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APPROPRIATE HUMAN SETTLEMENTS PLANNING IN THE ESCWA REGION: THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN PLANNING

92-0481

FOREWORD

The integration of the social, economic and physical dimensions of planning is a core theme of the Human Settlements Subprogramme's activities, and spans substantive, methodological and procedural issues. In this process, the application of geographic information systems (GIS) to planning and urban management functions, constitute a vital component of the procedural aspect of the issue. This in fact covers the main body of the report, which provides an up-to-date review on the adaptation, use and limitation of GISs in planning in the region of the Economic and Social Commission for Western Asia (ESCWA). Alternatively, the substantive and methodological aspects of integrating social, economic and physical planning are dealt with under separate technical publications planned in the current and subsequent human settlements programmes of work.

The review on the role of geographic information systems in human settlements planning is part of an ongoing process aimed at promoting appropriate analytical and managerial tools in human settlements planning as part of the stated objective to strengthen local resources and hence develop the existing managerial and technical capabilities.

It is intended to update the content of this report on a regular basis to present a periodic review of the implementation of geographic information systems in the ESCWA region and to keep up to date with new technological advancements in the field.

We wish to thank Mr. Geoff Connors (F.I.C.E. F.I.T.E. F.I.H.E), an expert on GIS and consultant to ESCWA, for his valuable contribution to this report.

Note: Information provided in chapters II-VI is the result of field-work and consultancies undertaken by Mr. Conners in the ESCWA region and elsewhere.

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EXECUTIVE SUMMARY

1. This report discusses approaches and means for integrating social, economic and physical planning to reflect the interactive and dynamic process involved in such work. The report assesses existing human settlements patterns in the region, focusing on the difficulties in making planning responsive to the complexities involved in urban and regional development. Alternatively, it discusses the basic requirements for an optimal planning process for the region of the Economic and Social Commission for Western Asia (ESCWA), which would allow the efficient implementation of geographic information systems (GIS) and land information systems (LIS), as an innovative and useful analytical and managerial tool for human settlements planning in ESCWA countries.

2. A GIS is a system of managing records within an organization -- or among organizations -- that allows records to be shared by all users. The records relate directly or indirectly to geographic information -- more usually to maps. A good GIS does not necessarily require computers for effective operation, although in contempory GIS literature, GIS and computers are synonymous.

3. The report discusses the uses and limitations of GIS, the activities it can be applied to, the requirements of a successful implementation of GIS and a discussion of the latest examples of micro computer (PC) based GIS systems and their advantages over a mini or main frame computer system.

4. Computerized GIS has passed beyond the research and development phase in the West and is now being implemented at least in pilot form in many organizations, particularly local governments. The major enabling factors precipitating the spread of GIS are wider availability of digital map data in vector form, cheaper and faster hardware and a growing awareness of GIS functionality.

5. A fully functional GIS in a single-user environment covers data input, display, storage, analysis and output functions. Within each function are many sub-functions, the sophistication of which depends upon individual departmental needs.

6. Hardware platforms are becoming less of a limitation to GIS implementation as the distinction between microcomputers, workstations and mini systems becomes more blurred. Microcomputer-based hardware is now sufficient to prove techniques in a GIS pilot environment, accepting that there may be restrictions in terms of memory, processing speed and networking capabilities. Reputable GIS software vendors tend towards making their software operate over a range of hardware platforms.

7. Of the various GIS software packages in existence, many are not fully functional GIS but specifically oriented to particular applications, such as thematic mapping, routing and scheduling, inventory control, etc. Full functionality in a GIS usually means reduced performance, increased complexity and less friendly user interfaces.

8. There is currently a large number of GIS software systems available, and the list is expanding. As business booms it can reasonably be expected that some suppliers will go out of business, leaving software unsupported. Potential users would be well advised to use multipurpose GIS software from a well established company unless their needs are particularly specialized towards a particular application.

9. In the main body of the report, five microcomputer GIS packages are reviewed, as has one mini-computer package (installed in Amman).

10. Raster or video map data (i.e., data stored as a picture) have distinct advantages for certain specialized GIS applications and may provide a cheap route for data supply. Raster or image data, however, has very limited "intelligence" and cannot be used for many analytical applications. Fully topologically structured vector map data (i.e. data stored as coordinated points and lines) is expensive to digitize but is easier than raster to maintain and can be sued for most analyses.

11. Applications which require several map scales will require input data from various scales, regardless of whether map data used is raster or vector. Automatic map generalization (the production of small-scale maps from large-scale maps) is still an academic research area and few positive results have been achieved so far. The mapping required to support a multi-user GIS should be at the smallest scale which supports the most demanding of applications.

12. A database management system is an integral part of a fully analytical vector-based GIS. Recent trends and developments have led to the establishment of the relational database management system (RDBMS) as being most appropriate for most GIS applications. Proprietary should support data input, analysis and querying through SQL (structured query language).

13. Creating the structure of the database (data modelling or entity relationship modelling) within an organization is a vital component in defining the functionality of a vector-based GIS. Data modelling is a complex, structured activity which is essentially machine or DBMS independent and should be carried out prior to pilot GIS implementation.

14. A GIS assumes that all data is equally reliable without additional information. Combining data from various sources with various degrees of reliability will therefore result in spurious accuracy of results.

15. Within a municipality or government organization, any activity which relates a set of records to an address, or map, or other spatial reference is a candidate for inclusion into a GIS. Consequently there will be a host of possible application areas withine one organization. It is most unlikely that all these applications can be supported economically in a GIS, and a pilot programme will be necessary to identify those activities which are economic.

16. Confronted with so many systems suppliers, a potential user should develop a detailed specification of needs, users, applications and analyses for use in the procurement process. This specification can emerge out of a pilot GIS implementation.

17. Because of the importance of data accuracy, preparation and input to any GIS, it is essential that each GIS installation start with a pilot study, using a limited area and reduced hardware, in order to test the system, to provide training in the operation of the system and to define the input capability and output requirements.

18. GIS encompasses a set of procedures, departments, data, software, hardware and management within any one organization. It is important to understand that GIS systems do not include data creation nor do they concern themselves with the accuracy of data. The availability of accurate data in suitable form for inclusion into a GIS is the most important prerequisite for successful implementation. Automated systems for map or data management do not make up for poor data. Thus an accurate and complete manual map and records system is a prerequisite for a successful computerized GIS.

19. The highest cost involved in creating a GIS is almost certain to be the vector digitizing of maps. If maps are not available or are outdated, the cost of initial survey and revision will be huge. Digitizing survey documents tends to degrade the inherent accuracy, and detailed quality assurance and control procedures will therefore be necessary.

20. As noted, the most important aspect of any GIS is the accuracy and timeliness of the input data, especially the mapping data. In the United States and Europe, this data is already available, and therefore GIS implementations can proceed with some confidence. In many countries in the ESCWA region, mapping data are not of the required accuracy; prior to setting up a GIS, data must be upgraded or, in some places, the base map completely resurveyed. If the required resurvey is major, consideration should be given to direct digital survey (survey data being transferred electronically, directly from the survey instrument to the computer graphics database) or the use of survey maps on video ROM.

21. It is obvious therefore that a great deal of planning must be carried out before any firm decisions are made on the type of GIS to be installed and the functions required; such decisions must be based on the data available and, very importantly, the budget available. Implementing a full-scale GIS within a government organization therefore takes several years from concept to initial data loading.

22. The main recommendations for further study are to investigate and review all mapping standards in the region, to investigate the availability and freedom of data and its timeliness and accuracy, to define existing problems in data management and to define what ESCWA and other users in the region actually want from a GIS.

23. A further recommendation is to ensure that top decision makers in government be made aware of all the implications of installing GIS, including cost, reorganization and, importantly, the freedom of information implied.

24. These recommendations and others concerning the implementation of GIS are detailed in the body of the report.

25. By itself GIS is a wonderful tool, but it has implications in its application which may require departmental reorganization; the need for this and the actions needed must be accepted, agreed upon and supported by the authorities or departments in question and their staff.

موجـــز

١- يبحث هذا التقرير نُهُج ووسائل تحقيق التكامل بين التخطيط الاجتماعي والاقتصادي والعمرانـــي، لتجسيد العملية التفاعلية النشطة التي تنطوي عليها تلك الاعمال. ويقيِّم التقرير الأنماط القائمـــة للمستوطنات البشرية في المنطقة، مركّزا على الصعوبات التي تكتنف تحقيق تجاوب التخطيط مـــع التعقيدات التي تنطوي عليها التنمية الحضرية والاقليمية. وعلاوة على ذلك، يبحث التقرير المتطلبـــات الأساسية لتنفيذ عملية تخطيط مثلى لمنطقة اللجنة الاقتصادية والاجتماعية لغربي آسيا (اسكوا) تساعـــد على تطبيق نظم المعلومات الجغرافية ونظم معلومات الأراضي بكفاءة، باعتبار ذلك أداة تحليلية واداريـــة مبتكرة ومفيدة لتخطيط المستوطنات البشرية في بلدان الاسكوا.

٢- وأي نظام للمعلومات الجغرافية مصمم لتنظيم السجلات داخل مؤسسة ما، أو بين عدد مـــن المؤسسات، يساعد على تبادل السجلات بين جميع المستخدمين. وهذه السجلات تتعلق، بصورة مباشـــرة أو غير مباشرة، بالمعلومات الجغرافية، ولا سيما الخرائط. وأي نظام كفء للمعلومات الجغرافية لا يتطلـــب بالضرورة توفر أجهزة حاسوب لكي يعمل بفعالية، رغم ان نظم المعلومات الجغرافية تعتبر مرادفة لأجهـــزة الحاسوب في المنشورات الحديثة الخاصة بنظم المعلومات الجغرافية.

٣- كما يبحث التقرير أوجه استخدام وقصور نظم المعلومات الجغرافية،والأنشطة التي يمكن ان تطبـــق فيها، وشروط نجاح تطبيق نظم المعلومات الجغرافية. كذلك، يتناول التقرير أحدث أمثلة نظم المعلومـــات الجغرافية القائمة على استخدام أجهزة الحاسوب الدقيقة، والمزايا التي تتفوق بها على أجهزة الحاســـوب الصغيرة او الكبيرة.

٤- وفي الغرب، تجاوزت نظم المعلومات الجغرافية المحوسبة مرحلة البحث والتطوير، حيث تطبـــق حاليا، على أقل تقدير، بشكل تجريبي في عدد كبير من المؤسسات، ولاسيما الادارات الحكومية. والعوامـــل الرئيسة التي ساعدت على التعجيل بانتشار نظم المعلومات الجغرافية هي اتساع نطاق توافر بيانـــات الخرائط الرقمية في شكل متجهات، وتوافر حواسيب أزهد في أسعارها وأسرع في عملياتها، فضلا عن تزايـــد الوعي بوظائف نظم المعلومات الجغرافية.

٥- وأي نظام للمعلومات الجغرافية يؤدي وظائفه بالكامل، لدى مستخدم واحد، يغطي وظائف ادخـــال البيانات وعرضها وتخزينها وتحليلها واستخراجها. وتشتمل كل وظيفة على عدد كبير من الوظائـــف الفرعية التي تتوقف براعتها على احتياجات كل ادارة.

٦- ولم تعد احجام أجهزة الحاسوب تشكل وجهاً من أوجه القصور الأساسية أمام تطبيق نظـــم المعلومات الجغرافية، نظراً لتضاؤل الفوارق بين أجهزة الحاسوب الدقيقة ومحطات العمل وأجهـــزة الحاسوب الصغيرة. فأجهزة الحاسوب الدقيقة تكفي حالياً لاثبات صحة الأساليب المستخدمة في مجـــال

من مجالات تطبيق نظم المعلومات الجغرافية، مع الاقرار بوجود بعض أوجه القصور من حيث الذاكرة، وسرعة التجهيز، والمقدرة على الربط بين الشبكات. كما ان ذوي السمعة الحسنة من بائعي برامج نظم المعلومات الجغرافية يميلون الى جعل البرامج قابلة للتشغيل على أجهزة الحاسوب بمختلف أحجامها.

٧- ومن بين المجموعات المتوفرة من برامج نظم المعلومات الجغرافية، فان الكثير لا يؤدي الوظائف الكاملة لنظم المعلومات الجغرافية، وانما يكون مصمما بالتحديد لتطبيقات معينة، مثل رسم الخرائط حسب المواضيع، والتوجيه، والجدولة، ومراقبة العهدة، وما الى ذلك. واداء الوظائف الكاملة لنظام ما للمعلومات الجغرافية عادة ما يعني انخفاض الاداء، وزيادة التعقيد، وقلة سهولة استخدام الوصلات البينية.

٨- ويتوفر حاليا عدد ضخم من مجموعات برامج نظم المعلومات الجغرافية. والقائمة تتزايد. ومع ازدهار التعامل التجاري في هذا المجال، فإن من المتوقع، كما يُعتقد، أن يخرج بعض الموردين من السوق، تاركين البرامج بلا دعم. ويُنصح المستعملون المحتملون باستخدام برامج متعددة الاغراض لنظم المعلومات الجغرافية من انتاج شركة معروفة، ما لم تكن احتياجاتهم تخصصية تماماً في مجال تطبيقي بعينه.

٩- ويبحث التقرير، في متنه، خمسا من مجموعات برامج نظم المعلومات الجغرافية المعدة لأجهزة الحاسوب الدقيقة، ومجموعة واحدة من برامج أجهزة الحاسوب الصغيرة (مستخدمة في عمان).

١٠- ولبيانات الخرائط المعدة بخطوط المسح أو المرئية (اي البيانات التي يتم تخزينها على شكل صورة) مزايا خاصة بالنسبة لبعض التطبيقات التخصصية لنظم المعلومات الجغرافية. كما انها قد تمثل وسيلة زهيدة التكاليف للامداد بالبيانات. غير ان البيانات المعدة بخطوط المسح أو بالصور تتسم بـ «ذكاء» محدود للغاية، ولا يمكن استخدامها في عدد كبير من التطبيقات التحليلية. اما بيانات المتجهات الخاصة بالخرائط، والمعدة جغرافياً بالكامل (اي البيانات التي يتم تخزينها على شكل نقاط وخطوط احداثية) فباهظة التكاليف من حيث تحويلها الى ارقام، وان كانت أيسر من خطوط المسح في ابقائها، كما يمكن استخدامها لمعظم عمليات التحليل.

١١- والتطبيقات التي تستلزم عددا كبيرا من مقاييس رسم الخرائط تحتاج الى بيانات ادخال من مقاييس رسم مختلفة، بصرف النظر عما اذا كانت بيانات الخرائط المستخدمة هي خطوط مسح او متجهات. والتعميم الآلي للخرائط (اي انتاج خرائط ذات مقياس رسم صغير من خرائط ذات مقياس رسم كبير) لا يزال يعتبر مجالا بحثياً اكاديمياً، حيث ان النتائج الايجابية التي تم التوصل اليها حتى الآن ضئيلة. ذلك ان رسم الخرائط اللازم لدعم نظام متعدد الاستخدامات للمعلومات الجغرافية يجب أن يكون بأصغر مقياس رسم يدعم اكثر التطبيقات صعوبة.

١٢- واي نظام لادارة قواعد البيانات هو جزء لا يتجزأ من نظام للمعلومات الجغرافية تحليلي بالكامل قائم على المتجهات. وقد ادت الاتجاهات والتطورات الاخيرة الى اقامة نظام ادارة قواعد البيانات العلاقية، باعتباره أنسب نظام لمعظم تطبيقات نظم المعلومات الجغرافية. والملكية الخاصة تعمل على دعم ادخال البيانات وتحليلها والاستفسار عنها من خلال لغة الاستفسار الهيكلية.

