Proceedings of the 1983
Winter Simulation Conference
S. Roberts, J. Banks, B. Schmeiser (eds.)

A DYNAMIC LONG RANGE BUDGET MODEL TO ASSIST NAVY PLANNERS

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Navy long range planning is a complex process in which a 15-yr budget is coordinated through numerous interested offices and agencies. In this administrative process it is difficult to capture all of the interactions between budget elements and the downstream influences of decisions. Alterations in one budget element affect not only other elements in the same year but, through a ripple effect, influence many other elements in subsequent years. The computer model described here, The Navy Resource Dynamics Model, has been developed and applied to assist in this process.

1. Introduction

The Resource Dynamics model, under development at the George Washington University, is a macroscopic planning model for long range budget and financial analysis. It is intended to capture, in an abbreviated but coherent and consistent form, the most important technological, economic, and organizational factors which combine to determine the Navy's annual budget requirements.

Navy long range planning establishes the intended allocation of the Navy's financial resources over a 15-year horizon. The process requires input data and coordination from a number of offices. Many of the inputs are dynamically interdependent so that revision of a given variable for one year of the plan may influence other variables in that year and all subsequent years. (For example, increasing procurement of aircraft in the first year of the plan, will, other things being equal, increase the funding required for aircraft operations in subsequent years.) Such revisions commonly occur as a part of the usual resource allocation process. The normal administrative planning process, however, is quite time-consuming and involves review and coordination of all the input data through directives and briefings between the numerous Navy offices involved. The process is not well suited for frequent planning revisions. It is particularly difficult to maintain internal consistency and coherence through such an administrative planning system in a process which involves complex time dependent dynamics (i.e., downstream ripple effects). The Resource Dynamics research was undertaken to assist in this process; it does so by combining a number of known statistical relationships in a fast-running computer model which allows rapid turnaround, and requires a minimum of detailed input data.

The Resource Dynamics Model is not a replacement for the normal Planning, Programming, and Budgeting System (PPBS). Rather, it establishes an independent estimating procedure to be used in quick response excursions providing approximate results for comparison to existing plans and programs.

Recently the Assistant Secretary of Defense (Controller) described the PPBS decision-making environment as one which:

-Is basically open-loop as it tends to give rudder directions but does not look back at the wake

and in which

Supported by Office of Naval Research Contract Number N00014-82-K-0150.

> -High-level managers are confronted with dynamic situations that consist of complex systems of changing problems which interact with each other
> (Borsting, 1982)

Recognizing problems and concerns such as these, Resource Dynamics attempts to close the loop and assist managers in the complex dynamic analysis required in long range planning and resource allocation.

2. The Model

The Navy Resource Dynamics model is essentially a 'parametric' long range planning tool. In the same way that parametric cost estimates are constructed for individual systems whose future cost is uncertain, so the Resource Dynamics approach constructs estimates of future force levels (i.e., numbers of ships and aircraft) and associated ownership costs. (Ownership costs include the costs of operating, maintaining, and manning a given force level). This kind of parametric estimation is appropriate for at least two purposes: 1) for estimations of events which are sufficiently far into the future that detailed information on the characteristics of the system are uncertain, 2) for independent estimations of nearer term cost which may be compared to the results obtained from more detailed methods.

The model establishes, at a macroscopic level, simple and direct relationships between Navy investment expenditures (i.e., expenditures for acquisition of capital assets such as ships and aircraft), the characteristics of the assets acquired, the future ownership costs of these assets, and the ownership cost effects of readiness policy changes (i.e., changes in manning, maintenance, or operating policies). Ownership costs are estimated largely as a function of the accumulated level of investment assets (i.e., the dollar cost of all ships and aircraft in the fleet). Ownership costs change in two ways 1) as a function of fleet characteristics such as ship tonnage, crew size and generating capacity, and average weight and thrust levels of aircraft, and 2) as a function of fleet maintenance, manning and operating policies. Both fleet characteristics and ownership costs (such as fuel prices and military salaries) change over time along historically-derived trends. The model reflects relative price changes, that is, it treats all costs and investment values in constant dollars so that inflation need be represented only in those costs which are growing faster or slower than the overall inflation rate.

Shown in Figure 1 is a simplified diagram of the basic model. This figure describes the budget process for only one year; the computer model repeats the cycle shown in the diagram each year, with each cycle dependent on the results of the previous years. The solid lines represent the parts of the model which are now operational. The dashed lines represent those parts which are experimental or projected for future exploration. The heart of the model is shown by the relationship between the budget, investment funding, cumulative investment assets, and required ownership funds. It is saying, simply put, that for a given budget level, a decision must be made as to the division of available funds between aggregate investment (including R&D) and ownership. Note that this decision, once made, inevitably affects the next year's decision through the feedback from levels of investment to required ownership funds. Higher levels of investment in assets eventually result in greater requirements for ownership funding, which in turn will limit the amount of procurement in future years. Ownership requirements may be underfunded to allow for more procurement as, for example, by reductions in readiness associated expenditures such as maintenance, manpower, or operations. The full model contains on the order of 1000 equations which represent the system shown in Figure 1. Clearly, a resource allocation process of this degree of complexity could not be exercised consistently and coherently by unaided mental processes.

