Final Report

Analysis of Geographic Information Systems (GIS) Implementations in State and County Governments OF MONTANA

by

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Introduction

Montana Governor Marc Racicot created the Montana Geographic Information Council (MGIC) in 1997 to provide policy level direction and promote *efficient* and *effective* use of resources for matters related to geographic information. In order to achieve this goal MGIC determined that one important aspect of policy formulation was the analysis and quantification of benefits and costs for geographic information systems (GIS) implementation by state and local governments. MGIC commissioned this economic study to assess methods used to measure costs and benefits of GIS implementation and to apply these methods to a number of case studies of state and local government GIS installations in Montana. The study also sought to go beyond justification for GIS implementation and to assess planning activities pursuant to GIS development. A total of 10 case studies were developed for this study including four from local governments and six from state governments. Interviews were the primary tool for obtaining information for both the economic justification and GIS planning portions of the report.

A literature review was conducted to determine the state-of-the-art for GIS benefit and cost analyses. Gillespie (1994 and 1997) conducted case studies of 62 federal government GIS installations. Based on the results of these 62 case studies, Gillespie (1997) developed a regression model for estimating the benefits of GIS implementation. The Gillespie model can be used to determine two types of benefits derived from a GIS: (1) *efficiency* and (2) *effectiveness* benefits. Efficiency benefits arise when a GIS is used to reduce the costs of a task that, in the absence of a GIS, would be handled by some other method. Effectiveness benefits arise when GIS is used to perform a task that could not or would not be done without a GIS (Gillespie, 1994).

The Gillespie (1997) regression model was used to measure economic benefits for a number of case studies of GIS implementation by state and local government agencies in Montana. Economic benefits were estimated from key GIS applications utilized by each agency included in the case study; however, the cumulative costs and benefits of all GIS applications for any single case study were not determined. The Gillespie (1997) model predicted B/C ratios ranging between 1.2 - 5.6 for case studies producing *effectiveness* benefits. In other words for every dollar spent on running a GIS application the return on investment ranged from $1.20 to $5.60. The Gillespie (1997) model was only used to estimate *efficiency* benefits in one case study, estimating 89% savings in Butte-Silver Bow's land records research. Efficiency benefits are more likely than effectiveness benefits to be directly measurable and therefore the efficiency model developed by Gillespie is not as relevant as the measure of effectiveness benefits.

Our study of the costs and benefits of GIS with the Gillespie (1997) model revealed some important benefits of using the model. First, the model allows effectiveness benefits to be estimated in a straightforward manner, which previous benefit/cost studies have been unable to do. In addition, the model deals with GIS on an application-by-application basis. GIS personnel using the Gillespie (1997) model will be better able to prioritize their applications based on the model results. The data collection process will also become more application-driven and data will only be collected with an endpoint in mind.

This study revealed a number of interesting trends in our analysis of planning tasks and issues for GIS implementation. The common issues or "lessons learned" are summarized below:

- GIS should be viewed as an information technology (IT) tool to improve decision-making rather than as map-making software.

- With the notable exception of the Missoula City/County GIS implementation plan there is minimal economic data being tracked or developed by state and local governments justifying investments in GIS technology.
- Political issues in determining directions for GIS implementation are more difficult to overcome than technical issues.
- In state agencies, GIS should be another tool available at the desktop of those needing the results. Centralized GIS coordination is important, but centralized GIS analysis is becoming less desirable.
- Agencies need to establish internal and inter-agency agreements on data standards and data maintenance responsibilities prior to GIS implementation. The elimination of redundant data maintenance and adherence to common data standards will provide the largest economic gains in the long run.
- Agencies and local governments need to understand how their existing IT structure will deliver GIS applications prior to proceeding with GIS implementation.
- Small local governments who can't afford to implement GIS should investigate a number of options including: (1) Contracting with private sector consultants or larger neighboring counties for GIS services; (2) Entering into cooperatives with other small local governments in the area to share expenses for GIS implementation.

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1 Introduction

1.1 Why do the study?

The Montana Geographic Information Council (MGIC) perceived a need for an economic analysis of geographic information system (GIS) implementations at the state and county government levels. This study was commissioned for the dual purpose of determining the monetary benefits for justification of GIS implementation and devising a set of guidelines for planning future GIS implementations at the state and local government levels.

It is important to assess the monetary benefits of GIS for a number of reasons. First and foremost, managers will be more supportive of GIS implementation if they can see their employees working more efficiently and effectively. Second, securing funding for GIS projects either through legislative decree or private sector cost sharing will be more accessible if a direct economic benefit can be identified. Third, with the limited resources available for GIS, it is important to prioritize GIS applications according to the expected B/C returns from each of the applications.

The guidelines from the study are also important to provide some resources for organizations considering GIS. The report will provide a number of references to help groups understand how to better quantify the benefits of GIS. Equally important, the report summarizes a number of lessons which have been learned in existing GIS implementations in Montana. If the report helps groups to avoid reinventing the wheel on GIS implementation, it will have achieved its purpose.

1.2 Case Study Methodology

MGIC determined that a case study methodology would provide the most useful results of the study at a reasonable cost. The case study approach has been used extensively in the available GIS literature. MGIC decided that the study should include case studies from both state government agencies and county or local governments. Ten case studies in Montana were selected for the report, as described below.

1.3 Case studies

1.3.1 Montana local government case studies

The following four city/county governments were selected as case studies for this report:

- Missoula/Missoula County
- Butte/Silver Bow County
- Lewis & Clark County
- Billings/Yellowstone County

These counties represent the spectrum of local government GIS in populated counties of Montana, from a reasonably mature system at Butte-Silver Bow to an up-and-coming system at Lewis & Clark County. The Yellowstone County case study is not summarized in this report, but the general findings contributed to the report's recommendations.

1.3.2 Montana State government case studies

The following 6 state government organizations were also selected as case studies:

- Montana Department of Transportation (MDT)
- Montana State Library Natural Resource Information System (NRIS)
- Montana Department of Environmental Quality (DEQ) Remediation Division
- Montana DEQ Environmental Management Bureau
- Montana DEQ Industrial & Energy Minerals Bureau
- Montana Department of Administration Information Services Division (ISD)

1.4 Report organization

The body of this report is organized into 6 main sections:

- 1(Introduction): Provides background information and introduces the case studies
- 2 (Cost Benefit Methodologies): Brief literature review, description of the methodology used in this study
- 3 (Case Studies): Discusses the data gathered from case studies
- 4 (Discussion of Results): Summarizes the key findings of the report in the issues of justifying GIS expenditures and planning for future GIS implementation
- 5 (Conclusions): Analysis of the methods used to accomplish the goals of the report
- 6 (Recommendations): How to justify and plan GIS implementations

2 Cost benefit methodologies

2.1 Literature Review

A literature on GIS cost benefit analyses was conducted. Several of the most pertinent articles are summarized in Appendix A

2.2 General cost benefit approach adopted for this study

The literature review revealed that the most effective way to obtain information on GIS costs and benefits is to conduct personal interviews of key personnel in the selected organization. With this in mind, our first duties were to identify a few people in each case study and to determine what information we really needed to gain in the interview process.

The Gillespie (1997) model seemed to be ideally suited for the goals of this study. That study comprised a comprehensive study of 62 GIS implementations at the federal government level. The model provides a more straightforward and less time intensive approach to estimating the benefits of GIS than the more traditional approaches discussed in the literature. Furthermore, the Gillespie (1997) model attempts to quantify both the efficiency benefits and effectiveness benefits of GIS implementations. These two types of benefits will be defined in the context of the Gillespie (1997) model in Section 2.4. Previously, effectiveness benefits have typically been disregarded or at best described qualitatively.

Most of the cost benefit analyses located in the literature review were comprehensive studies that required a great deal of time and resources to complete. Our budgetary limitations mandated a much broader scope for this study, particularly because we hoped to gain cost benefit information on a number of different case studies. Our interviews sought to gain some general information about the system and more detailed cost benefit information about one or more of the most important GIS applications in the system. We hoped that this approach would give us a representative sample of the level of benefits we could expect to see in a given case study. However, we would not be able to determine all the costs and benefits for an entire GIS installation.

2.3 What is a GIS application?

GIS applications really became focus of this study, so it is important at this point to define what is meant by a GIS application. An application is some set of software, data, GIS programming and a GIS user combined to produce a result that can solve a particular problem. GIS should be implemented with the goal of solving a known set of problems that could not previously be solved efficiently or effectively.

2.4 Gillespie (1997) model

The Gillespie (1997) model provides equations for calculating efficiency and effectiveness benefits. Gillespie (1994) states that efficiency benefits arise when GIS is used to reduce costs of a task that, in the absence of GIS, would be handled by some other method. The outputs must be equivalent. Effectiveness benefits arise when GIS is used to perform a task that could not or would not be done without GIS. The outputs are new or at least a significant improvement over existing products.

Gillespie (1997) also uses the term "pure" effectiveness benefits to indicate that effectiveness benefits are the only type of benefits for an application. Some applications produce both effectiveness and efficiency benefits. The net benefits of the application are the sum of the net effectiveness and net efficiency benefits.

2.4.1 Model equations

Two separate regression equations are used to calculate pure effectiveness and pure efficiency benefits per incident of an application (Gillespie, 1997).

1. Pure effectiveness benefits

LT = 3.752 + 0.673 INPLEX1 + 0.045 INTERACT + 0.429 OUTPLEX +

3.147 SMALL + residual

where: (Gillespie, 1998):

LT = Natural log of gross pure effectiveness benefits

INPLEX1 = Measure of input complexity

= LN (EXTENT) + LN (VOLUME)

- EXTENT refers to the total study area, reported in map units
  - A map unit is the physical area adjusted for the viewing scale
  - Number of map units = number of map sheets required
  - At a 1:24000 scale, 1 quad is 1 map unit
  - Number of map units = Study area/ Area per map (around 50 mi^2 for a 1:24000 quad)
- VOLUME refers to the Volume of relevant data, reported in megabytes

INTERACT = Measure of analysis complexity

= 0.5 * (MAX^2 -MAX)

- MAX is the maximum number of separate data themes overlaid concurrently
- Calculate this for the single most complicated step in an application

OUTPLEX = Measure of output complexity

= VARIETY / 3 + LIKELIHOOD / 25

- VARIETY is total number of separate groups concerned about an application
  - VARIETY ranged from 1 to 12 with most falling in 3-5 range for federal case studies
  - Potential concerns include environmental, developers, homeowners, various government agencies, real estate agents
- LIKELIHOOD is the likelihood an application will be used in an adversarial hearing
  - Examples include a lawsuit or a challenging to a zoning decision
  - Ranges from 0-100

SMALL = Dummy variable reflecting overall complexity of Application

- SMALL either a 0 or 1
- Value of small determined by changing previous 5 variables into size classes (S.C.)