١٣- ويعتبر انشاء هيكل قاعدة البيانات (بناء نماذج البيانات أو نماذج العلاقة بين الوحدات) داخل مؤسسة ما، عنصرا حيويا من عناصر تحديد وظائف نظام ما للمعلومات الجغرافية قائم على المتجهات. ويعد بناء نماذج البيانات عملية معقدة ومتراكبة ومستقلة عن الآلة أو عن نظام ادارة قاعدة البيانات، كما يجب ان تنفذ قبل التطبيق التجريبي لنظم المعلومات الجغرافية.

١٤- ويفترض في أي نظام للمعلومات الجغرافية تَساوي جميع البيانات في الصحة دون ما حاجة الى معلومات اضافية. لذا، فان تجميع البيانات من مصادر مختلفة بدرجات متفاوتة من الصحة يؤدي الى نتائج زائفة في دقتها.

١٥- وفي داخل بلدية أو مؤسسة حكومية ما، فان اي نشاط يربط مجموعة من السجلات بعنوان أو خريطة أو أي مرجع مكاني آخر انما يستوفي شروط ادراجه في نظام للمعلومات الجغرافية. وعليه، سيتوافر عدد كبير من مجالات التطبيق الممكنة داخل مؤسسة ما. ومن غير المحتمل، على الاطلاق، أن يتسنى دعم كل هذه التطبيقات دعما اقتصاديا في نظام للمعلومات الجغرافية، مما يستلزم تنفيذ برنامج تجريبي لتحديد الأنشطة التي تعتبر اقتصادية.

١٦- وعلى المستخدمين المحتملين، اللذين يواجهون عدداً هائلاً من مورّدي النظم، أن يحددوا المواصفات التفصيلية للاحتياجات والاستخدامات والتطبيقات والتحليلات للاستعانة بها في عملية الشراء. ويمكن استنباط هذه المواصفات من عملية تطبيق تجريبي لنظم المعلومات الجغرافية.

١٧- ونظراً لما لدقة البيانات واعدادها وادخالها من أهمية بالنسبة لأي نظام للمعلومات الجغرافية، فان من الضروري أن تُستهل اقامة أي نظام للمعلومات الجغرافية بدراسة تجريبية تستخدم فيها مساحة محدودة وعدد قليل من أجهزة الحاسوب لاختبار النظام والتدريب على تشغيله وتحديد مقدرة ادخال بياناته ومتطلبات استخراجها.

١٨- وتشتمل نظم المعلومات الجغرافية على اجراءات وادارات حكومية وبيانات وبرامج وأجهزة حاسوب وادارة داخل مؤسسة ما. ومن الأهمية بمكان ادراك أن نظم المعلومات الجغرافية لا تنطوي على انشاء بيانات، كما انها لا تُعنى بدقة البيانات. ويعتبر توافر بيانات دقيقة في شكل مناسب لادخالها في نظام للمعلومات الجغرافية أهم شرط أساسي لنجاح التطبيق. بل ان النظم المميكنة لادارة الخرائط او البيانات لا تعوض عن البيانات الرديئة. لذلك، يعد توافر نظام دقيق ومتكامل للادلة والخرائط والسجلات شرطا اساسيا لنجاح اي نظام محوسب للمعلومات الجغرافية.

١٩- ومن شبه المؤكد أن أعلى التكاليف المتكبدة في اقامة نظام للمعلومات الجغرافية ستخصص لتحويل الخرائط، بالمتجهات، الى أرقام. فاذا لم تتوافر الخرائط، أو كانت بالية، فان تكاليف عملية المسح والتنقيح التمهيدية ستكون ضخمة. كذلك، فان عملية تحويل وثائق المسح الى أرقام انما تنتقص من الدقة الذاتية. لذلك، فان الأمر سيقتضي اتخاذ اجراءات تفصيلية لضمان الجودة والتحكم فيها.

٢٠- وكما ذكرنا، فان أهم جانب من جوانب اي نظام للمعلومات الجغرافية هو دقة وحسن توقيت بيانات الادخال، خصوصا بيانات رسم الخرائط. وهذه البيانات متوفرة بالفعل في الولايات المتحدة وأوروبا؛ لذا، تطبّق فيها نظم المعلومات الجغرافية بقدر من الثقة. وفي عدد كبير من بلدان منطقة الاسكوا، لا تتوافر في بيانات رسم الخرائط الدقة المطلوبة. فقبل اقامة نظام للمعلومات الجغرافية، يتعين رفع مستوى البيانات أو القيام، في بعض المواضع، باعادة مسح الخريطة الأساسية بالكامل. واذا كانت عملية اعادة المسح المطلوبة كبيرة، توجب إيلاء الاعتبار للمسح الرقمي المباشر (حيث يتم نقل بيانات المسح الكترونيا، بصورة مباشرة، من أداة المسح الى قاعدة بيانات رسومات الحاسوب) أو لاستخدام خرائط المسح على ذاكرة قراءة مرئية.

٢١- وبذلك، تتجلى ضرورة القيام بقدر كبير من التخطيط قبل اتخاذ أي قرارات نهائية بالنسبة لنوع نظام المعلومات الجغرافية المقرر اقامته والوظائف المطلوبة منه. وينبغي تأسيس مثل هذه القرارات على البيانات المتاحة، والأهم من ذلك، الميزانية المتاحة. لذا، نجد أن عملية اقامة نظام متكامل للمعلومات الجغرافية، داخل مؤسسة حكومية، تستغرق عدة سنوات، بدءا بالتصور وانتهاءً بالتحميل التمهيدي للبيانات.

٢٢- والتوصيات الرئيسة المتعلقة بمواصلة دراسة الموضوع هي بحث واستعراض كافة معايير رسم الخرائط بالمنطقة، ودراسة مدى توافر البيانات وحريتها وحسن توقيتها ودقتها، وتحديد المشاكل القائمة في ادارة البيانات، والوقوف على واقع ما تريده الاسكوا وسائر المستخدمين بالمنطقة من نظام للمعلومات الجغرافية.

٢٣- وثمة توصية أخرى، هي التأكد من احاطة صانعي القرار في الحكومات بكافة الآثار المترتبة على اقامة نظم المعلومات الجغرافية، بما فيها التكاليف واعادة التنظيم، والأهم من ذلك، حرية المعلومات التي ينطوي عليها الامر .

٢٤- وترد في متن هذا التقرير تفاصيل هذه التوصيات وغيرها من التوصيات المتعلقة بتطبيق نظم المعلومات الجغرافية.

٢٥- ونظم المعلومات الجغرافية، في حد ذاتها، أداة رائعة. الا ان الآثار المترتبة على تطبيقها قد تقتضي اعادة تنظيم الادارات الحكومية. وعلى السلطات أو الادارات المعنية أو مسؤوليها أن يقبلوا ذلك وبما يرتبط به من اجراءات لازمة ويقرّوا بضرورته.

INTRODUCTION

Appropriate human settlements planning involves a multi-sectoral process devised to pave the way for, manage or react to continuous changes in the physical, social and economic environments of societies through an integrated and multi-disciplinary approach.

The pattern of human settlements development in the ESCWA region calls for such an approach, as the region is constantly subjected to political, economic and social upheavals, including notably the Gulf crisis and the war in Lebanon. These have not only generated massive flows of population, goods and services across the region, but have also necessitated the redefinition of national and regional priorities and rendered many of the existing development plans obsolete, particularly those involving detailed plans and designs for land-use, housing and infrastructure services.

In fact, the ESCWA region offers a wide array of human settlements schemes formulated to control the unmanageable growth of primate cities, expand the infrastructure networks, provide public housing or upgrade and revitalize derelict city centres. However, in many cases ambitious objectives are met with limited success. This is understandable, as the challenges of uncertainties and continuous changes facing human settlements planners and policy makers are often exacerbated by problems of inaccessibility to reliable information, disparity between physical plans and their corresponding policy framework, and the absence of a spatial dimension in economic and sectoral development plans.

Planners and policy makers in the ESCWA region are increasingly realizing that, given the dynamic and complex nature of urban growth in the region, there are numerous inter-linked variables in the process which necessitate the devising of a system or an approach that can accommodate such changes. Hence, reliable, integrated, accessible and up-to-date information systems are a sine qua non for initiating such a process and ensuring its efficient functioning.

Almost all central and local government agencies in the region are either planning for or currently developing data banks as an integral and vital function in their planning and urban management activities. Some government agencies, notably in Kuwait, Saudi Arabia, the United Arab Emirates and Jordan are even introducing highly sophisticated information technology, which interrelates economic, social, environmental and institutional variables with spatial localities at various scales. These involve geographic information systems (GIS) and land information systems (LIS), sometimes also referred to as Urban or Municipal Information Systems (UIS/MIS). Since this is a relatively new field, it would be worth exploring the scope of their use, potential applications and logistic requirements.

This report reviews existing GIS and LIS packages relevant to human settlements planning and municipality activities in the ESCWA region and the requirements for their installation, application and future development.

It starts with an overview of prevailing human settlements planning schemes in the ESCWA region, identifying common problems and priority issues for consideration before adopting information systems.

It then discusses the uses and limitations of GIS, the activities it can be applied to, the requirements of a successful implementation of GIS and a review of the latest examples of microcomputer-based GIS systems.

The report also provides recommendations for initiating future research work in this field and creating an environment conducive to developing GIS and other information technologies in the ESCWA region and exploiting all their potentials for a more efficient planning process.

An annex to the report is provided for an easy reference on the latest innovations and relevant facts regarding GIS.

I. A FRAMEWORK FOR APPROPRIATE HUMAN SETTLEMENTS PLANNING IN THE ESCWA REGION

A. Overview of existing human settlements planning in the ESCWA region

The countries of the ESCWA region present an interesting combination of homogeneity and diversity in the challenges and development priorities facing their human settlements patterns and consequently in the set of planning schemes developed to deal with them at the conception, design and implementation stages.1/

Thus, despite variations in the rates of economic growth and technological advancement and in the socio-political environments prevailing in the region, all ESCWA countries have over the past three decades had to adjust to the complexity of structural transformation that results from rapid urbanization.

Throughout the region, the capital cities have had the largest share of urban growth, and with it the burden of providing adequate serviced urban land, shelter, infrastructure and public facilities, education and employment opportunities to an ever-increasing urban population. This presents particular problems for cities like Cairo, Beirut, Baghdad or Amman, which respectively have to accommodate 34 per cent, 83 per cent, 39 per cent and 37 per cent of their respective urban population (1990)2/ and are thus draining already limited public resources, whether financial, managerial or technical. This accounts for much of the urban blight spreading in these cities, the growth of slums, the degradation of public services and the uncontrolled urban development on arable land.3/

On the other hand, the unmanageable growth of primate cities is matched by a weak urban settlements structure characterizing many countries in the ESCWA region, notably Lebanon, Yemen, Syrian Arab Republic, Egypt and the city-states of the Gulf countries. The secondary and tertiary urban centres in these countries still cannot attract the required threshold of population, investments and services, or provide adequate education and employment opportunities, to substitute for the primate cities. Such an inarticulate urban

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1/ United Nations Economic and Social Commission for Western Asia, "Report to the Commission: Human settlements development, problems of settlements planning and need of assistance in the ESCWA region", December 1987 (E/ESCWA/HS/87/2).

2/ Marwan Mohsen, "Patterns of Growth in the Arab City", Arab Conference on Population Policy, 9-13 March 1987.

3/ United Nations Economic and Social Commission for Western Asia, "Overview of the low-cost housing situation in the ESCWA region", paper presented at the United Nations Centre for Human Settlements (HABITAT). Regional Seminar on Housing and Development in Amman, October 1989.

hierarchy hinders the spatial diffusion of urban growth, which makes a balanced and sustainable process of development a problematic matter.

The countries of the region have attempted to deal with their human settlements problems at the urban, regional and national levels by formulating a whole array of planning schemes and creating institutional and legislative frameworks to implement them. Common planning schemes adopted throughout the region include national and regional development plans, master plans, and strategies for growth centres and new towns; these aim at controlling urban growth and spatially spreading out the development process. However, as shown in the following review, the approaches to existing planning schemes reveal disparities between the socio-economic and spatial dimensions of development. One of its main features is the urgent need to coordinate and inter-link the various aspects of the information base underlying the human settlements planning process.

Thus, national development plans, which in principle should provide a multi-sectoral framework guiding the process of development, are in most cases strongly biased towards economic growth. They rarely make clear reference to the spatial dimension of development, particularly when it comes to translating development objectives into specific courses of actions and allocating resources across the sectors and geographical boundaries. Development objectives are in almost all cases of the ESCWA countries clearly stated in terms of expected rates of economic growth.

Only a few countries, such as Jordan, Bahrain or Oman, have recently attempted to bridge the disparity between the socio- economic and spatial planning. Thus, in Jordan, a housing programme was formulated as part of its 1985-1990 Five-Year Development Plan, for providing affordable shelter, with a view to strengthening the urban hierarchy at the national level.[4/] In Bahrain, a national land-use plan is being developed, based on comprehensive land information systems as a means to coordinate all ongoing and proposed urban planning activities and promote a spatially balanced urban hierarchy;[5/] in Oman structure plans at the subregional level are formulated and coordinated within an overall development framework.[6/]

On the other hand, spatial development strategies, which include new towns, growth poles and growth centres, usually consist of detailed physical designs formulated in isolation from relevant policies to support them, or without realistically assessing the existing technical, managerial and financial capacity to implement them. This has been the case of several countries such as Egypt, Iraq, Bahrain and Kuwait prior to the Gulf crisis,

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4/ Jordan, Ministry of Planning, The National Housing Strategy, 1987.

5/ United Nations Economic and Social Commission for Western Asia, Highlights of the Human Settlements Situation in Bahrain, 1987 (E/ESCWA/HS/87/4).

6/ Oman, Development Council, Fourth Five-Year Development Plan, 1991-1995.

which had limited success in the implementation of their new-towns schemes.7/ Thus Subiya and Al-Wafrah (new towns) in Kuwait, or Isa Town in Bahrain, never succeeded in attracting the desired population threshold; although costly physical infrastructure and housing were provided, there were little economic, social or institutional incentives to promote their growth, particularly among the national population. In Iraq, the plans for developing Suwaira, Al-Madain and Al-Tharthar growth centres were interrupted because of financial constraints and the consequent erosion of political commitment to implement them. In Egypt, the new-towns schemes formulated in the late 1970s are even more problematic, for the huge capital investments and the strong organizational support required to take the pressure off Cairo and Alexandria are simply not available. In fact the implementation of the new-towns schemes would require about 40 per cent of the total budget available for urban development projects up to the year 2000, while it would only accommodate around 10 per cent of the expected increase in population for the same period.8/

At the urban level, efforts to control the growth of primate cities and to strengthen secondary and tertiary urban centres in order to ease the pressure on the major cities have also yielded limited success in the different countries of the region. The most prevalent planning activity in this respect has been the formulation of master plans, which should control and orient the physical, economic and social development of cities and urban centres. All major cities in the region have had master plans, usually covering a 20- or 25-year period, and many of them have been totally revised (in the case of Amman, Kuwait and Makkah) in the light of evolving situations. However, master plans on their own cannot respond to the dynamic process of urban growth; they must be coordinated with institutional and legislative measures which take into consideration financial, technical and socio-political constraints in the process of their implementation. This lack of coordination and the consequent shortcomings of the urban planning system are particularly problematic in the rapidly expanding cities of Beirut, Amman and Cairo.9/ Their overriding urban planning problem is that of enforcing legislation related to land-use, planning and building regulations, delivery and utilization of infrastructure services and controlling land and housing speculation as well as the phenomenon of urban sprawl and its encroachment on arable land. Egypt over the past 25 years has lost around 25 per cent of its

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7/ United Nations Economic and Social Commission for Western Asia, The Human Settlements Situation in the Republic of Egypt, 1986 (E/ESCWA/HS/86/2), and The Human Settlements Situation in the Republic of Iraq, 1985 (E/ESCWA/HS/85/4).

