Strategies for the Introduction of GIS

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0 INTRODUCTION

Many organizations require spatial information to achieve their goals. Geographic Information Systems, the modern information technology to manage spatial information, is a rapidly growing field, bringing together geography, surveying and computer science. The technology is developed and commercial systems are available readily. In order to make it useful, it must be integrated in the organization requiring spatial information.

The introduction of modern GIS technology in an organization is a complex process. Several perspectives are possible and a number of authors have approached the subject in the past. The scientific analysis and the reports from practical experience do not automatically lead to an operational method useful for the practitioner. The method proposed here is operational as it consists of a series of executable steps, which are connected by a consistent theory.

Development of technology, especially the development of hardware, has been extremely fast during the past decades. The pace of change is commanding much attention and technical advances in the detail appear as major break through. Indeed, hardware development over the past years has always been faster than what we have expected and there are no reasons to believe this will not continue. Hardware issues have absorbed more attention than they deserve and are often in the forefront of GIS discussions. This is not appropriate and leads to implementation plans written by the technologist. The resulting systems are technically correct, but do not serve the overall goals of the organization using the GIS. The documents are full of technical jargon and unintelligible to the users, and produce feelings of frustration and alienation on the side of the users.

The method explained here centers around the tasks the users of the GIS have to fulfil and the spatial information they require. It is possible to describe the tasks for which the GIS should be used and the information expected in detail and in a form understandable to the users. The method valuates the user and puts him in the center. The technical detail follow logically from the document the user can understand and agree to. The resulting system may be less jazzy, but hopefully serves the organization.

The material in this paper follows closely a graduate level course I have taught at the Technical University Vienna for the last 3 years as part of the Master in Geodesy program. About 30 students have applied it and drawn up feasibility studies for a wide range of GIS applications.

Sections 3 to 5 first describe how the analysis focuses on three steps: from the overall consideration of the organization, to the identification of the users and their task, resulting in the description of the information product the GIS should produce. Section 6 shows how technical issues follow from the description of the information product: data needs, data quality required, functionality of the GIS software and hard- and software architecture. Section 7 shows the contribution of the information product description to the cost benefit analysis of a GIS project.

1 BACKGROUND

Designing the application of GIS is a complex process. Often it is approached from a hardware or software perspective. The question is: which computer technology is available? followed by the question: how do we apply it best. This perspective was perhaps appropriate a few years ago, when the functionality of the systems was very limited and difficult to use.

Joel Morrison has listed some milestones for the development of GIS technology and observed that we have passed the important point, where GIS technology can reproduce economically the output of past technology. The technology has become sufficiently reliable that organizations are willing to depend on it, thus passing another important milestone. Products are commercially available and cost-effective.

The questions are not: do we need a GIS, does GIS technology work, is it cost-effective? These topics dominated the discussion in the 80s and filled many conference volumes. The functionality of modern 'full function' GIS is rich - some people think too rich - and the amount of functions or operations available to the user has reached several thousand. Consequently, the question is not how to use best the limited capabilities, but how to apply the rich functionality best. A new perspective for the introduction of the GIS is therefore called for.

The focus must be on the organization which uses the spatial information. In contrast to the development of the technology, changes in the organization are extremely slow and costly. Organizations evolve on the scale of 30 years, the length of a professional career, not the 3 years of technical obsolescence of computer equipment. This implies that the technology must serve the organization and must adapt to it; attempts to adapt the organization to the technology on short notice are doomed to fail. The adaptation required to fully use information technology must start with a deep understanding of the goals of the organization and the role spatial information plays to achieve these goals.

2 AN INFORMATION CENTERED APPROACH

A GIS is an information system, producing information for a user. A successful GIS provides useful information to a user. Information is defined here as 'answering a question of a human user'. Telephone directories, cadastral registers, etc. are not information, they are collection of data or documents useful to produce information when a question arises. Information is understood in the context and can be understood only within the context of the organization and the user.

Concentrating on the user of the GIS - not the technology - is the first step towards the successful introduction of the GIS:

- What are the tasks the users are involved in and for which they need additional information the GIS should produce?
- Which information is necessary for these tasks?
- Which form of information is easiest to understand for the user?

It is somewhat surprising that from these user-oriented questions most of the answers for the technical design of a GIS follow:

- Which data are necessary to produce the desired information?
- What is the data quality required (for the information produced, for the data collected),
- Which functions are necessary to transform the data into the desired information?
- Which hardware and software is necessary? What is the overall architecture?
- How to perform the economic assessment of the GIS project.