EXTENT:

S.C. (1) = LN (EXTENT)

VOLUME:

S.C. (2) = LN (VOLUME)

INTERACT:

S.C. (3) = INTERACT/3 and round up to nearest digit

VARIETY:

S.C. (4) = VARIETY/3 and round up to nearest digit

LIKELIHOOD:

IF (LIKELIHOOD = 0) S.C. (5) = 0

IF (LIKELIHOOD < 50) S.C. (5) = 1

IF (100>LIKELIHOOD >50) S.C. (5) = 2

IF (LIKELIHOOD = 100) S.C. (5) = 3

- SIZE = S(S.C. (i) where i= each of the 5 model variables)
- IF (SIZE>6) SMALL = 0
- Otherwise, SMALL = 1

Residual **= Error** term for the regression equation

- This term is not included in the model calculations; it is the error involved in estimating the regression coefficients from the data collected from the 62 case studies (Gillespie, 1998)

LT is the natural log of the gross pure effectiveness benefits. To determine the net pure effectiveness benefit, one must first take the antilog and then subtract the cost of running the application with GIS.

The effectiveness benefit calculated in this manner is the net effectiveness per incident of an application. To determine the net annual effectiveness benefit of an application requires that the benefit be multiplied by the annual frequency of use of the application. For the purposes of this report, a new variable called FREQUENCY is simply defined as the number of times an application is run annually.

1. **Pure efficiency benefits**:

RATIO = 0.477 + 0.100 INPLEX2 - 0.001 INTERACT + 0.051 OUTPLEX

+ 0.377 SMALL + 0.232 COST - 0.186 LAND + residual

where: (Gillespie, 1998)

RATIO = ratio of efficiency benefits to the manual costs (pre-GIS costs)

INPLEX2 = Measure of input complexity

= LN(EXTENT)

- EXTENT already defined

INTERACT = Already defined

OUTPLEX = Already defined

SMALL = Already defined

COST = Dummy variable reflecting cost of performing application with manual methods

- COST = 1 if cost of running the application without GIS is between $20k-$50k
- COST = 0 otherwise

LAND = Dummy variable reflecting subject area of application

- LAND = 1 if the application is concerned with the economic value of the land
- LAND = 0 if the application is only concerned with land because it is the location of other activities
- LAND = 0 for most applications

RATIO is the ratio of net efficiency benefits to the manual costs (pre-GIS). To determine the net efficiency benefits per incident of an application, one simply must multiply RATIO by the manual cost.

As with the effectiveness model, the net efficiency benefit per incident must be multiplied by FREQUENCY to determine the net annual effectiveness benefits of the application.

2.4.2 Using the model to estimate benefits of a GIS application

It is important to realize that by Gillespie (1994) definitions, a given GIS **output** can only have either effectiveness or efficiency benefits, but not both. A GIS **application** may produce both types of benefits, but only if the application generates multiple types of outputs. For instance, an application may automate some type of engineering calculation that was used previously, thus producing an efficiency benefit. The same application may also be used to generate a map of the area that could not be produced otherwise, thus producing effectiveness benefits for the same application.

To quantify the net annual benefits of this application, the net efficiency benefit should be multiplied by the FREQUENCY of the engineering calculations and the net effectiveness benefit should be multiplied by the FREQUENCY of map production. The net annual benefit of the GIS application is the then the sum of the net effectiveness and net efficiency benefit.

Another interesting way to describe the benefits of a GIS application is to determine the benefit/cost ratio. The benefit cost ratio is found by dividing the *gross* annual benefit by the annual cost of the application. A benefit/cost ratio of 1 indicates that the benefit just offsets the cost of the application. In this study, the benefits and costs of an application are typically compared on an annual basis for the present year.

A very important point to realize is that the discussions have focused thus far on the costs and benefits of an *application*. To quantify the benefits of an entire GIS installation, one would have to add up the net annual benefits of all applications within the installation. One would also have to include some estimate of the depreciation of all system components. Gillespie (1998) recommended that depreciation costs for a system not be included in the analysis because the model was really derived to determine the benefits of a GIS system already up and running. This study only goes to the point of estimating benefit/cost ratios of individual applications. To fully characterize the benefits of up to 10 case studies would have been an extremely time-consuming and unjustifiable task.

Another important point to make is that estimation of the model variables is quite a subjective process. It is important to estimate benefits conservatively, while at the same time remaining true to the spirit of the information coming out of the interview.

Additional information needed to run the model is available in Gillespie's papers in Appendix D of this report.

3 GIS Case Studies

The case study data were obtained for the most part from personal interviews. An interview worksheet was mailed to the interviewees ahead of time so that they could be prepared to answer the questions.

3.1 Missoula City/County GIS implementation plan

Missoula's *Geographic Information Management Implementation Plan* appears in its entirety in Appendix B of this report. The plan was compiled by Roy F. Weston, Inc. Seattle, WA. The key elements of the plan are summarized in the following sections. Additional information was provided by telephone conversations with Doug Burreson, Missoula County GIS coordinator.

3.1.1 Overview of the GIS implementation plan

Steps in strategic GIS Plan

- Needs assessment
- Conceptual data model for road network database
- Data development and maintenance plan
- Organizational analysis
- Hardware and software solutions
- Implementation plan

Missoula County data development tasks

- Control database
- Real property
- Political districts
- Transportation

City of Missoula Data Development Tasks

- Photogrammetry
- Digital orthophotos
- Digital elevation model and contours
- Wastewater facilities
- Storm drain facilities
- Traffic control facilities

GIS applications

As part of the Implementation Plan, GIS personnel for the City of Missoula and Missoula County came up with a list of GIS applications and developed a ranking system to prioritize them.

The first step in the ranking system involved deriving 8 categories among which each of the applications could be compared. Further, the categories were each assigned a weighting factor to describe their relative importance. The categories and assigned weighting factors were:

- Is the cost of the application small? (10)
- Is the application a cornerstone of the information system? (10)
- Does the application produce intangible benefits? (5)
- Does the application produce tangible benefits? (10)
- Does the application promote public access? (6)
- Is the application used by a large number of personnel? (7)
- Does the application reduce redundancy? (6)
- Is the application part of a continuing initiative for information services? (5)

For each application, Missoula's GIS personnel were then asked to assign scores between 1-3 for each category to describe how well the application answers the above questions. For instance, an application with a relatively low cost would receive a score of 3 for the cost category. A total score was calculated for each application by multiplying the score for each category by the weighting factor for the category and summing up these numbers for all 8 categories. Finally, the applications were ranked by descending score. The highest scoring applications would be implemented first.

The following is a partial list of GIS applications for Missoula County. The applications are not in any particular order of importance.

- Scan and index voter registration cards
- Weekly ownership update
- Survey document management
- Septic permit system
- Internet map browser
- County road maintenance management system

The following is a partial list of GIS applications for Missoula County. The applications are not in any particular order of importance.

- Maintenance management system (wastewater, drainage, traffic)
- Infrastructure map maintenance (wastewater, drainage, traffic)
- Permit and development tracking
- Web enabled parks and recreation reservation
- Map index to project plans
- Map index to park plans
- Property owner notification

Lessons learned

- Greatest expense involved in data development and training, not hardware/software
- Organizational issues in developing GIS more difficult to overcome than technical issues
- Cooperation between governments (i.e. city and county) is critical
- Cooperation between agencies in a government also critical. For example, agencies can dispute the division of responsibilities associated with the GIS
- GIS implementation requires excellent communication between all personnel involved
- City of Missoula/ Missoula County were able to overcome the organizational issues and cooperate well in the project
- Important for personnel to trust the process of GIS implementation and be flexible in the way they do things
- GIS implementation requires a great deal of time
- Training requirements for GIS are intense; it is difficult to cut corners
- Important for GIS to show immediate benefits from mapping capabilities in order to bring all agencies and decision makers on board

3.1.2 Cost benefit information

All cost benefit information in this report was taken directly from Missoula's Implementation Plan. The Gillespie (1997) model was not used in this case study.

Cost

- Total project cost of $2.25 million after 10 years
- Net investment peaks at $780,000 because benefits begin to accrue immediately
- Capital costs

    - Organizational activities
    - Data development
    - Hardware and software
    - Application development
- Operation & maintenance costs
    - Hardware/software maintenance (assumed equal to 15% of capital expenditure)
    - Communication services

Efficiency benefits

- 5 year break even period (annual benefit> annual cost)
- 10 year payback period (cumulative benefit>cumulative cost)

Effectiveness benefits

Effectiveness benefits were not determined for the Missoula GIS.

3.2 Butte/Silver Bow County GIS

The information for the Butte/Silver Bow (BSB) GIS case study was obtained by interviewing Jon Sesso and Tom Tully of the BSB Planning Department and Rob Macioroski of the BSB Land Records Department.

3.2.1 Overview of Butte/Silver Bow GIS

System description

Butte-Silver Bow is an example of one of the most advanced local government GIS implementations in the State of Montana. The system presently includes 6 Arc/INFO licenses and 4 ArcView licenses. GIS implementation at BSB began approximately 9 years ago. The Butte Superfund sites were the primary motivator for GIS implementation. Atlantic Richfield Corporation (ARCO) provided much of the funding so that there would be an adequate storage system for the Superfund-related data.

List of applications

The top four applications of the BSB GIS are:

- Automated land records searches
- Automated underground utilities information
- Environmental cleanup coverage
- Zoning issues

Lessons learned

- Don't get hung up on data accuracy

Example: GIS applications like water and sewer pipe locations can still be very useful even if the data is only accurate to a few meters

- Don't underestimate the necessity to maintain data as it is created

Example: Topology and building location data changes frequently and must be updated regularly

- Don't use topographic data from aerial photographs for engineering works
- Surface depressions are particularly unreliable
- In many GIS applications, users should not over-rely on data accuracy
- Cooperation between all offices involved is critical
- Cooperation has been critical to the success of BSB GIS
- Requires cooperation between many state and local government agencies and private organizations
- All agencies involved must commit to using compatible systems
- Unexpected difficulty in bringing GIS to the desktop of people not accustomed to GIS
- GIS implementation should occur simultaneously with data processing
- GIS applications must be as straightforward as manual methods or GIS will not be used
- GIS data must be documented with metadata as it is produced
- Must have an organized approach to data maintenance so that it won't get lost

3.2.2 Cost/benefit information

Cost information is provided below for the entire system. Additional cost and benefit information for the Gillespie (1997) model was provided for the application of automated land records searches. Mr. Sesso estimated that between 70-80% of his department's work involves land ownership research, so this application is by far the most important one.