8/ Manfred Poppe, "Structure planning for middle-sized towns in Egypt: a problem-oriented approach", Third World Planning Review, vol. 13, No. 4, (November 1991), pp. 335-355.

9/ United Nations Economic and Social Commission for Western Asia, "Urban planning and the environment in Lebanon, Egypt and Jordan", forthcoming paper (1992).

agricultural land to urban expansion.[10/] Such problems are further aggravated, particularly in the case of Lebanon, by the absence of a reliable database on cadastral registration, housing conditions and needs, among other things.

In the case of the Gulf countries, an orderly textbook approach to master planning has been adopted in their cities, which in most cases have been built on new ground, thus facing minimal financial or institutional constraints at the implementation stages.[11/] As long as the Gulf States' economies were booming, land, housing, infrastructure and public facilities were abundantly provided, based on existing and expected rates of growth and inflow of expatriates. However, the Western planning model of their cities hardly reflects the priority objective of strengthening national participation in all sectors of the economy and all aspects of urban development. In fact, these imported models of development reinforce the dependency on expatriate expertise and technology for the management and implementation of development projects, maintenance of construction work and running of the services sector's activities. In the absence of articulate policies coordinated with physical development plans and with the continued segregation of housing and service provision to nationals versus expatriates, the polyglot nature of these cities is likely to persist.[12/] On the other hand, with the recent slow-down in economic growth and the Gulf crisis, which have led to substantial reduction of the expatriate population, these cities are now faced with problems of housing surplus and underutilization of infrastructure services. Vacancy rates in the housing stock reached around 20 per cent in 1990 in some Saudi Arabian cities.[13/] This means that the planned expansion for these cities has to be revised and more emphasis be placed on urban management for the efficient use of existing resources.

Recently, the trend in the region has been towards incorporating institution building as an integral part of the planning process. This is reflected in a number of revised comprehensive development plans for Amman, Abu Dhabi, Makkah and Madinah, all undertaken in the mid-1980s, and in the most recently formulated reconstruction plan for Lebanon and the reconstruction of downtown Beirut.[14/] The innovative approach in these planning schemes is that they propose development guidelines for the cities

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10/ M. Tarek Shalaby, "Household productivity in new rural settlements in Egypt: perspectives on kitchen gardens", Third World Planning Review, August 1991, vol. 13, No. 3, pp. 237-259.

11/ A. M. Findlay, "Migrants' dreams and planners' nightmares", Cities, vol. 2, (November 1985).

12/ Ibid.

13/ Saleh Al-Hathloul and Mohammed Aslam Mughal, "City profile: Jeddah", Cities, vol. 8, No. 4 (November 1991), pp. 267-273.

14/ See Bibliography for a list of development plans.

within their respective regional and national contexts. Furthermore, physical plans are coordinated with legislative, institutional and financial policies and development-control measures for implementation, as well as strategies for developing data banks in the different sectors to ensure constant revision and updating of the ongoing planning process.

Hence, as Governments and concerned authorities are coming to realize that planning is an ongoing and multi-disciplinary process, requiring the integration of various sources of timely, standardized and systematic information, there is an urgent need to improve, strengthen and integrate the underlying information base of planning. Management of information and the development of spatially related information are among the most important components of information systems for planning. However, as will be indicated subsequently, there are important prerequisites to comply with in order to ensure an efficient and useful system of information collection, analysis, processing and management.

B. Considerations for an optimal planning process

The introduction of information systems in urban management and planning activities necessitates not only a good understanding of the underlying information technology, but also the envisaging of an optimal planning process in which information systems are adapted to suit the needs, conditions and potentials of the region. In this process, there are four important and interrelated issues that planners and policy makers should take into consideration when adapting information systems to their various planning and urban management functions. These are: (1) The "process" approach to planning; (2) the participation of the beneficiaries in the planning process; (3) the decentralization of decision-making in planning; and (4) the development of an integrated information base.[15/]

1. The process approach

As some countries in the region have already realized, human settlements planning should move away from the conventional "blue print" approach in which detailed designs are formulated without an adequate understanding of the dynamics of urban growth and change.[16/] Conversely, planning should be treated as an ongoing and continuous process which allows constant revision, updating and reformulation of plans within the pre-set guiding framework. This process is particularly important given the uniqueness of each planning environment and the substantial number of variables that have to be accounted for when devising plans and design schemes.

15/ Dennis Rondinelli, Development Projects as Policy Experiments (London and New York, Methuen, 1983).

16/ Dennis Rondinelli and Kenneth Ruddle, Urbanization and Rural Development: A Spatial Policy for Equitable Growth (New York, London, Sydney and Toronto, Praeger Publishers, 1979).

A typical case in point is the changing population movement between labour-importing and labour-supplying countries in the ESCWA region and the consequent fluctuation in demand for housing, infrastructure facilities and various other public services. As the recent Gulf crisis indicates, the fluctuation in demand for housing, public services and job opportunities has been even more accentuated. Thus, while Gulf countries have witnessed higher vacancy rates in their housing stocks, countries like Jordan, Yemen and Lebanon are being flooded with the majority of returnees and thus have to provide them with all necessary shelter, services and job opportunities. The returnees just from ESCWA countries were estimated at around 1.95 million, which constitutes 75 per cent of the total number of people who left the Gulf in 1990-1991.[17/] The conventional planning process consists of providing detailed plans and designs, based on an existing situation and expected (or desirable) alternative developments in the future. As such, the rigidity of this approach entails considerable waste in resources and time invested in producing these plans and can only increase the disparity between planning and implementation.[18/] This could in fact be avoided if there is a planning mechanism that ensures a regular and speedy flow of information among concerned agencies and consequently leaves room for continous revision of policies and courses of action.

2. Participation and feedback

The process approach to planning calls for the related and equally important functions of participation and feedback. In principle, these functions should be part of every planning process to allow accurate assessment and updating of information on needs, preferences, expectations, affordability, etc., of the various groups in societies. This in fact has been the main criticism about the failure of some of the new-town programmes, as indicated earlier, and of the turnkey public housing projects of the 1960s and 1970s in countries like Egypt, the Syrian Arab Republic, Iraq and Saudi Arabia.[19/] It was only after their unsuccessful implementation that the concerned authorities realized that the housing units provided were either unaffordable to the targeted beneficiaries, unsuitable to their social and cultural environment or simply not matching their needs. The importance ofincorporating participation and feedback into the planning process has been reflected recently by a tendency to promote upgrading, sites and services, land allocation and housing loan schemes which assume a considerable degree of involvement by the beneficiaries in the housing development process. Although

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17/ United Nations Economic and Social Commission for Western Asia, "The return of Jordanian/Palestinian nationals from Kuwait: economic and social implications for Jordan", September 1991, Amman, Jordan.

18/ A.M. Findlay, "Migrants' Dreams and Planners' Nightmares", Cities, vol. 2 (November 1985).

19/ United Nations Economic and Social Commission for Western Asia, "Overview of the low-cost housing situation in the ESCWA region", Regional Seminar on Housing and Development, United Nations Centre for Human Settlements (HABITAT), Amman, 1-3 October 1989.

these projects are still undertaken as pilot schemes (in Amman, Aqaba, Damascus, Cairo or Sana'a), they nonetheless have proved more appropriate than the previous generation of public housing programmes.[20/]

3. Decentralization of decision-making

However, the participation of the beneficiaries in the planning process cannot be effective, unless it is paralleled by administrative and financial decentralization of decision-making to the local level, with respect to planning and implementation. Indeed, much of the difficulties encountered in plan implementation, such as poor public services delivery, result from ineffectiveness in the urban management system, particularly when financial and administrative authority is highly centralized.[21/] In fact, local administrators are better positioned to understand the needs of local communities, mobilize them to ensure their support and achieve time and cost savings in the various urban management functions. However, this necessitates firm political commitment to strengthen local resources, and provide them with the necessary support in terms of training, equipment and finance.

4. Integrated information base

The efficient adaptation of information systems to human settlements planning necessitates, as indicated earlier, the integration of design with the policy framework and the urban plan within its regional setting. This calls for more systematic research into the spatial implications of social, economic and institutional policies. More specifically, planners and policy makers need to carefully assess the effects of the public investments and policies devised in national economic development plans on the human settlements hierarchy, and in turn assess the ability of the urban centres to act as recipients and generators of urban growth.[22/] This can be developed through an inventory of existing and required spatial linkages at the local, regional and national levels and would include information on transport and communication networks, commuting patterns and population movements, sizes of intermediate centres and the range of services they offer. In this way, the interrelation of information bases would allow the testing of the spatial impact of alternative policies. Moreover, such an approach falls in line with the revised development plans for Amman or Abu Dhabi, (see above) and their underlying concept of integrating urban and local plans within their respective regions, in order to strengthen their ability to diffuse and spread out growth to the periphery.

Finally, an equally important requirement for an optimal planning process is the establishment and updating of a well-integrated information base. As indicated above, many countries in the ESCWA region, notably Lebanon and Yemen,

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20/ *Ibid*.

21/ United Nations Economic and Social Commission for Western Asia, "City management in the ESCWA region", 1989 (E/ESCWA/HS/89/1).

22/ Dennis Rondinelli and Kenneth Ruddle, *op.cit*.

are constrained by the unavailability of reliable, timely and consistent data; in some other cases, a range of information on land-use, income distribution and ethnic composition of the population is labelled as restricted or confidential and therefore remains inaccessible to potential users. In particular, reliable and up-to-date base maps and other spatial data on land use, cadastral registry, existing and proposed infrastructure networks, development control measures, housing conditions, etc., are basic types of information required for setting up such a system.

On the other hand, the strengthening and interrelation of the database necessitates the institutionalization of the flow of information between central and local government agencies, through the development of communications linkages.[23/]

C. The role of information systems in human settlements planning

Many Governments in the region are now reviewing the substantive, procedural and institutional aspects of their respective planning machineries to make them more responsive to the complex and dynamic nature of urban growth.[24/] In this process, much emphasis is being placed on establishing data banks to provide a comprehensive and integrated information base for planning and decision-making activities. Information systems, which are growing along parallel lines, could provide vital analytical, organizational and managerial tools for such activities.[25/]

Information systems, notably geographical information systems (GIS), contribute to an integrative process of planning by interrelating demographic, social, economic and environmental attributes within geographical boundaries. For example, they can: compare the physical expansion of various cities; assess the linkages binding the urban hierarchy in terms of transport networks, flow of population, capital, goods and services; and represent them spatially. They can further analyse different land-use patterns and housing conditions, and can provide optimal locations for public facilities and industrial sites, and residential, employment and institutional uses at the local, urban or regional level.

More importantly, they allow the systematic and continuous updating of data -- and consequently the revision and reformulation of many and complex development alternatives according to new sets of variables or the introduction of unexpected changes in any related sector. This helps in establishing timely, consistent, standardized and up-to-date information bases as well as in formulating planning schemes tailored to the changing needs and development priorities of societies.

23/ United Nations Economic and Social Commission for Western Asia, "City management in the ESCWA region" 1989 (E/ESCWA/HS/89/1).

24/ Dennis Rondinelli and Kenneth Ruddle, op.cit.

25/ Britton Harris, "Beyond geographic information systems: computers and the planning professional", Journal of the American Planning Association, vol. 55, No. 1 (Winter 1989).

Similarly, through their networking functions, information systems promote the systematic flow of data and hence feedback among various agencies. Above all, they allow the coordination of public services, including planned maintenance, and upgrading and extension of the infrastructure networks, within the overall development framework of the urban centres.

However, as will be explained subsequently, the adequate implementation of GIS requires a clear vision of the purpose for developing GIS, their range of applications and their limitations. Most importantly, needs in information, base maps and training mechanisms should be defined and pilot projects undertaken prior to the development of such sophisticated systems.

II. INTRODUCTION TO GIS

A. Basic definitions

A system is a collection of interrelated elements or subsystems, and information is the result of processing data into a meaningful form. Thus, an information system is a data processing system that provides information to users in a quick and accurate manner so as to form the basis for decisions. A geographic information system (GIS) is an integrated information system that processes information relating to basic units of geographic data, land parcels, roads, habitats or zones.

This type information system goes under many guises: geographical information systems (GIS), land information systems (LIS) (usually related to land parcels and ownership), and municipal information systems (MIS) (serving the needs of municipal activities, e.g., that being installed for Baghdad municipality). Some are hand operated with simple records, some are complex automated digital systems, but all have one thing in common in that they are geographical in nature. For this reason, in this report reference is made only to GIS, but this is intended to encompass all other nomenclature.

Any organization setting out to implement GIS, from scratch is faced with a bewildering array of systems suppliers, possible applications, hardware configurations, software options and costs. In the West generally, the potential benefits of GIS technology have only recently begun to be realized, and the large number of systems suppliers are beginning to respond to the growing demands. The number of professional bodies with a central or peripheral interest in GIS is growing, and at many exhibitions and conferences of these bodies GIS are being actively and aggressively marketed. To outside visitors, the new systems may appear to answer many of their long-standing data and analysis problems; thus pressure for introducing these new technologies in developing countries is building. However, the introduction of GIS in developing economies is fraught with difficulties, as this report will investigate.

Today many organizations in Europe, the United Kingdom, the United States and Australia have begun to install GIS. Relatively few, however, are fully operational despite having relatively sophisticated information databases and communications facilities available. It would be true to say that GIS is still only in the research phase.

Countries in the ESCWA regions now wish to follow the example of the Western countries in the installation of GIS in an attempt to solve basic data problems by the use of computerized data management. This may show short-term benefits, but, as we shall see, in the long term, without adequate preparation, accurate data and an exhaustive pilot study, it may have catastrophic long-term results.

Choosing a GIS which is appropriate for any particular application is very difficult, as not all proprietary GIS have the same functionality. A significant part of this paper investigates the functions which are required for most applications in a GIS and looks at a handful of systems in more detail to see the range and sophistication of tools available.

Before looking at the details of GIS and its applications, it helps to define what a GIS is and does. Basically a GIS is a system of managing records within an organization -- or among organizations -- which allows those records to be shared by all users. The records relate directly or indirectly to geographic information, or more usually to maps. Maps have traditionally formed the core of a GIS, as they are a means of relating spatial data of various categories and carrying various attributes (such as names) in a single, easily stored and readable document. A good GIS does not necessarily require computers for effective operation, although in contemporary literature GIS and computers are synonymous.

A GIS is intended to convey information to its users. In addition, a GIS usually requires collaboration and communications among many departments within any organization, be that organization a national Government or some small commercial company. The benefits of sharing this communicated common data can be enormous, because this means there will be consistency between departments in the data they use to make analyses. Setting up reliable data communication and information flows among various departments in an organization is of paramount importance and, taken together with the accuracy of the input mapping data, represents the two biggest single risks to successful GIS implementation. It is therefore important that all departments involved in GIS development learn to share data and communicate openly with each other. If this does not occur, then the potential benefits of implementing GIS will not be realized. Unfortunately, this sharing of data between departments or organizations is often not the norm, in particular in developing countries.

