UNIT 65 - COSTS AND BENEFITS

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Compiled with assistance from Holly J. Dickinson, State University of New York at Buffalo

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A. INTRODUCTION

What is benefit/cost analysis?

- assessment of benefits of a GIS installation - what is the value of its products?

- assessment of costs (initial and recurring)

- comparison of benefits and costs
  - project should go ahead only if benefits exceed the costs
  - for comparison, benefits and costs must be comparable - measured in same units, over same period of time

Why do it?

- a major GIS implementation is a large monetary investment and upper management wants to know the expected benefits of the system before they agree to the purchase

  overhead - Costs of 3 example systems

- three uses of benefit/cost analysis of computer systems: 1. planning tool for choosing among alternatives
    - select the system which meets minimal benefit requirements and offers the highest benefit/cost ratio 2. quantitative support to politically influence a decision
    - a major factor in influencing the decision to proceed 3. an audit tool for existing projects
    - future planning for the system can be based on the outcome

- benefit/cost analysis is a standard procedure in many areas, including the information processing industry (see King and Schrems, 1978, p. 20)

Accrual

- an organization will want to know the costs and benefits that accrue to the organization (i.e. must be borne by and benefit the organization respectively)
  - these are not necessarily all of the costs
    - some costs may be borne by government through cost-sharing arrangements
    - some costs may be borne by the vendor
  - the benefits which accrue to the organization are not necessarily all of the benefits of the system
  - some government organizations may wish to make decisions based on costs and benefits to society as a whole, not to the organization alone

B. DEFINING COSTS

- the most important aspect of reporting costs is to include all costs, not just the acquisition of the hardware and GIS software

  overhead - Possible cost categories

  - not all of these categories will be relevant to all GIS implementations

- whether or not to include certain costs leads to questioning the purpose of the agency as well as the purpose of the GIS

- for example: should the cost of data collection be included in the total costs for a GIS implementation?
    - No - if the data would have been collected whether or not a GIS was to be implemented
    - Yes - if the data was collected specifically to create the GIS database
    - Partially - if the data would have been collected, but not at the higher level of precision preferred for the GIS database

One-time vs recurring costs

- one-time costs are incurred for hardware, software, possibly data, staff training

- recurring costs are incurred for maintenance contracts, staff salaries, rent, utilities, etc.

- one-time and recurring costs and benefits must be adjusted to identical time periods for purposes of comparison
    - e.g. sum the one-time and recurring costs and benefits over entire period of project, e.g. 5 years
    - e.g. express recurring costs and benefits on an annual basis, and apportion one-time costs appropriately
        - e.g. assign 1/5 of one-time costs to each year of project - may have to add interest charges on initial investment, allowances for inflation, etc.

C. BENEFITS OF A GIS

- benefits are much more difficult to quantify than costs
    - costs can be expressed in dollars
    - benefits are often intangible, difficult or impossible to quantify

- are generally tied to the expected products

- products may be:
    - the same products as before but created by using the GIS instead of the previous manual or CAD/CAM, (i.e., non-GIS) methods
        - generally the same amount can be produced for less cost, or more can be produced at the same cost
    - new products that could not be produced without the GIS

- types of products 1. simple map output of the database or subsets thereof 2. map products requiring the spatial analysis functions of a GIS 3. products which may not be end products, but input to a decision making process

- benefit/cost analysis based solely on map output is different from an analysis involving the spatial analysis and decision support system functions of a GIS
    - the latter type is much more complex
    - there is a need to understand how decision makers use information, specifically geographical information, and how they value that information

- difficult to define some "products"
    - e.g. the concept is clear enough in the case of a map or report but less so when the GIS is used to browse a database

- there is still much to be understood about supply and demand for GIS products

Classifying benefits

- tangible benefits:
    - cost reductions
    - decreased operating costs
    - staff time savings
    - cost avoidances
    - increased revenue

- intangible benefits:
    - improved decision making
    - decreasing uncertainty
    - improving corporate or organizational image

Examples of benefits

- total cost of producing maps by manual means was greater than total cost of making identical maps using GIS
    - tangible benefit

- use of GIS allows garbage collection company to reduce staff through better scheduling of workload and collection routes
    - tangible, possible to quantify

- emergency vehicles reduce average arrival time by using GIS- supplied information on road conditions
    - tangible if we can quantify the increased cost resulting from delayed arrival (fire has longer to burn, heart attack victim less likely to survive, etc.)