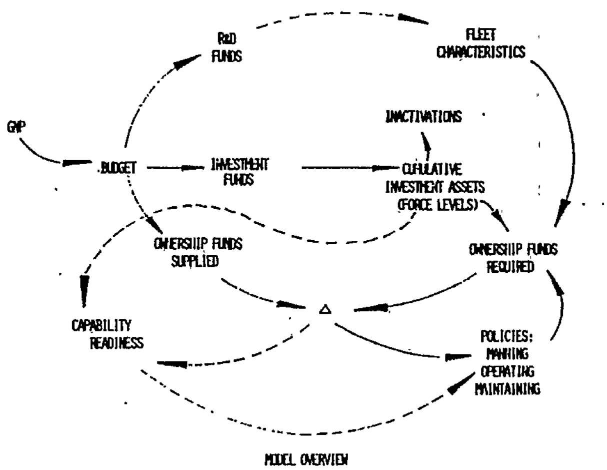

Figure 1

Note in Figure 1 that fleet characteristics (such as average tonnage and generating capacity for ships, and average weight and thrust for aircraft), influence required ownership costs. This influence reflects results of estimations which have been performed using historical data.

3. Estimations

In order to estimate maintenance and operating costs the model uses estimating equations which relate these costs to aggregate characteristics of the ship and aircraft fleet. Maintenance costs historically have been strongly correlated with the investment cost of the weapons systems. Statistical research in support of the model has shown, for example, that naval aircraft maintenance costs can be predicted reasonably well at the aggregate level as a function of aircraft investment cost, average aircraft age, and operating level in flying hours per year per aircraft. Figure 2 shows a plot of the ratio of maintenance cost to aircraft investment cost for three categories of aircraft based on four years of maintenance data.

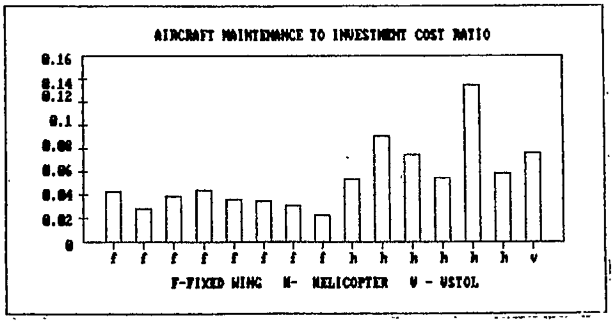

Figure 2

Note that this plot suggests a relationship between investment cost and maintenance cost which differs by aircraft category (e.g., fixed wing, helicopter and vertical/short take off). The variability of the ratio within categories suggests that other factors are at work as well. Using data such as this, estimating equations were derived through ordinary least squares techniques which predict aircraft annual maintenance. One of these equations (for fixed wing aircraft) is shown below.

$$c = .073 * Ic^{.88} * Na^{.15}$$

Mc Maintenance cost (1000's of 1983$)

Ic Investment cost (1000's of 1983$)

Na Average aircraft age (years)

Operating costs (primarily fuel) for both ships and aircraft are estimated in a similar way. The per hour fuel estimating equations for both aircraft and ships are shown below.

Aircraft

$$Gph = 79.0 * W^{.77} * Tw^{.37}$$

Gph Gallons per hour
W Weight (1000 Lbs)
Tw Thrust to weight ratio

Ships

$$Gph = 20.1 * W^{.30} * Gc^{.14}$$

Gph Gallons per hour
W Weight (Tons)
Gc Generating capacity (Kw)

Manpower costs are estimated using relationships to investment cost and a set of predicting equations developed by the Naval Personnel Research and Development Center (NPRDC) in San Diego, California. (Blanco and Liang, 1982) First, manpower afloat is predicted using historical relationships between afloat manpower and investment cost of assets (ships and aircraft are treated separately). Then the support manpower burden is predicted using the NPRDC relationships between manpower afloat and manpower ashore. Differences in personnel skill levels and associated costs will be included in the version of the model which is now in development.

Together, these costs (maintenance, fuel and manpower), constitute the bulk of ownership costs. Certain miscellaneous support costs, such as base operating support, medical support, and military construction are estimated as a constant or constantly growing percentage of other independent variables such as the total Navy budget or total cumulative investment value of the fleet. These ownership costs then become the model's estimate of the funding requirement to support projected force levels.

An example of some excursions and their results may serve to illustrate.

4. Results

Shown in Figure 3 is one of a number of output presentations which are available. In addition to the physical quantities (Ships and Aircraft) shown here, graphic or tabular output is easily produced for cost data by several different DOD accounting schemes (e.g. by appropriations, by mission elements, or by capability and readiness accounting). Cost data may also be output at several levels of detail from, say, total operations and maintenance budget, down to ship and aircraft fuel, maintenance, manpower, and various miscellaneous cost categories.

