공공부문 GIS활용에 관한 국제세미나

2ND ANNUAL INTERNATIONAL SEMINAR ON GIS APPLICATIONS IN THE PUBLIC SECTOR

October 16～17, 1997
Seoul Education and Culture Center
Seoul, KOREA

Organized by
Korea Research Institute for Human Settlements (KRIHS)

Sponsored by
Ministry of Construction and Transportation (MOCT)
REPUBLIC OF KOREA

KOREA RESEARCH INSTITUTE
FOR HUMAN SETTLEMENTS

INTERNATIONAL SEMINAR ON GIS APPLICATIONS IN THE PUBLIC SECTOR

SEMINAR SCHEDULE

October 16, 1997 (Thursday) : Seoul Education and Culture Center

9:30~10:30	Registration		
10:30~11:00	Opening Address	Hong, Chul	(President, KRIHS)
	Congratulatory Address	Kim, Kuen-Ho	(Vice Minister, MOCT)
11:00~11:30	Keynote Speech	H. Junius	(Professor, Univ. Dortmund)
11:30~12:00	Introduction to National GIS Initiative in Korea Min, Tae-Jung (Director, Land Use Planning Division, MOCT)		
12:00~14:00	Luncheon		

• Session 1 : GIS Applications for Underground Facility Management

Moderator :	Earl Epstein	(Professor, Ohio State Univ.)
Discussants :	Jung, Kyung Won	(Director, Information Promotions Committee, MOIC)
	Kim, Sung-ryong	(Director, Korea Telecom)
	Kim, Eun-hyung	(Professor, Kyung Won Univ.)
	P. Chagarlamudi	(Manager, Geomatics Canada)
	Philip Tickle	(Manager, Bureau of Resource Sciences)

14:00~14:40	Implementating GIS into Institutional Sets for Integrated Underground Facility Management Choe, Byong Nam (Associate Research Fellow, KRIHS)
14:40~15:20	Advanced GIS for Facility Management and Business Strategy in Tokyo Gas Takeshi Taniguchi (Manager, Tokyo Gas Co.)
15:20~15:30	Break
15:30~16:10	Large Scaled Digital Map as a Basis of a Facility Information System H. Junius (Professor, Univ. Dortmund)
16:10~16:50	Data Modelling for Underground Facilities Peter Woodsford (Executive Director, Laser-Scan)
16:50~17:00	Break
17:00~18:00	Discussion
18:00~20:00	Dinner

October 17, 1997 (Friday) : Seoul Education and Culture Center

08:30~09:00 Registration

● Session 2 : GIS Applications for Landuse and Environmental Planning

Moderator	:	Choe, Sang-Chuel	(Professor, Seoul National Univ.)
Discussants	:	Bahn, Jahng-Shick	(Director, Technology and Information Division, MOFE)
		Ko, Gae Yun	(Director, Ecosystem Conservation Division, MOE)
		Ryu, Joong-seok	(Professor, Joong-Ang Univ.)
		Dana Tomlin	(Professor, Univ. of Pennsylvania)
		Peter Woodsford	(Executive Director, Laser-Scan Ltd.)

9:00~ 9:40 GIS Application for Environmentally Sound Landuse Planning in Cheju Island, Korea
Yang, Ha Baek (Research Fellow, KRIHS)

9:40~10:20 GIS Utilization for the Multipurpose Cadastre: Development and Benefits
Earl Epstein (Professor, Ohio State Univ.)

10:20~10:30 Break

10:30~11:10 Using Spatial Information Systems to Support Australia's Sustainable Development
Philip Tickle (Manager, Bureau of Resource Sciences)

11:10~12:00 Discussion

12:00~14:00 Luncheon

● Session 3 : GIS Applications for Transportation and Emergency Management

Moderator	:	Lee, Jeong Sik	(Vice President, KRIHS)
Discussants	:	Park, Yeon-Soo	(Director, General Affairs for Disaster Management Division, MOHA)
		Kim, Kyung Soo	(Director, Topographic Information Section, NGI)
		Choi, Ki Joo	(Professor, A Jou Univ.)
		Takeshi Taniguchi	(Manager, Tokyo Gas Co.)
		H. Junius	(Professor, Univ. Dortmund)

14:00~14:40 Integration of GIS Implementation Program with ITS for Application to Transportation
Kang, Hoig (Cheil Institute of Construction and Transportation)

14:40~15:20 Cartographic Modelling Techniques for Highway Corridor Planning
Dana Tomlin (Professor, Univ. of Pennsylvania)

15:20~15:30 Break

15:30~16:10 The Utility of Geomatics in Emergency Planning and Management
P. Chagarlamudi (Manager, Geomatics Canada)

16:10~17:10 Discussion

GIS를 활용한 제주도 중산간지역의 환경보전적 토지이용계획

GIS Application for Environmentally Sound Landuse Planning in Cheju Island, Korea

양 하 백
국토개발연구원 연구위원

ABSTRACT

Cheju Island is the most attractive resort area in Korea for its exotic landscape, natural beauty, and traditional culture which is quite different from that of the mainland. Until now, most of the recreational facilities and accomodations have been constructed along the coastal areas. Recently, mid-mountain area has been under very heavy development pressure because it is suitable for new sites for tourism facilities and the land price in the coastal area is very high.

The mid-mountain area is the land located 200-600m above the sea level. It is a major source of water supply for the island and has exotic scenic beauty, which cannot be found in mainland but it is the area very vulnerable to water pollution. Therefore, it is very important to manage this area based on the concept of environmentally sound and sustainable development in order to meet ever increasing demand for the land development.

The purposes of this project are: 1) to establish Geographic Information System for the whole island, 2) to formulate environmentally sound landuse plan, and 3) to develop GIS application programs so that the public officers can utilize the programs in everyday's activities. There has been no technical problems in the process of the project technically. However, accuracy of the original map, defining criteria of analysis, updating of the data were identified for future tasks to be studied.