- timber company reduced costs of logging because GIS could be used to avoid costly mistakes in locating roads and other logging infrastructure
    - tangible but hard to quantify, implies we can predict the mistakes which would have been made in the absence of GIS

- information from GIS was used to avoid costly litigation in land ownership case
    - tangible but hard to quantify, implies we can predict the outcome of the case if GIS information had not been available

- Forest Service finds a better location for a campsite through use of GIS
    - intangible, implies we can predict the decision which would have been made in the absence of GIS

some of the problems with measuring benefits might be subject to research
  - e.g. take two managers, supply one with GIS information, compare resulting decisions - but the results would be hard to generalize

D. COMPARING COSTS AND BENEFITS

- those benefits easily quantified can be compared directly to costs

- however, it may be wrong to look at the problem as a matter of predicting costs and benefits as static, simple quantities
  - realistically, a system is likely to change substantially over any extended planning horizon
  - the ability to expand the system easily without major structural change may be a hidden benefit

- Dickinson and Calkins (1988) discuss a model of cost- effectiveness under varying levels of investment

  overhead - Cost-effectiveness curve

  - the manual system produces good performance for low levels of investment, but performance fails to grow rapidly as investment increases
  - the automated system has high initial cost, but expandability ensures that performance continues to increase as investment increases
  - Case A shows the reduction in cost from switching from manual to automated at current levels of performance
  - Case B shows the increase in performance from investing the amount currently spent on the manual system
  - the old (manual) system is replaced not because its costs are currently high but because additional investment will produce little increase in system performance relative to the new GIS

  - the appropriate point to switch from manual to automated is at the intersection of the two curves
  - this argument assumes that the benefits of the two systems are the same, and makes the decision based on cost
  - the argument is conservative if we believe that the benefits of GIS are at least as high as those of the manual system

- because of the difficulty of quantifying intangible benefits, one possibility is to document them as completely as possible and leave their evaluation to the final decision-making group (where the buck finally stops)

E. EXAMPLE - WASHINGTON STATE

- following is a brief analysis of the benefits and costs of a specific GIS implementation
  - (note: the full case study can be found in Dickinson, 1988)

Background

- the organization is Department of Natural Resources, State of Washington, Olympia, WA
    - seven regional offices and one central office in Olympia
- manages three million acres of state-owned land, two million are forested; the rest are in urban, recreational, or agricultural uses
- charged with producing revenue, management of the natural resources, and public service
    - involving such activities as: clearcutting, thinning, fire and insect control, stand conversion, market harvesting, replanting, land exchanges, recreation site planning
    - these activities can create up to 200 changes daily, in landuse and landcover, affecting up to 13,000 ownership parcels
- pre-1980, activity centered around sustainable harvest forestry
- two computerized systems were used during this time:
    - GRIDS (Gridded Resource Inventory Data System) - able to calculate sustainable harvest yields and produce forest inventory reports and line printer maps
    - CALMA (Calmagraphics Mapping System) - a computer aided drafting system used to maintain soil maps for the state
- in the 1980s, the Forest Land Management Program was adopted
    - required Multiple Use Forest Planning, environmental analysis, and overall, more effective analysis of geographic data
    - possible answers to this need were either more staff or a GIS
- the choice was a GIS, and expected products included: overhead - Washington State study - Examples of Products
        - base maps of land use and land cover data
        - land lease and land exchange maps
        - road and bridge maintenance maps
        - environmental impact analysis
        - potential debris flow hazard maps
        - fire hazard maps
        - timber harvest tracking
        - spatial allocation of workloads

