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'UNIVERSAL' GIS VERSUS NATIONAL LAND INFORMATION TRADITIONS: INTERNATIONALIZATION OF SOFTWARE OR ENDOGENOUS DEVELOPMENTS?[1]

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ABSTRACT. *There are large and surprising gaps between the diffusion of Geographical Information Systems (GIS) in European countries. Whereas in some countries, notably in the United Kingdom and the Netherlands, GIS technology has already become standard practice in cartography, local land management, and planning, other countries have been extremely slow in adopting the new technology. This paper discusses why this is so. The hypothesis is that national land information traditions determine the institutional environment and procedures into which the new technology needs to be integrated, and that this restricts the transfer of 'universal' GIS software developed in different national settings. The paper ends by drawing some conclusions out of this for a European GIS research agenda.*

INTRODUCTION

One of the many impacts of the explosive development of speed and storage capabilities of digital computers is the ability to efficiently handle large amounts of spatial coordinate data. The organization of such data in Geographical Information Systems (GIS) promises to revolutionize all fields in which geographic data are handled such as mapping, land management, and planning.

As the GIS revolution is part of the computer revolution, one might expect that it would take place at about the same speed in all countries where computers are freely available. However, whereas office automation, computer-assisted manufacturing, and advanced logistics are rapidly spreading across all countries with market-oriented economies, there are large and surprising gaps between the diffusion of GIS in European countries that cannot be explained by differences in affluence or technological advancement. In some countries, notably in the United Kingdom and the Netherlands, GIS technology has already become standard practice in cartography, local land management, and planning.

These two countries have launched extensive national research programmes to promote the expertise in handling digital geographic data. In Britain, the Economic and Social Science

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Research Council (ESRC) allocated £2 million for funding eight Regional Research Laboratories over a five-year period. In the Netherlands, the Dutch Science Council spends 1.8 million guilders over a four-year period for a National Center for Geographic Data Processing. Every international GIS conference in Europe is clearly dominated by participants from the UK and the Netherlands (Masser, 1988).

Not surprisingly, in both countries, the official base map systems have already to a large part been digitized across all map scales. In Britain, for example, the Ordnance Survey has used digital mapping techniques since 1972 and now digitizes some 5,000 of its 1:1,250 and 1:2,500 maps annually. It expects to have completed the digitizing of all major urban areas by 1995 and all other warranted digital conversions within a further decade (Ordnance Survey, 1987). Ordnance Survey digital map data can be ordered by anybody for an individual charge or by subscription. On the basis of ordnance survey map data and the Post Office's Postcode Address File (PAF) — which contains the postal addresses of 24 million locations in the UK — an immense commercial GIS industry has developed, of which *Pinpoint* was only the most spectacular. *Pinpoint Analysis Ltd.*, until its recent collapse, offered its customers a wide range of services centered around the *Pinpoint Address Code (PAC)*, a geographic reference attaching to every single address in Britain a 12-digit *National Grid* reference and its precise geographical location.

In contrast to this, other European countries have been extremely slow in adopting the new GIS technology. In some of them this was obviously a consequence of insufficient public funds for research and development or of lack of skilled staff or hardware. In other countries this simple explanation does not hold because they belong to the more prosperous countries in Europe and yet have surprisingly failed to take full advantage of the immense technical potential of computerization for the handling of geographical data. Because the authors are most familiar with the situation in their own country, the following discussion will focus on the slow diffusion of GIS technology in Germany, which has made only regrettably slow progress in the adoption of GIS technology.

This paper discusses why this is so. The hypothesis is that national land information traditions determine the institutional environment and procedures into which GIS new technology, if it is to be really successful, needs to be integrated, and that this restricts the transfer of 'universal' GIS software developed in different national settings. The paper ends by drawing some conclusions out of this for a European GIS research agenda.