요 지

제주도는 서울에서 450㎞ 떨어진 면적 1,828㎢의 섬으로, 독특한 경관과 자연·인문환경을 관광자원으로 하는 한국 제1의 관광지이다. 지금까지는 각종 관광시설들이 해안지역을 중심으로 발달되어 왔으나, 근래에 이르러서는 해안지역의 도시가격의 상승, 관광객의 다양한 관광활동 요구 등으로 인하여 표고 200~600m의 중산간지역의 개발론이 대두되고 있다.

그러나 중산간지역은 토양과 지질구조가 지하수 오염에 매우 취약하며, 제주도의 생태계를 유지시키는 완충지대의 역할을 하고 있기 때문에 환경보전적 토지이용이 절실히 요구되고 있다. 이를 위해서는 다양한 환경정보체계를 구축하고 분석할 수 있는 토지와 환경에 관한 종합정보시스템의 구축과 활용이 필요하다.

이 연구는 제주도의 위탁을 받아 시행된 것으로, 일차적으로 제주도 전역에 대한 각종 조사를 시행하고 그 결과를 GIS로 구축하였다. 여기에는 자연·인문·지하수·경관 등에 걸쳐 15개 항목에 대한 조사가 이루어졌으며, 42개 주제도가 구축되었다. 두 번째 단계에서는 구축된 GIS를 이용하여 지하수, 생태계, 경관보전을 위한 토지이용계획을 수립하고 이에 따른 관리방안이 제시되었다. 향후 난개발을 미연에 방지하고 환경에 부담을 주지 않으면서 개발을 유도할 수 있을 것이다. 세 번째 단계는 구축된 GIS를 효율적으로 활용할 수 있도록 응용프로그램을 개발하였으며, 향후 담당공무원이 제주도내의 각종 개발사업의 사전·사후적 평가업무에 유용하게 사용할 수 있도록 고려하였다.

본 연구를 수행하는 과정에서 기술적인 문제점은 크게 부각되지 않았으나, 도면의 정밀도 제고방안, 분석기준의 합리성 제고방안, 각종 데이터의 갱신방법 등이 앞으로 계속 추진되어야 할 과제로 대두되었다.

1. 서 론

지난 30년간 우리나라는 눈부신 경제성장으로 국민의 기초적인 의·식·주 문제는 해결되었지만 생활환경은 자연자원의 고갈 및 환경오염으로 악화를 경험하고 있다. 이러한 자원·환경의 문제는 그 범위가 매우 광범위하고 복잡하기 때문에 효과적인 처방이 매우 어렵다. 그러나 1970년대에 등장한 지리정보시스템(GIS : Geographic Information System)의 공간문제 해결기능과 정보처리기술은 이러한 문제를 효과적으로 대처할 수 있는 여건을 만들어 주고 있다.

지금까지 우리나라에서는 일부 시·도를 중심으로 특정 목적의 GIS 구축이 시도되어 왔으나, 국가 차원에서의 표준화 부재로 인한 시스템간의 호환성 부족 및 중복투자 등의 문제가 제기되었다. 이에따라 정부는 초고속정보통신망 계획과 더불어 국가경쟁력 강화 및 행정의 생산성을 높이기 위한 사회간접자본으로써 국가지리정보체계(NGIS : National Geographic Information System) 구축사업을 시행하고 있다. 이 사업계획에 따르면 1995년부터 1998년까지는 지형도를, 1997년부터 2000년까지는 공통주제도를 수치지도화하여 공간정보 데이터베이스를 구축하도록 되어 있다.

제주도에 대한 GIS 구축은 이러한 국가 GIS추진계획과 연계하여 약 2년간에 걸쳐 수행되었으며, 가능한한 범위내에서 제주도 전역에 대한 GIS 데이터베이스를 구축하고 중산간지역(589㎢)에 대한 환경보전적 토지이용계획을 수립하는 것을 목표로 하고 있다. 즉 GIS 데이터베이스의 구축은 국가 GIS 사업의 성과물인 수치지형도를 기본으로하여 각종 주제도를 구축하고, 구축된 주제도를 활용하여 환경보전적 토지이용계획을 수립하였다.

이 글에서는 제주도 중산간지역에 대한 환경보전적 토지이용계획을 수립하게된 배경과 목표, GIS 구축내용, 환경보전적 토지이용계획 내용, 지원시스템의 구축을 살펴보고, 마지막으로 본 연구에서 경험한 문제점과 향후 과제를 언급하고자 한다.

2. 배경과 목표

제주도 중산간지역은 표고 200~600m 사이에 있는 지역을 말한다. 중산간지역은 대부분 산림지와 초지로 이용되고 있고 경작지는 약 10%를 차지하고 있으며, 제주도의 농업, 축산업, 임산물의 생산기지 역할을 담당하고 있다. 또한 이 지역은 천혜의 자연조건과 독특한 경관을 지닌 지역으로서 녹지공간의 유지, 각종 동식물의 서식처 제공 등 자연생태계를 유지하는 역할을 담당하고 있으며, 한라산 국립공원과 해안지역에 대한 완충기능과 해안지역의 농업생산에 필요한 지력 보급상의 보완기능을 담당하고 있다. 또한 이 지역에는 육지의 다른 지역에서 볼 수 없는 독특하고 수려한 경관이 훌륭한 관광자원의 역할을 담당하고 있다. 그러나 이 지역은 토양 및 지질 구조상 지하수 오염에는 매우 취약한 구조를 지니고 있다.

현재 중산간지역에는 제주도개발특별법과 제주도종합개발계획 확정후 각종 개발사업이 활성화되고 있다. 그러나 개발사업의 영향을 평가하고 사업의 인·

허가를 결정할 수 있는 과학적인 근거가 없어 개발업자와 지방정부간에 갈등이 일어나고 있다. 따라서 과학적이고 효율적인 방법으로 중산간지역에 대한 환경특성을 규명하고 토지적정도를 평가하여, 환경용량내에서 개발할 수 있는 기준을 제시할 수 있는 개발 및 보전지침이 절실히 요청되고 있다.