Installed system

overhead - Washington State study - Description of GIS

- GIS was installed in November of 1983
- system is known as GEOMAPS (GEOgraphic Multiple use Analysis and Planning System)

- consists of ARC/INFO software and associated macros (procedures) built around ARC/INFO

Equipment: Central Office PRIME 9955 (upgraded as of 4/1/89) 6 Tektronix CRTs 11 other type CRTs 5 digitizers 2 pen plotters

Equipment: Regional Offices workstation consisting of one graphics and one alpha CRT, digitizer, pen plotter, line printer, modem communications

Staff: Central Office 1 administrator, 3 user-coordinators (to coordinate needs between regional offices and central office), 4 programmers, 11 production people

Staff: Regional Offices 1 GEOMAPS coordinator

Data

overhead - Washington State study - Data

- database is centralized
  - regional offices are responsible for updates to their area, but actual update to the master database is performed in the central office, only after the updates have been checked and verified

- two main data layers exist: 1. POCA - Public Land Survey Data, State Ownership Parcels, County and Administrative Boundaries
    - 60% of this layer is at a scale of 1:12000; 40% at 1:24000
    - this layer took 3-8 people over an 8-year time period to digitize (40 person years) 2. LULC - Land Use and Land Cover Inventory Data; scale: 1:24,000
    - no records on digitizing time were available
    - updates to this data layer occur approximately 2,000 times per year

- these two data layers were combined (polygon overlay) to produce the composite layer called POCAL
  - approximately 64,600 polygons, each with 77 attributes; updates occur at a rate of about 35 polygons per week

- the other major data layer contains all soil data (300,000 polygons, 1:24000 scale)
  - existed in digital form before GEOMAPS

- entry of road and hydrological data was being planned in 1988

Costs

overhead - Detailed costs of Geomaps

- shows the detailed costs recorded for Fiscal Years 1984 to 1987
  - note the percentage of total costs that the different categories of costs cover:
    - hardware and software = 33%

- maintenance contracts = 9%
- staff = 43%
- travel = 1%
- supplies and services = 14%

overhead - Resource management system costs

- taken from a DNR report and shows costs of all three systems
- total costs for each system are:
    - GEOMAPS (FY 82-87) =$ 4,611,000
    - CALMA (FY 80-86) =$ 947,302
    - GRIDS (FY 80-81) =$ 1,162,613

Benefits

overhead - Summary of GEOMAPS benefits

- shows the summary of tangible benefits from GEOMAPS as estimated by the DNR staff
    - figures appeared in the Post-Implementation Review approved by the DNR executives as well as State data authorities
    - all estimates are considered to be very conservative
- the categories of tangible benefits are as follows:

1. increased revenue
    - due to the increased net value of timber by optimal thinning choices based on analysis of information about physical parameters of timber stands, location of work camps, and market prices
2. decreased costs
    - better stewardship by means of better management based on improved calculations, planning tools, and the effective use and storage of data
    - intensive management produced an estimated decrease of $7 per acre for thinning operations due to decreased number of ground visits, automatic preparation of contract maps, and ability to rank sites for priority harvest based on market information
3. staff savings
    - estimated staff time savings by using GEOMAPS (this includes salary only, not benefits)
4. cost reductions
    - DNR also claimed benefits from the cost reductions resulting from the phasing out of the two prior systems

Benefits vs Costs

- there are two ways to treat the cost reductions from phasing out the old system:

  1. cost reductions can be added to the benefits of GEOMAPS and compared to the costs of all three systems over the total time period (call this version 1)

  overhead - Benefits vs costs

  - version one shows there is a positive benefit/cost ratio between total benefits and costs for all three systems for the fiscal years of 1982, 83, 84, 86, and 87

  overhead - Benefits/costs - Version one graph

  2. if we only want to look at the benefits and costs of GEOMAPS, we could subtract the cost reductions from the GEOMAPS costs, and then compare this total to the new tangible benefits of GEOMAPS only (version two on overhead)