GIS IN GERMANY

The history of GIS in Germany is one of early enthusiasm, misconceptions, exaggerated hopes and great disillusions, many failures and few successes. The first advances into the field were connected to the perceived needs of a particular kind of end users, the planners. Already in the 1960s, some information about the use of computerized 'planning information systems' in large cities of the United States swept across the Atlantic. Stimulated by a large research program of the U.S. government to establish pilot information systems for urban planning, the West German government funded a pilot project for the development of an urban planning information system in the city of Cologne. A similar project was launched by the city of Munich. However, inadequate computing power, batch processing, primitive mapping facilities, and the lack of efficient software made these systems unattractive, so the planners returned to their traditional ways of information collection and processing. The Cologne project was completely abandoned during the 1970s, while the Munich system, though it exists still today, has never played an important part in the planning process.

The basic misconception underlying these systems was that, understandably, they started from the users' end but neglected the basic processes of data collection and updating. The

Munich system, for instance, did its own large-scale digitization of the whole city area but had to find out that the task of keeping up with the constant flow of alterations made necessary by explosive city growth in the early 1970s was far beyond the capacity of even the most enthusiastic city planning department. The same applied to the nongraphical data associated with (in the Munich case) individual addresses. As it turned out, only the most rudimentary population data could be routinely updated using periodical excerpts from the city's population register. However, as public sensitivity for the privacy issues brought up by computerization grew, even that became infeasible for political reasons. More interesting information, e.g., about household composition or the distribution of workplaces, either proved too costly to be periodically collected or increasingly became off-limits for the same privacy reasons that eventually toppled the 1980 West German census.

The importance of privacy issues for the slow progress in GIS applications in West Germany cannot be overestimated. In effect they turned out to be a serious restriction for any advancements in two ways. For once, through excesses of data collection and surveillance revealed during the antiterrorism campaigns of the 1970, the West German public became more sensitive in this respect than probably in any other country in Europe. Even well-intended proposals for the utilization of personal data for public service provision or planning became stigmatized as potentially dangerous and open for misuse. Second, exactly for that reason, new planning information systems were not established, and existing ones were not updated and, hence, quickly became outdated and void of any meaning; this erosion of the significance of the information provided by the systems made it difficult, if not impossible, even for their defenders to demonstrate their usefulness.

However, even if it had been possible to overcome the privacy problems associated with disaggregate planning data by appropriate safeguards, the failure to be firmly linked to the digital base map system of the city or country would have been sufficient to kill these early planning GIS. In this respect, only a close cooperation with the institutions responsible for surveying and mapping could have helped. This cooperation, however, did not work because the surveying people played their own cards.

To understand this, it is necessary to know that, unlike Britain, West Germany has no central surveying and mapping institution. Rather, for historical reasons, surveying and mapping in Germany is highly decentralized or, more precisely, fragmented, reflecting the federal organization of government in the country. Local or county government surveying departments are in charge of 1:1,000 city maps; medium-scale maps, such as the 1:5,000 German Base Map (Deutsche Grundkarte), and 1:25,000, 1:50,000, and 1:100,000 topographical maps are prepared by the surveying departments (Landesvermessungsämter) of the states (Länder), and the 1:200,000 and 1:1,000,000 maps by the Institute of Applied Geodesy (Institut für Angewandte Geodäsie), a Federal agency in Frankfurt. To make things worse, in some states medium-level regional planning authorities are in charge of maintaining a special set of registers and maps, the so-called Regional Planning Inventory (Raumordnungskataster). One further specialty of West Germany is the dual model of administrating land properties. There are two registers belonging to this system: the land register (Grundbuch) and the cadastre (Liegenschaftskataster). The land register contains information on the ownership of properties and all property rights, especially mortgages. It is administered by special authorities at courts of law (Grundbuchämter). The cadastre, on the other hand, contains information on the physical characteristics of properties such as size, inclination, and location by geometric coordinates and is maintained by local surveying departments (in some states, however, by the state surveying agencies). The two registers are only indirectly linked by a common referencing system based on a hierarchical numerical code for each property. Grundbuch and Liegenschaftskataster might, directly or indirectly, be linked to the files of the local population register, planning and budgeting departments, and the commission for land value assessment. Figure 1 visualizes this complex set of relations.