토지이용계획이 수립되기 위해서는 먼저 이 지역에 대한 종합적인 공간정보의 구축이 선행되어야 한다. 기존의 현황자료를 바탕으로 인문·사회환경, 자연·생태자원, 지하수환경, 경관 등 40여개의 주제에 관한 종합조사를 실시하고, 조사결과를 GIS에서 이용할 수 있도록 공간정보 데이터베이스로 구축하는 것이 일차 목표로 설정되었다. 두 번째는 GIS를 이용하여 중산간지역의 환경특성을 파악하여 각종 모델링 기법과 GIS가 결합하여 중산간지역에 대한 환경보전적 토지이용계획을 수립하게 되며, 각종 개발사업의 인허가시 평가자료로 활용토록 하였다.

3. 현황조사 및 GIS DB의 구축

3.1 현황조사

1) 조사항목

현황조사는 자연환경, 인문환경, 지하수환경, 경관에 대한 4개의 항목을 15개 소항목으로 구분하여 각 부문별 전문가들에 의하여 수행되었다. 자연환경에서는 지형, 수계, 식물상, 동물상에 대한 조사가 수행되었으며, 인문환경에서는 토지이용현황, 각종 법령에 의한 토지이용제한지역, 인구 및 취락지, 산업 및 지역경제, 문화재, 주요시설물 등이 조사되었다. 또한 지하수 환경에서는 기존 지하수에 관한 현황, 토양, 투수성지질, 잠재오염원 등이 조사되었고, 경관에서는 경관미 시각흡수능력, 주요도로 및 지점에서의 가시거리가 조사되었다.

2) 조사방법

각 항목에 대한 조사는 조사항목별 특성, 기존 자료의 유·무에 따라 적정 조사 방법을 선택하였다. 지형, 수계, 주요시설물은 국가수치지도를 활용하였으며, 토지이용제한지역, 문화재, 지하수 현황 등은 기존자료와 관련문헌을 이용하였다. 식물상, 동물상, 토양, 투수성지질, 경관 등에 대한 조사는 기존자료를

활용하고 현장조사를 통하여 보완하였으며, 토지이용현황조사는 항공사진과 인공위성 탐사자료를 이용하였다. 또한 토양의 물리·화학적 특성과 오염취약성 조사는 현장에서 시료를 채취하여 실내 실험조사를 실시하였다.

3) 조사과정

조사는 3단계의 과정을 거쳐 수행되었다. 1차로 사례지역을 선정하여 해당 자료의 유·무상태를 파악하고 조사의 방법을 결정하였으며, 2차 조사에서는 각 항목별로 전수 조사를 실시하였다. 또한 전수조사결과 미비한 점은 3차 조사를 통하여 보완되었다.

3.2 GIS DB 구축

1) 라이브러리의 구축

제주도 전역에 대한 데이터베이스는 대용량이기 때문에 이를 하나의 커버리지로 만들어 관리·운영하는 것은 비효율적이다. 따라서 데이터를 조직적으로 관리하고 일관성을 유지하기 위하여 격자형 Tile 구조를 기본구조로 선택하였다. 이 경우 공간인덱스는 모두 주제도가 1/5,000 축적으로 구축되어 있으며, 향후 자료의 조회, 출력 등의 업무도 1/5,000 축적단위를 사용하기 때문에 현재 사용하고 있는 1/5,000 도엽인덱스 체계를 따르도록 설계하였다. 또한 도면좌표 기준점(Master Tic)은 제주도 전역을 1/50,000 도엽을 기준으로 6개의 대분류 번호체계를 부여하고 1개의 대분류 번호체계에 1/5,000 도엽이 100개가 포함될 수 있도록 소분류 번호체계를 부여하였다.

2) GIS DB 구축

앞서 조사된 항목을 기본으로 하고 필요한 경우 각 주제도를 재분석 또는 파생시켜 총 42개 항목에 대한 GIS DB를 아래와 같이 구축하였다.

< Contents of Cheju Island GIS Database >

Environment Condition	Survey Item	Layers & Description
Natural Environment	Topography	• contour line : 5m interval • slope : 5% interval • aspect : from north to north–west in clockwise
	Hydrology	• stream : stream, narrow, dry • watershed : analyzed from surface modelling • basin : watersheds integrated into sixteen region
	Vegetation	• vegetation species : deciduous, mixed, coniferous, rare community • diameter : 10cm unit • age : 10year interval • density : high, middle, low
	Wildlife	• habitat : grassland, forest etc.
Groundwater Environment	Groundwater	• wells : location(3,989) • owner : public or private • usage : series(63) agriculture and live–stock, industry, salty • geologic profile : 598 wells
	Soil	• soil series : series(63) • type : soil type • depth : valid soil depth • erosion : per soil unit • agricultural suitability : 7 levels • risk index of soil pollution : soil series(54)
	Vulnerability to soil pollution	• potential soil pollution testing sites : location(274) • measured concentration for soil samples:sample sites • measured concentration soil series : series(54)
	Permeable geology	• permeable geological area: lava tunnel, column joint, clinker, clastic zone etc.
Socio–economic Environment	Land use	• land use: urban, settlement, farmland, orchard, forest, grass land etc.
	Restricted land use area	• national landuse planning: urban, semi–urban, agricultural, semi–agricultural, nature protection area • conservation area: absolute, relative, special • grass–farming encouraged area • prevented area for waterworks: fifteen areas • agriculture promoted area • agricultural and industrial area: three areas • park • recreational area • hot springs :
	Population and settlement	• settlements: 32 settlements, population, education, jobs
	Industry and regional economy	☞ this doesn't have geographic data. only table data is available.
	Cultural assets	• registered : treasure, historical monument, natural monument etc. • non–registered: prehistorical sites war sites
	Main facilities	• road network: national, local, city and county etc.
Landscape	Landscape	• scenic beauty: very high, high, medium low • visual absorption ability: high, medium, low • viewing distance area : near, mdeium, far

4. 환경보전적 토지이용계획

4.1 계획수립 원칙

제주도 중산간지역에 있어서 개발과 보전에 대한 논쟁은 지하수보전, 생태계보전, 경관보전 문제로 압축된다. 즉 지하수 보전문제는 중산간지역의 토양·지질구조가 지하수오염에 취약하다는 점이고, 중산간지역이 해안지역과 산악지역의 중간에 위치하여 동·식물 등의 생태계에 주요한 역할을 수행하고 있고, 중산간지역의 독특한 경관을 적극 개발하여 관광자원화 하자는 주장과 영구히 보전해야 한다는 주장이 대립하고 있다. 따라서 본 연구에서는 이러한 주장들에 대하여 과학적이고 합리적인 준거를 제시하고 적정용량 개발을 유도하기 위하여, 지하수·생태계·경관에 대한 각각의 환경보전적 토지이용계획을 수립하였다.

