# Towards a Taxonomy of Geographical Information Systems

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## ABSTRACT

*This paper places geographical information systems (GIS) in the context of information systems generally and specifically illustrates how GIS may be classified by adapting an earlier taxonomy of information systems. The recent literature on information systems taxonomies is critically reviewed and an earlier taxonomy is tested and applied against several case study organisations who use GIS. It is suggested that the test of a taxonomy should be its utility in helping to describe, analyse, or predict. The paper concludes by suggesting that the proposed taxonomy can be used as a diagnostic tool by business organisations to help choose an appropriate management strategy for adopting GIS.*

## INTRODUCTION

The purpose of this paper is to explore the applicability of previous information systems taxonomies to GIS. Such a taxonomy is needed to provide a framework for undertaking and communicating research, for aiding understanding by the practitioner and for pedagogic reasons. It is hoped that the framework proposed in this paper will go some way to reducing the "compartmentalising" of information systems in the literature. The introduction discusses the differences between GIS and IS. The second section goes on to review earlier IS taxonomies. The third section proposes a taxonomy for GIS which is based on an earlier IS taxonomy with some significant changes made in the light of critical review. The fourth section discusses applying the taxonomy and the concluding section closes with some comments on the limitations of the proposed taxonomy and pointers towards further research.

The term *geographical information systems* can be traced back to 1966 when it was used to name the Land Inventory System of the Canadian Forestry Department (Tomlinson [1]). But the Canadian system was not the first GIS; that distinction is more difficult to attribute. The Doomsday Book must certainly be a contender - making GIS around 900 years old.

The precise definition of a GIS has been discussed widely in the literature (see for example Maguire [2]). One of the most widely, if not the most widely, adopted definitions, in the UK, is that put forward in the Chorley Report: "A system for capturing, storing, checking, manipulating, analysing, and displaying data which are spatially referenced to the Earth" (DOE [3]). It has previously been argued (Grimshaw [4]) that the Chorley definition places an undue emphasis on geographic data and that a GIS is simply an information system where the data have a geographical dimension. Talking generally of GIS hides the point that such systems are currently diverse in their structure and function. The major common feature is the presence of geographic information and the notion that data with a spatial component demand unique processing.

Some authors, most notably de Meyere [5] and Waters and Ternouth [6] have argued the case



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for dropping the emphasis on "geographic". The points put forward by de Meyere [7] emphasise that GIS are similar to other information systems, that there is nothing sufficiently unique about geographic data to warrant separate treatment. There is a danger, with this view, that it leads to ignoring the special characteristics of spatial data. The points put forward by Waters and Ternouth [8] are rather different. They argue that some of the disappointments of failed GIS could be avoided if organisations learned the general lessons of information systems development and implementation.

What is the relationship of GIS to other information systems? The literature contains much debate around the distinguishing features of GIS from other systems like computer aided design (CAD), cadastral or land information systems, database management systems (DBMS), automated mapping and facilities management (AM/FM), global positioning systems (GPS), spatial information systems, geo-data systems, and remote sensing (see for example, Cowen [9]). No doubt the academic debates about definitions will continue at the conferences for many years yet. For practical purposes it matters more that we have a working definition of GIS and that we understand the relationship of GIS to related software products. In this paper the definition of a GIS from Grimshaw [10] will be used: "a Geographical Information System is a group of procedures that provide data input, storage and retrieval, mapping and spatial analysis for both spatial and attribute data to support the decision making activities of the organisation".

Figure 1 (adapted from Grimshaw [11]) shows the relationship of GIS to other information systems in terms of two variables: the intensity of the spatial data and the intensity of the attribute data. The two by two grid defines the total data space for both IS and GIS. Looked at in this way, GIS can be understood to be a subset of IS. Systems with little or no spatial data, for example retail systems are often referred to as transaction processing systems. More complex attribute data may require the flexibility of a database management system. Systems with a high intensity of spatial data but limited amounts of attribute data like automated mapping, facilities management or computer aided design are not fully fledged GIS. Not only are the origins of such systems different, and their application functions different but also they contain limited amounts of attribute data. The full GIS is distinguished by an ability to integrate data from a number of sources and by an ability to be able to handle intense amounts of both spatial and attribute data, to map that data and analyse it.