The interview revealed that there are two basic types of land records requests: some people simply request verbal ownership information while others request a map to show ownership. For the purposes of the Gillespie (1997) model, these two types of requests were differentiated because they produce different types of benefits. The verbal requests produce efficiency benefits because those requests could be satisfied prior to GIS. The map requests produce effectiveness benefits because these maps were not produced prior to GIS.

The interview further revealed that there are approximately 40 requests per day for simple ownership information. This figure corresponds to 250/week or 10,400/year.

The number of maps produced per week was also roughly determined during the interview. The Land Records Department receives 10-15 requests for blueline maps per week. The Planning Department receives approximately 40-45 requests for maps per month. The difficulty in estimating benefits is in determining what is a typical request for maps. Some requests are for a single map, while some Superfund-related requests could produce as many as 3 dozen maps.

Costs

The annual GIS budget for BSB is currently approximately $200,000 per year.

Prior to GIS, the cost to satisfy a verbal ownership request was approximately 10 minutes time of a person making $7/hr. Assuming a benefits multiplier of 1.32, the cost of a single request is $1.50. The cost of satisfying these requests with GIS was not determined in the interview. This information is estimated from the Gillespie (1997) model in the next section.

It was indicated in the interview that the typical minimum charge to produce a map is $25. The fee is charged primarily to cover the cost of plotter time and ink, but apparently also includes some labor fees. The $25 figure is probably the bare minimum cost for the simplest type of map request. No information was given on the cost of the more detailed map requests.

Efficiency benefits

As mentioned previously, the simple verbal ownership requests produce an efficiency benefit. To calculate the efficiency benefit from a single request requires a number of assumptions in order to estimate the variables:

- Application run 10,400 times per year (FREQUENCY=10,400)
- 1 map sheet viewed to satisfy the request (EXTENT=1 in model)
- 3 data themes (MAX=3)
- 2 groups concerned about the results of the request (CONCERNS=2)
- 5% chance that the results of the request would end up in an adversarial hearing (LIKELIHOOD=5)
- Application concerned with the land primarily as a location of other activities (LAND=0)
- Cost much less than $20,000 per occurrence (COST=0)

The model predicts an efficiency benefit of 89% with these variables. The result was quite sensitive to the choice of the LAND variable, which is somewhat of a subjective variable. A value of 1 would shrink the efficiency savings to 70%. The net annual efficiency benefit (with LAND=0) for 10,400 requests at an original cost of $1.50 is $13,920.

Effectiveness benefits

The production of ownership maps results in effectiveness benefits for the agency, individual or private company making the request. The Gillespie (1997) model was used to estimate the level of effectiveness benefits for these map requests.

Due to the great variety of map requests, the BSB personnel were not able to describe a "typical" request. A number of assumptions were made in order to use the Gillespie (1997) model to make conservative estimates of the effectiveness benefits. Map requests were divided into bluelines for the Land Records Department and more complicated planning maps for the Planning Department. It was assumed that there are 12 bluelines requests per week for the Land Records Department and 10 requests per week for the Planning Department maps.

In order to make a conservative estimate of the effectiveness benefits; the following assumptions were made about a typical blueline request in the Land Records Department

- Application run 624 times per year (FREQUENCY=624)
- 1 map sheet viewed and/or printed to satisfy the request (EXTENT=1)
- Information requested about a single parcel
- An average volume of data per parcel was calculated by dividing the total volume of land ownership data by the number of digitized parcels in the county (350 megabytes/19,000 digitized parcels; VOLUME= 0.018 megabytes)
- 4 data themes (MAX=4)
- 2 groups concerned about the results of the request (CONCERNS=2)
- 10% chance that the results of the request would end up in an adversarial hearing (LIKELIHOOD=10)

The gross effectiveness benefits were conservatively estimated for each blueline request in the Land Records Department at $140. The interviewees indicated that a simple map request like this would require about an hour's time. The approximate cost for this type of request is $25, resulting in a net effectiveness benefit of $115 per request. The benefit cost ratio for the group making the request is 5.6. Summed across 624 requests per year, the net annual effectiveness benefit for this type of request is at least $71,760. Many requests come from within the city/county governments or for Superfund-related data, so those effectiveness benefits accrue to those responsible for funding and maintaining BSB's GIS.

A number of assumptions must be again made in order to estimate the effectiveness benefits from the typical request for maps from the Planning Department. Based on the interview, the following pieces of information were used to estimate the model variables:

- Application run 520 times per year (FREQUENCY=520)
- 3 map sheets at 1:2400 scale (EXTENT=3)
- Calculate average parcel size in county by dividing county area by 22,178 parcels (0.032 mi^2/parcel)
- Estimate total number of parcels per sheet by dividing the average number of square miles on a sheet (0.6) by 0.032 mi^2/parcel (19 parcels per sheet)
- Estimate volume of data required to produce 3 map sheets by multiplying 57 parcels by .018 megabytes per parcel (VOLUME = 1.03 megabytes)
- 4 data themes (MAX=4)
- 3 groups concerned about the results of the request (CONCERNS=3)
- 15% chance that the results of the request would end up in an adversarial hearing (LIKELIHOOD=15)

The gross effectiveness benefits for a Planning Department map request using these variables are probably unreasonably high at $3580. The numbers could probably be refined by a more in-depth interview to better determine what information is used to satisfy the typical request. However, it might also be reasonable to assume that the person requesting the map is not interested in every parcel on a given map sheet. For instance, a request from ARCO for a map of streamside tailings might show a wide area adjacent to the Clark Fork River, but the only parcels that are really important are those near the river. If one assumes that 10% of the parcels on a given map are important and all other variables the same as shown above, the model predicts a gross effectiveness benefit of $761 for this request.

This type of map request might take about a day to fulfill, resulting in a cost of $200, assuming $25 per hour for labor and plotter time as shown for the Land Records Department maps. The net effectiveness benefit would then be $561 and the benefit cost ratio would be 3.8. Summed across 520 such requests per year, the net annual effectiveness benefit for the Planning Department would be $291,720. Adding in the Land Records Department results estimates a net annual effectiveness benefit of land records mapping of $363,480, or $10.71 per capita annually.

Cost benefit summary

The net annual benefits of automated land records searches can be determined by adding up the net efficiency benefits for verbal ownership requests, net effectiveness benefits for Land Records Department map requests and net effectiveness benefits for Planning Department map requests. The net annual benefit of these GIS applications is equal to $377,400 or $11.12 per capita annually.

3.3 Lewis & Clark County GIS implementation

The information on Lewis & Clark County GIS was provided by an interview with R.J. Zimmer, a GIS analyst for the county.

3.3.1 Overview of Lewis & Clark County GIS

System description

Lewis & Clark County is still in the process of implementing GIS. GIS activities have been going on for about 3 years, but there has not been a lot to show for their efforts so far. However, the County has recently been working on a Strategic Plan to better coordinate their GIS efforts. The City of Helena has also recently agreed to join the GIS effort.

Currently, Lewis & Clark County maintains 2 Arc/INFO and 1 ArcView licenses, with 4-5 more ArcView licenses planned for the coming year. Mr. Zimmer and an intern are working with the system, in addition to a person in the assessor's office working on parcel mapping.

List of applications

Lewis & Clark County's GIS efforts to date have been more data-driven than process-driven. They are currently identifying and prioritizing their data needs before they begin assessing applications for the data.

For most people in the county, the GIS is so far a tool that will provide them with better access to data. The next step will be for personnel to realize that GIS is also an excellent mapping and analysis tool.

The first applications for Lewis & Clark County GIS will be:

- Mapping

Some maps have already been completed, including a watershed boundary map and a map showing the locations of paved and unpaved roads in the county

- Rural addressing
- Flood plain delineation

Lessons learned

- Must be able to show GIS outputs early in the process or administrators making funding decisions will lose faith
- Communication between groups is critical, particularly about such matters as the great time and money required to produce data
- Communication with other local governments also very important in order to avoid reinventing the wheel on projects like rural addressing
- GIS should be pushed to the desktop; personnel should be able to produce their own GIS outputs because they have a better understanding of the data
- Personnel must see beyond GIS as simply a better way to access data

3.3.2 Cost/benefit information

Cost and benefit information was not discussed in the interview. The implementation is in the early stages and no applications were available for further discussion.

3.4 Montana Department of Transportation (MDT)

The information for the MDT case study was obtained by interviewing Mr. Skip Nyberg, Information Specialist III.

3.4.1 Overview of MDT GIS

System description

MDT first implemented GIS in 1985. The system currently includes 10 floating ArcView licenses and 1 Arc/INFO license. More licenses will be added as more personnel begin to use the software. MDT is actively pursuing a policy of encouraging the end user to become comfortable with ArcView and use its capabilities. MDT currently has 1.2 FTE devoted to GIS support for the agency.

List of applications

- Road reports

MDT is working with Travel Montana to make updated road report data available at information kiosks and eventually on the web. Automatic weather feeds will be included.

- Road rating

Roads will be tested every 1/10 to 1/100 of a mile to determine the condition of the road. The information will be used in prioritizing road repairs.

- Project analysis

The Planning Department must determine how money will be divided among 5 districts in the state for road repairs. The project analysis incorporates the available data on road conditions and financial considerations to decide which projects will be undertaken in a given year.

Lessons learned

- Better accuracy of data corresponds to better decision-making
- ArcView requires a steep learning curve; GIS personnel are attempting to automate mapping processes so that not everyone needs to become ArcView experts
- Data redundancy can kill you; sophisticated databases with cross-linked tables are critical for organizations with large amounts of data
- Don't over-collect data; only get the data really needed
- MDT's Environmental Bureau data needs to be accessible to other MDT Bureaus so that environmental concerns of a road project are better defined
- GIS should be more than a cartography tool; it should also be used to help make better decisions

Recommendations for other state agencies

- Oracle databases are the way to go, particularly with a spatial database engine add-on
- MDT's data can only be available to agencies using Oracle databases
- ArcView must be available to the end user; sophisticated GIS support personnel must also be available within the department to help with GIS and data management

3.4.2 Cost/benefit information

MDT's GIS applications did not fit well into the Gillespie (1997) model. The primary reason that they don't work is that MDT's applications are almost strictly linear projects, so it is difficult to determine an areal extent for the application. Another difficulty is that some of them (i.e. road reports) are run continuously statewide; it is difficult to determine what a single "run" of the application consists of.