3 INFORMATION NEEDS DEPEND ON TASKS OF USERS

The GIS is introduced in an organization to improve its functioning. The contribution of the GIS may be of different nature, improving the decision making, speeding up decisions, serving the user better, reducing the cost of operation, etc. etc. In all cases, it is crucial to understand the goals of the organization and how they are achieved. Very often a 'goal statement' (charge) can be found in the charter of a public organization - it is worth to read it carefully.

Important hints can be found in this charter. If the word 'manage' or 'maintenance' appears, then think database, objects.... If the goal is 'studies', then long term maintenance of data is probably less important. But the goal statement can also help to assess the relative importance of 'quality of information', 'timeliness of response', 'cost of producing the information'.

Typically the GIS is set up to serve specific users in the organization - it is difficult to consider the GIS as independent from the users who work with it. The users of the GIS have a certain function in the organization and fulfil some task within it. The GIS must support this function, these tasks - not anything else. The first step in introducing the GIS must be to analyze the tasks within the organization which need geographic information. Which information is required for which specific step of the task? How does the information influence the outcome of the task? What happens if the information is not available, not available on time, or available but not correct?

The GIS is applied by an organization to improve its operation, to improve the activities it carries on. The organization consists of people who perform some tasks. The GIS must support these in order to contribute to the overall goal of the organization. If a GIS does not contribute to the overall goal of the organization, it will not succeed and the organization cannot make resources available for it; indeed, it must not. This information will be necessary to assess the contribution GIS can make and set the terms of reference for the evaluation.

4 WHAT INFORMATION IS REQUIRED TO PERFORM THE TASK

Having identified the task of the users which the GIS should support, we must proceed to the information needs of the users performing these tasks. Which are the decisions the users must take? Information is used - this is the only use of information of economic importance - to take decisions. Typically information reduces the uncertainty in a decision.

Tasks which require spatial information lead to a decision, sometimes through a multi-step process, where information is collected and filtered in several phases and by different persons till a decision is ultimately reached. These decisions can be very complex strategic decisions for a company - where to build a new manufacturing plant; they can involve a political process as the elaboration of a plan for urban development. But decision can also be very mundane as the assessment of the tax value of a property for property taxes or the task of an employee of a public utility company who needs to know the name of the occupant of an apartment to send a bill for electric energy. In every case, some information is necessary to complete the task. The information may be compulsory - the task cannot be completed without the information - or it may be additional - the performance of the task is improved with this additional information.

The information necessary to complete a task can be identified. Users collect the information necessary for a decision and then use this information in making the decision. The data collection can be observed when the task is performed: the user is consulting a data collection and extracts some part - the piece necessary for the task at hand.

In many cases the user is not free to select the information he wants to use. Administrative decisions follow rules set forth in a law or additional regulations, indicating which information must be considered, often giving details on its presentation, data quality etc. These instructions are part of the instructions from the legislator how a decision must be reached and have to be observed to assure that the administrative process is equitable, not using information of different quality levels.

It is highly recommended to visit the users in their offices and observe them as they work. A copy of the documents consulted, of forms filled in and other information included in the decision process; this collection will be very helpful for the following steps.

5 HOW IS THE INFORMATION PRESENTED TO THE USER

The next step is to identify the form in which the information is presented to the user. Understanding the task a user needs to perform and having identified which information the GIS can contribute to it, we can decide on the channel to communicate this information to the user. This can be a written or drawn document, but it can as well just be a screen consulted by the user and never printed, or a drawing which is used in 'cut and paste' operation to be included in a report or at the extreme, a verbal information given to the driver of a car to 'turn at next intersection'.

In most cases, spatial information is communicated in a visual form. It is recommended to make drawings, in order to assure that all the information necessary is present, that it can be understood from the context and that the quality of the information communicated is sufficient for the task at hand. The education and training of the users and the task they are working on indicates what background information is necessary to make the specific data which is necessary for a decision understandable. To find the information of importance the location must be identified, which often requires some general locators, toponomy etc. But also the symbols customarily used in an application form part of the context and are crucial for effective communication.

Considering the usage of the information, not only the graphical presentation of the information needs to be discussed, but also its medium. If the task requires a small amount of information quickly, a graphical screen is the optimal solution. For decision processes which require a large amount of complex information, but progress slowly, output on paper can be more appropriate. If documentation of the decision and its justification is important, a paper copy must be printed and added to the case documentation. The environment of the task indicates also where the information is used and what equipment can be used.