토지이용계획을 수립하는 데에는 원칙적으로 보전의 목표를 달성하데 필요한 모든 요소가 고려되어야 하나, 모든 요소에 대한 조사는 쉽지않고 또한 단기간내에 이루어질수 있는 것도 다니다. 따라서 이번 연구에서는 현황조사에서 파악된 조사결과를 중심으로하여 계획을 수립하였다.

즉 지하수보전을 위한 토지이용계획서는 투수성지질구조 요소와 토양의 오염취약성 조사결과를 이용하였으며, 생태계 보전을 위한 토지이용계획은 실물상요소와 동물상요소가 이용되었다. 경관보전을 위한 토지이용계획에서 경관미, 시각적 흡수능력, 거시거리 분석결과가 사용되었다. 또한 각각의 계획에서는 전체 토지를 5개 등급으로 구분하여 I등급지역은 현상태로 보전하고 V등급지역은 개발을 허용하는 등 단계적으로 개발행위의 허용기준을 제시하였다. 각 요소간 상이한 등급이 도출될 때에는 상위등급 우선원칙을 적용하는 전반적으로 보전으로 위주로한 기준을 채택하였으며, 향후 추가 조사가 있을 것에 대비하여 융통성있는 GIS체계를 구축하였다.

4.2 토지이용계획 수립

1) 지하수보전을 위한 토지이용계획

지하수보전을 위한 토지이용계획에는 토양요소와 투수성지질구조 요소가 사용되었다. 토양요소는 기존 토양도에 나타난 토양통별 물리적, 화학적 특성을 SEEPAGE 모형으로 분석하여 산출한 오염위험지수와, 중산간지역 300여개

소에서 채취한 시료를 분석하여 제주도에서 많이 사용하고 있는 농약인 Alachlor의 잔류농도를 SESTAN 모형을 사용하여 산출한 대표 돌출농도의 정도에 따라 등급을 설정하였다. 다만 제주도 중산간지역의 토양이 오염물질을 충분 여과할 수 있는 토양을 가지지 못하다고 판단되어 모든 개발이 허용되는 Ⅴ등급지역을 설정하지 않았다.

또한 투수성지질구조 요소는 지질의 투수정도에 따라 Ⅰ·Ⅱ등급지역만 설절정하였다. 즉 우수가 아무런 방해없이 지하수위까지 도달할 수 있는 숨골·함몰지 등의 지질이 분포된 지역은 Ⅰ등급으로 설정하였으며, 절리구조발달지역, 파쇄대발달지역 등 토양이 어느정도 분포된 지역은 Ⅱ등급으로 설정하였다. 이 결과 Ⅰ등급지역이 전체면적의 9.0%, Ⅱ등급지역이 23.4%로 타나났으며, Ⅲ등급지역이 가장 넓은 41.5%를 차지하였다.

< Criteria for Groundwater Conservation >

level	factors		Area	
	soil factor	permeable factor	㎢	%
I	risk index : over 55 concentration : over 3,000㎍/ℓ	sink hloe, lava tunnel, mar, column joint, clinker	526	9.0
II	risk index : 40~54 concentration : 1,000~3,000㎍/ℓ	joint, clastic zone, scoria layer, baked zone	139.0	23.4
III	risk index : 25~39 concentration : under 1,000㎍/ℓ		224.6	41.5
IV	risk index : under 24 concentration : below 200㎍/ℓ		153.8	26.1

2) 생태계보전을 위한 토지이용계획

생태계보전을 위한 토지이용계획은 식물상 요소와 동물상 요소로 구분하였다. 식물상 요소에서는 희귀식물, 멸종위기식물 분포지 등 보호대상 식물군락지를 Ⅰ등급으로 설정하였고, 자연림 및 주요식생군락지는 Ⅱ등급, 2차림군락지는 Ⅲ등급, 조림지, 억새군락, 자연초지 등은 Ⅳ등급으로 설정하였으며, 경작지, 인공초지, 취락지 등은 Ⅴ등급지역으로 설정하였다. 동물상 요소에서는 동물의 서식환경을 고려하여 희귀동물, 멸종위기 동물서식지는 Ⅰ등급, 활엽수림 고밀지역은 Ⅱ등급, 활엽수림 중밀지역과 침엽수림 고밀지역은 Ⅲ등급, 활엽수

림 저밀지역과 침엽수림 중·저밀지역은 Ⅳ등급으로 하였으며, 경작지, 취락지 등은 Ⅴ등급지역으로 설정하였다. 이 결과 Ⅰ등급지역은 전체면적의 3.0%, Ⅱ등급지역은 5.7%, Ⅲ등급지역은 12.8%, Ⅳ등급지역이 가장 넓은 66.1%를 차지하였다.