Costs

Detailed cost information was not discussed in the interview.

Efficiency benefits

One general type of efficiency benefit described by Mr. Nyberg was the labor savings involved in the project analysis application. Prior to GIS, this project required 2-3 people over a month. Now, this analysis can be conducted in a matter of hours

Effectiveness benefits

Efficiency benefits were not calculated for MDT applications.

3.5 Montana State Library Natural Resource Information System (NRIS)

The information for the NRIS case study was obtained by interviewing Mr. Jim Stimson, NRIS director.

3.5.1 Overview of NRIS GIS

System description

The Montana State Library implemented GIS through NRIS in 1989. NRIS maintains 10 GIS licenses, used by about 15 personnel. About 500 databases are available for GIS applications. NRIS provides a wide variety of GIS services, including providing GIS analyses for private and government agencies and serving as a clearinghouse for the state of Montana's natural resources data. State agencies utilizing NRIS' contract GIS services include the Departments of Environmental Quality, Fish, Wildlife & Parks and Public Health & Human Services. As some of these agencies begin to consider implementing GIS in-house, NRIS also serves an advisory role in selecting and purchasing software, maintaining licensing agreements, building applications and providing training.

List of applications

- Watershed analysis
- Interactive well-finder on the web

- Drought monitoring
- Natural Heritage Program
- Underground Storage Tank (UST) analysis

Lessons learned

- Internet GIS applications are very successful for 4 main reasons;
  - Users are more comfortable with web browsers than GIS software
  - They require little technical support
  - They reduce the number of requests that have to be handled by agency personnel
  - They provide an easy means for tracking use, which in turn can be used to demonstrate the benefits of the applications
- Attitude of management must get beyond the idea that GIS is a program for making nice maps
- Attitude of management can suffer from complicated issues related to GIS implementation

Example: Implementing GIS on a new operating system (i.e. Unix) with expensive workstations (i.e. Sun workstations) can make it difficult to keep management on board

- Critical to demonstrate to management that GIS makes employees more efficient and more effective; it is especially helpful to show quantitative monetary benefits
- GIS is just another tool for improving decision-making

Example: legislative and agency level committees responsible for determining statewide policies use Drought and other maps

- GIS training requirements are intense; it can take a year and a half to get a programmer/analyst up to speed
- Data is very expensive to generate and maintain
- GIS pilot studies are very important to identify what works and what doesn't
- Web applications also helpful to NRIS in justifying GIS expenditures because numbers of users and web sessions are easy to determine
- Sometimes it is more effective for an agency to use an outside entity for developing databases and GIS applications; easier for the outside entity to see the bigger picture about how databases will fit in with an agency's existing databases

Recommendations for future GIS implementation in Montana State government

- It makes sense for agencies to have some GIS capability in-house. There are different levels of GIS deployment that can be considered. Some agencies may need to have highly qualified GIS programmer/analysts in-house, others may choose to contract with another entity for that level of service. For other agencies it may be more efficient to deploy a desktop GIS application like ArcView or ArcExplorer.
- Agencies' decision whether or not to implement GIS in-house should depend partly on the level of GIS sophistication required (Heavy-Arc/INFO; Moderate- ArcView; Light-ArcExplorer)
- It would be helpful for someone to itemize the capabilities of the various GIS products (ArcView, Arc/INFO, etc.) so agencies could compare their needs and select software
- Believes that NRIS' contract GIS services may diminish with time, but should maintain role as a clearinghouse for all of Montana's natural resource data
- Believes that establishing a separate clearinghouse for non-natural resource information may not be a realistic model for managing GIS data in a cost-effective manner. Such a model should be examined closely to determine if it really makes sense and is cost effective.
- A data clearinghouse is important for agencies considering implementing GIS because it can cut down on their initial costs of data generation and storage and provide higher speed delivery of data

3.5.2 Cost/benefit information

Mr. Stimson provided cost benefit information on all of the applications listed in Section 3.5.1. Two of the applications were chosen for further study with the Gillespie (1997) model: watershed analysis and interactive well finder. The watershed analysis application was completed for the Natural Resource Conservation Service (NRCS). It allows them to choose a watershed of any extent within the state and characterize and analyze the land use, vegetation and soils types contained within the watershed. Among other things, the application can be used for calculating runoff and sediment loads from a watershed. The well finder application allows Internet users to locate wells within a given area and obtain information on the productivity and depth of those wells.

The watershed analyses were conducted to some extent prior to the development of GIS. By Gillespie's (1994) definitions of efficiency benefits, watershed analyses would produce an efficiency benefit. Watershed analyses also produce effectiveness benefits, however, because GIS allows many more of the analyses to be done and also produces better analyses. Furthermore, the GIS application makes possible analyses of larger watersheds that could not be done feasibly without the tool. For the purposes of this study, only the effectiveness benefits were considered because the GIS analyses were so much better than the previous outputs. The watershed analyses are currently conducted approximately 18 times per year.

Like the watershed analyses, the information on wells in a particular area could be obtained prior to GIS. However, no information was available on the frequency of use of that application before GIS was available. It is quite evident that the GIS application allows many more users to determine that information. The application was therefore assumed to produce only effectiveness benefits for this report. The interactive well finder application is run on approximately a daily basis.

Costs

Cost information was not provided for the system as a whole. Cost information was provided per incident of each of the applications, both with and without GIS.

Prior to GIS, a watershed analysis would cost on the order of $3000 for a small watershed. With GIS, the analysis costs an average of $65.

To obtain well information on an area without the GIS application would cost an average of $300. The well finder GIS application costs nothing to run because the user can do it over the Internet.

Efficiency benefits

As mentioned previously, efficiency benefits were not analyzed with the Gillespie (1997) model for either the watershed analysis or the interactive well finder. However, based on the cost information provided by Mr. Stimson, it is possible to calculate the efficiency benefit per incident of those applications. The GIS watershed analysis produces an efficiency benefit of 98%, while the interactive well finder saves 100% of the pre-GIS costs.

Effectiveness benefits

The Gillespie (1997) model was applied to the watershed analysis application to determine the effectiveness benefits. The interview answers provided information on the typical watershed analysis. The following parameters were used as typical values. As with many model applications, it was necessary to use some judgment on the chosen values in order to conservatively estimate the benefits and still remain consistent with the interview findings:

- Application run 18 times per year (FREQUENCY=18)
- Areal extent of 600 mi^2 displayed at 1:24K scale (11 map units, EXTENT=11)
- Volume of data: 35 megabytes (VOLUME=35)
- Number of data themes: 5 (MAX=5)
- Number of groups concerned: 5 (CONCERNS=5)
- Likelihood of use in adversarial hearing: 25% (LIKELIHOOD=25)

Using the typical numbers for the parameters, the gross effectiveness benefits per occurrence of the application are $7910. The gross annual effectiveness benefits of the application are $141,210. The benefit cost ratio from the application appear to be outlandishly high (i.e. 122). However, if one realizes that the cost of producing the application prior to GIS was at least $3000, the number is not unreasonable. If the gross effectiveness benefits were not at least $3000, the analysis would never have been performed manually. If the cost of obtaining the remote sensing data had been included in the cost of running the application, the benefit cost ratio would have been much more in line with reasonable expectations.

The Gillespie (1997) model was also applied to the interactive well finder application to determine its effectiveness benefits. The following parameters were used in the model:

- Application run 365 times per year (FREQUENCY=365)
- One 1:24K map sheet viewed in the typical incident of the application (EXTENT=1)
- Volume of data: 35 megabytes (VOLUME=35)
- Number of data themes: 3 (MAX=3)
- Number of groups concerned: 4 (CONCERNS=4)
- Likelihood of use in adversarial hearing: 5% (LIKELIHOOD=5)

The gross effectiveness benefits per incident of the interactive well finder are $646. The cost of the application (not including the cost of generating and maintaining the data) is $0, so the net effectiveness benefits are also $646. The net annual effectiveness benefits are $235,790. With a cost of $0, it is impossible to determine a benefit cost ratio, although the number would have been reasonable if the data costs had been included in the application. However, the gross effectiveness benefits of $646 are in line with the $300 cost of doing the analysis without GIS. As in the case of the watershed analyses, the well finder analysis would never have been conducted manually if the effectiveness benefits did not exceed the cost of producing the output.

Cost benefit summary

The two GIS applications studied for NRIS produce a net annual effectiveness benefit of $377,000. Benefit cost ratios for the two applications are somewhat meaningless in this case. The important concept to realize is that the applications continue to generate a great deal of effectiveness benefits even though little cost goes into each incident of the applications.

3.6 Montana Department of Environmental Quality (DEQ) Remediation Division

The information for the DEQ case study was obtained by interviewing Mr. Jim Hill, director of the Remediation Division's Technical Services Bureau.

3.6.1 Overview of DEQ Remediation Division GIS

System description

Montana DEQ began using GIS in 1988. Much of DEQ's GIS work has been performed by NRIS, which was established in 1988 to deal with Superfund data. Up to this point, the programs operating under DEQ have essentially compiled databases and GIS applications that suit their own needs, rather than contributing to an enterprise-wide system. As a result, communication is poor between databases and much repetitive data is maintained.

DEQ has begun conducting studies in-house and with BDM, Inc. in order to begin moving the organization's IT capabilities (including GIS) towards an enterprise-wide system. A great deal of effort will be required to convert more than 30 database platforms to some compatible standard and to implement GIS so that the majority of those services can be provided in-house. The IT Planning Team in the DEQ is recommending a multi-tier approach to IT. By this, they seek to establish an enterprise-wide system but they allow individual programs to make their own decisions about GIS implementation. A trend of increasing appreciation for compatibility should insure that certain minimum standards are met in all programs. Ideally, DEQ will hire a GIS coordinator who will be responsible for setting standards that all programs' applications and data should conform to.

Applications

DEQ Remediation division's GIS applications are primarily one-time applications. For instance, GIS might be used to calculate the volume of material to be removed from a tailings pile. After that application is run, the work is performed and there is no need to re-run the application. No information was provided about other applications.

Recommendations for DEQ's GIS needs

- Everyone in DEQ needs to work towards the enterprise model and standardization, but DEQ can't afford to delay GIS implementation until standards are set and GIS personnel are hired
- DEQ should hire GIS coordinator as soon as possible to insure compatibility of data and GIS applications
- Communication must continue to be excellent between GIS coordinator, DEQ bureaus, DEQ's IT Planning Team and IT technical users group, DEQ management
- Training must be a coordinated effort; GIS users must have proficiency at basic computer skills (directory structures, etc.)