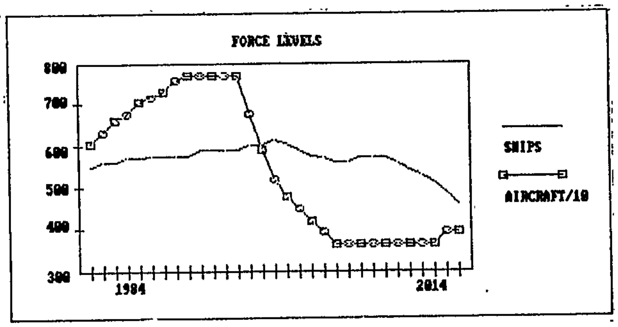

Figure 3

The output shown in this example is for a hypothetical 30 year run of the model from 1984 to 2014. The run assumes seven percent real growth in the total Navy budget for the first five years followed by one percent for the remaining 25 years. Other assumptions include real growth in manpower costs of 1.5 percent per year and two percent real growth in fuel costs. Note that a fairly steady growth rate in the fleet is maintained until the late 90s. The growth occurs as a result of a substantial excess of funds available above ownership spending requirements during the first five years of accelerated (seven percent) budget growth. The fleet's growth rate then tapers off and finally becomes negative as, during the outyears of moderate (one percent) growth, the available funding for investment declines as ownership requirements grow along with the fleet. The same dynamic is present in the aircraft line, with substantial growth during the first years followed by decline as the ownership costs of increased force levels require more and more of a more slowly growing budget. Aircraft fleet levels fall off faster primarily due to their short life span (15 years average) compared to ships (30 years). Note that while lagged effects such as these are relatively simple to represent in a computer model such as Resource Dynamics, they are most difficult to trace through by intuition or manual calculation.

One of many possible financial presentations of the same excursion is shown as Figure 4. Here, the relationship between investment and ownership costs is shown. Investment expenditures (as a percentage of the total budget) begin at 40 percent, and grow to about 43 percent before beginning a decline which continues to the end of the run. Ownership costs (here including only maintenance and operating costs) begin to grow with a short lag behind investment. This growth reflects the increased ownership costs which are projected as the higher procurement adds to the level of total investment in ships and aircraft. (Recall that these ownership costs are strongly correlated with cumulative investment.) Minor cycles are apparent: for example, during the late 90's enough excess (after deducting required ownership expenditures) becomes available to increase the percent of budget to investment slightly; this excess is eliminated in about five years, as the increased force levels that it funded arrive in the fleet and add again to the ownership costs.

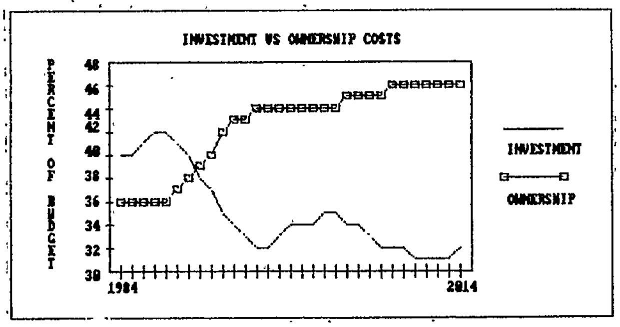

Figure 4

Similar to the many comparative excursions which were conducted for the Navy is the one shown in Figure 5 (here using hypothetical data).

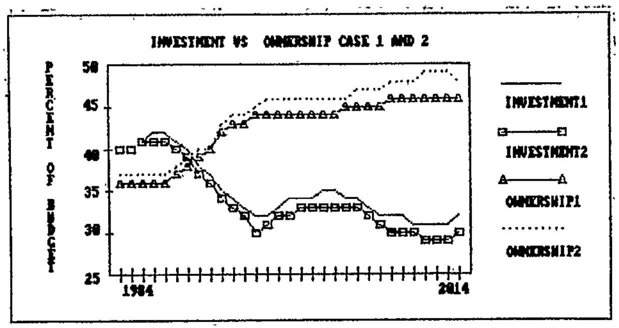

Figure 5

The Resource Dynamics model was used to assess the sensitivity of total budget requirements to such contingencies as increases in manpower compensation growth rates, and increases in fuel cost growth rates. The excursion shown here assumed a doubling of fuel cost growth rates from two percent annually to four percent. The figure compares base case (case 1) allocations toward investment and ownership to those which result when fuel cost growth is doubled (case 2). Under the alternative assumptions, the percentage of budget to investment is typically lower by about one percent.

The model is suitable for other excursions in addition to the cost excursion illustrated here; for example, it may be used to examine the effects of policy alternatives such as changes in the overall budget or changes in the force mix and thus in the aggregate fleet characteristics.

In all, approximately ten procurement plans extending over a fifteen year period were examined by the Navy during the fiscal year 1984 extended plan preparation process. Each of these cases was prepared in part through the use of the Resource Dynamics model described above.

Acknowledgment

This research was supported by ONR contract N00014-82-K-0150.

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