< Criteria for Eclolgical Conservation >

level	factors		Area	
	vegetation	fauna	㎢	%
I	rare, endangered	rare and endangered	17.6	3.0
II	natural forest	good habitat (high-dense deciduous and mixed forest)	33.4	5.7
III	secondary forest	fair habitat (mid-dense deciduous and mixed, high-dense coniferous forest)	75.6	12.8
IV	plantedtion forest, brush, and grassland	bad habitat (low-dense deciduous and mix, mid-dense and low - dense coniferous forest, grass land)	389.4	66.1
IV	etc(farm land and settl-ement)	etc(farmland and settle area)	73.0	12.4

3) 경관보전을 위한 토지이용계획

경관보전을 위한 토지이용계획은 경관미, 시각적 흡수능력, 가시지역 분석 결과를 이용하여 설정하였다. 먼저 제주도를 대표하는 경관지로 경관미가 매우 높은 지역을 Ⅰ등급으로 하였으며, Ⅱ등급은 주용조망점에서 근경에 포함되는 지역으로 경관미가 높고 시각적 흡수능이 낮은 지역을 대상으로 하는 등 경관미, 사각적 흡수능력, 가시지역의 조합에 따라 등급을 설정하였다. 이결과 Ⅰ등급지역이 전체면적의 11.0%를 차지하였으며, Ⅱ등급지역 9.4%, Ⅲ등급지역 58.1%, Ⅳ등급지역 19.9%, Ⅴ등급지역 1.6%의 분포비율로 나타났다.

< Criteria for Landscape Conservation >

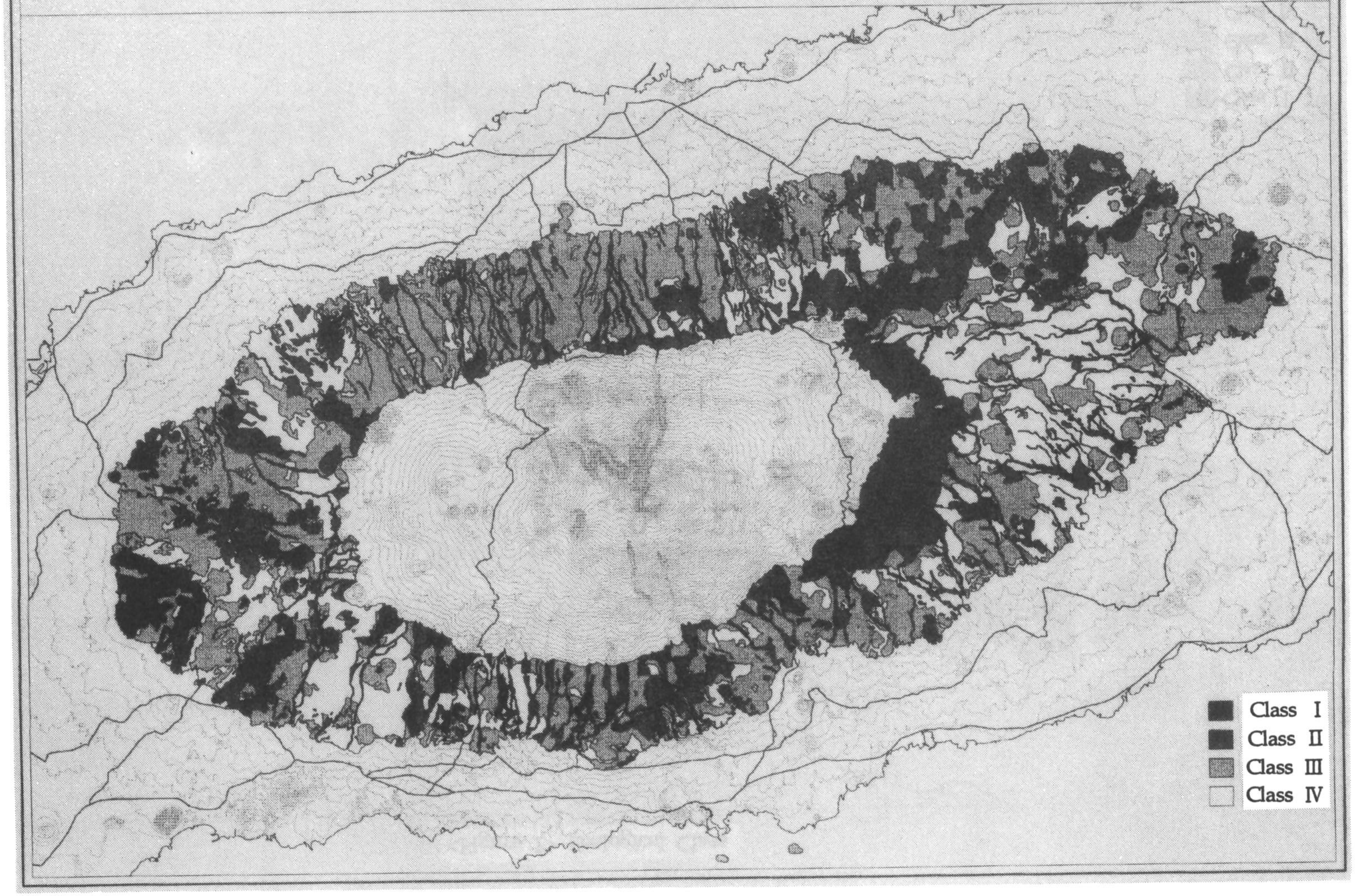
level	factors	Area	
	scenic beauty−visual absorption ability−viewing distance	㎢	%
I	H+	64.8	11.0
II	H−L−N	55.3	9.4
III	H−H−N, H−M−M, H−L−F, M−M−N, M−L−M, L−L−N	342.2	58.1
IV	H−H−M, H−M−F, H−H−N, M−M−M, M−L−F, L−M−F, L−L−M H−H−F, M−H−M, M−M−F, L−H−N, L−M−M, L−L−F	117.2	19.9
IV	M−H−F, L−H−M, L−M−F, L−H−F	9.6	1.6