3.6.2 Cost/benefit information

Costs

DEQ began spending money in 1988, establishing NRIS to maintain the spatial Superfund data. The Remediation Division spent $300,000-$500,000 annually through the early 1990's and $100,000-$200,000 annually since then.

Efficiency benefits

No information was provided about efficiency benefits.

Effectiveness benefits

Quantitative effectiveness benefits were not calculated for the DEQ Remediation Division. One important type of effectiveness benefit described by Mr. Hill is the future ability of DEQ to integrate information from different bureaus. For instance, it would be important for DEQ personnel permitting a subdivision to have information about other DEQ sites in the area, such as a hazardous waste remediation project. Currently, those types of information are separated along bureau lines.

DEQ will also be able to serve the public much better once all the databases can be interfaced through a GIS. The public will be able to call up the DEQ and quickly obtain information about any environmental problems associated with a particular site. The DEQ does not presently have the ability to answer those types of questions.

3.7 DEQ Environmental Management Bureau

The information on DEQ Environmental Management Bureau (of the Permitting and Compliance Division) was obtained by interviewing Tom Ring, Environmental Specialist and Nancy Johnson, Environmental Impact Specialist. Mr. Ring and Ms. Johnson are both part time GIS analysts and the primary personnel in the Environmental Management Bureau using GIS.

3.7.1 Overview of DEQ Environmental Management Bureau GIS

System description

The Environmental Management Bureau began using GIS in 1993. The system originally ran on a Sun workstation, but has recently been converted to run more economically on a Windows NT Workstation. The system consists of 1 Arc/INFO, 1 TIN, 1 GRID and 1 NETWORK license.

GIS has been used as a tool for assessing impacts of proposed mines, water resources developments, a wind farm and linear facilities like powerlines and pipelines. GIS has also been used as a tool for comparing alternative routes for linear facilities.

List of applications

The following list of applications are some of the ways GIS has contributed to determining the impacts of the projects mentioned previously.

- Aesthetics

Example: Viewshed analysis for proposed mines

- Wildlife

Example: Potential fishery impacts of a proposed pipeline

- Soils
- Land use
- Hydrology

Lessons learned

- Up front training investment is critical
- Well-trained system maintenance personnel also critical
- GIS has become less of a tool for GIS experts and more of a tool at the desktop of resource specialists
- GIS is just another tool for decision makers; there should be no expectation that GIS will make decisions

Recommendations for DEQ's GIS needs

- Critical for DEQ as a whole to adopt uniform databases (currently 30+ different database platforms within the agency)
- Programs within DEQ must communicate better so that it easier to determine all types of historic activities for a particular site (i.e. subdivisions, abandoned mine reclamation work, hazardous waste facilities)
- Programs should develop and use their own GIS applications, but technical support should be available department wide (either supplied in-house or through a group like NRIS)

3.7.2 Cost/benefit information

Cost information is provided below for the entire system. More detailed cost benefit information is provided for the Gillespie (1997) model for the application of viewshed analyses.

Viewshed analyses are conducted for high visibility projects that require DEQ permits, such as mines or a windfarm. Viewshed analyses have been conducted on approximately an annual basis since 1993. Viewshed analyses generate only effectiveness benefits because they were very crude prior to GIS.

Costs

The current GIS costs in the Environmental Management Bureau are around $4000 per year, including hardware, software and training. The labor costs are quite small because GIS takes up a small portion of the analysts' time. Expenditures were greater in previous years due to the much greater costs of purchasing Sun workstations.

It is possible to estimate the cost per incident of generating a viewshed analysis. The analysis takes a total of up to 40 hours of an FTE, combining time of summer interns and GIS analysts. The average salary was estimated at $20,000. Assuming a benefits multiplier of 1.32 (used in the Missoula Implementation Plan), the total annual cost of that employee would be $26,400. The total cost of 40 hours labor is then $530. Finally, some fraction of annual system costs should be added on to determine the total cost of the application. If one attributes 10% of the annual GIS budget (not including personnel) to a viewshed analysis, the total cost of a single viewshed analysis would be about $1000.

Efficiency benefits

Efficiency benefits were not discussed for any GIS applications.

Effectiveness benefits

The Gillespie (1997) model was applied to the viewshed analysis application to determine the effectiveness benefits. The interview answers provided information on a typical viewshed analysis, which combined information from viewshed analyses of the McDonald Gold Project near Lincoln and the proposed Asarco Rock Creek Mine.

The following parameters were suggested as typical values:

- Application run 1 time per year (FREQUENCY=1)
- Number of map units: 6 quads (EXTENT=6)
- Volume of data: 9 megabytes (VOLUME=9)
- Number of data themes: 3 (MAX=3)
- Number of groups concerned: 6 (CONCERNS=6)
- Likelihood of use in adversarial hearing: 50% (LIKELIHOOD=50)

Using the typical numbers for the parameters, the gross effectiveness benefits per occurrence of the application are $4000. This figure is also the annual gross effectiveness benefit from a viewshed analysis because they are completed approximately once a year. This estimate of the gross effectiveness benefits results in a benefit cost ratio of 4.0.

3.8 DEQ Industrial & Energy Minerals

The information on DEQ Industrial and Energy Minerals Bureau (of the Permitting and Compliance Division) was obtained by interviewing Loretta Reichert, Information Systems Specialist.

3.8.1 Overview of DEQ Industrial & Energy Minerals Bureau GIS

System description

The Industrial & Energy Minerals Bureau established GIS in 1992. The original funding was a $250,000 grant from the USGS to create base maps, purchase a workstation, licenses and training, and fund GIS personnel. The system originally ran on the Unix platform but is evolving to run on a Windows NT workstation. Currently, the system includes 1 ArcView license, 1 local Arc/INFO license and one shared Arc/INFO license provided by the federal Office of Surface Mining (OSM) and 1 Earth Vision license also supplied by the OSM. OSM provides other support as well, including 2/3 of Mrs. Reichert's salary.

GIS is a tool for permitting of coal mines and assessing reclamation bonds, as well as maintaining all the data related to the coal mines.

List of applications

- Volumetric analysis for coal mine reclamation
- Reclamation plan analysis

Example: Assessing the potential for revegetation based on slope, aspect and vegetation type

- Database of groundwater wells in vicinity of coal mines

Lessons learned

- Developing databases takes a longer time than expected
- Better to have a dedicated GIS person than to train new people who may not stay long enough to justify the training expenditures
- "If you build it, they will come"- new GIS applications arise once the system is established
- Better relationships have resulted with coal mining companies because DEQ has helped them to clean up data through GIS
- AutoCAD data doesn't always go into Arc/INFO smoothly
- GIS greatly improves the ability to establish an electronic permitting system
- GIS is a necessity to provide a scientifically sound analysis of mine reclamation
- Some tasks are still easier to do by hand than to use GIS

Recommendations for DEQ's GIS needs

- DEQ must implement a centralized GIS structure, but programs must be able to maintain their individual applications

Example: OSM provides much of the funding for the Industrial & Energy Materials Bureau's GIS. Those tools can only be used for coal mining projects.

- Important for personnel doing the GIS work to be familiar with the material and the DEQ program conducting the work
- GIS personnel dedicated to a particular DEQ program will have a better vision of future GIS needs for that program

3.8.2 Cost/benefit information

Cost information is provided for the system as a whole. More detailed cost and benefit information is provided for two GIS applications: volumetric analysis and reclamation plan analysis.

Volumetric analysis is the process by which cut and fill volumes are calculated in order to establish reclamation bonds. The application is used approximately once a month. For this cost benefit analysis, the volumetric analysis is divided into two parts: volumetric calculations that generate efficiency benefits and difference maps that generate effectiveness benefits. The net benefit of GIS for volumetric analyses is then the sum of the efficiency and effectiveness benefits.

Reclamation plan analysis is a GIS application in which the potential for revegetation of coal mining excavations is assessed based on the slope and aspect of the ground and the type of vegetation. This information will then be used in decisions to release reclamation bonds. This application only generates effectiveness benefits because it could not be done prior to GIS.

Reclamation plan analyses are a new GIS application for the Industrial & Energy Materials Bureau. It is not clear yet how often this application will be used, what level of resources will be required to complete them and how they will be used in the process of releasing reclamation bonds. The uncertainties inherent in this application make the model predictions quite uncertain as well.

Costs

The annual GIS expenditures for the Industrial & Energy Materials Bureau include a $7000 support contract through NRIS to provide hardware and software maintenance, plus roughly $2000 per year for workstation upgrades, plus half of Mrs. Reichert's time at a salary of $30,000.

A volumetric analysis requires approximately 2 days of an engineer's time and 1 day of Mrs. Reichert's time. The engineer's annual salary is around $35,000. Assuming a benefits multiplier of 1.32, 2 days of the engineer's time is worth $370 and one day of Mrs. Reichert's time is worth $160. The total cost of a volumetric analysis is $530 plus some percentage of the annual system costs of $9000. As a rough guess, one could assume that no more than 4% of the system cost should be attributed to a single volumetric calculation, resulting in an additional cost of $360. The ballpark 4% figure was estimated by first realizing that the volumetric analysis is performed once a month. If volumetric analyses were the only application, each occurrence would be responsible for 8% of the annual cost. Assuming quite conservatively that volumetric analyses comprises half of the annual GIS budget, 4% of the annual costs could be attributed to each occurrence of the volumetric analysis. The total cost of the analysis is then $890.

It is also possible to estimate the cost of volumetric calculations in the absence of a GIS. Mrs. Reichert indicated the analysis formerly required 20 days of an engineer's time. Assuming an annual salary of $35,000 and a benefit multiplier of 1.32, the cost of the analysis would be $4000.

The costs of conducting a reclamation plan analysis are now discussed. Only one reclamation plan analysis has been conducted to date. The project consumed approximately 6 months of Mrs. Reichert's time. The cost of this time is worth approximately $19,800 using a benefit multiplier of 1.32.

