) \leq USER(s,t).$$

It is difficult to identify service criteria that are universally accepted and it is sometimes difficult to isolate the service contribution of each individual project. At the present time the service part of the system is not being used by the GTE operating companies.

The model features of portfolio optimization include the capability to override the optimization and lock any project into the portfolio ($x(p) = 1$) or lock any project out of the portfolio ($x(p) = 0$). Projects that are divisible can be locked into the portfolio at any value between 0 and 1 or limited to a subinterval between 0 and 1.

Output of the optimization specifies a portfolio by giving the level, x(p), and NPV contribution of each project, NPV(p)*x(p). The output includes for the optimal portfolio the consumption of capital and resources as well as the levels of the service criteria. Also included is the funds statement for the complete company for all five years based on the optimal portfolio.

The description of the model thus far has not included the mechanisms for including the trade-offs between NPV and the near-term financial, resource and service requirements. After motivating the "penalties" approach, the remainder of the model will be presented.

"JUSTIFIABLE" VIOLATIONS OF THE CONSTRAINTS

The constraints of the financial, resource and service requirements over the first five years are the near-term restrictions on the long-term goal of maximizing NPV. The model can be extended to allow these constraints to be violated in a systematic way to achieve portfolios with greater NPV. By contrast, the logical constraints cannot be relaxed; every portfolio must satisfy them. There are, however, several reasons for allowing "slight" violations of the financial, resource and service constraints:

1. The numbers that are specified for the limits are really objectives rather than fixed numbers. This is especially true for the out years (3, 4 or 5) where the values for the limits are not as critical. The constraints can be viewed as "soft" in that the limits can be varied slightly without changing the intent of the restriction.

2. The limitations are objectives that are set relative to the marginal opportunities for investments. That is, the limitations can be stretched to include projects with significant NPV or shrunk if the optimal portfolio contains some low value projects. This is the fundamental question of balancing long-term gain against short-term restrictions. This kind of analysis has become more critical as deregulation has opened up new opportunities and brought new risks.

3. The nature of project design with indivisible projects is such that slight modifications of a few constraints often makes possible a different portfolio with significantly higher NPV.

The last point can be demonstrated with a greatly simplified example with only three indivisible projects and only a one year capital constraint:

Project	NPV 1000$	Capital Requirement 1000$
P1	20	30
P2	30	50
P3	50	55

(the capital limit is 84 thousand dollars.)

This can be written as an integer linear programming problem:

maximize $20*P1 + 33*P2 + 50*P3$

subject to $30*P1 + 50*P2 + 55*P3 \leq 84$

P1, P2 and P3 must be 0 or 1

Of the eight possible portfolios (including the one with no projects), five satisfy the capital constraint; the optimal portfolio contains P1 and P2, has NPV 53 and a capital requirement of 80.

If the capital limit could be violated by one thousand dollars, then a significantly better optimal portfolio is P1 and P3 with NPV 70 and capital requirement 85. It is typical of optimization with indivisible projects that slight modifications of the limits yield portfolios with better NPV.

THE MODEL FOR PORTFOLIO DESIGN WITH PENALTIES

Recognizing that slight violations of some constraints can lead to better capital decisions still leaves a dilemma : 1) With tens or hundreds of constraints, which should be violated ? and 2) what is a "slight" violation ?

The economic principle of marginal prices yields a solution to both difficulties: the financial, resource and service constraints can be violated for a price. This is incorporated into the model by assessing a penalty for violations of the constraints. This penalty is the unit price (in NPV dollars) of allowing the constraint to be violated. For example:

1. The penalty for the capital constraint is the cost to obtain one extra dollar of capital (the "marginal" cost of capital).

2. For a constraint on the number of labor hours consumed in a critical skill, the penalty is the cost to obtain one more labor hour; this could be either the overtime rate or the hourly rate of an outside contractor.

3. The penalty for violating the limit on the number of lines to install could be the cost to hire and train additional staff and purchase additional equipment.

The units of the penalties are dollars of NPV per unit constraint violation. This expresses the economic tradeoff between long-term goals and short-term restrictions.