GIS has to do with maps, be they line maps on paper or digital maps on computer, and an organization which has a central survey department which creates and maintains maps at a variety of scales which fully meet the needs of all other departments already operates a successful GIS. If, on the other hand, each department maintains its own maps, at a scale which suits them because the survey department either doesn't exist or because it can't provide a reasonable update or revision service, then the local GIS is not operating effectively.

The concept then of sharing common data, of common currency which reflects a consistent model of the real world, is central to GIS, whether it is computerized or not.

Regardless of the sophistication of the analyses required by user departments, GIS must have the ability to capture relevant data from the real world and model this data in a consistent and timely way. A GIS must allow the latest version of a given map to be stored and distributed to all required users efficiently and quickly. There must be some type of locational referencing which allows all departments involved to locate an appropriate map and to define positions on that map with sufficient accuracy for the task at hand. Each department must have the skills and techniques to add detail to the mapping and to make subjective numeric analyses of the results. Traditionally, many analyses are made by overlaying two or more maps of the same area and defining areas of commonality or adjacency. A basic requirement of this is that the various map layers, e.g. base topographic map and geological overlay, are of the same area, at the same scale, of common timeliness and of similar geometric accuracy. If any of these basic criteria are not met, then errors will be propagated as a result of inconsistencies in the data.

In any effective manual GIS, a user department may have records which are stored separately but which relate to the mapping. Land ownership and tax records provide a good example. The link between outline and text detail on the map and associated records about ownership, cost, tax, restrictions, etc., is vital and may be made through a grid reference, a common address, a street name, a town name or some other form of address referencing. In most practical cases the quantity of associated data is too much to display on the map surface itself and a separate database or records system is required.

It can be seen, then, that even in a manual GIS the problems of concurrence, accuracy and communication between user departments within any organization may be complex. The use of computer systems to handle the data and to assist in storage and analyses is designed to simplify the complexity, but to do this it is of prime importance that the initial input data is accurate and timely. Otherwise, the problems and complexity are compounded.

B. Growth in computerized GIS

Over the last 20 years, the developed world has been investing in digital techniques for record keeping at an accelerating pace. Digital mapping was developed to make the production of maps cheaper than by manual means. In this respect, it has only been marginally successful, but it has allowed mapping organizations to have some sort of mapping information available in digital form as the user requirement for digital mapping increases. Many map users have been systematically digitizing their respective data for some time, using appropriate database techniques to suit their own applications. In Europe and the United States especially, a significant part of the major cost to computerize GIS, that is converting data from analog to digital form, has already been met. It will be emphasized again and again in this report that this preliminary data conversion has hardly yet begun in many countries in the ESCWA region and these countries cannot expect to immediately jump onto the GIS bandwagon without a great amount of preliminary work.

The technologies and philosophies that have recently developed and which have allowed computerized GIS in developed countries to become popular are complex, but a certain level of understanding is nevertheless important, so that a better understanding of the requirements for GIS in developing countries is gleaned. Very simplistically stated, the underlying concepts are:

(a) There is a growing awareness that shared data saves money;

(b) The growth of digital systems for mapping and for record systems has been taking place for some time. It is but a short hop to integrate these two basic data types: maps and associated attributes;

(c) Under increasing economic pressure and competitiveness, organizations view digital data as providing a means of expanding the usefulness of data, particularly in terms of automating analyses and creating new products;

(d) There has been a rapid growth in data availability through more efficient surveys. A single scan of thematic mapping data, captured digitally from a United States space-borne sensor in 10 seconds, contains approximately 30-40 megabytes of data;

(e) The costs of computer software and (especially) hardware continue to fall, while the capabilities, standards and user-friendliness of systems continue to increase;

(f) Processors continue to become faster, hard-disc storage and retrieval is cheap, optical storage technology is maturing, and graphics technology has made monumental advances recently;

(g) There is a growing proliferation of uniform standards in the West, both in terms of hardware platforms, and software and operating systems, and in data transfer formats;

(h) Software systems for handling massive databases have evolved recently which allow efficient storage and analysis of tabular data. These database systems have become standard and operate more easily than they did previously in a wide range of hardware platforms under various operating systems. In particular the role of the microcomputer in these areas has increased dramatically;

(i) There is growing awareness and familiarity with digital systems as they become more and more a part of everyday life.

The result of this activity is that, in the West, most local authorities and regional governments are at least considering the benefits of GIS. Some are actively engaged in detailed pilot projects to assess in more detail the complex issues of combining data from various sources. The positive approach of potential users and central government has led, in part, to the growth in available GIS systems. The annex provides a selective list of GIS available to date and their main features. The list is expanding almost daily.

C. Which GIS to buy? Major characteristics

Any GIS should have a number of basic functions available. The sophistication of these functions should be assessed against a defined user requirement. The functions must:

(a) Allow data to be fed into the system, both from maps and from other sources, and be stored in the system;

(b) Allow some analyses to take place; this can take the form most simply of overlaying two independent sets of data or at a more complex level may allow three-dimensional modelling or network analyses to take place;

(c) Allow outputs of either maps or related data.

These few basic features -- input, storage, display, analysis and output of data -- form the basic criteria against which the applicability of proprietary GIS can be measured. In order to add weight to these criteria, the applications and potential benefits to an organization must be fully understood so as to narrow options to a handful. Once this has been done it may be possible to undertake benchmark tests to evaluate the particular package which meets the needs of an organization. In other words, one prerequisite to installing a GIS is the development of a specification against which the effectiveness of proprietary systems can be measured. The risk of not defining carefully what a GIS will do or is required to do can be great; the wrong system may be purchased, which does not do a basic task; alternatively, an expensive, sophisticated toolset will be bought to undertake a very simple set of operations. It is often better for an organization which is considering installing a GIS, but which is inexperienced in digital techniques, to start development on a cheap GIS system in order to develop awareness in-house, to learn of techniques to transform data from analog to digital and to establish the inter-departmental communication links necessary to successful long-term implementation

D. Constraints to GIS in the ESCWA region

There is a trend in the developing world to grasp at new technologies to solve some of the basic problems of data management. Whilst the problems at hand may be solved with proper use of these technologies, it is essential that the problems be fully identified before the new technologies are introduced, and wherever possible be manually rectified.

An effective GIS operates well with good, consistent and timely data, both map-based and map-related (attributes). It has been shown that by far the greatest cost of GIS installation and application is the data conversion process. This cost will invariably be greater than all the hardware, software and training necessary to maintain a GIS. In many parts of the West, highly accurate and up-to-date, large-scale topographic mapping is already available in paper form. The cost of digitizing the maps is small compared to the initial survey and compilation procedures which are required to create the map in the first place. Unfortunately, all too often in the developing world the quality of the base mapping is poor or is not at a sufficiently detailed scale to depict accurately the positions and classifications of features required by map users.

Although the costs of map digitizing may be kept relatively low -- through map scanning as opposed to vector digitizing, for example -- poor quality or old mapping entering the GIS will form an unstable base onto which other data will be related and analyses made. A prerequisite of any GIS, therefore, is that up-to-date mapping is available, that a revision programme is operational and that the base mapping is at a suitable scale and accuracy to support the most demanding of applications. This may well require a complete revision of the old mapping and will cost as much, if not more, than the installation of the GIS itself.

In countries of the ESCWA region, there are often departmental constraints to GIS development. As has already been mentioned, GIS implies sharing data among departments. This implies that all departments within a municipality, for example, have common goals and resources allocated to them. It is sometimes the case that funds for GIS projects become available to meet a specific application only within a particular department, without addressing the needs of other departments, at great long-term cost to the organization as a whole. Successful GIS implementation therefore requires coordination from the top of an organization to ensure that the needs of all users are taken into account. For successful implementation of GIS in the ESCWA region, therefore, interest, commitment and direction must come from the highest level of the organizations involved. This direction and coordination would lead to setting data standards to which all departments should conform, and would require liaison, training and education amongst all departments. It is in this aspect that the benefits of a pilot project using a limited geographical area to a limited specification could assist in developing familiarity, conformity and expertise. A pilot project, of course, incurs expense, as duplication of records must occur; however, it would be inappropriate for a GIS to "go live" without first having proven its functionality over a small area.

Unfortunately, there tends to be a lower level of familiarity and expertise in handling digital data and computer systems in the ESCWA region as compared to the West. Training of staff in these techniques must go hand in hand with pilot GIS development to ensure a balanced growth and acceptance.

Backup support and maintenance for hardware and software in the region is generally not as good or as cheap as in the United States or Europe, except in the most common of items. Even with the best of systems, hardware failures and software faults still occur, and can be catastrophic if not quickly rectified. There is a strong case for countries in the region to invest in only tried and tested GIS, which are only as complex as are necessary for the required job. It is inevitable that from the plethora of GIS available, some will not survive due to intense commercial competition. One would be well advised to choose a system that is known to be reliable, has world-wide service and maintenance facilities, and, where possible, operates on standard hardware and operating systems.

III. GIS APPLICATIONS

A. Growth in GIS installation

Although there is much increased commercial activity and interest in GIS in developed countries, there are yet only a few fully functional systems in place which span all geo-related activities within organizations.

In the United Kingdom, it is intended that all councils or municipalities be linked by a common GIS, and this is already in the process of planning and installation. Similarly, in South Australia common mapping data is to be shared by State and local government authorities throughout the State; in Sweden an extensive GIS allows land data to be shared by local authorities and real-estate institutes. However although a few local authorities have initiated projects of limited scope to test and validate systems, most local authorities are only at the stage of considering GIS and installing pilot projects. Although pilot projects serve to educate and train, the full benefits of GIS are unlikely to be met until the system encompasses all the activities of an organization.

The major factors inhibiting GIS are probably managerial rather than technical. Most departments within government organizations are relatively insular, whereas GIS implementation is essentially a tool for corporate strategy. Senior management may find GIS intriguing technically but will only be convinced of its application if money is saved, if overall speed of service is increased or if organizational strategic plans can be better implemented.

There is a great deal of interest in developing countries where GIS may (erroneously) be seen as a means to improve the functionality of inherently poor data; this is, of course, a potentially dangerous situation. Certainly the rapid growth in urban population in those countries and the very urgent need to gather and manage records relating to people and housing is probably the stimulus to seek high-technology solutions. Most capital cities in the region are at least considering the use of computerized records systems, but the temptation to keep these proposed systems within limited departments should be avoided if the potential benefits are to be realized.

B. Potential advantages of GIS

By far the greatest advantage of a well-designed GIS is the concept of shared data or a corporate resource of data available in a consistent form to all users. A GIS should, when fully verified, replace all existing geo-related manual records, many of which will have been previously duplicated, leading invariably to inconsistencies in quality and currency (this was seen in Baghdad, where some maps were "maintained" by several departments). A GIS should hold these records only once but should communicate data to the many users in a fast, user-friendly and accurate manner to avoid user departments returning to their old ways. Holding the data only once provides one definitive source, the management and updating of which can be carefully controlled. Updating becomes simple (providing accurate update data has been collected) and drastically reduces redundant and wasteful paper chasing. Whilst this should result in reduced operational costs, it does, of course, depend on good interdepartmental communication.

Where many departments are involved in GIS, and where different "views" of the database are required, some form of distributed database may be appropriate so as to minimize data transfer times and to keep the appropriate data and the responsibility for its maintenance and update with the responsible department. This distributed architecture for a GIS does not detract from the concept of minimal redundancy.

There are, however, some basic trade-offs and constraints which need to be appreciated. Complex information systems will need complex GIS, and greater functionality in a GIS is usually related to increased processing times, a lower level of user-friendliness and a greater need for training. In many applications, much simpler GIS may be appropriate, for example using simple raster or imaging systems for map display. Such systems are cheaper and easier to set up but more difficult to update and have less functionality.

C. Major applications

Most records held within municipalities and other government organizations are likely to be spatially related, that is they relate to a property, address, person, zone, piece of infrastructure, etc. Any such record is a candidate for inclusion into a GIS; it is important that the extent of these records is established in the design phase. Any application which involves mapping is a prime candidate for GIS. Such applications include most activities of the survey department and any related activity which involves overlaying data (either spatial data or attribute information) upon the base mapping. Organizations should not underestimate the extent of its geo-related records, nor should they underestimate the effort required to keep them up to date and mutually consistent.

Whilst this report is specifically addressed to the role of GIS in urban planning and human settlement, it is relevant for a full understanding of GIS to discuss some wider major applications.

1. Survey and mapping

As well as being the greatest input area for GIS, the survey departments are likely to be the largest users of a GIS. Indeed, in some applications it may be cost-effective to install GIS purely to enable consistent map production. Storing map data, in either a simple raster form (i.e., as a composite picture) or as more complex, topologically structured vector data (i.e., as two- or three-dimensional coordinates) is a central role of any GIS, and all systems should have the capability of producing high-quality graphic outputs. If vector data is created representing map points, lines and text as a series of coordinate pairs and ASCII text files with an appropriate position, GIS provides the opportunity to deselect particular feature codes and to change the scale and presentation of map data, within limits. There is, however, a common misconception of GIS, that vector map data will support mapping at any plot scale; unfortunately, this is not the case, and if a wide range of map scales are required, then a range of source maps will have to be digitized. Digitizing maps with sufficient feature codes and accuracy to support all conceivable applications is a very expensive enterprise, not to be taken lightly. Regular updating of mapping and its input into the GIS need to be considered at the outset.

The benefits of being able to produce graphics for many departments which require the same map data in the database -- thus eliminating redundant map upkeep -- saves space, time, effort and potentially expensive errors.

2. Cadastre, land records and tax

All municipalities maintain records of land ownership for tax or title purposes. In many areas, land records may be directly related to base mapping, where land-parcel identification numbers and parcel extent may be shown. A wide range of attribute information is associated with land parcels: owner, sale, buildings, tax, restrictions, charges, type of ownership, etc. Providing that the land parcel can be readily recognized on the base mapping at a consistent scale, a GIS is particularly well suited to the maintenance of related records. The GIS may provide the functionality needed to retrieve and display parcel plots to support title as well as a wide range of text reports for owners and administrators alike. This application is one of the major modules in the GIS being installed in Amman. There may well be a role for this GIS application in settlements planning, as data on existing settlements can readily be obtained through the system.

3. Infrastructure records

Municipalities and other government organizations have responsibility for the supply and maintenance of water, sewerage, electricity, telecommunications, etc. Records of these networks are normally held on maps with associated file records relating to size, upkeep, capacity, etc. Providing that the network can be represented on the base mapping with accuracy, this type of record is very well suited to GIS applications. Great potential savings are possible if all network information can be viewed simultaneously for road and utility maintenance planning, as this can avoid the all-too-common problem associated with multiple disruption of services.

4. Routine and emergency services

Activities such as street cleaning, lighting, environmental control, police, fire and ambulance services can be improved through the use of GIS. If appropriate infrastructure information is logically attached as attributes to a vector representation of the road network, for example, most GIS will provide the ability to make network analyses for optimal routing or inventory control. Such analytical capabilities allow more efficient day-to-day collection and distribution services to be maintained, provided that input data is correct and that the database is designed to optimize record handling. In more advanced GIS, the possibilities of real-time command and control, applicable to emergency services, can be exploited.

5. Land use and urban planning

GIS can allow statistics of land-cover classes to be stored centrally and for thematic or chloropleth maps, based on the most up-to-date maps in the system, to be created. In more complex GIS packages, there may be the facility to incorporate raster image datasets from remote sensing satellites and three-dimensional data with overlay and modelling facilities. Although the data and processing requirements of such a sophisticated system are high, the potential to undertake environmental impact analyses for major planned developments, taking all available map-related data into account, may be cost-justified. An effective GIS allows planning departments to continue their routine functions, but using map data which is common to all other departments. Expensive mistakes can thus be avoided, and map maintenance costs to the department can be reduced.