Efficiency benefits

The volumetric calculations generate efficiency benefits because those calculations were performed prior to GIS. The following pieces of information were obtained in the interview or were assumed in order to estimate all variables in the efficiency model:

- Application run 12 times per year (FREQUENCY=12)
- Areal extent and map scale: 5500 acres @ 1:4800 scale (EXTENT= 5 map units)
- 4 data themes (MAX=4)
- 6 groups concerned about the results of the analysis (CONCERNS=6)
- Not very likely that the results will end up in an adversarial hearing (LIKELIHOOD=10)
- Application concerned with the value of the land itself (LAND=1)
- Manual methods to perform volumetric analysis cost less than $20,000 (COST=0)

With these variables, the efficiency model predicts an efficiency benefit of 57%. As in the Butte-Silver Bow analysis of efficiency benefits, the result was sensitive to the choice of the somewhat arbitrary LAND variable. With a value of 0 for LAND, the efficiency savings would increase to 75%.

In this case, there is a more appropriate way to determine the efficiency savings of volumetric calculations due to GIS. As mentioned in the previous section, the analysis costs $890 with GIS and $4000 prior to GIS. This analysis is assuming that all of the analysis costs can be attributed to the volumetric calculations and not to the production of difference maps. From the interviews, it appeared that the difference maps were a product that essentially fell out of the volumetric calculations and didn't require much extra work. Thus, GIS results in a net efficiency benefit of $3110 or 78% of the manual cost for the volumetric calculations. It is interesting to note that this value nearly corresponds to the model prediction when LAND=0. Based on the measured estimate (as opposed to the predicted estimate) of the net efficiency benefit, the net annual efficiency benefit of GIS for the volumetric calculations is $37,320 ($3110 per analysis x 12 analyses per year).

Effectiveness benefits

The Gillespie (1997) model is now used to estimate the effectiveness benefits resulting from the difference maps produced during the volumetric analyses. The net benefits of GIS for the application of volumetric analyses can then be estimated from the sum of net efficiency benefits for volumetric calculations and net effectiveness benefits for difference maps.

The pure effectiveness benefits model is now used to estimate the net effectiveness benefits of the difference maps. The same variables were used as above for determining the efficiency benefits of the volumetric calculations. In addition to those variables, the effectiveness benefit model requires a value for VOLUME, or the total volume of data required for the analysis. A value of 7.5 megabytes for VOLUME was reported by Mrs. Reichert.

The effectiveness benefits model estimated a value of $1790 per occurrence of difference map production. Recall that this value is a gross benefit by definition. However, in the previous section it was described that the difference maps resulted in essentially no additional cost. Thus, the net annual effectiveness benefit for difference maps is $10,750 (1790 x 6 difference maps per year).

The effectiveness benefits model is now also used to assess the application of reclamation bond analyses. The following pieces of information were used in the effectiveness benefits model.

- Application run 1 time per year (FREQUENCY=1)
- Areal extent and map scale: 5500 acres @1:4800 scale (EXTENT=5 map units)
- 6 data themes (MAX=4)
- 6 groups concerned about the results of the analysis (CONCERNS=6)
- Reasonably likely that the results will end up in an adversarial hearing (LIKELIHOOD=60)
- 52 megabytes of data required for the analysis (VOLUME=52)

The effectiveness benefits model predicted gross effectiveness benefits of $23,320 per incident of the reclamation plan analysis. Compared with a cost per incident of $19,800, the application produces a net effectiveness benefit of $3520. A benefit cost ratio of 1.2 results from the application. The ratio may well increase as the process becomes better defined and is used more frequently.

Cost benefit summary

It is now possible to determine the net annual benefits for the volumetric analyses. The volumetric calculations resulted in a net efficiency benefit of $37,320. The difference maps resulted in a net effectiveness benefit of $10,740. The net benefit is therefore $48,060, compared with a total cost of producing 12 volumetric analyses of $10,680. The volumetric analysis application generates a benefit cost ratio of 5.5.

As stated previously, the reclamation plan analysis resulted in a net efficiency benefit of $3520 and a benefit cost ratio of 1.2. Between the two applications, GIS produces a net effectiveness benefit of $51,080 and a benefit cost ratio of 2.7.

The spreadsheet used to calculate the benefits for these applications is attached electronically to this document as an Excel spreadsheet in Appendix C. Those results are slightly different than the results reported here for the efficiency benefits from volumetric calculations. The spreadsheet reports the results of the Gillespie (1997) model for efficiency benefits. This analysis used a direct measure of the efficiency benefits in summarizing the system benefits.

3.9 Montana Department of Administration Information Services Division

The information for the Cadastral Mapping Project case study was obtained by interviewing Mr. Stu Kirkpatrick, GIS services section manager for the Department of Administration's Information Services Division (ISD).

The effort to develop the land ownership database is called the Cadastral Mapping Project. It is the only GIS application in ISD that this report will focus on.

3.9.1 Overview of the cadastral mapping project

Project description

The Cadastral Mapping Project is a cooperative public/private partnership to produce a digital land ownership database that can be accessed through GIS. The project is managed by the Information Services Division of the Department of Administration. The project receives funding from state and federal government agencies and private sector groups. The data will be available for the public and private sectors and will contribute to a great variety of applications.

List of applications

These are some of the applications of digital land ownership data that were provided by Mr. Kirkpatrick.

- Property maps
- Disaster and emergency planning
- Automated tax assessment using other data sets such as soil, topography and climate to describe land productivity
- Right-of-way assessments
- Internet property research
- Growth analysis
- Wildlife habitat monitoring and protection
- Resolving areas of public/private conflict such as hunting and fishing access

This list of applications of the land ownership for local governments was provided during the interviews with Butte-Silver Bow personnel and Doug Burreson from Missoula County.

- Tax assessment- Locating untaxed parcels
- Establish institutional controls on land use near Butte Superfund sites
- Zoning/master planning
- Address information can be included in enhanced 9-1-1
- Weekly ownership updates for county government
- Septic permitting system
- Automated property owner notification

Automated permit and development tracking

Lessons learned

- Multiple partner projects move very slowly
- Political issues are more difficult to overcome than are technical issues

3.9.2 Cost/benefit information

Cost information is readily available on the entire cadastral mapping project. The project was not particularly well suited for analysis with the Gillespie (1997) model because it is essentially a database and not a GIS. Another difficulty with applying the Gillespie (1997) model is the fact that the project is just underway whereas the Gillespie (1997) model was developed to analyze systems that are already in place.

Despite these caveats, the Gillespie (1997) model was used to analyze the benefits of the cadastral project. The project was divided into two distinct applications for the purposes of the study. The first application is the act of creating the database of land ownership records. This application partially uses an automated process and produces an efficiency benefit over the manual methods used previously to digitize parcels. The efficiencies inherent in this application can be well quantified without the use of the model.

The second application is the act of accessing the digital land records. These benefits were described previously in Section 3.2.2 for Butte-Silver Bow. Both efficiency and effectiveness benefits resulted from the accessing of digital land records. Information is not available to make statewide estimates of the benefits that can be expected. However, some attempts will be made in this section to estimate the benefits throughout the state based on the Butte-Silver Bow results.

Costs

The costs of building the database are estimated currently at around $4 million, with 50% coming from the private sector, 25% from state government funds and 25% from federal government funds. Furthermore, the annual maintenance costs for the data have been estimated at $300,000-$500,000.

Efficiency benefits

The efficiency benefits from the automated parcel digitization application can be calculated by comparing the costs of generating parcels with and without this process. The International Association of Assessing Offices has adopted a standard of ten minutes per parcel generated. A normal person might work efficiently for 5/6 of the day, resulting in creation of 40 parcels per day. Assuming a salary of $10/hr and a benefit multiplier of 1.32, results in a cost of $2.64 per parcel.

Currently, the automated process for digitizing parcels from the Department of Revenue's CAMA database results in the creation of 60 parcels/hr. Assuming the same work efficiency and salary, results in a cost of $0.26/parcel or a 90% efficiency benefit.

It is difficult at this point to determine how many parcels in Montana can be created using the automated process. Mr. Kirkpatrick estimated that about 350,000 parcels could be generated using the automated methods. The net efficiency benefit of generating these parcels would be $831,600.

An additional efficiency benefit of the land records database will result when counties or other agencies access the data. The Butte-Silver Bow case study estimated a net annual efficiency benefit of $13,920, or $0.41 per capita. A number of assumptions were required to abstract these results to the entire state.

It is probably reasonable to assume that there are fewer requests per capita in rural eastern Montana counties than in Silver Bow County. As a best guess, the counties were lumped into 4 population groups:

- Group A: Less than 5000 residents (21 counties)
- Group B: Between 5000 and 10,000 residents (15 counties)
- Group C: Between 10,000 and 20,000 residents (11 counties)
- Group D: Greater than 20,000 residents (9 counties)

Silver Bow County is in Group D, so all 9 of those counties were assumed to gain the same efficiency benefit per capita. Groups C, B and A were assumed to gain 75%, 50% and 25%, respectively of Silver Bow county's per capita benefit.

With these assumptions, the net annual efficiency benefit for the state would be $277,150. It should be pointed out that this is the efficiency benefit for simple land records requests at county governments. It does not include efficiency benefits for other government agencies.

Effectiveness benefits

Quantifying the monetary effectiveness benefits of digital land ownership data is an extremely difficult process because the data will be used for so many different purposes. The following list demonstrates qualitatively some effectiveness benefits that have already occurred.

- Add value to other data sets

Example: Makes Department of Revenue's forestry inventory database accessible

- Business development opportunities

Example: Helped locate ASiMI Silicon Manufacturing Complex in Butte

- Better emergency services

Example: Flathead County developed flood evacuation and utility shutoff plans

- More efficient tax assessment

Example: Analysis of Silver Bow County Mosquito Control District located 25 untaxed parcels

- Improved coordination between participating groups

It is also possible to quantitatively estimate the effectiveness benefits of the land records database based on the findings of the Butte-Silver Bow case study. In that study, net effectiveness benefits were estimated as $363,480 annually, or $10.71 per capita annually. Using the same population groups and assumptions as in the efficiency benefits, the net annual effectiveness benefit in the state was estimated to be $7.24 million. Again, this figure represents the effectiveness benefits of land records maps produced by county governments. It does not include land records mapping in other government or private agencies.

Cost benefit summary

The net benefit of the land records database is equal to the sum of the efficiency benefits in generating the database with the automated methods, plus the efficiency and effectiveness benefits resulting from people accessing the completed database through county governments or other agencies. The efficiency benefits that result from the process of developing the database are reported as a total benefit of $831,600, not an annual benefit. Therefore, that number cannot be readily added onto the annual savings estimated for land records requests from the Butte-Silver Bow case study.