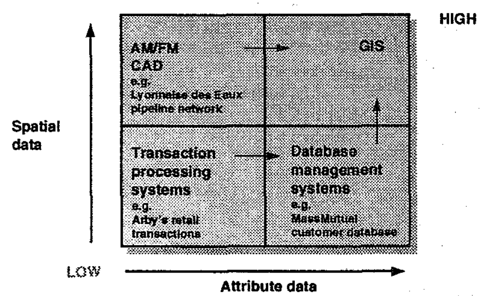


**Figure 1** **GIS and Related Information Systems**

One of the things that GIS and IS have in common is that they both facilitate the input, storage and retrieval of data. Looked at from a data perspective there is a prima facia case for searching the IS literature for ways of further classifying GIS.

## PROBLEMS with Previous Information Systems Taxonomies

The lack of a commonly agreed taxonomy raises the barriers to entry to the subject of information systems and potentially leads to a waste of energies chasing the same thing by a different name. Many disciplines contribute to information systems - this is a healthy state. However, this leads to a tendency for each discipline to use its own framework as the basis of research depending on whether the study has, for example, an organisation, a technology, or a system perspective. Earlier work (Grimshaw [12]) rejected previous taxonomies for two major reasons. First the oversimplification of a one discipline viewpoint tends to provide a range of concepts that are not mutually exclusive. Second, there is an implicit assumption of *ceteris paribus;* however, it is in the nature of information technology and organisations that things change.

The earlier (Grimshaw [13]) taxonomy put forward was built on existing frameworks from Anthony [14], Gorry and Scott-Morton [15], Gibson and Nolan [16], and Galliers and Sutherland [17]. The technology and timeframe dimensions explicitly allowed for change. In terms of technology, over time the point at which it becomes economic to apply a particular technology will change. In terms of timeframe, organisations learn and move from one stage to another.

At first reading the notion of a taxonomy (or classification) of information systems may appear to have little to do with GIS. However, the utility of a taxonomy for placing case study organisations into a common classification will be demonstrated. Additionally, GIS, being a new kind of information system, presents a challenge to earlier taxonomies such as that of Alter [18]. Interestingly, Doke and Barrier [19] cite the advent of systems such as GIS as a reason for needing a new taxonomy of information systems, whilst Mentzas [20] ignores GIS altogether. Part of the motivation for writing this paper has arisen out of reading earlier conference papers discussing the question: "is GIS a DSS" (Murphy [21]). Whilst such a debate is both necessary and intriguing it addresses a single dimension of the topic and therefore is an insufficient explanatory framework.

Doke and Barrier [22] review a number of taxonomies, including Grimshaw [23]. They state that Grimshaw [24] puts forward a, "new model encompassing a broader range of information systems and is an important improvement" (Doke and Barrrier [25]). However, they go on to say that existing taxonomies (meaning those pre-1994) are unworkable because many current systems do not fit in them. As an example Doke and Barrier [26] say, "where does GIS fit in the previous taxonomies?" This question will be answered directly in the section which proposes a new taxonomy of GIS.

For the moment let us concentrate on the arguments they use to reject the Grimshaw [27] taxonomy. The argument put forward is that the technology and time dimensions are too rigid to allow for change. This is a misinterpretation of these dimensions. For example the view of Doke and Barrier [28] that the time dimension would need updating to account for new organisational paradigms is false because embedded in the time dimension is the seven 'S' framework (Pascale and Athos [29]). As the originators of this framework point out the seven 'S's' are generic levers that managers use to influence large complex organisations. The differences between American and Japanese culture influences the combination of 'S's' used but not the definition of those 'S's'. Therefore, the time dimension of the Grimshaw [30] taxonomy is flexible enough to take into account any new organisational paradigms. Although it may be conceded that some of the labelling may need to be changed, for example the fact that "dictatorship" may no longer be observable, does not render the time dimension useless, it means that new combinations of the seven 'S's' warrant a new label. In practice such an amendment might be achieved by extending the time dimension by another column, or a change of label. This is illustrated with reference to GIS in the next section of this paper.

The application of western IT to China had been described as a clash of cultures (Zhang and Angel [31]). The applicability of the notion of stages of growth to a completely different environment and culture has been tested out by Zhao and Grimshaw [32] who criticised the implicit idea of an historical progression embodied in the notion of stages of growth. In other words the historically observed set of sequences in the west can be seen as relative to the technological development current at the time. A further important point made is that the greatest development (in China) is required in the staff, style, skills, and superordinate goals elements. It is these 'soft' elements that facilitate measures of organisational change and go a long way to meeting the objections noted earlier of Doke and Barrier [33]. It is apparent that there is no one commonly agreed framework for discussing information systems. Each contributory discipline has tended to use its own framework for a basis of a study, depending upon whether the study has, for example, an organisation, a technology or a system perspective.