  - also shows a positive benefit/cost ratio between the new tangible benefits from GEOMAPS and the costs of GEOMAPS itself for fiscal years of 1984, 86, 87 and 88

Intangible benefits - Orphan roads project

- a very specific application of GEOMAPS was not entered into the benefit/cost analysis, primarily because the benefit could not be easily quantified
  - however, the benefit is by no means trivial

- before the 1970 Forest Act, forest road construction was unregulated
  - loggers would build temporary roads and bridges when they moved in to log a new area
  - when the task was finished, the roads were left behind (i.e., orphan roads)
  - since they were only temporary roads, many were constructed on steep gradients without usual engineering controls
  - this create a high potential for debris flows where these roads cross streams

- two disasters, resulting in the loss of lives, were caused by the poor placement of such roads
  - each of these disasters cost the DNR over two million dollars in law suits

- many other orphan roads exist and are still being used across the state

- GEOMAPS was used to locate potential hazard locations by locating potential debris flow trigger points

- data used included:
  - road locations, categorized by year of construction (1941, 1947, 1956/62/65, 1969, 1976/78, and 1983)
  - stream locations
  - elevation data in a TIN data structure

- procedure:
    - ARC/TIN was used to create a contour map from the elevation data
    - this was overlaid with the stream data to trace to the stream heads, calculate gradients, and categorize the streams into those with a gradient of less than 3.6 degrees, between 3.6 and 8 degrees, and greater than 8 degrees
    - ARC/ALLOCATE was used to flag all intersections of roads and streams with a gradient greater than 8 degrees
        - for the allocation model, the impedance factor was the gradient, and the resource was the debris in the stream
    - these intersections were potential trigger points for debris flow
- obviously, a benefit exists by using GEOMAPS in this type of analysis
    - but how to quantify the benefit, and how (or if) to include it in benefit/cost analysis?

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EXAM AND DISCUSSION QUESTIONS

1. Summarize the issues involved in assessing costs and benefits when a) a manual system is

replaced by a digital system, b) an existing digital system is replaced, and c) a digital system is introduced to an organization which does not have any existing equivalent, manual or digital.

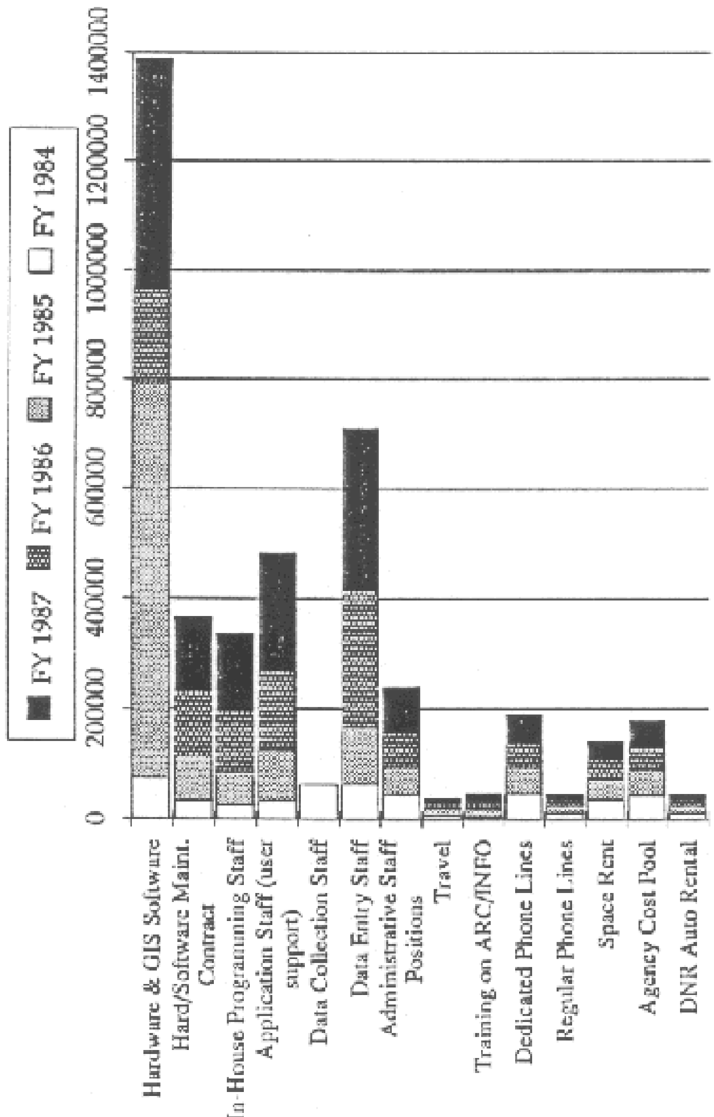
2. Design a series of experiments to determine as far as possible the intangible benefits which accrue from GIS-based decision- making in an organization such as a National Forest.