6 THE INFORMATION PRODUCT METAPHOR

In a factory industry transforms raw materials into a product, sold on a market. This metaphor can be applied to GIS. The spatial data collected serves as raw material, the software represents the factory and the information in the form 'output from the system' is the product. The output from the GIS is the 'information product'. This should indicate that it is produced by the GIS, it is the result of the GIS seen as a production process, transforming raw materials (i.e. the spatial data collected) into a valuable product for a user.

The metaphor is important because it stresses many important aspects linked to the GIS:

- is the GIS producing information somebody uses?
- is the product of value in a decision process?
- is the quality of the product adequate for the user?
- is the product easy to use.

The product metaphor draws attention to the marketing issues which need to be addressed. But the information product points also to the applicability of the cost-price and other economic theories well developed for industry products.

7 WHAT FOLLOWS FROM THE IDENTIFIED INFORMATION NEED?

From the information need identified should follow all, or at least most, of the elements necessary for the design of the GIS. From the information need follows first the data necessary to produce the information and the functions in software to transform the data into the information desired.

Secondly, the understanding of the decision process and the task in which the information is used in leads to an assessment of the quality of the information required. This is then translated into a requirement for the data quality of the input data.

Thirdly, the physical environment in which the information is used determines what technical equipment can be used to pass the information to the user. If the information is used in an office, a desktop system connected over a network to the central information server may work. If the information is used in the field, then a self-contained system is necessary - and it must be rugged to withstand the impact from a hostile environment.

8 BENEFIT: GIS DESIGN DOCUMENT THE USER CAN UNDERSTAND

The description of the organization's goals, the users and tasks, the questions and the information products responding to them are all written in the language of the user. They describe issues the organization is familiar with and managers in the organization can assess, feel familiar with, can support wholeheartedly and the impacts of which they can judge.

This is important to assure management support and a positive attitude of the future users. The technical jargon so much loved by many GIS consultants and vendors is not

inspiring confidence in the users: they have to believe in lieu of understanding and being convinced. Management has to sign off on documents the implications of which they do not fully understand; they cannot defend the document without help from experts to assure resources, etc. Documents which are not understood by the users allow them to excuse themselves if the system does not work. Who has not heard the argument "We have told you so, but nobody wanted to hear our concerns, the poor users".

The method described here produces a design document completely in the language of the user and understandable to him. The document discusses the results of the GIS as they are visible to the user - we call them 'information product' - and give examples for them. The user can therefore assess if the proposed output from the GIS is serving his needs. It remains to show how the technical details follow from this ‘user language’ document.

Identification of Data Necessary

From the description of the information product follows what data are necessary to produce it. Once we understand what information must be produced, the data that goes into it can be listed. But not only can we conclude which data must be collected and stored, but also which other data are not necessary (much effort and money can be saved if data not necessary is clearly identified; the saving is not only when collecting the data but the long term effect of maintaining the data as well.)

The presentation of example output does draw attention not only to the data of primary (direct) influence in the decision, but also to the context information necessary for the interpretation of this data.

Understanding Data Quality Requirements

The information products, drawn up realistically, not only show what data is necessary, but also give an indication of the data quality required. Data quality is a widely discussed issue, but operational rules are seldom provided. The topic commands much interest, because there is an implied fear that insufficient quality of the data could lead to wrong decisions (and potentially to liability claims). At the same time, we know that the collection of data of better quality is also more expensive. The design must find the optimal solution with minimal risk and lowest data collection cost.

The form of the presentation, graphical or as reports, imply and convey information about the quality of the information presented. One often assumes a graphical precision of 0.5 mm, which translates on a map drawn in the scale of 1:25'000 implies an accuracy of sharply defined points of 10 m and no reasonable professional will use it for the design of a single family home, where accuracy in the sub meter range is necessary. If the ‘information product’ example shows a drawing of pipes in a 1: 100 scale, then we may deduce that the user requires an accuracy of few centimeters.

The expectation level for other data quality parameters is more difficult to identify. Sometimes the law states that a document must be not older than 3 month, indicating the level of update required. The legend of specialized maps indicates which types of objects must be shown - and implies completeness for these - and which attributes re differentiated.

Amount of Data Storage

For the technical design of a GIS installation the amount of data storage is important. From the description of the data necessary and some measuring of the amount of date per area, or the number of objects and the amount of data per object follows quickly the amount of data to be stored. This figure must be increased for storage overhead. A database may double the amount of storage space necessary, in order to build indices to assure quick access, etc. Such estimates are sufficiently precise to decide on the type and number of storage devices.

Data Maintenance Procedures

The data used must be maintained; this is often the most difficult organizational problem and a very substantial part of the cost of running a GIS. The description of the information product indicates what level of update must be achieved. Observation of the current

organization and its present mechanism to assure that the data used for a decision are up to date give us further insight in the requirement for data maintenance.