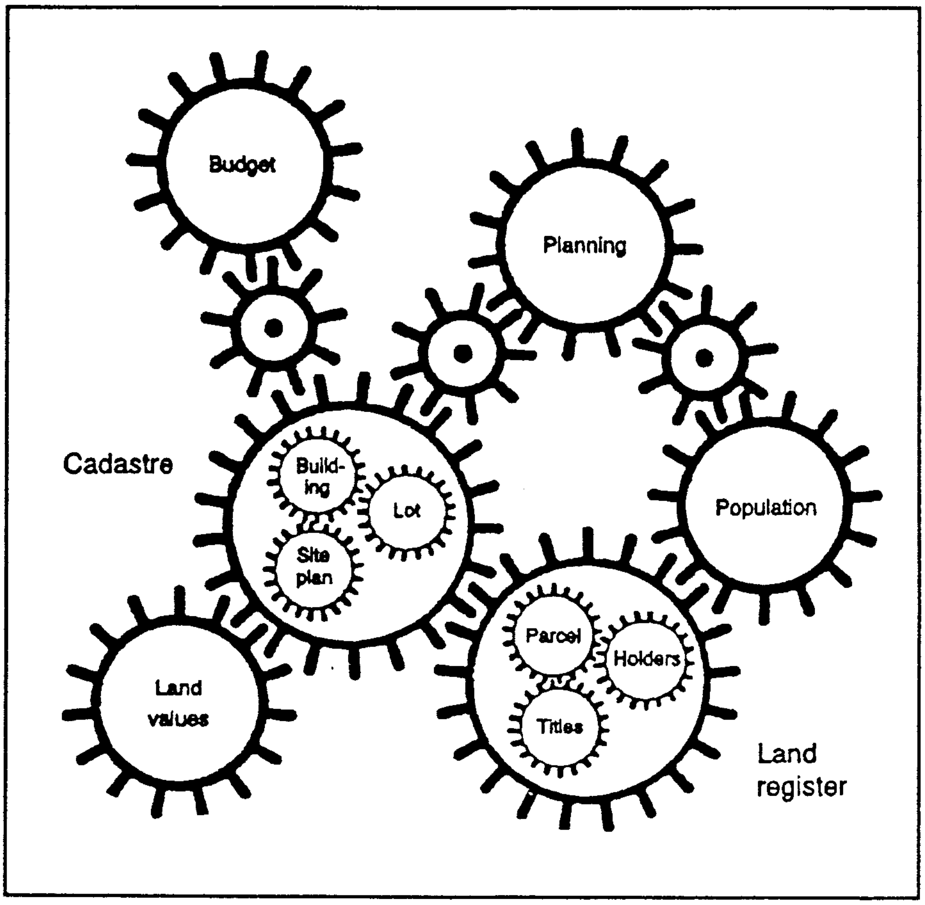

FIGURE 1. Cadastre and Land Register and the Network of Local Government Files (adapted from Stöppler, 1983).

To make this multi-level system work, a complicated set of procedures is necessary which guarantee that queries and updates performed by a multitude of users in a wide range of agencies and institutions are processed according to defined rules with access control and data integrity being maintained. In short, surveying and mapping in a federal system requires a multi-user, multi-agency database management system.

In order to develop such a system, already in 1971 a working party with representatives of state surveying departments submitted a proposal for automating both registers, but only the automation of the cadastre has since been implemented. The first project started was the Automated Cadastral Register (Automatisiertes Liegenschaftsbuch), in short ALB, designed as a standard DBMS. The second project, started in 1976, is the Automated Cadastral Map (Automatisiertes Liegenschaftskarte), or ALK. Both systems together form a land information system (LIS). The ALK system is characterized by a strict separation of the users from the database management system (DBMS) through a standardized interface or data transfer format, the EDBS ('Einheitliche Datenbankschnittstelle'). Figure 2 shows the evolution of the EDBS from single user to multi-user and finally distributed multi-DBMS interface.

The implementation of the EDBS is very similar to a graphics metafile format consisting of records identified by a record identifier, a header, and any number of data fields. Figure 3 illustrates how a typical ALK object is coded into the EDBS format and decoded at the user's application. In the ALK terminology, an object is a collection of attributes and coordinates. Attributes of a building object, for instance, are its label, shading, or all sorts of annotations, while geometry attributes are its label coordinate and the coordinates of, say, its perimeter: In other words, objects primitives such as line objects can be nested within more complex objects.