H : high, M : medium, L : low, N : near, F : far

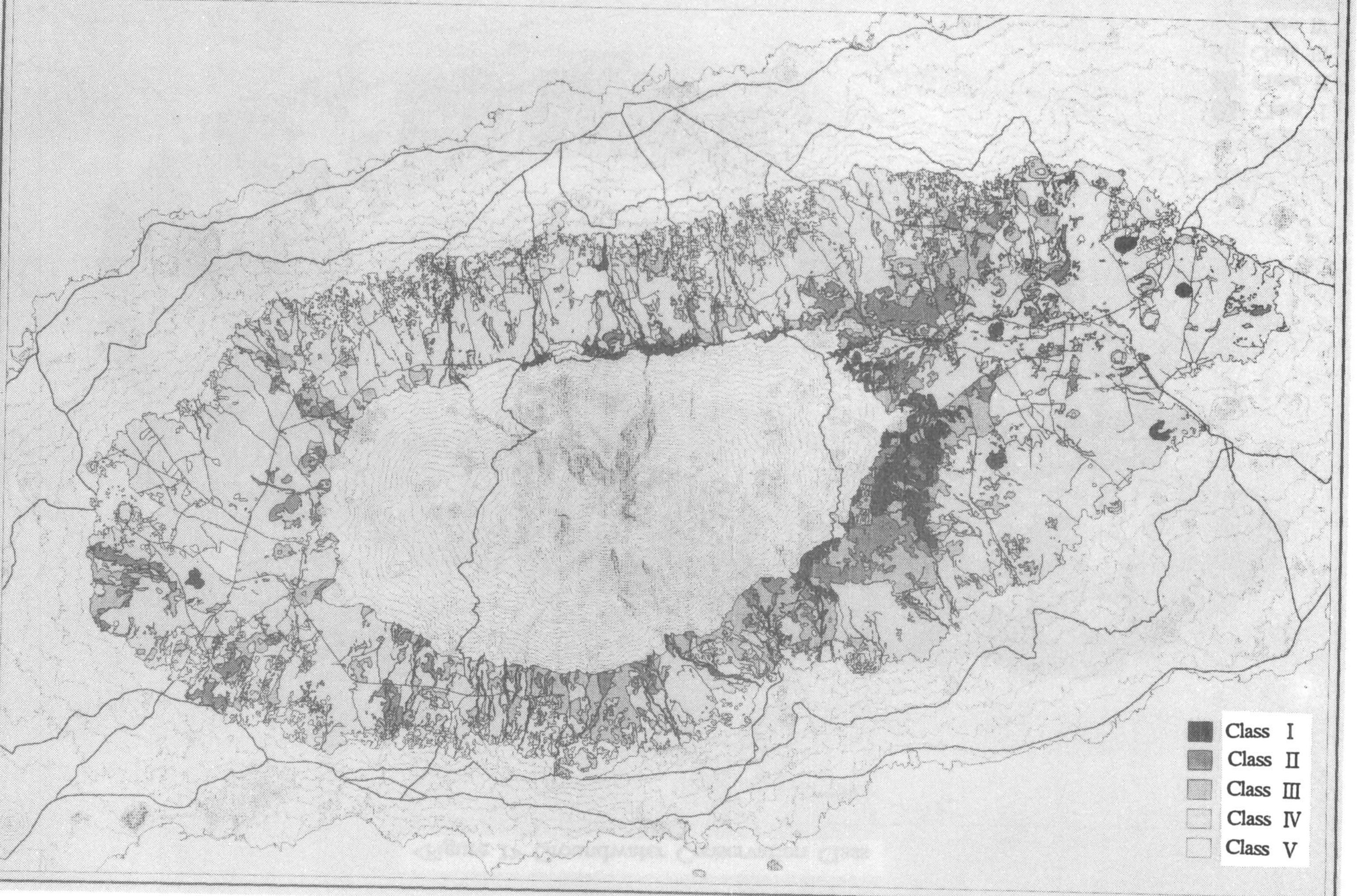
4.3 계획의 관리

지하수, 생태계, 경관보전을 위한 토지의 관리는 각각의 특성에 따라 등급별로 관리방안을 마련하였다. 지하수 보전을 위해서는 각종 시설물에서 배출되는 방류수의 수질을 규제하는 관리방안을 마련하였으며, 생태계보전 지역에서는 산림, 농지 등의 훼손·전용규모를 제한하는 방안을 제안하였다. 또한 경관보전계획에서는 각종 시설물의 길이와 높이를 제한하는 방안을 제시하였다.