GIS Functionality

The operations necessary to translate the stored data into the desired information are immediately identified. The comparison of the data stored with the information desired shows what kind of spatial analysis, database retrieval, graphical presentation tools are necessary. This allows us to decide what kind of GIS software will be necessary for the application.

Terminals and other Output Devices

Having identified the users and the form of the communication of the spatial information leads to an estimate of the type and number of terminals necessary for the users to access the information. If the information product is a printed paper map, quality of plotters can be deduced from the examples provided.

Overall Architecture, Data Sharing and Communication

The user level document shows the data which is shared among the users. It describes the users and where they are located. This helps to define the requirements for the distribution of data between different sites (move the data where they are used!) and the communication lines between these sites.

9 ECONOMIC ASSESSMENT OF THE PROJECT

The assessment of the economic viability of a project requires a comparison of the cost with the benefits. The total cost of a project must be less than the total benefits it produces, otherwise the project should not be realized.

The description of the technical project is used to estimate the cost of the solution. Prices of hardware and software are available from the vendors, but also the cost of data collection, software adaptation, user training, and the cost of maintaining data, etc. can be estimated.

To estimate the benefits of a GIS project is more difficult, but the metaphor of ‘information product’ shows two approaches:

- avoided cost, and
- price of the product.

Following the avoided cost method, we compare the cost of producing the ‘information product with the traditional method, e.g. manual cartographic methods, maintenance of card files, with the cost of producing the same information product with modern GIS. It can be assumed that the traditional method the organization has used for years is beneficial to the organization - otherwise it would have stopped to use it a long time ago. Then the current cost of carrying it out is a conservative assessment of the benefits the information product contributes to the organization.

Usually the argument is translated into a simple comparison of the cost of the current method with the cost of the new solution. If the new solution has a lower cost than the current method, then it is assumed that it is beneficial for the organization to switch from the current method to the new method.

Estimating a fair price for the information product is the appropriate method if the same information product is not currently used. The idea is to consider how much a user would pay for the information product. A user is willing to pay at most the amount she benefits from the information; therefore we consider the task, the risk involved in the decision, how much the risk is reduced by the information received, etc. Reduction of risk is comparable to buying insurance - its value to the user and thus its market price can be assessed.

This reasoning can be applied to GIS information products: Assume you produce information about restaurants for foreign guests in a city. The decision involves an outlay of $20 per person for dinner; individualized information about good restaurants produced on demand with maps can improve the decision - this may be of a few dollar value to the client. The price for the information product is thus estimated as one dollar per information proved.

If the decision involves more money, then the value of the information provided is likely to be larger.

10 SUMMARY

The design of a GIS for an organization must be based on the understanding of the organization goals, of the task the users of the system perform and the information required to fulfil these tasks. The GIS can be seen as a production system, producing information which then is used as input in the larger production process of the organization setting up the GIS.

Success of the adoption of GIS technology for an organization is assured if the GIS makes a positive contribution to the overall goal of the organization, a contribution the value of which is larger than the resources it consumes. The cost of the GIS - including all costs of data collection, maintenance, etc. - must be less than the value of the information it produces. The value of the information results from the improvement in the decisions the users make in using the GIS. The 'information product' viewpoint leads to an economic understanding of GIS and sets the stage for a cost-benefit comparison.

Discussing GIS technology with users is notoriously difficult. They are often overwhelmed with a host of jargon and technical questions, the relevance of which they cannot judge. The 'information product'-centered approach divides the introduction of a GIS in two separate discussions:

A discussion with the user on the points she fully understands:

- Identification of goals of the organization;
- Tasks or decisions which the GIS should support;
- Information needed for these decisions;
- Information product which the GIS produces to fulfil these needs.

This part of the discussion is completely carried on in the language of the user, the terminology of the organization in which she works and the tasks she performs, and free of GIS jargon. The result can be documented as a set of tasks, example questions and the output from the system, presented as realistically as possible. The user can easily judge if these are:

- the task she needs help with;
- the questions are those she needs answers for, and
- the information is in a format, level of detail and with context, such that it is useful.

The second part of the discussion is then technical, namely

- identification of the data required;
- GIS functions to transform the data into the desired information product;
- assessment of data quality;
- architecture and hardware needs, etc.

The user need not understand these details, as it is the GIS consultant's job to assure that the technical solution meets the requirements of the user. The technical detail follow logically from the 'user level' document produced in the first step and it is not necessary that the user understands them fully; it is the consultant's responsibility to assure that the technical solutions fulfil the organizational requirements.