The example of the previous section can be resolved by leaving the capital limit at 84 and assigning a penalty of one dollar NPV per extra dollar of capital. The objective function becomes:

$$\text{maximize } 20*P1 + 33*P2 + 50*P3 - 1*(\text{violation})$$

The three portfolios that were previously ignored because they violated the capital constraint are now evaluated. For example, the portfolio with P1 and P3 has objective value 20 + 50 - 1*(1) to give 69. The other two portfolios evaluate to 52 and 62. The five portfolios that do not violate the capital constraint have the same value that they had before. For this example with penalties, the optimal portfolio contains P1 and P3 with objective value of 69 and capital requirement 85.

The portfolio optimization model that has been implemented at GTE includes penalties for the financial, resource and service constraints and the software constructs the portfolio that maximizes the sum of the NPV minus the sum of the penalties times the violations. In effect the optimization evaluates every portfolio that satisfies the logical constraints and applies a penalty for all portfolios that violate any of the other constraints.

The incorporation of penalties into the model is conceptually similar to what is called "goal programming" in the management science literature. Although conceptually similar, the scale of the GTE capital planning problems requires that the optimal portfolios be constructed in a different and much more efficient manner.

The penalties are chosen by high level executives to quantify their understanding of the economic tradeoffs. In a series of executive level seminars on Portfolio Management being conducted at GTE, the participants have been excited about having a quantified measure of tradeoffs that have always been an implicit (and critical) part of the capital planning decision process.

The results of calculating optimal portfolios using penalties are exactly what would be expected in a stable and well-run company: the optimal portfolios involve either no violations or just minor violations of a few constraints (often in years 4 or 5). This shows that the executives have made good choices for the limits on the constraints. "At the margin" at most a few projects have sufficient NPV to justify violating constraints to get them into the portfolio. Although only few in number the extra projects yield a better portfolio at the price of only a few "slight" violations of some constraints.

USE OF THE OPTIMIZATION IN PORTFOLIO DESIGN

The process of designing a capital portfolio begins when the proponents of the various projects build the database of financial, resource and service information. As the projects are developed the logical restrictions for the projects are developed. The NPV is calculated for each project. The data on the financial impact, resource consumption and service contribution that is not related to the portfolio is gathered. The data necessary to generate the funds statement is collected and validated. This information constitutes the project and financial databases that then remains stable throughout the portfolio design process.

At the beginning of portfolio construction, the executives select limits for the financial, resource and service constraints. They also select the value of the penalties for these constraints. An optimal portfolio can then be constructed. The work of considering the non-quantifiable factors then begins.

The portfolio construction process includes side studies by the planning staff to explore options, answer questions, investigate tradeoffs and in general to gain an understanding of the projects and their impact on long and short-term objectives. The guidance from the executives might be, for example, to tighten or loosen certain limitations, to lock certain projects in or out of the portfolio, to change one or more of the financial assumptions, etc. Each side study will involve identifying a set of slightly different problems, constructing an optimal portfolio for each and then studying the results. The staff will then present summary results and an explanation for any changes in the optimal portfolio. The main goal of the studies is to gain insight into the company's capital opportunities, the explanations that the several runs produce will be often as important as the numbers.

Throughout the year new opportunities and new problems will prompt a reconsideration of the capital plans. As the year proceeds, the projects that have begun or have been committed to are locked into the portfolio. The new projects then compete against all other projects for a place in the new capital plan. In this process any new project does not have to compete as a budget augmentation, rather each new project can compete on an equal footing with all projects that have not already been locked into the portfolio.

THE OPTIMIZER AND OPTIMAL PORTFOLIOS

The optimizer provides GTE the capacity to construct optimal portfolios for capital planning problems of unprecedented size and detail. A remarkable combination of good capital projects, conscientious data development, sound economic modeling and high technology optimization software works to use all the available quantifiable data to construct the best possible capital portfolio.

The previous paragraph contains a bold claim that the system solves to optimality a problem that is known to be extremely difficult to solve. This section outlines an argument that specifies precisely in what sense the optimizer constructs the optimal (that is, the best possible) portfolio. This section explains in what sense the problem is difficult, discusses the complicating issues of numerical precision and data resolution, gives some details about the state-of-the-art system that performs the optimization, develops some reasons why the optimizer is so successful on this very hard problem, and finally explains in what sense the portfolio that is constructed should be regarded as optimal.