The net annual benefit of statewide land records requests at county governments is estimated as $7.52 million ($11.12 per capita). This does not include the lump sum savings in developing the database, nor does it include land records research conducted elsewhere besides the county governments. Furthermore, there is a great deal of uncertainty inherent in the Butte-Silver Bow estimates and in estimating the % of per capita benefits at other counties based on their population. However, the assumptions in this and all cost benefit calculations in this report were made as conservatively as the data would support.

The net annual benefit of the land records database of $7.52 million, or $11.12 per capita, might seem like a very high number, especially considering that the figure does not include the benefits which would accrue from people accessing the data elsewhere besides the county government. However, it is useful to put this figure in perspective of the Larsen Report from Wisconsin, which is summarized in Appendix A. Back in 1978, local, state and federal agencies and some private utilities were annually spending more than $17 per Wisconsin resident for land records information. In that context, a benefit of $11.12 per capita for an automated system that can be used for many types of analysis and map making does not seem inappropriate.

4 Discussion of results

4.1 Cost benefit analyses: Justification for GIS implementation

Justification of GIS expenditures was the overriding goal of this study. All GIS organizations should begin to perceive a need to quantify the costs and benefits of their system. This section summarizes the model used to estimate benefits, comments on the robustness of the model for this purpose, summarizes the case study results and finally describes what organizations should do to go beyond this work to fully characterize the benefits of their GIS.

4.1.1 Description of the Gillespie (1997) model

The Gillespie (1997) model is a regression model incorporating the results of 62 case studies of GIS at the federal government level. The model has not previously been used at the state or local government levels, but Mr. Gillespie was confident that the model would work for these case studies. The magnitude of the GIS applications described in this report appear to be consistent with the magnitude of the federal GIS applications.

The basic premise of the model is that the benefits of GIS are related to the complexity of the model inputs, analysis and outputs. Upon this premise, two separate model equations can be used to estimate efficiency and effectiveness benefits per incident of a GIS application. An application can produce both types of benefits, but by the definitions a single output of the application can produce either efficiency or effectiveness benefits, but not both. For both types of benefits to result from an application, at least one output must produce efficiency benefits and at least one must produce effectiveness benefits.

The benefits (efficiency or effectiveness) per incident of an application must be multiplied by the frequency of use of the application to estimate the annual benefits. The net annual benefit of an application is equal to the sum of the net annual efficiency and effectiveness benefits. The net annual benefits of a GIS installation are equal to the sum of the net annual benefits of all applications within the installation.

Surprisingly, one of the greatest difficulties of using the model to assess these case studies was determining what the applications were and what one occurrence of the application comprises. Until that point, people tend to answer interview questions in an aggregate fashion. For instance, when determining the benefits of requests for digital land records data, one cannot use the entire volume of land records data as the value of the VOLUME parameter because the benefits would be huge for each occurrence of the application. Instead, one has to determine what volume is data is used in a "typical" request for land records data and then calculate the benefits of the typical occurrence. The net annual benefit of the application can then be determined by estimating the annual number of requests and multiplying by the benefit for each request.

Once the application and an individual occurrence of the application have been defined, most of the other required information can be determined more easily. However, that is not to say that the values of the variables are easy to pin down.

4.1.2 Model strengths and weaknesses

Weaknesses

The greatest weaknesses of the model discovered in this analysis can be summarized as subjectivity and sensitivity. Subjectivity refers to the "tweaking" of model parameters that is required of the person running the model. To get reasonable results out of the model sometimes requires that the operator play around with the parameters within the range suggested during the interview. For every case study in this report, the variables were estimated as conservatively based on the interview. Some parameters are particularly subjective, such as the value of the CONCERNS parameter. There is no uniform way to define what types of groups can be included in that variable.

In addition to subjectivity, the model sensitivity warrants some concern. For instance, the LAND variable in the efficiency model changed the results of the Butte-Silver Bow case study by 20% depending on the choice of a 0 or 1. An additional area of sensitivity not discussed previously involves the SMALL variable. SMALL goes from 0 to 1 when the sum of the size classes for the model variables becomes less than 7 (see Section 2.3.1). The result is that as the values of variables get smaller, the effectiveness benefit shrinks. However, when the variables get small enough to make SMALL go up to 1, the effectiveness benefit jumps up again. Therefore, the predicted benefits are not always nice continuous functions of the complexity variables. When using the model, one must be careful to look for consistent results.

Strengths

Despite the weaknesses described in the previous section, the model is an excellent tool for assessing the benefits of GIS installations. The greatest attribute of the model is that it can be used to estimate effectiveness benefits, which are very difficult to assess directly. Most groups are not willing to spend the time to make good estimates of the effectiveness benefits. The result is that effectiveness benefits are typically ignored and the benefits of GIS are drastically underestimated. More attention should be placed in the future on estimating effectiveness benefit and the Gillespie (1997) model provides one nice tool for doing so in a low-cost fashion.

Perhaps the greatest strength of the Gillespie (1997) model is one that was not perceived until the data had been run through the model. The model forces one to focus on the applications of a GIS, rather than the data. It was a surprising realization in some of the interviews that the applications were not always easy to define. If the model were used to assess a system prior to implementation, it would help to identify the most important applications. By assessing the potential benefits of each application, the most beneficial applications would receive attention first. More importantly, the applications would drive the data collection process and unnecessary data would not be collected.

4.1.3 Results obtained with the model

The benefits estimated for the case studies are summarized in Table 1 below. As mentioned previously, benefits were calculated for up to one or two applications within a case study. No case studies were assessed for their total benefits and costs.

Table 1 : Benefit / cost summary for case studies

Case study	**Application**	**Type of benefit**	**Net annual benefit**	**Benefit cost ratio**
Butte Silver-Bow	Automated land records	Both	$377,400	3.8-5.6
NRIS	Watershed analyses	Effectiveness	$141,210	N/A
NRIS	Interactive well finder	Effectiveness	$235,790	N/A
DEQ- Env. Management Bureau	Viewshed analysis	Effectiveness	$4000	4.0
DEQ- Industrial & Energy Minerals Bureau	Volumetric analysis	Both	$48,060	5.5
DEQ- Industrial & Energy Minerals Bureau	Reclamation plan analysis	Effectiveness	$3520	1.2
Information Services Division	Generating land ownership database	Efficiency	$831,600 (lump sum, not annually)	N/A

Information Services Division	Accessing land ownership database statewide	Both	$7.52 million	3.8-5.6 (assume the same as Butte-Silver Bow)

4.1.4 Going beyond our results

The benefit/cost information from the case studies were obtained for only one or two applications. For an agency to estimate the total benefits would require an assessment of all applications. The Missoula Implementation Plan in Appendix D is an excellent example of a study estimating the cumulative benefits (efficiency only) for an entire GIS installation. In that study, the system costs and benefits were estimated on an annual basis for the first 10 years of operation. That type of analysis allows the agency to determine additional information like the payback period for the GIS investment.

The Gillespie (1997) model could certainly be used in a complete study like the Missoula Implementation Plan. In that case, the group conducting the study would need to determine the system costs and benefits on an annual basis for some period of time. The model has only been used to assess the benefits of existing GIS installations, but it is conceivable that the model could be used to assess the benefits of an installation prior to implementation. In that case, the group conducting the study would need to be in contact with Mr. Gillespie to discuss how the model might used to forecast the benefits. As mentioned in Section 4.1.2, this type of preliminary analysis could then be used to prioritize applications and data collection.

Another unexpected strength of the Gillespie (1997) model is that it also highlights the need for better tracking of GIS use. Organizations interested in justifying GIS expenditures should be keeping track of the frequency at which an application is used.

4.2 Planning for GIS implementation: Lessons learned

This section of the report summarizes the lessons learned from each of the case studies. The lessons are divided along the lines of data issues, IT structure issues and organizational issues.

4.2.1 Data issues

- Agency-wide data standards should be adopted to insure compatibility of databases and GIS applications
- There should be a clear understanding of who is responsible for each type of data to avoid data redundancy and insure maintenance of the data
- Data creation and maintenance is the greatest expense in developing GIS applications

4.2.2 Issues in IT structure

- An agency's IT structure should be well organized so that GIS applications and databases can be accessed through intranets and the internet
- Internet GIS applications are very successful for 4 main reasons;
    - Users are more comfortable with web browsers than GIS software
    - They require little technical support
    - They reduce the number of requests that have to be handled by agency personnel
    - They provide an easy means for tracking use, which in turn can be used to demonstrate the benefits of the applications

4.2.3 Organizational issues

- Communication between participating groups or agencies is critical to the success of GIS
- Political issues are more difficult to overcome than technical issues related to GIS implementation
- Small local governments should consider a number of options for obtaining GIS services, including:
    - Contract services through private consultants
    - Contract services through neighboring counties with GIS already available
    - Entering into cooperatives with other counties to share GIS costs
- Joint city/county GIS implementations make sense in order to avoid redundancy and share costs
- Each agency implementing GIS should have at least one GIS coordinator to avoid redundancy and insure compatibility between databases and GIS application

- GIS analysts should be available within each division or program of a state agency to build applications and provide end-user support
- GIS analysis should be performed at the desktop of the decision-maker

5 Conclusions

5.1 Did the study accomplish its goals?

The primary focus of our study was to identify benefit/cost analysis methods and apply them to a number of case studies in Montana State and local governments. We hoped to develop a set of tools that could be used by other groups to simplify the process of estimating costs and benefits. The Gillespie (1997) model, the Missoula Implementation Plan and the other literature reviewed provide those tools. The 9 case studies described in Section 3 provide excellent examples on how to apply the Gillespie (1997) model and the Excel spreadsheet in Appendix C will perform the calculations automatically.

The study did not set out to develop bottom-line cost and benefit numbers for any or all case studies. In times of tight budgets, however, agencies should consider going to that detail with their own GIS installations in order to justify past and future expenditures. Hopefully this report provides all of the necessary information for the agency to accomplish that task.

The other goal of the study was to summarize the lessons agencies have learned thus far in their efforts to implement GIS. If there was one question that was easy for the interviewees to answer, it was the question about the lessons they have learned. Every person we talked to was certain about what things had caused the greatest problems. GIS implementation does not happen smoothly without a great deal of planning and coordination. If this report can save other agencies from experiencing some of these same difficulties, then it has achieved its second goal as well.

5.2 Analysis of the Gillespie (1997) model as a tool for justifying GIS

The Gillespie (1997) was shown to have a number of strengths and weaknesses. Like any model, the answers are not perfect but they offer a more reasonable alternative than adding up every single benefit and cost. Used with care, the model can provide sensible answers in line with reasonable expectations of the benefits of GIS. The model is also useful for focusing the GIS agency's attention on what applications are most important and what pieces are needed to accomplish that application.