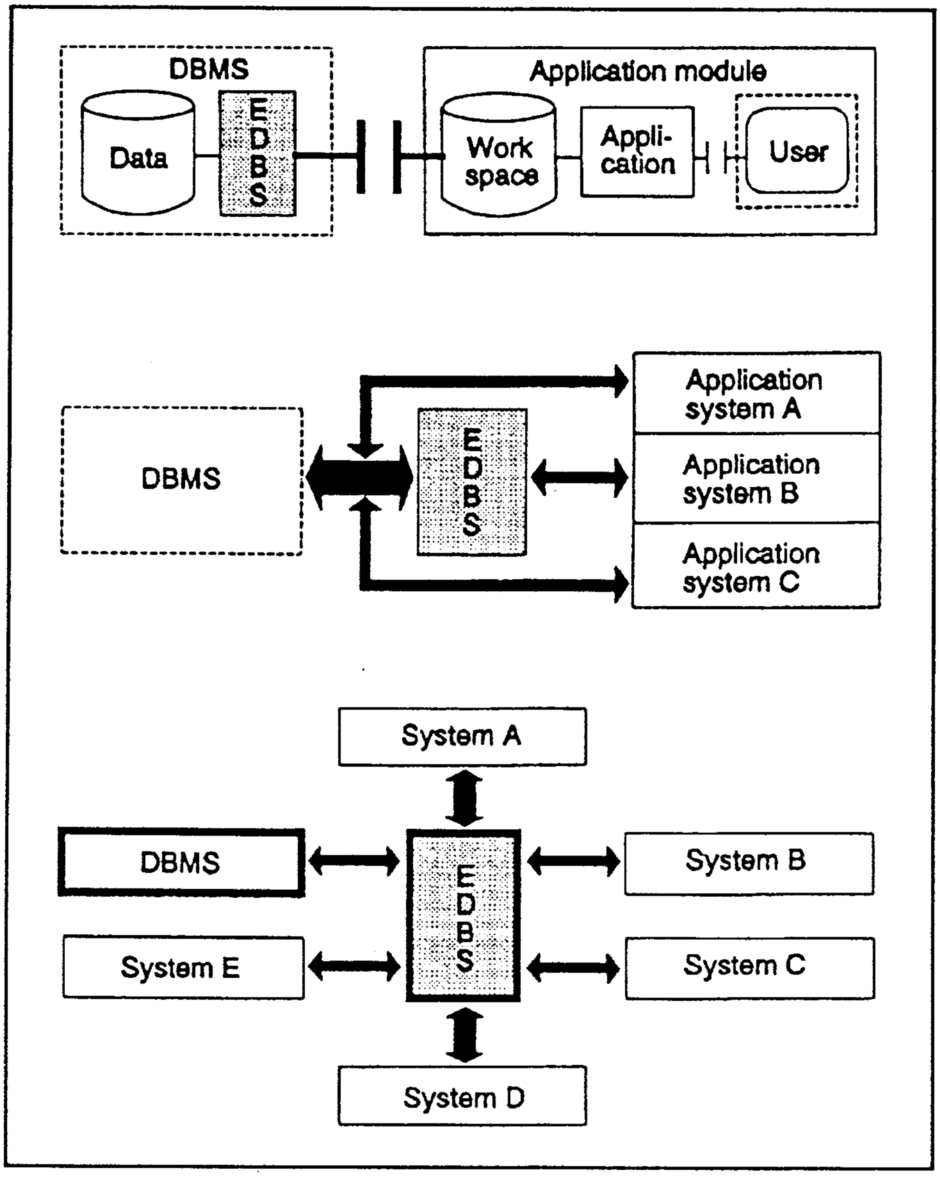

FIGURE 2. Evolution of the EDBS (adapted from Stöppler, 1989).

This data model 'object' is mapped to the logical data model of the respective DBMS, but also to the data transfer format of the EDBS. At the application end, the data are decoded and translated into the representation required by the specific application. In Figure 3, it is assumed that the application consists of an interactive session at the GIAP (Graphischer Interaktiver Arbeitsplatz), the graphical workstation functionality defined by the ALK system (which may be implemented on any kind of real workstation).

Figure 4 shows how the user application communicates with the ALK-DBMS. Each query or update request by the user is translated into the EDBS by the EDBS interpreter and put into the job queue of the ALK-DBMS. After processing, the response or acknowledgment is sent back to the EDBS interpreter which reconverts it into the format required by the application.