Integer programming is a member of a class of problems that are extremely difficult to solve. Computer scientist theorists believe (but have not yet proven) that there never can be an algorithm to effectively compute optimal solutions for large problems of this type. For a problem with only 100 indivisible projects, there are 2 to the power 100 (more than 1 followed by 31 zeros) different portfolios. The only known exact algorithms can in the worse case take roughly this many steps. An example of a worse case would be a problem where each different portfolio would have a unique total NPV; thus any algorithm would somehow have to consider each one before declaring it had found the optimal. This somewhat overstates the difficulty because it assumes a rare, pathologically complex problem, but average behavior on randomly generated problems is also very bad.

Almost all commercially available integer programming systems have been designed to solve any possible problem. The usual result of this strategy is a system that requires considerable computer time and displays high variability in solution quality and computer costs from problem to problem.

The size of the GTE capital portfolio problems is significantly beyond the state-of-the-art. The system is presently configured for 2000 projects and 1250 constraints (roughly 250 for financial, resource and service constraints and 1000 for logical constraints). For each project there are usually 25 to 100 different data values (NPV, financial quantities, resource consumption and service contribution). For 2000 projects this yields 50,000 to 200,000 pieces of data. The optimizer uses all this information. Currently, the GTE telephone operating companies are phasing in the use of the optimizer; no company is far enough along to have approached these size limits. The larger companies will eventually go beyond these size limits; we expect to extend the system (and create the necessary technology) to keep pace.

The optimizer is the INSIGHT X-system. The X-system is an experimental testbed that includes all the standard pieces of contemporary optimization methods plus many features that are at the cutting edge of advanced research in the field. In addition to its advanced capabilities, it has features that make it a stable, reliable production system. It is presently installed at seven GTE telephone operating companies.

Despite the gloomy prospects for solving integer programs, the X-system constructs an optimal portfolio for the largest problems in at most a few hundred CPU seconds. How does the optimizer achieve this seemingly impossible feat? The first answer is to customize the software to solve only capital portfolio problems that are structured as the GTE problems. There has also been considerable work done in adjusting the numerous control parameters to tune the software to the characteristics of GTE's problems. There has been extensive experimental work over several years. This, however, is only part of the answer.

Jerry Brown and Glenn Graves, the developers of the X-system, have had considerable experience over the last 20 years solving real problems in many areas for corporate customers and government agencies. Their series of observations on this topic can be summarized in this hypothesis: careful modeling of real systems that have been shaped by genuine economic forces yield problems that are dramatically easier to solve than random or poorly modeled problems. The GTE capital program exhibits the following relevant characteristics:

1. The existing capital plant base has been shaped over many years by economic forces.

2. The capital projects are not random they are the result of hundreds of employees carefully developing projects that will benefit the company and fit in with existing and other new projects.

3. CPMS has developed procedures to develop the data in a consistent way and to protect the integrity of the project database.

4. The model of portfolio optimization includes a sophisticated financial model and contains marginal prices that quantify critical economic tradeoffs.

5. The system was developed and tested and tuned with real GTE project data.

All this supports the hypothesis and so predicts success. It should be noted that the above elements are not obvious. There have been four years of development that have included several major changes to the model and the data.

The numerical precision of calculations on a digital computer is another important factor. Calculations are not carried out in the ideal world of exact arithmetic; rather, digital computers implement a finite precision model of arithmetic. The X-system works in double precision arithmetic with 16 decimal digit representations. The X-system uses sophisticated numerical methods to maintain precision and accuracy. There are intricate methods to perform basis factorizations and to maintain a structure of the numerical representation that minimizes numerical difficulties. One of the practical consequences of finite precision arithmetic is that after the extensive calculations to construct portfolios, many portfolios have the same NPV value. Although a problem with 1000 indivisible portfolios could have 2 to the power 1000 portfolios with unique NPV values, on a contemporary digital computer not all can be represented uniquely. This necessitates revising the definition of optimality. Using exact arithmetic there may be a unique portfolio with the maximum NPV value, but on the computer, many portfolios could have the same (maximum) value and thus any one could be regarded as the optimal solution. Thus we can only talk about a portfolio being optimal "within the numerical precision of the computer".

The optimization in the X-system constructs a sequence of better and better portfolios using a branch and bound strategy. Simultaneously, it produces a sequence of decreasing upper bounds on the value of the optimal portfolio. If the upper bound at some point in the branch and bound tree becomes equal to the value of the current best portfolio, the systems stops and the current solution is guaranteed to be optimal ("within the numerical precision of the computer"). This preemptive termination occurs with remarkable frequency. For calculations that don't terminate this way, the system terminates when the percentage difference between the value of the current best solution and the upper bound becomes so small that it is less than the resolution of the project data. In spite of the careful development of costs for all the candidate projects, the data is at best accurate for only the first few most significant digits; the remaining digits are meaningless. The resolution determines a termination criterion for the system. For example, if the difference between the current best solution and the upper bound is $1000 and no project NPV is accurate to the nearest $1000, it is time to terminate the system and declare the current best portfolio to be optimal "within the resolution of the data".