The next section proposes the development of the Grimshaw [34] taxonomies by taking into account some of the criticisms above and by trying to calibrate the dimensions of the taxonomy with illustrative GIS case studies.

## PROPOSED Taxonomy of GIS

A review of the literature found only one previous work which used the stages of growth idea to describe GIS applications (Crain and MacDonald [35]). However, the observations leading to their model were limited to the Canadian GIS. A new attempt to apply the stages of growth idea was felt worthwhile if it included an analysis of organisational factors and was rooted in observations made in the business domain.

The main feature of the taxonomy is that it uses a three dimensional framework (each based on established prior work) to provide a classification system that reflects a dynamic environment.

### DECISION dimension

The kind of decisions that need to be made (described as tasks to be performed in Grimshaw [36]) are a useful starting point. Under this general question are the issues of what data is required, how this data might be assembled and who is going to use the system? There will usually be a trade-off between long run and short run requirements and the demand to summarise the data. The "decision" dimension, builds on frameworks based on the work of both Anthony [37] and Gorry and Scott Morton [38] which, as a result of a review of information systems frameworks by Lucas et al [39] were recommended. Sub-classes on this dimension cover the type of decision being supported, for example, structured or unstructured and the level of the decision, for example, strategic, tactical or operational.

The applications of GIS are the *decisions* that organisations use the systems to support. Traditionally, classifications of applications has been on functional grounds. For example, applications for forestry, environmental management, retail location, etc. Applications here will be thought of in terms of the decisions. Remember that information systems generally seek to provide decision makers with information. Thus we might think of "*tasks*" as being to do with the types of decisions that managers wish to make to help the organisations manage scarce resources.

### TECHNOLOGY dimension

Present and future technologies may be considered. There will usually be a trade-off between flexibility and cost. Over time, the point at which it becomes economic to apply a particular technology will change. The "technology" dimension of Figure 3 builds on frameworks based on the works of Burn and Caldwell [40], Earl [41], and Istel [42], as illustrated in Table 1.

## Table 1 TECHNOLOGY Dimension

| | | |
|---|---|---|
| 1. | Computers | |
| 1.1 | - Digital | |
| 1.1.1 | - General purpose | |
| 1.1.1.1 | | - mainframes |
| 1.1.1.2 | | - minicomputers |
| 1.1.1.3 | | - microcomputers |
| 1.1.2 | - Experimental | |
| 1.1.2.1 | | - optical computers |
| 1.1.2.2 | | - data flow computers |
| 1.1.2.3 | | - parallel computers |
| 1.1.3 | | - Special purpose |
| 1.2 | - Analogue | |
| 1.2.1 | | - General purpose |
| 1.2.2 | | - Experimental |
| 1.2.3 | | - Special purpose |
| 1.3 | - Hybrid | |
| 1.3.1 | | - General purpose |
| 1.3.2 | | - Experimental |
| 1.3.3 | | - Special purpose |
| 2. | Communications | |
| 2.1 | - Computer intraconnect | |
| 2.2 | - Computer system interconnect | |
| 2.2.1 | | - DEC DECNET |
| 2.2.2 | | - IBM 3270 |
| 2.2.3 | | - IBM SNA |
| 2.2.4 | | - OSI |
| 2.3 | - LANS | |
| 2.4 | - MANS (Metropolitan Area Networks) | |
| 2.5 | - WANS | |
| 2.6 | - GANS (Global Area Networks) | |
| 3. | Data | |
| 3.1 | - Data schema | |
| 3.2 | - Data dictionary | |
| 4. | Tools | |
| 4.1 | - Operating Systems Software | |
| 4.2 | - CASE tools | |
| 4.3 | - Database management systems | |

Adapted from Istel [43], Earl [44], & Grimshaw [45].

Sub-classes to this dimension cover computers, communications, data and tools. Some organisations who need to collect and analyse information about new technology as it becomes available and the opportunities that might be available tomorrow from exploiting that technology have developed their own "in-house" taxonomies (Istel [46]). Any discussion about specific commercial products would rapidly become out of date and it is not the intention of this paper to discuss them.