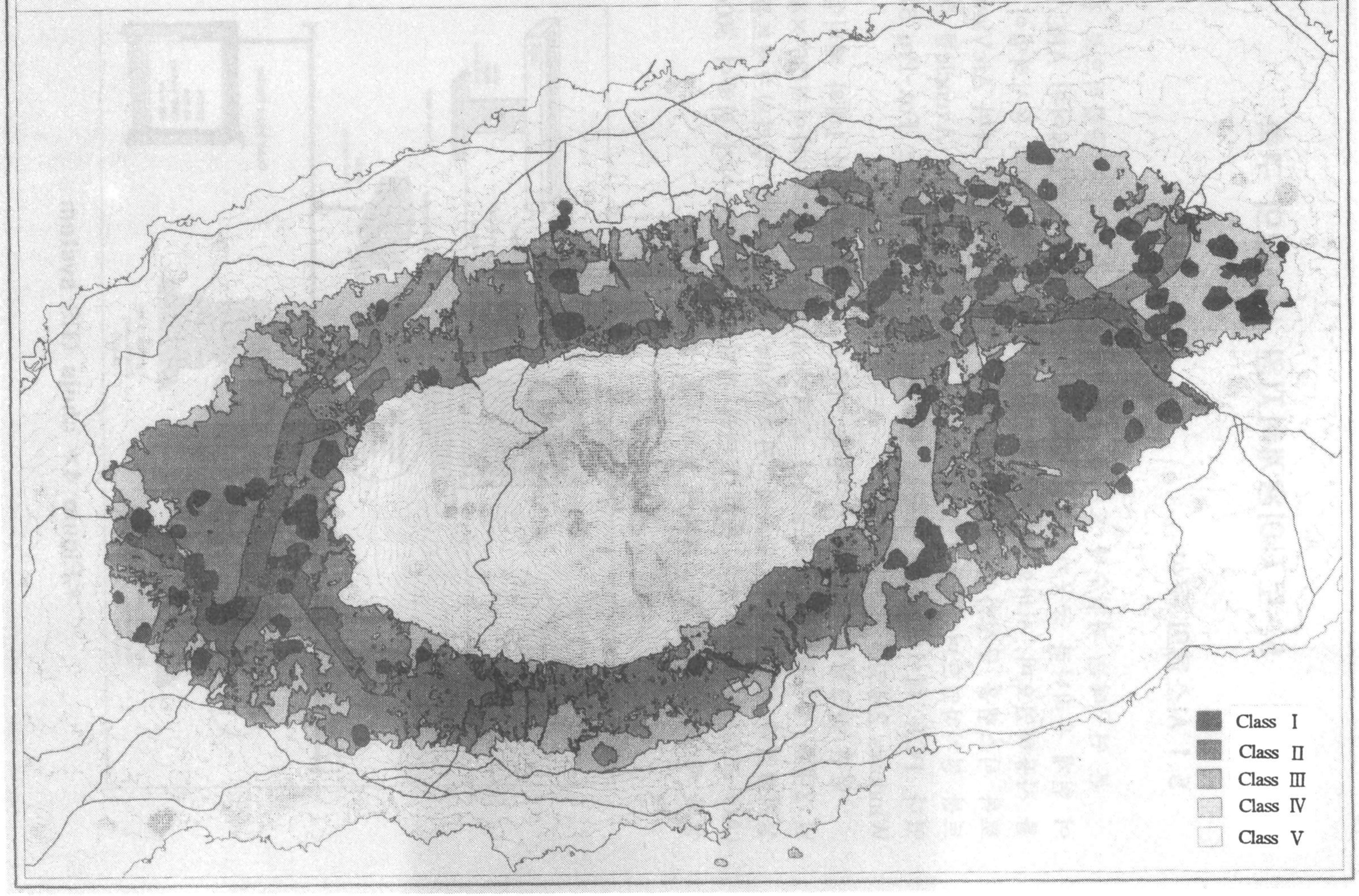
<Figure 1> Groundwater Conservation Class



<Figure 2> Ecological Class



<Figure 3> Landscape Conservation Class

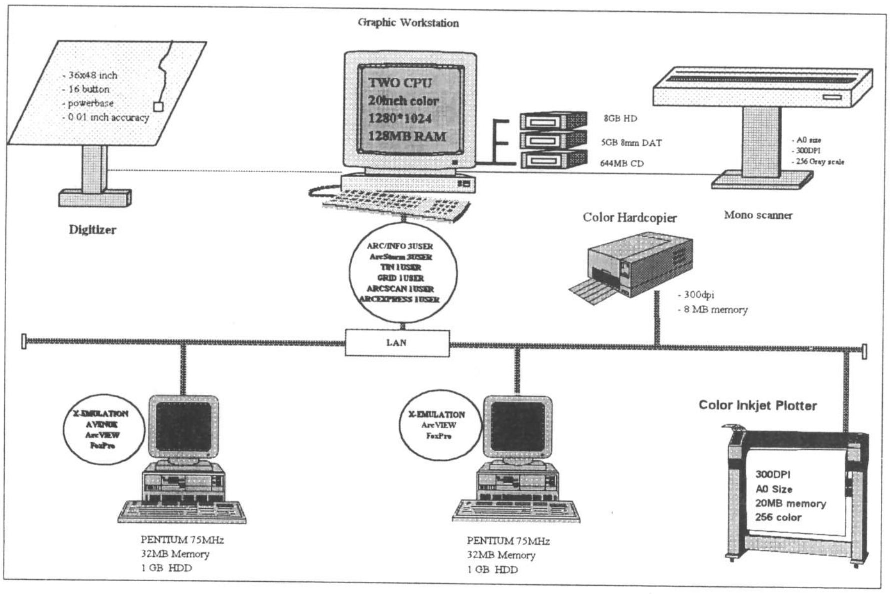


5. 토지이용계획지원 시스템의 구축

5.1 시스템의 구성

본 연구에는 과업수행 요원의 사용경험, 기술축적 등을 종합적으로 감안하여 현재 우리나라 공공기관에서 널리 사용되고 있는 소프트웨어인 ARC/INFO를 사용하였으며, 서버와 터미널 2대를 기준으로 최대 3인의 동시작업이 가능토록 시스템을 구성하였다. 또한 데이터의 조회와 출력을 위하여 ArcView 2세트를 설치하였으며, 이중 1세트에는 응용프로그램개발 도구 Avencle를 추가하였다. PC용 데이터베이스 도구는 윈도우스 환경을 지원하는 Fox-Pro 3.0 for Windows 2세트를 설치하였다.