The discussion of this section can be summarized:

1. GTE is an operating firm with an existing capital plant that reflects years of careful planning;

2. GTE has many conscientious employees that are developing capital projects that will improve the system;

3. CPMS has incorporated business practices to assure that project data is produced in a consistent way and is correctly gathered and stored;

4. A sophisticated model of capital portfolio design based on sound economic principles has been developed and refined;

5. A state-of-the-art optimization system of advanced design and concept has been customized and then finely tuned on actual GTE portfolio problems;

6. Several years of experience has produced procedures to use the system effectively; and finally

7. A managerial and technical overview is continuously monitoring the system and is prepared to make adjustments when any of the preceding items cease to be true.

We conclude that the CPMS optimizer constructs portfolios for GTE capital portfolio problems that are optimal within the numerical precision of digital computers and the resolution of the project data.

CONCLUSION

The quantifiable aspects of constructing optimal capital portfolios have been effectively automated. The timely and cost effective construction of optimal portfolios by the optimization software allows "What if..?" questions to be answered and side studies to be executed. This allows management to focus on the critical non-quantifiable factors in capital planning. A particularly important aspect of the process is the ability to relate the long-term financial health of the company to near-term requirements and objectives through the use of economic penalties.

The CPMS optimizer provides GTE with unprecedented capability to make the best use of the available quantitative information to construct optimal portfolios.

CAPITAL PORTFOLIO OPTIMIZATION RESULTS

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ABSTRACT

The Capital Program Management System (CPMS) and its portfolio optimization model are being introduced at GTE to help management evaluate alternative business strategies. Management's attention is drawn to the value creation potential of the capital investment portfolio through CPMS.

This paper discusses the approach being used to integrate CPMS with the strategic planning process at GTE and briefly describes some of the obstacles encountered during implementation. It concludes with a description of a real problem that was analyzed using the new process.

INTRODUCTION

The most consequential decisions in any corporation are those concerning how best to use limited resources. The process of capital planning is becoming critical for survival in a business environment that is increasingly competitive but still burdened, however temporarily, with the regulation of basic "bread and butter" services. This paper begins by describing how portfolio optimization will fit within the overall integrated strategic planning process at GTE. One of the key benefits of portfolio optimization and capital program management is a better understanding, through quantitative evaluation, of the business and financial implications of the firm's strategies.

Obstacles that we encountered when implementing CPMS are discussed. Introducing this "state of the art" decision making process necessitated the resolution of many fundamental questions before CPMS can be effectively employed.

Finally, some of the results from actual use of CPMS are presented to provide an appreciation for the potential such techniques can offer a firm.

STRATEGIC PLANNING

Portfolio optimization supports strategic planning by identifying which investment opportunities to fund (and not to fund) and what amount of money should be (re)invested in the business. The objective is to find a capital portfolio that maximizes net present value while meeting any constraints management chooses. It is believed that this objective will result in the creation of shareholder wealth. Management now has the ability to evaluate different Portfolios and set financial targets based on the Portfolio chosen.

The value to strategic planning comes from the evaluation of various portfolios representing numerous scenarios. These portfolios inform management of the risks inherent in the pursuit of various strategies and the effects of changing business conditions. With the introduction of sophisticated computer based models in CPMS, effective capital planning is becoming a reality at GTE. Using these tools, changing business forecasts, different competitive scenarios, or new business opportunities can all be evaluated promptly on a quantitative basis. Therefore, it is now possible to select a plan which reflects the business direction chosen by management and also to have the knowledge of what mid-course corrections to make if circumstances warrant.

GTE is able to make judgments about combinations of capital investments that go beyond current, primarily financial, evaluation techniques applied to single investment opportunities. For capital portfolio planning to have a favorable long term impact, strategic plans and executive performance must be evaluated in rational economic terms. What is needed is an economically sound, consistent basis for evaluating all strategic capital portfolios. The experience being gained at GTE by implementing CPMS suggests that it is not only offering conceptually appealing modeling techniques, but a wholly operational process that focuses on shareholder's wealth creation as the key economic measure of success. Its adoption and gradual linkage to executive performance measurement should improve opportunities for creating economic value and should also provide the longer-term orientation needed to to be successful in a competitive environment.