**STRATEGY dimension**

The strategy dimension of the taxonomy (described previously as time, in Grimshaw [47]) is based on the notion of a stage of growth (after Gibson and Nolan [48], Nolan [49], and Galliers and Sutherland [50]). These models have evolved over the years in response partly to changes in technology (for example the extension of the four stage model into six stages to account for the impact of the introduction of the microcomputer and advances in database technology) and partly to changes in the way organisations learn and behave (especially Galliers and Sutherland [51]). Basing the strategy dimension of the taxonomy on the notion of a stage of growth model was designed to meet criticisms of lack of dynamics in previous taxonomies and provide a dimension that could reflect organisational changes.

An adaptation of the time dimension of the Grimshaw [52] taxonomy to fit the observed organisational features of GIS in a number of case study organisations is presented in Figure 2.

| Element \ Stage | Opt out | Stand-alone | Linking | Opportunistic | Corporate |
|---|---|---|---|---|---|
| Strategy | Ad hoc | Audit | Top-down | Technology led | Integrated |
| Structure | Informal | Finance led | Centralised | Coalition | Cooperative |
| Systems | Operational | Duplication | Decision support | Strategic | Comprehensive |
| Staff | Non-technical | MIS Manager | Business analysts | IS planners | IS Director |
| Style | What is GIS? | Do your own thing | Partnership | Run with it! | Team building |
| Skills | Scarce | Technical | Project mgt | Marketing | Innovative |
| Shared Values | Efficiency | Indeterminate | Effectiveness | Strategic | Transformation |

**Source: Grimshaw (1994)**

**Figure 2 GIS Management Strategies**

Figure 2, shows a modified version of the Galliers and Sutherland [53] model. The model is modified to fit the observations made in GIS case study organisations. Fifteen organisations were investigated as case studies: they show three 'opt-out', two 'stand-alone', three 'linking', one 'opportunistic' and six 'corporate' strategies. The significance of this model is that it provides a way of profiling an organisation against the seven 'S's'. Such diagnosis can then be used by management to help choose a GIS strategy that is the most appropriate to that organisation.

Figure 3 illustrates a three dimensional presentation of the proposed classification system for geographical information systems. Three case studies of information systems are discussed below to illustrate the use of the proposed taxonomy.

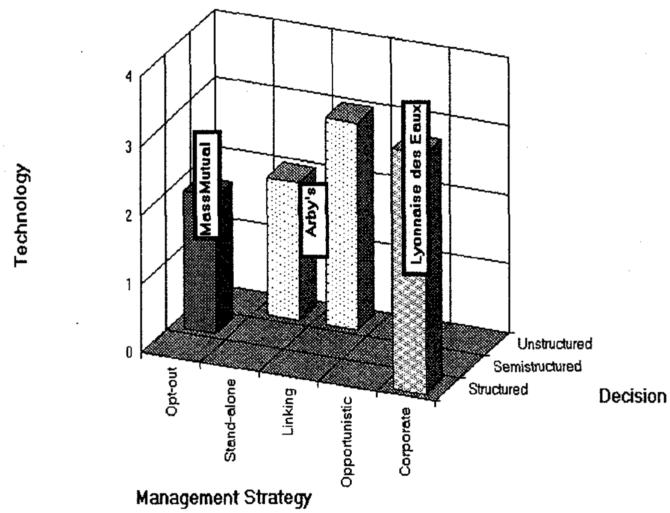


**Figure 3.** **A Proposed Taxonomy of Geographical Information Systems**

Firstly, the simplest case might be that of an insurance company using a GIS to help decide on territory boundaries for salespeople. The three dimensional classification would place the insurance company's decisions as semistructured, using tried and tested technology. MassMutual is an example of such a company using GIS as a stand-alone system.

Secondly, let us take the case of a utility using GIS to map the location of water pipes and manage the maintenance schedules. The three T's can be applied to place such a system as performing largely structured decision support, with use of a GIS package linked to corporate databases providing both facilities and customer data and developed in an organisation that has substantial maturity in terms of IT usage, placing it in the corporate stage for operational support (structured decisions).

Thirdly, where would a GIS project embarked on by a fast food retailer be placed in the IS taxonomy? A system which has not as yet been fully developed is much more problematic in terms of where to place it within the taxonomy. Here is the utility of using the x axis of Figure 3 to denote strategy. The stand-alone and linking stages will involve the development of pilot and prototype systems, for example small scale decision support systems. Basic geodemographic systems will typically be developed in a stand-alone stages. At a later stage in the development of GIS within the organisation there will be a need to integrate with other information systems. So, schematically, the development can be plotted as shown in Figure 3.