6. Other application areas

The list of application areas is long; other notable areas would include: pollution and monitoring systems, demographic/census data display, storage and analysis, health services records for management and analysis, and marketing and business development planning.

Given a well-planned and well-implemented GIS, and good interdepartmental communication and freedom of information, the actual applications of GIS have the potential to far exceed initial expectations. Ongoing development of applications and analysis functions is therefore an activity which should run concurrently with initial GIS development.

D. Database management systems

In a complex GIS where many departments are supplying data to a centrally controlled database, there is a critical need for careful data management. There is a need to avoid two or more departments updating the same data simultaneously and a need for all users to "view" the current state of the database. Where redundancy has not been completely eliminated, there is a need for all related records to be simultaneously updated without affecting other users' views.

Similarly, if there is not strict control, there may be too much data available to any one department at any one time, potentially clouding the issues. There is a need in all GIS for some type of system or database administration. In the more complex GIS this can be achieved with attribute and map data held in a database environment with access to the database restricted in some way to avoid excessive data flows and to keep privileges to those departments authorized to make changes to the database. Each user of a GIS in a multi-user environment will not necessarily need to see all the data and will almost certainly only be entitled to change certain elements of data (each department therefore will have its own "view" of the data and limited specific read/write access to those views).

Building a database for a GIS can be a complex issue if there are many client departments to serve. Current moves in database design indicate that the relational database structure is the most appropriate for GIS. Several proprietary databases now exist (ORACLE, INGRES, INFO) which are supported by an emerging de facto standard, SQL (structured query language). SQL allows a database to be loaded, queried and analysed in a uniform, relational way.

The design of a database is a critical component in a multi-user GIS, as it defines all the objects or entities which the database will hold, the relationships between them and the accessibility of views which client departments may have. The exercise of creating the database structure is known as data modelling and is essentially a machine-independent activity designed to optimize database performance through the reduction of redundancy.

Once an entity relationship structure is defined and implemented on a GIS, changing it to allow for new users or departments can be a time-consuming and costly affair. It is therefore important, prior to implementing a GIS, to plan for all possible applications from all possible departments, even if these applications are not used in the first instance.

It should be noted that whilst GIS systems suppliers may provide a database management system with the GIS package, most are unlikely to be able to provide consultancy services necessary to develop the comprehensive data model and database administrative capabilities needed by the system.

A data model, based on the identified needs of all departments, using common data entities, needs to be defined and linked prior to GIS implementation. This is a very specialized task taking possibly several years to develop for a complex system. In simpler geographic information systems, such a comprehensive data model may not be necessary; several PC-based GIS packages have either direct links to relatively unsophisticated databases (such as Dbase III or IV) or provide a very simple data model implementation with a proprietary database management system (such as STRINGS with INGRES).

Prior to GIS implementation, therefore, the requirements of all the departments involved need to be established, the common links or relationships and data flows between departments should be identified and a solution should be found which is straightforward enough to support the most complex application. The answer is not necessarily quickly found and involves an iterative approach.

IV. GIS FUNCTIONS

A. Overview: data and database structures

In most geographic information systems, map data and attribute data are stored in two separate but linked databases. Maps are usually held in a graphics database which is optimized for display and access purposes. Attributes relating to defined entities are more usually held in a proprietary database, often of the relational type and optimized for a range of ad hoc analytical queries, such as joins, selects, projections, etc. Links are usually established between both databases by the use of unique identifiers for each geometric detail and entity.

The complexity of data storage in a GIS is a function of the type of data which the system is handling, the complexity of the attribute data, and the intended application of the system. More complex data structures are more expensive to create and maintain than simple ones, but they allow a more comprehensive range of spatial and statistical analyses. In a simple microcomputer GIS, for example, limited attribute data may be held as tables in a non-relational database, such as Dbase III or IV. The advantage of such an approach would be low cost; the disadvantages would include slow response or limited spatial analyses.

Similarly, there is a range of complexity at which map, or graphic data, can be stored, again reflecting variations in cost of data capture and functionality. Maps are required in a computerized GIS in electronic form, and in the most simple form this can be achieved by acquiring a machine-readable facsimile of a map by either digitally scanning or video-digitizing the maps. Scanning involves pixellating (or reading bit by bit) a map and attributing a digital number to the spectral (or colour) response of that part (or bit) of the map. The resolution, both spatial and spectral, needs editing to achieve the desired result, but in general the resulting raster image, in black and white or colour, requires large volumetric storage. Video capture is an alternative which has been used successfully in some GIS applications. In this application, video images may be held on a videodisc, where up to 55,000 images can be stored. As each video image is a discrete picture of a small part of a map, there is a requirement for carefully standardized data capture and overlap between scenes, and a need to scan or video-capture maps at various scales to achieve optimum viewing performance at varying view levels. Both raster scanning and video imaging are relatively cheap but can only provide coarse backdrop mapping onto which attribute information from the GIS database can be laid. Updating this type of map data may be problematic, particularly when the large volumes of data are stored on optical media such as CD ROM or videodisc. Such an approach does have advantages: it is robust, cheap and can meet the needs of the more simple GIS. Where the main reason for a GIS is to display attributes (regional or detailed) on a base map background, this may be the preferred approach.

At a more complex level, used by most analytical GIS, map data can be vector digitized. In this case, every point, line, or text detail on the map face is digitized by a cursor to yield eastings and northings, or latitude and longitude, for each and every point. Lines are made up of a series of points, and text is digitized as an ASCII file with coordinates for its position, angle and font. The data generated may be used for map plotting and production but has little use for many types of analysis unless topology, or structure, is introduced into it. Structure is created by linking together lines to join at unique points and by attributing links with topology. In other words, each link would have, as a logical attribute, a polygon to which it belongs. Every point and line needs to have some feature code attributed to it, such as road edge, pipeline, street light, edge of building, etc. The use of a large number of feature codes adds greatly to the cost and time of digitizing but adds flexibility to the display and analytical characteristics. As a rule of thumb, it would be prudent to digitize the fewest feature codes necessary to achieve the analytical objectives of the GIS.

Each point, line or polygon feature which is vector-digitized should have a unique reference number attached to it, as an identifier. It is this number which provides the linkage between the graphics database and the attribute database. For example, a line may have several attributes; it may be part of an administrative boundary, a fence line and the edge of a planning zone, all represented by a single set of geometry. The geometry records are therefore held only once, but the geometry identifier is an attribute of the tables or relations called administrative area, fences or planning zones. Thus a unique pointer is defined in all appropriate attribute tables to the single link.

Keeping the map geometry in a vector database separate from the relational database management system (RDBMS) can allow optimization for display of graphics. Other than for display of graphics, the actual map geometry is not frequently used. Lines may be of any length and thus contain a variable quantity of coordinate pairs. If this variable geometry is held as attributes in the RDBMS, there is a risk of allocating too much space to the storage of geometry, thus reducing performance. In an RDBMS, the attribute fields are of fixed length in any one relational table, so although point geometry records may be efficiently stored, line geometry would be very wasteful of storage space.

B. Input

A good GIS package will allow a range of data-capture techniques: hand digitizing; raster scanning; software-vectorizing from raster-scanned imagery; it will do this directly from digital field surveys or will provide bulk inputs of digital map data in a standard United States or United Kingdom format. Attributes should be entered by manual or bulk input.

1. Hand digitizing

Hand digitizing is the transfer of geographic detail in vector form using a digitizing tablet to transfer coordinate pair values to the graphic database. The software should allow both blind and interactive digitizing of point, line or polygon geometry and map-face text as an attribute. Features are captured using a cursor on a digitizing tablet which records eastings and northings either at discrete points or in stream mode. Each feature should have a unique identifier, be scaleable, and have one or more feature codes or classifications attributed to it. Manual digitizing causes some errors, such as closed loops not closing or unique intersections that do not intersect correctly. The GIS software should have the capability to manipulate, edit, move, delete, and change classifications or feature codes of all detail, create structure within user-defined tolerances and create new points where line features intersect. The software should allow different map levels to be defined and edited separately. It should have sufficient flexibility for the user to define special command files or macros to undertake special, oft-repeated tasks. Finally, the system should allow existing map files to be edge-matched with other map files to within tolerable limits and allow a map once digitized to be re-setup on the digitizing table to add revision data of new detail.

2. <u>Raster scanning</u>

In more simple GIS there will be a need to import raster data files either through scanning or by accepting data scanned outside by some bureau. The system should recognize the various common formats and data compaction routines. In some specialist GIS, there may be a need to allow satellite remote-sensing data to be fed into the system and for simple image-processing functions to take place. The system should handle standard imagery such as Thematic Mapper or SPOT data.

3. <u>Field survey or photogrammetric data</u>

Hand-digitizing maps is invariably a labour-intensive and error-generating activity, even if comprehensive quality controls are applied. It represents capturing data twice, once in initial survey and again in digitizing. To eliminate capturing data twice involves a direct line from either sophisticated field survey total stations or from digital analytical photogrammetric plotting instruments. This is a complex activity, outside the scope of this report, but if data capture is a large task and digital photogrammetric or survey instrumentation is available, the interfaces from these systems into the GIS need to be considered and evaluated. In particular, if the existing mapping is inaccurate or out of date and in need of updating, then this option should be seriously considered.

4. <u>Bulk inputs</u>

In the developed world, digital map data in standard formats is becoming more widely available from the major map manufacturers. In the United Kingdom, for example, National Transfer Format is being produced for all map data at all scales. In the United States, DIME and TIGER file formats have been developed specifically for census applications, and the data is in the public domain. In the ESCWA region it is unlikely that map data, or elements of map data, are already available; however, it is worth considering that an interface from commonly accepted international formats into the local GIS format for subsequent editing and manipulation may be appropriate.

5. <u>Software vector-digitizing</u>

Currently, the scene of intense software development is a set of procedures which automatically transforms raster map data into a set of vectors. The successful implementation of such software would yield great benefits for GIS users, as it would do away with the costly activity of hand-digitizing. The process works on the basis of pattern recognition on the raster data, but to date no fully automatic system has emerged which is more cost-effective than manual work. This software is related to optical character recognition (OCR), which is now implemented in some desktop publishing packages to good effect. Neither automatic feature recognition nor OCR yet work effectively on map data, where line work tends to be complex and where text is often of variable font, size and angle on the map. It is an area currently being developed and major breakthroughs are possible.

6. Attribute capture

Most GIS map-capture and editing software allows a reasonable degree of interactive attribute capture, such as point, line and area types, and names. Related records, such as those required in the relational database attribute fields, need to be entered either as the geometry detail is captured or in a bulk or form-filling mode directly into the database tables. If the former approach is used, the map-data editor needs to be flexible enough to allow user-defined attributes to be connected to each feature in a friendly way; this is unlikely with existing microcomputer systems. Alternatively, SQL can usually support a query by a forms approach to loading data into tables interactively. The GIS software ideally would provide a graphics check that the rows being entered relate to the appropriate graphic entity.

Data input is almost certainly the major cost activity in establishing a database for a GIS. Great care is necessary in defining not only the required functions of a GIS but also the user friendliness, ease and speed of use, accuracy and repeatability and need for user-defined functions.

C. Display

This function is normally associated with data capture, in that in most interactive editing software the user can see the map being generated. There are, however, some features of map display which warrant special attention.

In addition to queries and analysis functions of the attribute database, display on screen of selected maps and layers of the GIS can be regarded as an additional analysis function. Display is, in fact, probably the most widely-used element of analysis.

In a simple GIS, where raster or video mapping is used, there is limited flexibility in display. Essentially, the GIS user will see what was scanned in its entirety. In scanned maps the user should have the facility to roam and zoom into the mapping, although it is accepted that these features will be limited by the nature of the data. Zooming into the image will only increase the pixel size until a point is reached at which the map image becomes blurred. Where a large range of scales of maps needs to be viewed (different applications require different scales), it may be necessary to scan maps at various scales of the same area so that, in zooming, a totally different map image of the same area is displayed. Various GIS are able to do this, but depend on a range of scales of paper maps being available initially.

Roaming, or panning across map sheets, is limited by the extent of the scanned image; some overlap between images may be required to minimize excessive hopping between scenes. Although the use of scanned or video images has advantages (it presents a familiar image, for example), the data is not as "intelligent" as vectors, and it requires large amounts of screen or cache memory to hold the image data. Access to the display should be through a grid reference, or page or sheet number, through a range of gazetteers or by selection such as querying database tables.

Vector mapping, on the other hand, provides a great deal more flexibility, and good GIS software allows map types to be pre-defined and features to be deselected to simplify the screen image. Limited scale changes are possible using vector data, but if a wide range of map scales are required, then a range of maps of different scales will need to be digitized, adding significantly to the overall cost. There have long been efforts to automate map generalization, so that a large-scale map can be displayed at any scale, but so far research has met with only very limited success. The problem is essentially one of filtering out detail with reducing scale, and physically moving detail and text where there would be a clash. Handling large quantities of large-scale data for a small-scale output presents an input/output (I/O) and computational load for a GIS.

For practical purposes, most GIS software should allow limited scale changes (plus or minus two or three times the original scale) and a means to define map-display characteristics for major users of the system. Header, legend, border and grid data design software should be available. Map design from digital map data is a complex field which the major digital map producers are only now beginning to tackle. It is most unlikely that off-the-shelf GIS packages have the ability to produce graphics of the high quality expected of hand-drawn maps.

Graphic symbols for vector mapping should be available in a library residing in the GIS software, to allow attribute database features to be displayed in user-defined shapes, colours and sizes. In addition, this (on-line) library should define at what scales the features are to be turned on or off, so as to minimize the clutter of text and detail for small-scale display.

D. Storage

As has already been mentioned, in a sophisticated GIS, graphics data usually reside within a graphics database, separate from the relational tables of the attribute database. The main reason for this is that line lengths can be highly variable, and to define a fixed field width for a variable-length line is very wasteful of space and will slow the performance of the database. Point data, on the other hand, is of fixed length (east and north coordinates) and can therefore be stored in the database more efficiently. Graphics data is normally held in a "flat file", or sequential format.

The range of attribute data, regardless of its source, will be held in a database, preferably relational and preferably accessible by the user of SQL. Relational database technology has emerged over the last five years as the most appropriate technique not only for GIS but for other large databases.

The RDBMS should control read/write access and all security and privileges of the data, and be able to sort out deadlocks and provide journals of data transactions in the event of power failure or disc crashes.

The use of relational tables, if carefully designed in the data-modelling phase, optimizes performance while minimizing redundancy and required disc storage. Good GIS software allows automated and clustered indexing of tables on input or deletion of data to reduce search times for SQL queries. The use of indexes avoids making the system read all files sequentially to obtain an appropriate record, and thus speeds performance.

RDBMS allows rigorous techniques to be defined in data storage. This approach ensures that all queries defined in SQL will be efficiently executed. There are, however, trade-offs involved; for example, if the database is fully normalized (i.e. all redundancy eliminated), some of the queries can take excessive time to be processed. If it is expected that most queries of the database will follow a particular path, the database schema can be designed to optimize for these particular queries at the cost of storage and the speed of ad hoc queries.

Very simple GIS may provide links to proprietary microcomputer-based database packages, such as Dbase III. The functionality of the system will be limited by Dbase, but the advantage, of course, is reduced cost and simplicity of operation.

A full-scale GIS should offer the user the ability to define, create and edit relational tables and to feed data in and out of tables using SQL. Embedded SQL in another third-generation programming language should be available for batch operations into or out of the database. Lastly, the database should allow for bulk import and export of data files into and out of tables, to and from ASCII or EBCDIC files.