To fully characterize the costs and benefits of a GIS installation would require a more detailed study than the one conducted for this report. A study like the Missoula Implementation Plan is excellent to identify the applications and data needs and estimate the efficiency savings from those applications. A report combining the methods of the Missoula Plan with the Gillespie (1997) model would provide an excellent analysis of the costs and benefits of GIS.

6 Recommendations

- The Gillespie (1997) model or other methods should be used to assess both efficiency and effectiveness benefits of GIS
- GIS implementation should focus first on applications, not data
- Costs and benefits of GIS should be determined prior to implementation and should also be an ongoing process
- In new GIS installations, applications should be prioritized in order of expected benefits to focus resources where the returns are greatest
- Data should be collected to satisfy the needs of the most beneficial applications
- Applications should be built so that their frequency of use is automatically tracked
- Agencies serving the public are well-served to develop GIS applications in order to cut their costs and quantify benefits of the application
- GIS should be pushed to low-levels within an agency

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Appendix A-Literature review

Silva, E., Cost Benefit Analysis for Geographic Information System Implementation Justification: Literature Review, 1998.

http://gis.ny.gov/costanal.htm

- Advocate this approach:
  1. Calculate tangible costs
  2. Calculate tangible benefits
  3. Intangible benefits = Potential benefits x probability of achieving the benefit
  4. Net benefits= Tangible costs-tangible benefits-Intangible benefits
- Tangible benefits include labor savings, material cost savings and minimization of out-house expenditures
- Intangible benefits:
- Reduced potential for maladministration and liability
- More rigorous data management
- Enhanced visualization of graphical data
- Improved analytical procedures
- Improved data security

- The provision of better information
- More consistent access to data
- Improved services to customers
- Ability to integrate data
- Ability to generate new 'understandings' and easier access to data
- Advocate the option of a data-sharing cooperative (enterprise-wide option)

Worral, Les. 1994. "Justifying investment in GIS: a local government perspective." Internation Journal of Geographical Information Systems, Vol. 8, No. 6, 545-565.

- Costs of GIS implementation
  - Hardware integration with pre-existing computing infrastructure
  - Evaluation, selection, acquisition and installation of software
  - Undertaking requirements/needs analysis
  - Contractual aspects
  - Consultancy support
  - Systems customization
  - Applications portfolio development (and/or customization)
  - Interfacing to other 'data servers' and operational systems
  - Training, human resources planning, skills development and re-skilling
  - Additional vendor services (e.g. possible turnkey development)
  - Business analysis
  - Project management
  - Delivery and installation
  - Communications
  - Business process re-engineering
  - Documentation redesign
  - Transitional costs (i.e. parallel running of old and new systems)
  - On-going revenue implications (i.e. staff costs and consumables)
  - Data modeling, data flows analysis and redesign
  - Data purchase (e.g. Address Point, Census)
  - Data capture, data conversion
  - Data re-survey and validation

Korte, G., Weighing GIS benefits with financial analysis, *GIS World,* July 1996, p. 48-52

- Three steps involved in a GIS financial analysis:
  1. Estimate GIS program costs
  2. Estimate GIS cost savings
     - Estimate current costs of using maps & map related attribute data; include employee benefits and overhead
     - Estimate portion of costs saved through increased productivity and decreased contracted costs
  3. Employ standard techniques to determine attractiveness of investment
     - Tabulate GIS costs and savings
     - Calculate net present value, payback period, or real rate of return
     - Assume 3% discount rate (OMB recommendation)
- Intangible benefits and residual value of the investment are not included in this analysis
- Included an example GIS cost benefit study from Edwards AFB
  - 8 year payback period after project initiation (4 years after full implementation
  - 7.5% real rate of return after 10 years
  - greatest savings in construction change orders

  Costs:

  - Implementation: services, hardware/software, database creation
  - Maintenance: updating data, hardware replacement every 4-6 years, software upgrades

  Benefits:

  - "Conservative" assumption of 50% increase in employee productivity
  - Decrease in contracted services

- Reported results of Joint Nordic Report on 16 GIS projects in North America and 2 in Italy
  - GIS systems used for mapping and updating: B/C=1
  - GIS systems used for planning and engineering: B/C=2 (4 if all commonly used data sets have been automated)

- GIS system used for information sharing between relevant organizations: B/C=4
- GIS system replaces a poor system for manual map production: B/C=7

GIS Business Plan, Imaging and CADD Technology Team, EESB, FSED, Langley Research Center, Hampton, VA, February 16, 1995

- Development resources over 5 years- $4.06 million total
  1. Hardware (25%)
  2. New licenses (2%)
  3. License maintenance (3%)
  4. Personnel (38%)
  5. Training (1%)
  6. Conversion (31%)
- GIS Operational resources-
  1. Manpower (50 elements identified in which GIS will be applied)
  2. Software maintenance
  3. Hardware maintenance
  4. Training
- Resource reduction (benefits)
  - Predicted GIS usage in each element classified as low, medium, high
  - Number of FTE's required after GIS implementation calculated from these classifications
  - Total annual operating costs for GIS related elements reduced by 43%
  - Savings of $2.28 million/year after full implementation
- Break even analysis
  - Payback period of 3 years
  - Despite $4 million cost, total net investment never exceeds $1 million
  - Net savings of $3.9 million by end of 5 year development period (B/C=2)
- Categories of Benefits
  - Differentiate between efficiency savings and effectiveness savings
  - Effectiveness benefits categories: visualization, complex analysis, information access, increased accuracy
  - Effectiveness benefits are less tangible, not necessarily intangible
- Other
  - Assumes $70K/FTE
  - All $ values reported in 1995 dollars
  - Redundant databases should be maintained by organization requiring most detailed information
  - Quotes a USGS report (an unpublished Gillespie report) which estimated an **80%** efficiency savings in federal GIS implementations achieving efficiency benefits
  - USGS report estimated effectiveness savings as **8x** greater than efficiency savings in federal GIS implementations achieving effectiveness benefits

Larsen, B. et al. 1978. Land Records: The cost to the citizen to maintain the present land information base; a case study of Wisconsin. Department of Administration, Office of Program & Management Analysis, 64pp.

- Determined that annual expenditures on land records by local, state and federal governments and some private utilities totaled $17 per resident or $2.25 per acre
- The study also identified a significant number of problems with the way the current (manual) system functioned
- The categories of problems with the existing system:
  - Accessibility
  - Lack of data aggregatability
  - Nonintegratability of information
  - Duplication of efforts to gather and record land information
  - Questionable cost-effectiveness or need for some land records
  - Confusing confidentiality requirements
  - Vertically organized, single-purpose land record-creating institutions
- Some causes for governmental land record problems
  - Government is "problem oriented" instead of planning for the future
  - Agencies are organized along single program lines
  - Government agencies operate in a vertical structure
  - On each level of government, no one agency is charged with integrating land data and records within and between government levels

- Types of intangible benefits of land records modernization
    - Provides the needed information to regulate from an informed basis
    - System is an aid to economic development
    - System contributes to a campaign for energy conservation
    - Overcomes institutional problems plaguing those using the present system
    - Better foundation for value judgments upon which decisions are made
- Specific benefits
    - Money saved with improved methods for collecting, storing and displaying land information
    - More useful data and products from integrated information
    - More informed public decisions
    - Reduced duplication of effort and compatibility of products
    - Dollar savings in product sales, map production, research and development and remote sensing
    - Gaps in land information system will become apparent
    - Advanced manual systems would lead to computerized systems at the local government levels

Gillespie, Stephen R., GIS Technology Benefits: Efficiency and effectiveness gains, United States Geological Survey, Reston, VA 22092, 1994.

- **Efficiency** benefits arise when GIS is used to reduce costs of a task that, in the absence of GIS, would be handled by some other method; equivalent outputs
- **Effectiveness** benefits arise when GIS is used to perform a task that could not or would not be done without GIS
- Most federal government GIS applications are single purpose (either efficiency benefits or effectiveness benefits)
- At federal government level, GIS is primarily important because it helps agencies work better, not cheaper (i.e. effectiveness >> efficiency)
- Failure to quantify effectiveness benefits weakens a study and distorts its results
- USGS developed a model which predicts efficiency and effectiveness benefits for GIS applications based on easily measurable characteristics of the application's complexity

Gillespie, Stephen R., A model approach to estimating GIS benefits, United States Geological Survey, Reston, VA 22092, unpublished article, 1997.

- Creates and applies a framework for analysis of factors affecting the value of GIS technology
- Complexity of a GIS application key factor influencing level of benefits
    1. Input complexity- number of data themes, volume of input data, areal extent of application
    2. Analysis complexity- maximum number of concurrent overlays, number of steps in analysis, number of intermediate data themes, number of potential interactions between data themes
    3. Output complexity- number of distinct uses for outputs, likelihood that outputs will be used in adversarial hearings
- General relationships between complexity and level of benefits
    1. Input complexity
        - Input complexities log linearly related with both efficiency and effectiveness due to economies of scale.
    2. Analysis complexity
        - Analysis complexity linearly related with efficiency benefits (no economies of scale)
        - Analysis complexity curvilinearly related with effectiveness benefits due to diminishing returns
        - Number of interactions between data themes increases geometrically as number of data themes increases arithmetically
    3. Output complexity
        - Output complexities linearly related to both efficiency and effectiveness benefits
- Benefits model
    - Two independent multiple regression equations for calculating efficiency and effectiveness benefits based on 62 cost/benefit studies of federal GIS implementations
    - Equations used to calculate benefits for individual applications; benefits aggregated across applications to compute total system benefits

Appendix B-Missoula Implementation Plan

The linsk below open up the spreadsheets containing the cost benefit calculations.

Cost Benefit Calculations - Part 1

Cost Benefit Calculations - Part 2

Appendix C- Spreadsheet for calculating effectiveness benefits

The attached spreadsheet contains the information gained in the DEQ Industrial & Energy Minerals Bureau interview. The file contains 3 different worksheets. The "Questions" worksheet is the list of questions sent out to each interview candidate and then discussed in the interview. The "Answers" worksheet contains the answers to the questions required in the model. Answers to questions not required in the model were not included in this file. The "Calcs" worksheet contains the model equations and summarizes the efficiency and/or efficiency benefits for the DEQ Industrial & Energy Minerals Bureau.

Spreadsheet for Calculating Effectiveness Benefits

Appendix D- Copies of Gillespie's papers describing the model

These papers were only available in hard copy.

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