The taxonomy of information systems suggested in this paper is based on tried and tested components. Each dimension has already been applied in practice and found to be useful. The thrust of this paper has been to advance arguments in favour of using a multidimensional framework to provide a classification system (or taxonomy) that reflects a dynamic environment.

## APPLYING the Taxonomy

An important test of a taxonomy is: can it be used in practice? Mentzas [54] recognises this as important when concluding his paper by suggesting that the way forward is to apply his taxonomy to existing information systems. Embodied in the stages model are two essential notions: that of time and strategy. Both these ideas have been referred to above so it is worth clarifying what the stages of growth are and are not. Zhao and Grimshaw [55] make an important point about the time aspect, namely that there is a certain order of IT progress, although it does not say anything about the speed or time-scales of implementation. Over time many organisations may travel through different stages (not necessarily sequentially). However, this is not a requirement. The utility of the model is in terms of the diagnosis of the organisation. The main question to have in mind is: "where are we now?" The empirical evidence for the application of the stage of growth model to GIS is best discussed in relation to each of the five strategies below.

**'OPT-OUT' Strategy: purchase GIS services from a data agency**

As reported in Grimshaw [56] many building societies in the UK, have decided to purchase GIS services from a data agency. There were many reasons for this, and they are reflected in the seven 'S's' of the 'opt-out' column of Figure 2. A particular reason for building societies to take this course of action was the fact that a great deal of information systems development effort was going into conversion of accounts data into customer databases.

Other financial institutions in other countries took similar action, for example the clients of Verdi Ryan. Interestingly, IKEA in Ottawa opted-out and in the end rejected the use of GIS.

**'STAND-ALONE' Strategy**

This stage was often observed to follow the 'opt-out' stage, for example MassMutual. Frequently there was frustration on behalf of users, often in the marketing department, at the lack of progress made by central IT services. From a technological point of view the introduction of desktop GIS running on personal computers has made this stage feasible for many non-technical users.

**'LINKING' Strategy: in house development**

The study reported in Grimshaw [57] dubbed this the in house development because many building societies that had used geographic data since the 1970's had developed their own systems (often before proprietary generic GIS were available). Typical of such systems are the strong links to customer databases run on mainframe computers. Arby's are another example of this approach from another industry in another country.

**'OPPORTUNISTIC' Strategy: strategic technology opportunity**

The classic case of the 'opportunistic' strategy has been discussed earlier in relation to the Woolwich Building Society case (Grimshaw and Hinton [58]). Generally it would be unlikely for an organisation to go through the preceding stages, although subsequent progression to the 'corporate' stage is highly likely.

**'CORPORATE' Strategy**

Organisations that would adopt the 'corporate' approach would be advanced in their use of information technology. The objective of an organisation at this stage is to transform the business. Use of GIS is likely to be strategic. Examples of such systems were investigated include Alcoa in Australia and Isuzu in the USA (Grimshaw [59]).

## CONCLUSION

This paper has reviewed the need for a taxonomy of geographical information systems and proposed a modification of the Grimshaw [60] taxonomy which is based on observations made in several GIS case study organisations. Some general applications of the taxonomy were illustrated by Figure 3 which shows how three of the case studies (taken as examples) can be represented within the taxonomy. The utility of the strategy dimension is well illustrated by these three cases where the MassMutual and Lyonnaise des Eaux systems are placed in specific strategy or organisational contexts, namely 'opt-out' and 'corporate' respectively. In contrast, the Arby's case illustrates how that system changed from 'stand-alone' to 'linking'.

Like all taxonomies, there are limitations to the classification presented here. Attempts have been made to allow the taxonomy to cope with the inevitable changes of technology and organisational strategy. But these aspects of the taxonomy can still be criticised for relying on the notion of a "stage of growth".

The significance of the taxonomy is that it is built on well established frameworks in the information systems literature, it takes account of technology but is not driven solely by it, kinds of decision support, and organisational strategy. Flexibility of the taxonomy is demonstrated by its ability to be adapted to a new kind of information system, in this case GIS. Applied to GIS the taxonomy is significant because it allows the stage of growth notions to be used to explain generic strategies for the adoption by business of these systems.

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