E. Analysis

The analysis functions of a GIS are perhaps the most dynamic and the most important from the users' point of view. As processing speeds increase and memory becomes cheaper, more complex processing can take place. The gradual introduction of parallel processing techniques is likely to have a major impact on GIS analysis functions in the near future.

This review will attempt only to highlight the major analysis functions one might expect to find in the most comprehensive GIS. Most microcomputer-based GIS will have only some analysis functions; however, not all users need all functions. Analysis of data in a GIS performs the core function, that of processing data to yield results in either graphic/map form or as tables or statistics. In modern database structures, most analyses will take place through applications programs with embedded SQL functions. A good GIS package includes features that allow users to define and create their own applications programs in addition to "off-the-shelf" packages.

In the most simple of raster-based GIS, only limited functions will be available, which for many applications (command and control for example) should be sufficient. These include primarily map and attribute display (as previously explained) and tabular reports and statistics to be made from database tables through SQL queries.

In more complex GIS, the following functions and applications may be available:

1. <u>Point in polygons, line in polygons and polygons in polygons</u>

These procedures allow graphic objects, be they points, lines or polygons, to be processed in the context of other objects. A simple example would be an order to find all particular point features which lie in a particular polygon. In essence, this function is an extension of SQL, which may require significant memory and processor resources. Polygon-in-polygon searches are the most complex, as many resulting new polygons can be created. The more sophisticated GIS packages may allow software-created polygons to be held separately and relational tables to be defined for the output features. This function can effectively answer a query such as "What is the result of mixing group A land cover polygons with group C geological or soil polygons?" The resulting new polygons can be stored as a separate GIS layer with appropriate attributes and derived statistics.

2. <u>Buffering</u>

This procedure allows buffer zones or polygons to be built automatically around points, lines or objects. The resulting enlarged (or reduced) polygons can be processed in a polygon/polygon analysis described above. The application of such software is particularly relevant in "what if" queries. For example "If I build a road along this particular alignment, what are the names and addresses of all occupants/owners of land within 100 metres?"

3. <u>Boolean algebra</u>

Most GIS have the ability to handle 'and', 'or', and 'not' queries, and SQL functions allow for this. This is particularly useful in defining display or print characteristics. Boolean functions have particular advantages in handling raster datasets.

4. <u>Statistics</u>

SQL allows a wide variety of statistics to be generated both to answer technical queries and to provide management information. For example, "How many occurrences are there of 'x' in 'y' area, and what is the mean/medium/total value of 'x'?"

5. <u>Routing</u>

Vector digital data in a GIS, if structured rigorously, allows network and locational analyses to take place. Some GIS may have network software in place, others may not. Either way, a good GIS should at least allow imported software to operate on the graphics database.

6. <u>Image processing</u>

In a GIS requiring scanned imagery, air photography, or satellite remote-sensed imagery to be used for classification or data extraction, a large range of image-processing functions will be required. This is a relatively specialized requirement with demands on I/O, disc space, processing and display which generally exceed those for manipulating vector data. Several raster-based GIS packages exist, some of which now provide a link to vector-based GIS to provide a powerful tool. Traditionally, image processing has been a function of mini or mainframe systems, but recent improvements in hardware have allowed these activities to migrate to microcomputers and graphics workstations.

In brief, the main functions required are:

(a) Geometric and spectral rectification and re-sampling;
(b) Classification techniques;
(c) Image operators (Boolean algebra);
(d) Noise reduction;
(e) Spatial and spectral filters.

As satellite remote-sensing imagery is at relatively low resolution and scale (10 metres in SPOT), the applications in detailed municipality GIS are likely to remain rather limited to broad-brush classifications and map-revision intelligence. Due to this factor, imagery may best be interpreted in manual form and resulting classifications or line work entered into the GIS as vectors.

7. Terrain modelling

This is another specialized application which can use height data (digitized contours for example) to create a digital terrain model (DTM), a gridded raster pattern of heights. The DTM can be processed using image processing-type functions which operate on raster images. Other image data or vector line work may be overlaid on the DTM and viewed from oblique angles or in cross-section to improve environmental impact assessment.

Some sophisticated GIS packages offer DTM production and analysis functions, but on microcomputer systems the capabilities are almost certainly limited to restricted areas or small datasets, as the processing requirements are significant. The results of terrain modelling can be appealing, and much use is made of this type of analysis function by system vendors.

F. Maintenance

No information system is static. The real world changes, so the GIS model of it should reflect these changes. GIS editing and database tools should be available to periodically update either the graphics or attribute database. Where raster-scanned or video-based maps form the base of the GIS, maintenance can be more problematic, as scanning newly published maps may be an unnecessary overhead. In this case, it may be more appropriate to vector-digitize changed information for graphic overlay on the map image. Any GIS which allows data entry and editing will support maintenance, provided a set of procedures has been defined by the system administrator to manage updating.

The use of date tags as attributes for each feature can assist in querying the database for time-dependent queries, e.g., "Illustrate developments between year x and y." Incorporation of history records in a database provides more flexibility, but at a cost of extra operator effort in data loading. This trade-off should be assessed in the database design phase. The use of date tags can also prove beneficial in enhancing management information statistics.

G. Output

So far output has only been discussed in the form of screen images. There will inevitably be a need to output tabular data, statistics and maps in hard-copy form for client departments and possibly a need to export data files in some standard format to external users or client departments not included in the GIS network. Hardware required for the range of output products will be discussed in the following chapter. This section investigates the main types of output which need to be supported in a GIS.

1. Tabular reports

SQL queries of the database can be made in a variety of ways: query by forms, query by example or user-defined queries. A good database will provide all these options and a range of line-printer options. In addition, some proprietary databases provide statistics functions such as pie charts, spreadsheets, graphs, etc., which can be generated as a result of SQL queries and printed in black and white or in colour.

2. Screen dumps

For quick looks at graphic data, screen dumps usually provide the cheapest solution. Most good GIS support this function. Resolution of output is limited by the screen pixel resolution.

3. Line maps and thematic maps

High-quality line-map production on a range of vector or raster plotters is usually available. In most cases, output files and data dictionary information are passed in standard interchange format (SIF) to the plotter's dedicated processor. The GIS software should allow map design to take place and all border information to be defined, while the plotter processor will define necessary screens and tints.

Sophisticated GIS should allow for several map files to be combined to allow cover over several adjacent sheets. Earlier map-editing software should ensure that all adjacent sheets' edges match. For commonly used output types and formats, it should be possible to define plot program criteria for particular users, to avoid redefining parameters each time a plot is required.

4. Data files

If data from the graphics or attribute database is to be dumped or transferred from time to time, to answer specific user queries or to supply client departments not on a network, some interface into a standard system format or file type needs to be available.

V. HARDWARE REQUIREMENTS FOR GIS

A. Core system

Most GIS are now capable of operating in a microcomputer environment, but this imposes certain limitations in storage and processing speed. Several GIS vendors, ARC/INFO for example, market two types of GIS, one for mini or mainframe environments and one for microcomputers. As the distinction between microcomputers and workstations becomes more blurred -- as memory and as processor speed increase -- the microcomputer becomes more suitable for many applications.

It is difficult to assess the storage and memory size required for any particular GIS without careful study, but even a relatively small pilot GIS will probably require upwards of 100 megabytes (Mb) storage and an expanded memory of 1 to 2 Mb. Specialist applications, such as digital terrain modelling or image processing of remote-sensed imagery, will increase the requirements of both memory and storage.

The minimum requirements for display are a variable-gain amplifier (VGA) colour monitor, but even this is rather limiting in an operational environment. A high-quality colour monitor of 1000 x 1000 resolution would be sufficient for most imaging purposes, in addition to the alpha, or text, screen of the microcomputer.

Even using a top-end microcomputer with an 80386 processor chip running at 33 Mhz, managing a database of anything greater than a pilot area is likely to cause slow response. However, the author believes that a microcomputer environment is appropriate for any new GIS installation, due to the relatively low hardware cost initially; moreover with a microcomputer system, installing a pilot system can assist in sizing a complete GIS while testing the full functionality at relatively little cost.

Microcomputer-based GIS works in a network environment. A common network would include a high-end dedicated server holding the disc-based database management system (DBMS) and linked to individual microcomputer terminals and peripherals, and operating applications software, such as graphics editing, SQL, printing, etc. The server should house the relational database management system, such as Ingres. Such an arrangement keeps data management close to the data and applications close to the user, thus minimizing transfer between the two.

Larger distributed databases are likely to need mini-computer DBMS servers to cope with increased I/O, but applications-oriented terminals are capable of being fully supported by microcomputers for most GIS applications. Current trends in distributed GIS involve keeping the data for which an individual department has responsibility close to the department.

Major processing loads are encountered in image analysis, digital terrain model (DTM) manipulation, and in vector map compilations, where a large number of large-scale maps may be required together in order to edit at a small scale. As previously mentioned, scale changes within limited bounds are feasible, but excessive scale changes should be avoided. If they are necessary, another layer or scale of mapping held within a parallel database should be digitized.

For countries in the ESCWA region who are considering investing in GIS hardware, issues such as local availability, support and maintenance should be an important factor. Training and familiarity of staff with particular hardware may be an issue as well. Most reputable GIS software operates on standard IBM microcomputer-compatible machines, and on SUN and DEC VAX equipment.

B. Peripheral equipment

1. Input devices

The main input requirements of a GIS depend on the availability of existing data in the department. Where maps are to be digitized manually, a high-quality large-format digitizing table and puck are required. Costs of such equipment amount to $5,000 upwards. Compromising on the quality of tables would be false economy, as the basic map-data accuracy may be jeopardized. The table should be at least as large as the largest document to be digitized.

If remote-sensed data is to be processed or there is the likelihood of other bulk inputs of data required of the system, a standard 1600 or 2400 bits per inch (bpi) 1/2-inch tape streamer is needed. It is most probable that such a device will be available to the user if other computing facilities are already available in the organization.

Raster scanning, as discussed earlier, presents a relatively simple option for GIS but requires significant storage space, even with data compression techniques. Scanners vary enormously in specification and cost. An A4 300 to 400 dots per inch (dpi) monochrome scanner costs in the region of $2,000 but is of limited use in a mapping environment. At the other extreme, an A4 400 dpi to 700 dpi colour scanning device may cost in excess of $80,000 and prove an excessive processing load for a microcomputer managing other peripherals and software.

2. Output devices

In addition to a high-quality line printer or laser printer for outputing reports from the database, there is a wide range of plotting devices for hard-copy map output. In defining the requirements of a GIS, the system designers should consider the requirements of users, the scales and colour requirements of output, and the nature of the data. If, for example, there is a requirement for output of continuous tone images or thematic maps or colour fills, a raster colour plotter will be required. If output is limited only to colour line maps, then a vector drum plotter may be sufficient. Plotters vary in size, accuracy and type of plotting. They may use pens, thermal transfer, electrostatic or laser devices, and prices vary enormously.

If printing plates are to be made from the GIS output, then high-quality laser plotters, supported by their own processor and possibly editing system, may be necessary (e.g. Scitex 300 system). The cost is likely to be in excess of $200,000 and may exceed all other hardware and software costs.

For most multi-purpose line and thematic applications, where small-volume outputs are required, colour electrostatic printers, either roll-fed or sheet-fed, provide sufficient quality. A raster device, which could support both vector and raster inputs, would cost in the region of $30,000 to $50,000 for an A4 colour machine. Such machines, produced by Calcomp, Versatec, Precision Images, etc., contain a dedicated microcomputer processor but are proven, reliable systems whose cost continues to fall.

VI. REVIEW OF GIS SOFTWARE

A. Trends in GIS software

The annex provides an indication of the wide range of GIS software available. Only a limited number listed there can be regarded as fully functional GIS with all or most of the functions described earlier. Many of the simpler systems are dedicated to a particular application which is GIS-orientated. If the user's requirement can be precisely defined and is limited in its application area, the use of specialized, low-cost software has distinct advantages: it is cheap, it is likely to be very effective in running the given application, and it is likely to be very user-friendly. There is often a trade-off between functionality and user-friendliness.

Software systems are developing rapidly in the field of GIS. However, unlike the hardware market, where costs tend to fall, software costs generally rise as the functionality of software improves. There is a definite trend towards modularity and hardware transportability, and for the major systems, the user's hardware platform and operating system pose less of a constraint than before. There has been much development in improving the user interface, with the realization by software companies that in an operational environment, speed and friendliness are paramount. Many systems now provide the option of windows, pull-down menus and command language to operate the system. Where databases are used to store attribute information, these are usually proprietary but only in top-end software suites are databases fully relational.

The following pages briefly highlight five microcomputer-based packages which are either available now or are being planned. Restricting the review to a microcomputer base allows some sort of comparison to be made between systems, which becomes more problematic when dealing with a plethora of hardware platforms. Most microcomputer-based GIS will support a limited range of input and output peripherals, the minimum would be a digitizing tablet and screen-dump facility. A microcomputer approach is likely to support a pilot GIS project at minimum cost while testing data-capture and analysis functions.

In addition to the five micro-packages outlined herein, the mini-computer-based GIS being installed in Amman has been briefly considered.

In choosing a GIS software package for a user, one should attempt to define all possible uses of the system and to assign a weight or importance to each use. Generally, a user pays for functionality by increased cost and decreased performance.

The systems summarized below include maps on CD ROM and AIM maps on videodisc. These two systems can be regarded as very simple and cheap GIS which perform map-display and graphic-overlay capabilities quickly and easily. They have very limited input facilities, as the map or graphic data is held on optical media which requires pre-processing to capture. Fully fledged GIS reviewed include STRINGS and ARC/INFO, which appear fully functional and broadly similar in applications. The final microcomputer GIS reviewed is a raster-based system, ERDAS, which is a software suite designed for manipulating remote-sensed imagery but has recently been provided with an interface into ARC/INFO.

B. Maps on CD ROM

Supplier: Ordinance Survey of U.K. and Clarinet Systems

Hardware: IBM PC AT with EGA or VGA graphics
CD ROM drive an integral component

General description:

Maps on CD ROM is a project still being defined in the United Kingdom but reflects a growing need for cheap, quick, and easily managed digital maps on a microcomputer platform. The product uses scanned mediumscale mapping at a resolution of 400 dots per inch (dpi) to provide the basic map material. The perceived GIS market in the United Kingdom for such a product is seen as small businesses or retail outlets that have an interest in managing their infrastructure. Maps on CD ROM could be widely distributed; any organization with relatively constant base mapping could potentially benefit from a product of this type.

As map data is bulky in storage, it is stored on CD ROM (capacity of 600 Mb). System software accesses and displays maps at 400, 200 and 100 dpi on screen. Map images are chosen through atlas page number, name of city/town/village and street name, or by grid reference. The massive storage capacity of CD ROM allows a large area of existing paper maps to be stored.

Mapping is linked to a user-defined non-relational database or to the proprietary microcomputer database Dbase IV. Entities defined in the database can be displayed graphically on the mapping, and any related text can be displayed over the screen image. The user can easily create new graphic features and associated text. High-quality screen dumps are possible using a laser printer.

Limitations:

There are no analysis functions yet available. The use of raster mapping speeds up map availability and speed of access but inhibits sophisticated spatial analysis. The system requires a standard CD ROM drive and is limited by the availability of scanned maps on CD ROM.

Comment:

This simple approach is seen as satisfying a wide range of users who wish to have a rapid, spatially referenced management and indexing system. Such an approach may satisfy the needs of a single utility company, for example, to replace map filing cabinets and paper records. Map updates and the cost of scanning, processing and CD ROM production may be an inhibiting factor. Whilst there is at present no CD ROM mapping available in the ESCWA region, future GIS applications should consider this as a cheap option requiring little training and (when the mapping is available) little data preparation. The system is well designed to show regional variables as thematic maps superimposed on high class base maps and could be used in work carried out by ESCWA.