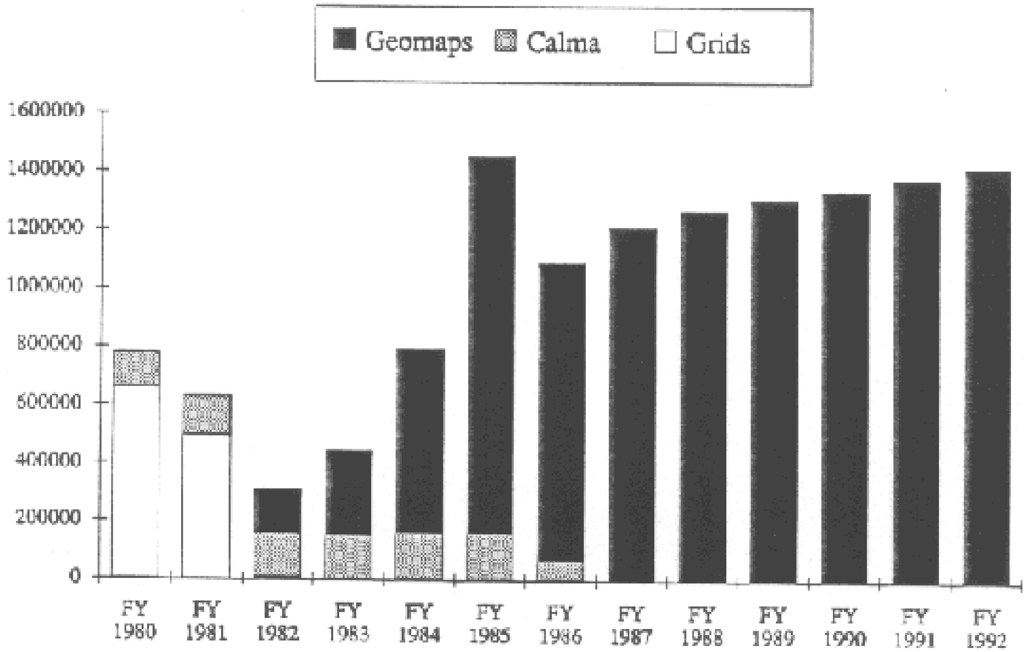
3. A parcel delivery service plans to install vehicle navigation systems in each of its vehicles. These feature continuous display of maps of the area surrounding the vehicle, and of the location of the vehicle in relation to a specified destination. Design a study to assess the benefits of such a system.

4. Discuss the problems presented by the dimension of time in the evaluation of costs and benefits.

Last Updated: August 30, 1997.