The ALK system as it has been sketched out above, is supposed to be the basic GIS standard not only for the local cadastre and associated base map system, but, in a bottom-up fashion, also for the middle-scale topographical maps of the state surveying agencies under the acronym ATKIS (Amtliches Topographisch-Kartographisches Informations System).

Today, two decades after the initiation of the project, only first steps have been made towards implementation of the ALK system. Only 3 of the 12 federal states of the former Federal

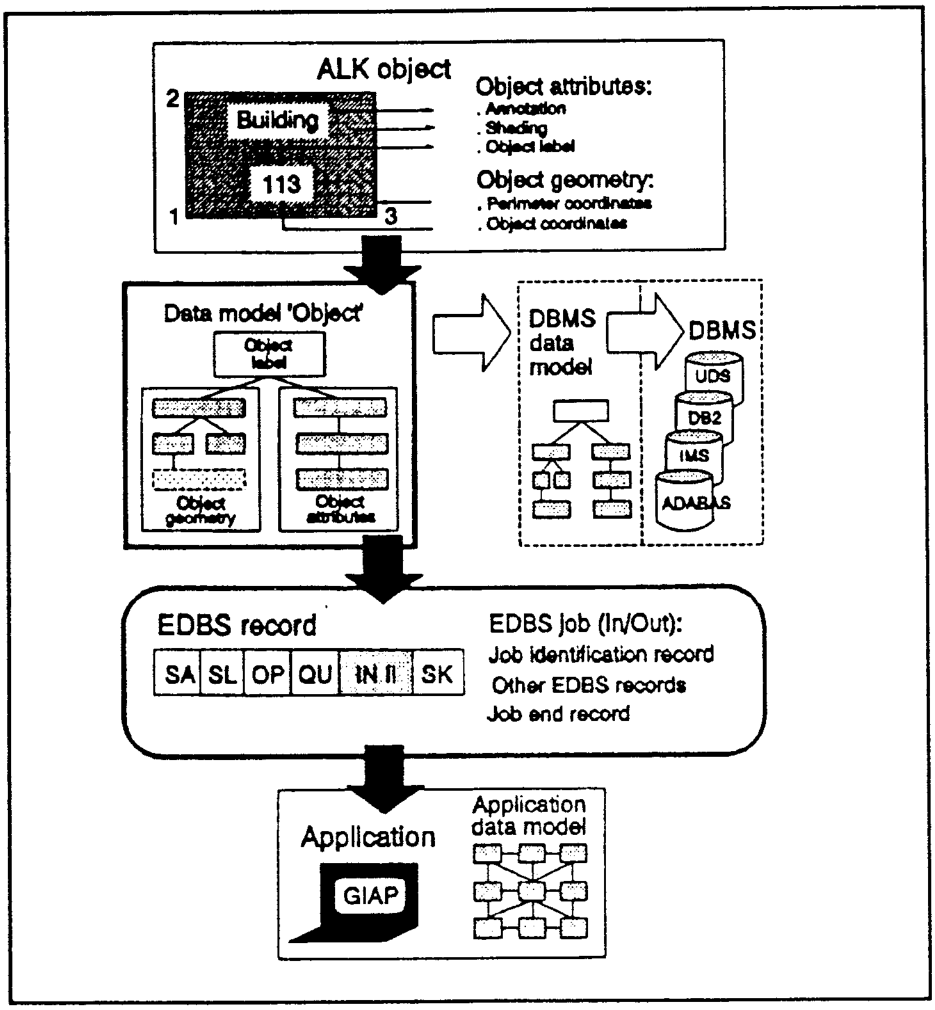

FIGURE 3. ALK Objects and Data Models (adapted from Stöppler, 1989).

Republic (Hessen, Niedersachsen and Nordrhein-Westfalen) have actually started to implement the data collection component of ALK (digitizing of existing analog maps or converting existing noncompatible digital map formats). A few other federal states are preparing themselves to join the ALK system. Some federal states have already decided not to join. Needless to say that the five new federal states (the former GDR), where a different, much more centralized surveying system had developed since the war, present new unforeseen problems.