C. Action Maps (maps on videodisc)

Supplier: AIM Ltd. U.K.

Hardware: IBM PC AT, EGA screen, Multisync Touchscreen Monitor, video/graphics mixing card, laser-vision videodisc player

General Description:

Action Maps is a GIS product, broadly similar to CD ROM but with greater flexibility and more sophistication. Paper maps, available at a range of scales, are video captured, digitized and rastered onto a laservision disc which can store up to 55,000 map images on a single disc.

Access to mapping is through grid reference, gazetteer, or by touchscreen techniques; response time for any single map image is less than one second.

Graphic attribute data for points, lines, polygons and text can be overlaid on the mapping, and all attribute information is held in a non-proprietary flat-file database with a limit of 19,000 records (each record having up to 90 fields).

Hard-copy screen images of video maps and graphic overlays are possible using a colour laser printer device. Response times for maps on videodisc are particularly rapid, making this type of system well suited to command and control or emergency applications. Networking capabilities of the system are not known.

Limitations:

As with CD ROM, once map images have been rastered onto videodisc, it is expensive to provide updates. Map data is not in vector format and is not topologically structured, so only limited analyses are possible.

Comment:

Despite its limitations, maps on videodisc have great potential for many inventory applications. Access speed is impressive, the map display is familiar to map users and the system uses basic, off-the-shelf hardware with proven reliability. As with maps on CD ROM, there is a high cost for videodisc rastering and replication, which requires specialized techniques to produce. However, once a disc is produced, copies are cheap and highly resistant to environmental disturbances. It would be quite reasonable to expect that such a technique could have applications within a government organization where common data among departments were limited to mapping. In such a situation a group of independent (non-networked) workstations supporting the activities of individual departments may be cost-effective, while the survey department would ensure that frequent updated videodiscs of revised maps are produced and supplied to client departments. The comments on Maps on CD ROM (above) *vis-à-vis* ESCWA's work are relevant here also.

D. STRINGS (vector-based, fully functional GIS)

Supplier: Geobased Systems

Hardware: IBM-compatible microcomputer using MS-DOS. Supports a wide range of digitizing tables for input, and pen and electrostatic plotters for output.

General description:

STRINGS is a vector-based, fully functional GIS package which has interfaces into both Britten Lee-dedicated RDBMS and to INGRES. The relational structure of its attribute records therefore gives STRINGS the potential to offer a wide range of analytical functions. STRINGS is modular in its approach, with separate packages for map creation, editing, display, database loading, analysis and export. STRINGS is limited in its use to microcomputer-based systems and when used in conjunction with INGRES uses more than the normal 620 kilobytes (Kb) or 1 Mb memory conventionally available in a microcomputer. Consequently, unless extended memory is used, the system is rather slow in performance, particularly when there is a need to move into or out of INGRES.

STRINGS has a wide range of map data and editing routines which allow a topological structure to be defined in the map data. As a result, line detail, for example, can be optionally defined as part of a polygon. A wide range of attribute classification codes is available to flag map detail. This will inhibit full GIS functionality and cause extra operator effort in digitizing.

STRINGS, when used in conjunction with INGRES, defines two primary entities in the database: points and lines, with their associated attributes. The resulting simplistic database is not well normalized. Consequently there is much wasted disc space. A fully functional and normalized GIS requires more than two database entities, but the STRINGS documentation is not particularly helpful in assisting database design. Most coordinates are held within the graphics database (part of STRINGS), where they are not readily accessible.

Limitations:

The documentation is poor, and the software appears optimized for relatively simple thematic applications. Although it is claimed to operate in a network environment, its performance has yet to be seen and is likely to be slow.

Comment:

STRINGS does have full GIS functionality but to exploit it requires advanced programing skills. The software does not have a particularly friendly front end and is not optimized for production tasks. However, it is cheap and provides an excellent tool for pilot GIS work, as all GIS functions can be experimented with. Geobased Systems is a small company and not well known. As a result, the reliability and stability of the company and its product support is still not proven. STRINGS is the chosen software for the pilot study of the Baghdad municipality GIS. As noted above, problems have been occurring because of poor documentation. However, Geobased Systems provides extensive training in the system at their United States headquarters, and it is expected that following the training of the Baghdad municipality staff the problems should be overcome.

E. ARC/INFO (PC)

Supplier: ESRI (United States), DORIC (United Kingdom)

Hardware: (Microcomputer version) DEC, PRIME, IBM, etc.

General Description:

ESRI has long been in the business of developing and researching GIS tools and techniques and in marketing one of the most widely known and respected GIS vector-based packages. Within the last two years, ESRI has developed a version of ARC/INFO which operates with somewhat reduced functionality and performance, specifically for microcomputers. ESRI is currently porting ARC/INFO to run on many other standard hardware platforms. ARC/INFO, like many GIS packages, is essentially comprised of two components: ARC is a graphics capture, editing and display system which interfaces to INFO, a relational database management system with full RDBMS functionality.

ARC has the capabilities of providing fully structured topological data with multilevels of attributes. Its sophisticated software allows sliver polygons to be identified and removed; this is an important feature when digitizing data from various overlying maps.

The sophisticated interface into INFO allows complex analytical queries and analyses (such as buffer zoning and "what if" queries). The software contains three-dimensional modelling capabilities and more recently has developed interfaces to raster-based image-processing software suites, such as IMPELL and ERDAS. The result is that scanned images or remote-sensed data can be fed directly into the system and viewed simultaneously with any appropriate vector data. Vectors and their associated structure and topology can be updated using the raster as an intelligence source.

Limitations:

The problem raised by full GIS functionality on a microcomputer is very limited speed and performance, even on relatively small datasets. ARC/INFO was originally designed to operate on minis/mainframes. With the increased performance and multi-task capabilities of workstations, ARC/INFO operates effectively, but use on microcomputers remains slow. Many complex processing functions tie up processor time, which in the multi-task environment of a workstation is more acceptable.

Comment:

ARC/INFO now has interfaces into other proprietary databases including INGRES and ORACLE. As a result, the full power of SQL can be used. ARC/INFO interfaces to a very wide range of input and output devices and formats. The software has operated successfully in a distributed network environment. ESRI has a very good reputation throughout the world for its product, which now has a healthy client base. Its full functionality means in practical terms that it is complex to learn and to exploit; However, training, support and maintenance from ESRI and its regional sales outlets are good. In any fully functional, vector-based GIS, ARC/INFO should be one of the favourite candidates.

F. ERDAS

Supplier: ERDAS (United States), CGI (Europe)

Hardware: IBM PC AT or 386 compatible, 1 Mb memory, colour monitor (VGA), 80287 or 387 math co-processor

General description:

ERDAS is a group of software modules for undertaking image processing, analysis and limited GIS functions. This is one of several image-processing packages available in the GIS-related market and is important in that it allows raster data (either scanned maps, scanned photographs or digital satellite remote-sensed data) to be input, processed, classified and attributed. The latest ERDAS software (version 7.3), for example, has a wide range of core modules for data input, output, format, etc. An important image-processing module allows enhancements, classifications, and radiometric and geometric transformations. Using these techniques, images containing errors, due to earth rotation for example, can be "rubber sheeted" to fit the local map.

This is a useful GIS module which allows polygons to be built and various images to be overlaid and analysed. Resulting vector polygons and associated attributes can be stored in database files. The use of raster data simplifies some GIS analysis functions, particularly polygon searches, buffer generation and Boolean functions. Various other modules allow high-quality hard copy or export of standard raster files to plotting devices. Recently, ERDAS developed the ERDAS ARC/INFO Live Link, an interface to ARC/INFO.

Limitations:

Full-functionality image processing is particularly memory- and processor-intensive, and most operations are likely to be slow in a microcomputer environment. The limited resolution of VGA graphics implies that only small areas of high-resolution imagery can be processed at any one time.

Comment:

Image processing and raster data handling is becoming more commonplace as raster scanners fall in price, making raster data cheaper and more abundant. Several GIS-type analyses are better performed on raster data (area analysis and buffering), and the penalty of large storage requirements and intensive I/O operations is becoming less of a problem as microcomputer processors improve. Although ERDAS may have limited functionality as a fully operational GIS, raster processing systems increasingly have a role to play in supporting vector-based analyses.

G. GAMIS (Greater Amman Municipal Information System)

Microcomputer-based GIS packages have only been available for approximately the last five years. For instance, when the original decision was made to install a microcomputer-based GIS in Baghdad municipality, there was only one viable microcomputer package available (STRINGS). Now there are many more packages available on the market (see annex), some with superior attributes. There have, of course, been many GIS packages available for mini and mainframe computers for some time, although most of these require extensive customization for each client, and there are some mini-computer-based systems which do use microcomputer terminals and workstations, with the mini-computer used as a central server for storage.

One such system is that being installed for Amman Municipality using the General Design System (GDS) of McDonnell Douglas Information Systems Limited with an interface to an EROS database system, also from McDonnell Douglas. Because this system is being installed in the ESCWA region, it is briefly reviewed here. It should be noted that the system was also considered for Baghdad municipality but was rejected in favour of a networked micro system, mainly because of cost and existing commitment to PC hardware.

Supplier: McDonnell Douglas Information Systems Inc. (United States).

Hardware: DEC VAX 11/750 super-mini 6 Mb RAM, 1 gigabyte storage (cf. 1-2 Mb RAM and 100+ Mb storage for PC-based systems)

General description:

The Greater Amman Municipal Information System (GAMIS) will ultimately incorporate eight major modules. These are:

(a) Cadastral module: to handle land plot identification, ownership, area, layout, etc.;

(b) Development control module: to relate laws and regulations to geographic features (roads, land-use, etc.);

(c) Existing development module: to use the two previous modules and relate existing development (roads, buildings) and their compliance with zoning regulations;

(d) Administration and finance module: mainly to control administrative divisions such as road numbering, plot addressing and all land and building taxation matters;

(e) Terrain module: to handle land surface definition such as contour, spot height, slope, etc.;

(f) Traffic and transport module: to handle the road and transport network, parking, traffic flows, traffic management, etc.;

(g) Infrastructure module: to handle all utility lines (underground), electricity, water, sewerage, telecommunications, etc.;

(h) Socio-economic module: to handle population and household, social, ethnic, educational, etc., characteristics.

It was accepted that a pilot system would need to be installed first and, rather than test the total system in a small area, it was decided to test just part of the system. Thus three modules, cadastral, development control and existing development are being installed and tested, staff are being trained on this system, and through this pilot the whole system is being evaluated.

The mapping data for the cadastral model is provided by the Lands and Survey department and the National Geographic Center, and the data input is land plots, plot reference, ownership, registration, area, boundary and history. At the present time the individual plot boundaries only are digitized into GAMIS as individual plots, as absolute plot coordinates are not yet available, and thus the plots cannot be joined with any accuracy. The associated data is stored in the database (EROS) and this can therefore be referenced by single plot reference number and updated or displayed.

The development control module relates zoning regulations and standards to the mapped land-use and road system. It is hoped that eventually the zoning process will be fully automated by using feedback from previous approved zoning schemes. This will require a huge amount of time-related data, and it is not expected that it would be achievable in the near future. It is hoped that the system will be able to produce zoning maps, site plans, road inventories, land-use characteristics, etc., but it is obvious that improvements in the existing system will be required before any success is achieved. One of the first improvements required is a logical road-numbering system, as the road is to be the basic spatial unit of the module.

Comments:

The experience in Amman with this GIS points up some major problems in GIS installation. The first is the absolute necessity of accurate and timely data before deciding on any GIS package. It is of little use committing funds to a complex GIS if the input data is such that much of the power of the GIS cannot be used. Amman municipality will have to carry out a great deal of work in rationalizing the cadastral and road data before the system can be used as other than a simple database; all land plots must be coordinated, and roads numbered. Unless the plots are coordinated, then the system cannot be considered a true GIS, as there is no absolute geographical connection between the plots.

A second problem or task which has come to light in Amman is the huge amount of training required, not only in data processing and systems operation but also in all the departments that will be concerned with data collection and preparation (e.g. zoning departments, road departments). The extent of this training must be appreciated and some commitment made to allowing the time required for training, before a decision is made on the extent of the GIS to be installed.

The third point highlighted is the drawback of commitment to an integrated customized package (hardware and software) with high up-front costs, before the true extent of the capabilities of adapting the existing system is recognized. This is one of the reasons that countries in the ESCWA region, which do not usually have complete and accurate existing mapping and data systems, should consider the use of modular networked microcomputer (PC) systems which have low up-front costs, are flexible, and can be expanded as the system becomes more productive.

H. Micro versus mini for GIS

As we have considered one mini-based GIS package in this review, it is appropriate to briefly discuss the pros and cons of microcomputer-based GIS compared to mini and mainframe GIS. This was considered in some detail in the selection of the GIS package for Baghdad municipality, and the following discussion reiterates some of the points considered.

A criticism often heard of microcomputer-based systems is that the micro hardware is not powerful enough for the eventual GIS system. This criticism is usually made by those promoting the use of mini-computers, which are fast being replaced by microcomputers, and is therefore to be expected. It should not, however, be ignored. It is true that at the present time, even with the use of 80386 CPU chips, microcomputers are not as fast or as powerful as the larger 32-bit mini-computers, although internal and external storage capabilities are equal. However, in the last 12-24 months, the power and speed of microcomputers tripled (12 Mhz to 33 Mhz), and with the advent of the new 80486 CPU chip, another leap forward is anticipated. This will, of course, mean future upgrading to these more powerful machines. However, the cost of the 80486 micros is expected to be much less than the cost of existing, less powerful minis.

A further drawback to the mini-computer-based systems is the cost of software and software licences. The initial cost of the Amman software (as offered to Baghdad) was over twice as expensive as micro software with similar capabilities. Further software costs would have included a relational database, at ten times the cost of the micro-based database, and a very high software licence cost for each terminal used in the system. Micro software packages, by contrast, usually have an all-in network software cost allowing the use of unlimited terminals connected to the one system.

Given all the above, it is apparent that the choice of the mini system should only be contemplated if it gives substantial advantages over and above its hardware and software capabilities. These were not apparent given the GIS requirements proposed for Baghdad municipality.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The fact that so many countries are prepared to invest so much money in creating GIS databases indicates the conviction of users regarding its enentual usefulness in rationalizing and regulating the many records and processes of government in dealing with an increasingly complex situation involving many different authorities within both national and local government.

The central support or basis of a GIS is a system of coordinated reference points which have been surveyed in position on the ground. On a national scale, these can be related to the, Universal Transverse Mercator Grid (UTM) used for a given country's maps. For smaller areas, they can be referenced to any local grid used for balanced mapping by the mapping authority/survey department or the land department which keeps records of land ownership in the vicinity.

This basic input is missing in many developing countries, including some in the ESCWA region. Thailand, for example, is presently investing a very large sum of money, including $30 million through a World Bank loan, in addition to aid, in a ten-year programme to digitally map the entire country as a preliminary for adopting GIS.

Before introducing GIS, therefore, it is necessary to have certain basic input in place, that is, accurate digitized mapping, freely available and with the means for keeping the mapping database continuously updated as the record details change, for example land ownership, addition of new utilities, alteration to existing utilities, etc. That is to say the rules and regulations have to be applied to Government and public alike: any change relative to the GIS must be correctly surveyed and coordinated with submission within a specified length of time to the GIS. Without provision for this continual updating, adhering to a given standard of accuracy, the GIS database can become corrupted within a very few years, and could become possibly unreliable and a great waste of public funds.