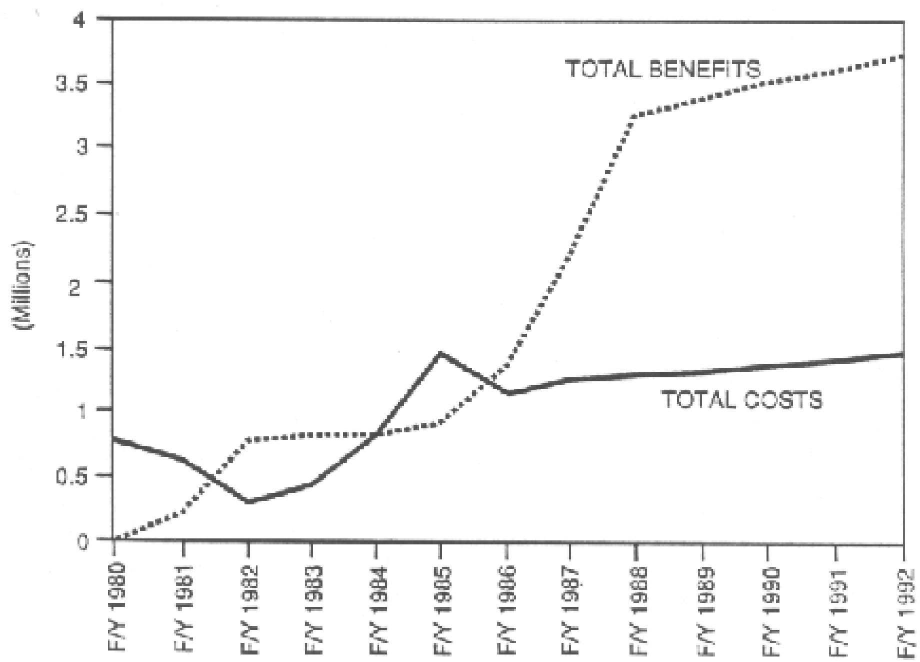
UNIT 65 IMAGES





BENEFIT	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988
Increased Revenue:					
Intensive Management			240000	741000	1527000
Digital Data Sales			20000	10000	21000
Decreased Costs:					
Better Stewardship		5000	20000	41000	85000
Intensive Management			7000	14000	74000
Calma System Sale			5000		
Staff Savings:					
Harvest Tracking				25750	53000
Environ. Impact Planning				31000	32000
Public Inquiries			5000	10000	16000
Staff Turnover	10000	10000	10000	20600	21000
Ownership Records			5000	10300	10000
Forest Practices					25500
Special Projects		10000	25000	51500	80000
Urban Lands Tracking			5000	10300	10600
Block Plans				62000	65000
Cartography				28000	58000
Management Atlas					15000
New Tangible Benefits	10000	25000	342000	1055450	2093100
Cost Reductions	830000	864000	991000	1091000	1124000

TOTAL SYSTEMS COSTS* AND BENEFITS
(GRIDS, CALMA and GEOMAPS)



U.S. DOLLARS UNADJUSTED FOR INFLATION

* includes salaries and benefits, travel, hardware, software, consulting, general supplies and services; does not include field data collection for F/Y 1983 ($889,291).

Version one

	FY 1981	*FY 1982*	*FY 1983*	*FY 1984*	*FY 1985*	*FY 1986*	*FY1987*	*FY 1988*
Total Cost Reductions	230500	771000	796000	830000	864000	991000	1091000	1124000
New Tangible Benefits	0	0	0	10000	25000	342000	1057000	2093100
Total Benefits	230500	771000	796000	840000	889000	1333000	2148000	3217100
Total System Costs	630000	310000	445000	796000	1454000	1091000	1213000	1256000
Benefits Less Total System Costs	-399500	461000	351000	44000	-565000	242000	935000	1961100

Version two

	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985	FY 1986	FY1987	FY 1988
GEOMAPS Total Costs	0	153000	292000	636000	1294000	1023000	1213000	1256000
Cost Reductions		771000	796000	830000	864000	991000	1092000	1124000
Actual Cost for GEOMAPS Only	0	0	0	0	430000	32000	121000	132000
New Tangible Benefits from GEOMAPS				10000	25000	342000	1057000	2094000
GEOGMAPS Benefits Less GEOMAPS Costs				10000	-405000	310000	936000	1962000