Understandably, the system components implemented so far concentrate on the primary function necessary for data collection, updating, map editing, and data communication between the subsystems. More complex GIS functions, such as union or intersection of coverages, buffering, digital terrain models, or network analysis, are still under development. More specialized applications for statistical analysis, thematic mapping, or land use planning are still far away in the future.

So even in the most advanced federal states such as Nordrhein-Westfalen only few local governments have made substantial progress in setting up their digital base map system. Also on the state, level only first experiences with the ATKIS mapping standard have been made. The idea that one could order any scale digital map from the Landesvermessungsamt, as it is common practice in Britain, would appear quite inconceivable here. Also the data exchange between the different agencies and institutions of the ALK system with the EDBS data transfer format to date works only off-line, i.e., via bulk batch processing; more far-reaching interface problems such as, for instance, the problem of exchange of geographical data between mapping systems

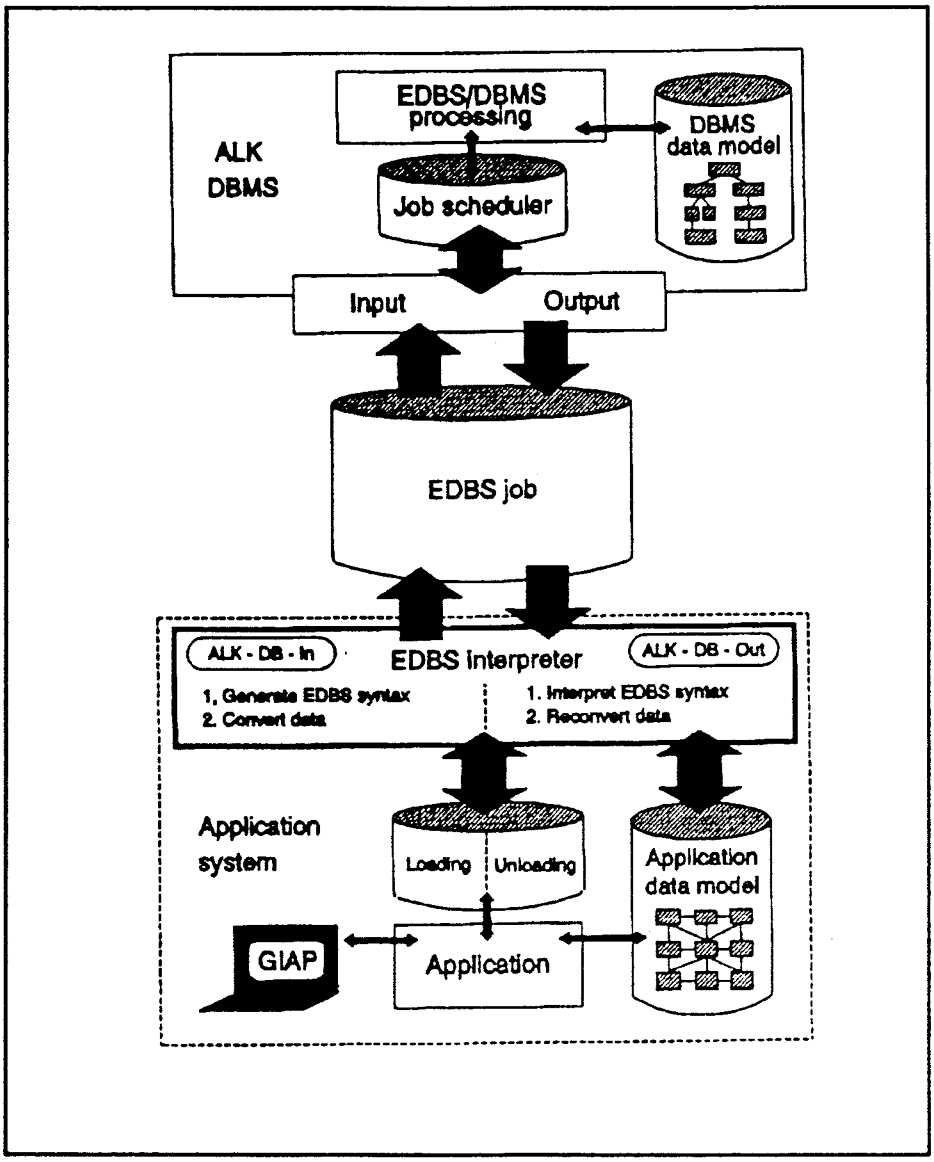

FIGURE 4. Communication with the ALK DBMS (adapted from Stöppler, 1989).

in different European countries or between European institutions, have hardly been taken into view. Most importantly, the whole system is totally under control of the surveying departments without any consultation, let alone participation of other potential users, e.g., the planners.