In circumstances where it is not yet possible to guarantee the validity of the GIS database and its continual updating, there are other options which, whilst not enabling the full benefit of GIS to be obtained nevertheless can help substantially in various aspects of Government such as planning, public utilities, etc. These ends can be achieved through the use of video maps, which can provide an intermediate cost-effective introduction to GIS. Two such systems are included in the reviews in chapter VI.

In any event, GIS are evolving at a rapid rate, as is the hardware associated with them, in line with trends in the computer world away from the use of mainframe computers to the use of very powerful desktop microcomputers, with even larger and cheaper means of data storage. It pays therefore to proceed with caution, hence the emphasis in this report on pilot projects as an introduction to GIS.

Whilst the present report emphasizes the need for all relevant departments to share data, it must be realized that this is not always easy. The government decision makers must be made aware of all the implications of GIS, the freedom of information implied, access to the system, etc. Bounds have to be placed on the confidentiality of and access to information.

There is a need, therefore, in the countries of the region to have these questions explored and resolved prior to any introduction of GIS; the recommendations below include some details of the answers required.

By itself GIS is a wonderful tool, but it has implications in its application which may require the reorganization of departments; the need for this and the particular changes needed must be accepted, agreed and supported by the authorities or departments in question and their staff.

The mechanics of GIS are relatively straightforward. Applying GIS, however, depends on people, who must be persuaded to accept the system. The cost of doing this and the time involved are most often understated.

B. Recommendations

The recommendations in the present report can be divided into two groups, those relating to further research into GIS application in the region, and those relating directly to the installation of GIS in the region. The first set of recommendations should be implemented well prior to any definite decisions on the role of ESCWA in GIS implementation.

1. Recommendations relating to further research into GIS implementation in the ESCWA region

(a) There should be a review of all mapping standards in the region, between countries and inside countries. This review should include mapping standards, dates of major survey, standard of mapping, accuracy and uniformity. It should also detail the departments or organizations responsible for the mapping in each country which is likely to be used as input to GIS, the extent of cooperation among the departments and the conformity of the mapping;

(b) There should be a review of the availability, timeliness and accuracy of attribute data from departments. This would include details of which departments are responsible for which data, the level of redundancy between departments and, where the data is geographically related, the standard of the associated mapping;

(c) A definition of existing problems in the region in data management is needed. This would partly be included in (a) and (b) above but would also include an assessment of freedom of data use, managerial commitment and personnel limitations, standard of knowledge in digital and database techniques and standard of existing computerized data management;

(d) Definition of what potential users want from a GIS. This would include:

(i) A review of existing GIS applications in the region, with particular reference to the achievement of goals and the problems encountered;

(ii) A review of how each Government or department thinks it can use GIS, and of what users think GIS can actually do;

(iii) A realistic assessment of whether a GIS can fulfil these aspirations;

(iv) An estimate of the costs of implementing GIS to fulfil these goals, including any preliminary costs such as updating of mapping;

(v) An assessment of how ESCWA can assist in fulfilling these requirements.

Whilst all of these can be combined in one overall study, the first step must be for ESCWA to set some broad guidelines as to what they are attempting in encouraging GIS in the region. It should then compile a "decision questionnaire" to send to all Governments and/or relevant organizations in the region. This should contain questions to be answered regarding the areas in which GIS is required, what data is available and with what restrictions, what mapping is available at what scale, timeliness and accuracy and with what restrictions and what commitment would be given to the installation of GIS and at what level. These questionnaires would then provide the basis of further detailed study, as set out above, in each country in the region interested in implementing or expanding GIS.

Another use of the questionnaires would be to give government decision makers some idea of the problems of installing a successful GIS, the time, the cost and the commitment. It is essential that the decision makers in government be made fully aware of all the implications of GIS, including freedom of information. It may be feasible for ESCWA to arrange study tours to senior officials to GIS installations overseas; these are a prerequisite to GIS installation. It is emphasized that, to obtain the appropriate commitment and cooperation, these tours must be for responsible heads of departments, not middle or junior staff.

2. Recommendations relating to GIS installation in the region

(a) As detailed above and emphasized in the report, feasibility studies into the applications and planning of GIS in municipality or urban environments should include, as an integral component, an assessment of the quality, accuracy, reliability and "up-to-datedness" of the base mapping;

(b) GIS implementation within specific departments of government organizations should be avoided if possible. Feasibility studies in GIS should take a corporate-wide view, a top-down approach, and aim at sharing the maximum amount of data throughout as many departments as possible;

(c) Where computerized GIS is being taken up for the first time in any organization, the use of a pilot project is strongly recommended. A pilot should aim to:

(i) Familiarize all users with GIS techniques and technology and thereby develop confidence;

(ii) Define an interim data model for organization entities and data flows;

(iii) Assist in defining a system specification to be used in a subsequent procurement and bench-marking process;

(iv) Identify those activities which are least likely to be economically undertaken in a GIS.

GIS software used in a pilot programme may not have sufficient power or feasibility to handle local problems and data. The use of software for the pilot should not constrain the choice of software for full implementation;

(d) Prior to GIS installation, therefore, the requirements of all the departments involved need to be established, the common links or relationships and data flows between departments identified and a solution found which is simple enough to support the most complex application. The answer is not necessarily quickly found and will involve an iterative approach.

Annex

Features of Selected GIS

No.	Software Name/Company	Year First Install	Number of Users	Base Price US $	Software Type	Computer Environment	Data Structure	Data Entry/Input Devices	Data Management	Output Devices
1	ARC/INFO / Environmental Systems Research Inst.	1982	23,000+	n/a	GIS, FM, AM, DBMS, DZ, FC, RS, CAD, Other	UNIX, DOS, Other	Raster, TV, NTV, TIN, 3D, Other	DZT, Scanner, BPS, PGS, Mouse, COGO	DB2, Dbase, DS, Fox, IMS, INFO, Informix, Ingres, Orc. OS/2, Rbase, Sybase, Other	PP, IJP, EP, FR, LP, DMP, Other
2	ARIES / Dipix Technologies, Inc.	1978	1,000+	$20,000	GIS, RS	DOS, VMS	Raster	DZT, Scanner, Mouse	I.DB, Ingres	IJP, EP, FR, LP, DMP
3	Atlas GIS / Strategic Mapping , Inc.	1990	–	$2,495	GIS, FM, AM, DBMS, DZ, FC	UNIX, DOS	Raster, TV, NTV, 3D	DZT, Scanner, Mouse, COGO	I.DB, Dbase	PP, IJP, EP, FR, LP, DMP
4	CAD Core/Tracer / Information & Grpaphics Systems, Inc.	1989	1,000+	$4,500	GIS, FM, AM, DBMS, DZ, FC, CAD	DOS	Raster, NTV	DZT, Scanner, Mouse	Oracle	PP, IJP, EP, LP, DMP
5	Delphi/GIS / Austin McDanial Corp.	1990	40	$8,000	GIS	DOS, Other	NTV	DZT, Scanner, Mouse, COGO	Oracle	PP, IJP, EP, FR, LP, DMP, Other
6	EASI/PACE / PCI	1982	1,200	$5,000	GIS, RS	UNIX, DOS, Mac, VMS	Raster, NTV, 3D	DZT, Scanner, Mouse	I.DB	IJP, EP, FR, LP, DMP
7	ERDAS / ERDAS, Inc.	1979	5,000+	$2,500	GIS, FM, AM, DZ, FC, RS, Other	UNIX, DOS, VMS	Raster, NTV, 3D, Other	DZT, Scanner, BPS, Mouse	I.DB, Sybase	PP, IJP, EP, FR, LP, DMP, Other
8	FMS/AC / Facility Mapping Systems, Inc.	1986	3,000	$3,000	GIS, FM, AM, DBMS, DZ, CAD	UNIX, DOS	TV, NTV	DZT, Scanner, BPS, PGS, Mouse, COGO	I.DB, Dbase, Fox, Orc., Other	PP, IJP, EP, FR, LP, DMP
9	GENAMAP / Genasys	1986	1,000+	n/a	GIS, FM, AM, DBMS, DZ, FC, CAD, Other	UNIX	Raster, TV, NTV, TIN, 3D, Other	DZT, Scanner, Mouse, COGO	I.DB, DB2, INFO, Informix, Ingres, Orc., Other	PP, IJP, EP, FR, LP, DMP
10	Geoaxses / Axses, Inc.	1990	12	$1,200	GIS, DBMS, FC	DOS	Raster, TV, NTV	Mouse, COGO	Dbase, Fox	IJP, LP, DMP
11	GEODIS, INFOGIS, GEOMIP / IFM Infomaster	1986/90/91	400/30/10	12k/45k/3.6k	GIS, FM, AM, DBMS, DZ, FC, CAD	UNIX, Other	Raster, TV, NTV, TIN	DZT, Scanner, Mouse, COGO	I.DB, DB2, Informix, Ingres, Orc., Other	PP, IJP, EP, FR, LP, DMP
12	Geolink System / GeoResearch	1988	120	$3,850	GIS, FM, AM, DBMS, DZ, RS, Other	UNIX, DOS	Raster, TV, NTV, TIN, 3D	DZT, Scanner, BPS, PGS, Mouse, COGO	Dbase, Fox, INFO	PP, IJP, EP, LP, DMP
13	GIS Plus / Cliper Corp.	1988	400+	$2,995	GIS	DOS	TV	DZT, Scanner, BPS, Mouse	DB2	PP, EP, LP, Other
14	Graphics Design System / McDonnell Douglas	1981	>6000	$9,500	GIS, FM, AM, DBMS, DZ, FC, CAD, Other	VMS, Other	Raster, TV, NTV, TIN, 3D	DZT, Scanner, BPS, PGS, Mouse, COGO	DB2, Orc., Other	PP, IJP, EP, FR, LP, DMP
15	HI-VIEW / Horler Information Inc.	1991	10	$8,500	GIS, FC, RS, Other	DOS	Raster			
16	InfoDAC / Digital MAtrix Services, Inc.	1987	n/a	$12,500	GIS, FM, AM, DBMS, DZ, CAD, Other	UNIX	Raster, TV, TIN, 3D	DZT, Scanner, Mouse, COGO	I.DB, Orc.	PP, IJP, EP, LP, DMP
17	Infomark for Windows / Equifax Marketing Decisions Sys.	1991	3800	$20,000	AM	DOS, Other	TV	DZT, Mouse	Dbase, Other	PP, IJP, EP, FR, LP, DMP
18	KARTO / DeltaCAD	1985	30	$22,000	GIS, FM, AM, DZ	UNIX, DOS	NTV	DZT, PGS, Mouse	Dbase, Ingres, Orc.	PP, LP
19	Map Designer / Unimaps Corporation	1989	20	$5,500	GIS, AM, DBMS, DZ, FC	Other	Raster, NTV	DZT, Mouse, COGO	I.DB, Other	PP, IJP, EP, LP, DMP
20	Mapaccess / ETAK	1989	100	$9,000	Other	UNIX, DOS	TV		I.DB, Informix	
21	IDRISI / Clark Univ./Grad. School of Geog.	1987	3,000	$400	GIS, RS, Other	DOS	Raster, NTV	DZT, Scanner, Mouse	Dbase, Fox, Other	PP, IJP, LP, DMP
22	MapPower Desktop GIS / MApPower Corporation	1990	20	$7,000	GIS, Other	Mac	NTV	DZT, Scanner, BPS, Mouse, COGO	I.DB, Orc.,Sybase, Other	PP, IJP, EP, LP, DMP
23	MetaMap / Unique Graphic System	1990	30	$3,999	GIS, FM, AM, DBMS, DZ, FC	DOS	TV, NTV	DZT, Scanner, BPS, Mouse, COGO	I. DB.	PP, EP, LP
24	Modular GIS Environment	1989	n/a	$7,000	GIS, AM, DZ, FC, CAD	UNIX, DOS	Raster, TV, NTV, TIN, 3D, Other	DZT, Scanner, BPS, PGS, Mouse, COGO	DB2, Informix, Ingres, Orc.	PP, IJP, EP, FR, LP, DMP, Other
25	QuickMap / Environmental Sciences Ltd.	1989	300	$720	GIS	DOS	NTV	DZT, Mouse	DB2, Foxbase	PP, IJP, EP, FR, DMP
26	Strings/Landtrak/GeoBlocks / GeoBased Systems-Infocel	1979	300+	$3,800-9000	GIS, AM, DZ	UNIX, DOS	TV, NTV, 3D	Mouse, COGO	I.DB, Orc., Sybase	PP, IJP, EP, FR, DMP
27	"TIGER" GIS / System Dynamics, Inc.	1990	40	$9,995	GIS, AM, DBMS	DOS	Others		Other	Other
28	VTRAK / Laser-Scan	1988	80	$50,000	GIS, AM, DZ, FC	UNIX, VMS	Raster, TV	DZT, Scanner, Mouse	Ingres, Orc., Other	PP, IJP, EP, FR, LP, DMP

LEGEND:

GIS : Geographical Information Syste
FM : Facilities Ma nagement
AM : Automated Mapping
DZ : Digitizing
FC : Format Conv ersion
RS : Remote Sensi ng
CAD : Computer Aided Design
TV : Topological Vector
NTV : Non-topolo gical Vector
DZT : Digitizing T ables
GPS : Global Positi oning Systems
FGS : Photograme tric Stations
COGO : COGO su pport
IDB : Internal Dat abase
Fox : Foxbase
Orc. : Oracle
OS/2 : OS/2 E.E. Database Manager
PP : Pen Plotter
IJP : Ink Jet Printe r
EP : Electrostatic Plotter
FR : Film Recorde r
LP : Laser Printer
DMP : Dot Matrix Printer

Source:
The 1991 GIS World Software Survey

GLOSSARY

ASCII (text file)	American Standard Code for Information Interchange. A standard code for representing alphanumeric and special characters on a computer.
Attribute data	Data relating to defined entities (e.g., ownership of land).
Analogue data	Data which is copied without conversion.
Boolean algebra	Logic algebra, a means of symbolically expressing the relationship between two logic variables with a true or false state only.
Chloropleth map	A map which shows combinations of attributes. Similar to thematic maps.
CD ROM	A compact disc containing a large amount of data which can be read many times but written only once.
Database	An aggregation of related operational data used by an applications system. A database can contain one or more data files.
Data Modelling	Creating a database structure and the relationship between different items in the structure.
Digital data	Data represented by numbers.
EBCDIC	Extended Binary-Coded Decimal Interchange Code. Another common code for representing alphanumeric and special characters (see ASCII).
Joins, selects, projection	Types of database queries (e.g., joins: all houses in Region 1 over 5 years old).
Optical character recognition	A means (by software) of converting raster-scanned characters into vector characters so that scanned text can be converted into ASCII files.
Polygon	A closed set of lines or links in a GIS graphics database, usually with associated attributes or features.

Query by example	An interactive query language for relational databases (e.g. "Find all records over 5 years old").
Raster scanning	Scanning or copying graphics or text by pixellating (or reading bit by bit) a map and attributing a digital number to the spectral (or colour) response of that part (or bit) of the map.
Raster maps	Maps created by raster-scanning or copying.
Relational database (RDB)	A database system with more than one file of data; the files can be accessed from each other by unique relations between data records in each file.
Sliver polygon	A polygon caused by misalignment of identical links in overlapping or overlayed maps or caused by digitizing errors. Software procedures are required to eliminate sliver polygons.
Structured query language (SQL)	A standard relational database language providing standard data definition, data manipulation and data control statements.

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