It is still too early to see the results of linking the CPMS concepts with the strategic planning process. In fact, at this time, the details of how this linkage will be accomplished are under development. It currently appears that implementation will begin with the synthesis of GTE's "core strategies" into a small number of Business Strategies. The Business Strategy will guide the development of Investment Profiles for each market segment. The resultant Investment Profiles describe the types of investments GTE will make (if selected) in a market to support the particular Business Strategy. The Investment Profiles will then guide planners in developing investment alternatives. Investment alternatives might involve using different technology, various timing alternatives, etc.

The intelligent application of portfolio constraints coupled with the ability to simultaneously analyze large numbers of investment alternatives (well linked to the strategies each supports) will provide senior management with the capability to choose between various courses of action and make adjustments due to various environmental changes.

OBSTACLES TO IMPLEMENTATION

The first difficulty encountered in the implementation of these new techniques was the problem of "What to optimize?" This seemingly easy question took a great deal of time to answer. Finding a workable answer was a critical milestone to ultimate success. For years the capital planning process centered around well defined "programs." Programs make sense; they are understandable and describe what investments the company makes. Programs such as "modernization," "growth," and "service improvement" are very familiar to telecommunications managers and are (and will continue to be) meaningful in describing the nature of investments.

However, attempts to optimize the programs met with failure due to the numerous interrelationships between them. They simply could not be defined as discrete investments and, therefore, it was impossible to uniquely relate expense and revenue cash flows to individual programs.

Capital projects seemed the next likely choice for optimization, but attempts to optimize them also failed. In the telecommunications industry a "project" might consist of the cost and work effort associated with the addition to a switch. A separate project might be for the replacement of a cable with fiber optic. Although projects normally represent discrete investments, it is difficult to identify the associated revenues and expenses, a necessary condition for effective optimization.

The dilemma was solved through the development of the Investment Cluster concept which simply aggregated **related** projects (representing a discrete and common investment) to the point where revenues and expenses could be attributed in a meaningful way. The Investment Cluster can be defined at virtually any level (such as an entire company) depending on what question is being asked. In the case of an Investment Cluster defined as an entire company, the question might be "Should we acquire it?". There is a natural lower limit of definition that still allows revenues and expenses to be attributed to the common investment without arbitrary allocation.

Full management acceptance of the results of portfolio management is the next major hurdle before implementation can be completed. Two issues must be resolved prior to the integration of CPMS into the strategic planning process. First, management must direct greater attention to the strategic decisions regarding capital investments. Their objective must be to maximize the portfolio's value creating potential and gain a better understanding of the risk in these decisions. Secondly, management must gain confidence in the new process and learn to what degree they can rely on the tools.

EARLY RESULTS

The process and models are increasingly being used at GTE. Current emphasis is on full integration of their use in strategic planning.

Results have been obtained for a limited scope test in GTE's California Company where various central office construction re-entry intervals were studied using the CPMS investment planning and portfolio optimization models. A base plan was created with two year construction re-entry intervals. Five alternative construction re-entry intervals were developed for 133 central offices. The model was used to evaluate the capital funds required for various portfolios, the total number of engineering and construction hours and work order starts were tracked through the analysis.

The results of the test are encouraging. Total capital was reduced by 3% (the same level of service was still provided), and engineering labor hours were reduced by 30%. Total construction hours required were reduced by 10%. Although no direct benefit was associated with the almost 30% reduction in work order starts, administrative handling of work orders by accounting and other departments was surely reduced.

GTE's Midwestern Telephone Operations will use the techniques to develop their entire five year strategic plan. Our test data indicates improvements of approximately 5% in the net present value of the portfolio are expected. GTE's Florida company has now taken a leadership role in the further development and implementation of these techniques and is moving aggressively to full implementation.

The results equate to many millions of dollars in value to GTE. The benefits to GTE from better Strategic Plans is not immediately measurable, but is critical to our future success in the marketplace. As the deregulation of our business continues and competition drives prices, a new tool is needed to assist in the selection of good investment decisions. This risk inherent in new investment must be built into the decision process. We feel that CPMS will give us this necessary tool to make informed, profitable investment decisions.

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