'UNIVERSAL' GIS?

Considering the small progress made in the introduction of the ALK so far, one might ask why the responsible actors decided to go through all the pains of developing their own 'endogenous' GIS instead of buying a commercial GIS software product off-the-shelf. This strategy has, for instance, been adopted by the Hong Kong government, which after an international competition between major vendors of GIS selected ARC/INFO of ESRI Environmental Systems Research Institute (Redlands, CA) for its surveying/mapping and planning information system.

A comparison between Hong Kong and Germany reveals the main reasons why in Germany a different decision was made.

Language. Since ARC/INFO as commercially available GIS is of U.S. origin, all of its command language, user interfaces, manuals, etc., are in English. This presents no problems as long as either the country is English-speaking (as Hong Kong), or the users are multi-lingual academics. For the average officer in a municipal surveying department in Germany, however, it presents a serious language barrier. Of course, this could be circumvented by custom-tailoring a German-language user interface shell around the original GIS software, but this alone would be a serious undertaking with uncertain success.

Networking capability. The multi-level and multi-user organization of surveying and mapping in Germany require more elaborate support for access control, data communication, and data integrity than a GIS designed for a single client or a centrally organized city state such as Hong Kong can provide. This restriction, of course, does not apply for stand-alone inhouse applications, which is why the Institut für angewandte Geodäsie recently chose ARC/INFO as GIS for the preparation of their 1:250,000 and 1:1,000,000 maps.

The underlying data model. As it was shown, the cadastre system in Germany suggests complex object types such as the 'building' object used as an example in Figure 3, which themselves contain geometrical primitives as objects, such as the perimeter line object in Figure 3. Such a data object is presently not supported by, say, ARC/INFO, which only knows point, line and polygon objects. Moreover, there are more subtle differences in the traditions and algorithms used in surveying between Germany and the United States which would render the unmodified adoption of a U.S.-based GIS impractical.

Cost. Commercial GIS software is expensive to buy and expensive to maintain. In contrast, the true costs of developing an endogenous GIS such as the ALK system are hidden in general administrative budgets. Once existing, endogenous solutions have to be used. For instance, in Nordrhein-Westfalen the municipalities get the ALK software free, which means that they simply do not any longer have the option to choose an external expensive system.

As a results of these considerations, the GIS scene in Germany is divided into two worlds. The public surveying and mapping world is committed to the endogenous development ALK, whereas universities and other public and private research institutions are linked to the international world of (mostly English language) 'universal' GIS. This has significant implications for university education and research in the GIS field.

CONCLUSIONS

The answer to the initial question: "'Universal' GIS or endogenous developments?" will come as no surprise: Of course, both. In particular, in non-English-speaking countries with a complex institutional setup, custom-tailored endogenous solutions combining software *and* procedures seem indispensable. At the same time in the research realm 'universal' GIS designed for single-client use are likely to be the more efficient choice.

The problems arising out of this division of the GIS field for university education and research in the GIS field are obvious. On the one hand, state-of-the-art GIS such as ARC/INFO are the natural choice for introductory courses in the GIS field and for inhouse university research projects. On the other hand, students would be poorly prepared for the likely GIS environment in their future practice in the public service if they would not get exposed to the ALK system at all. This, however, would make it necessary for universities to install an ALK implementation on the campus, something to date only few surveying departments — and no planning schools — at German universities have yet achieved.

For a European research agenda, the problems discussed in this paper suggest more emphasis on the organizational and institutional environment of GIS in the land information field taking account of the different traditions and restrictions of each particular country. Also, under a

European perspective, problems arising from the integration of incompatible geographical data bases between European countries or between European institutions deserve increased attention.

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