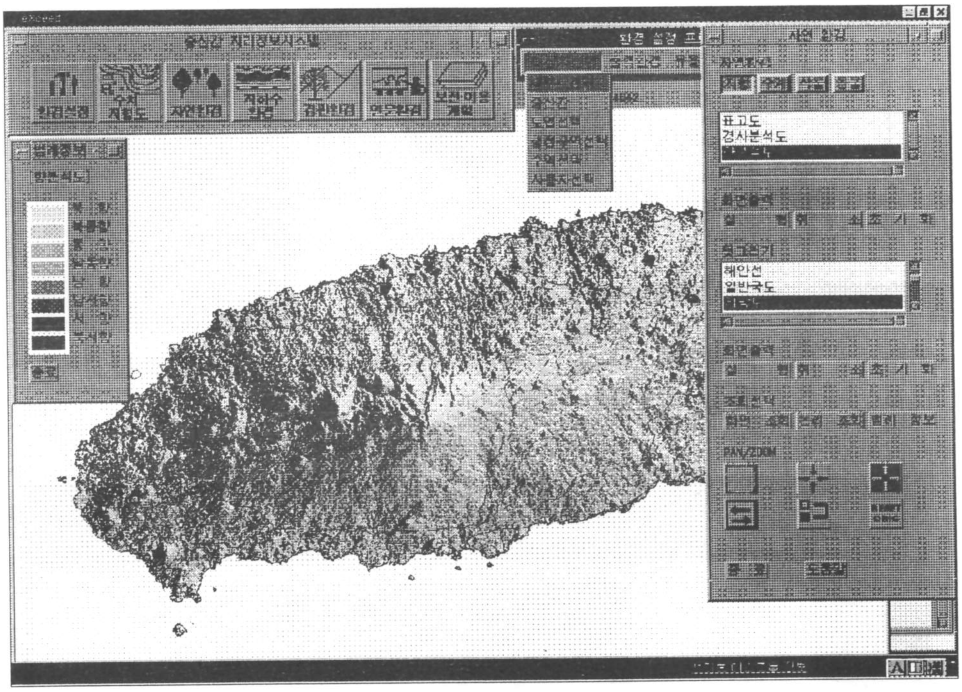
한편 하드웨어는 3인 동시사용을 기준으로 워크스테이션 1대와 펜티엄터미널 2대를 설치하였고, 입력장치는 스캐너(AO 크기)와 디지타이저(36″×48″)를 설치하였다. 출력장치는 칼라하드카피어(A4 크기)와 대형 칼라잉크젯트플로터(AO 크기)를 설치하였다. 특히 도면의 정밀도와 질을 높이기 위하여 300dip이상의 해상도를 가지는 스캐너와 플로터를 설치하였다.



<Figure 4> cheju GIS system

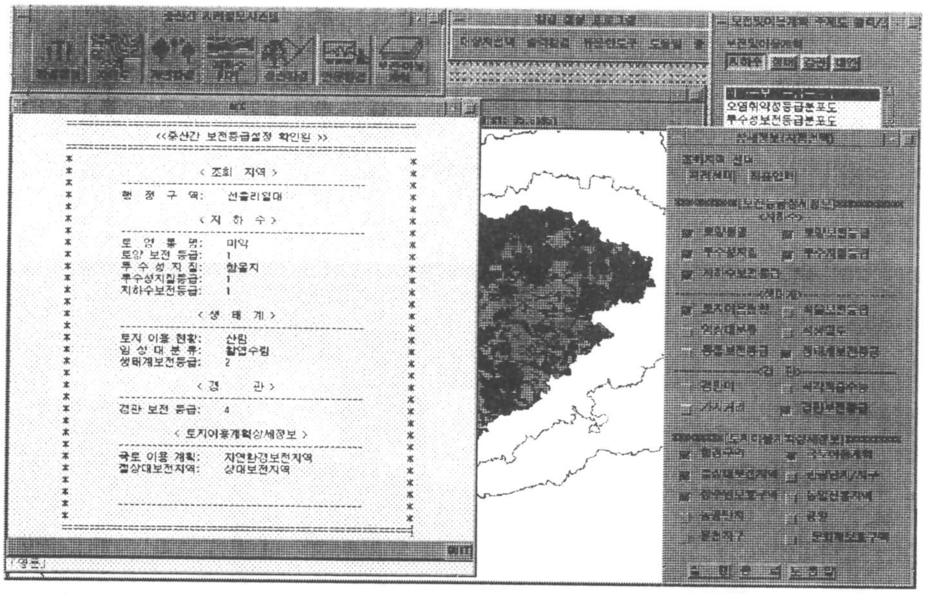
5.2 응용프로그램의 개발

서버의 응용프로그램은 Arc/Info의 AML(Arc Macro Language)을 이용하여 개발하였으며, 환경설정, 자연환경, 지하수환경, 인문환경, 경관환경 및 보전 및 이용계획 등 6개의 모듈로 구성하였다.

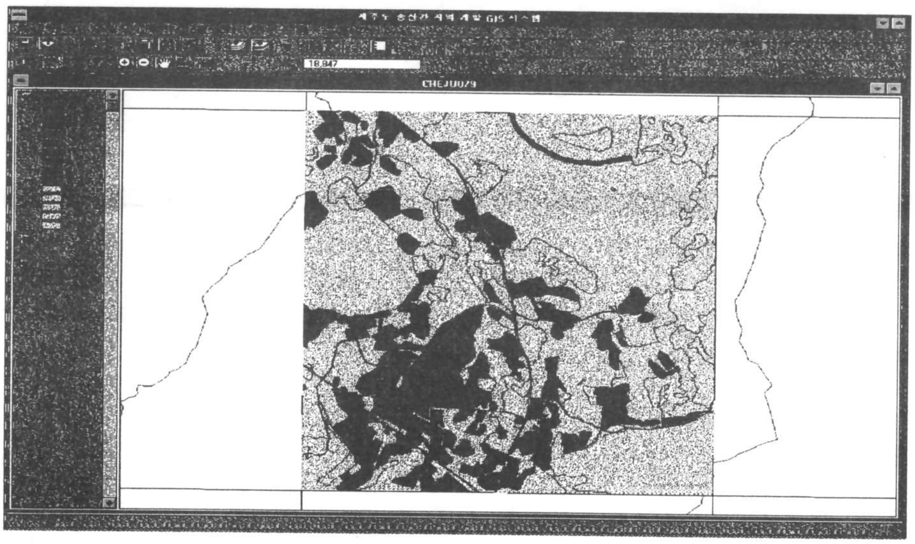


<Figure 5> 응용프로그램의 인터페이스는 다양하고 방대한 데이터베이스를 쉽게 이해하고 사용할 수 있도록 설계하였다. 자연환경 서브메뉴의 위쪽 창은 관련주제도가, 아래쪽 창에는 참조데이터(Framework)가 보이고 있다.

응용프로그램의 메뉴구성은 사용자가 다양하고 방대한 데이터베이스를 쉽게 이해하고 사용할 수 있도록 하는데 초점을 두었다<Figure 5>. 특히 개발의뢰지역에 대해서는 토지이용계획등급의 조회 및 근거자료를 출력하여 민원을 해할 수 있도록 하였다<Figure 6>. 한편 클라이언트인 PC의 응용프로그램은 ArcView의 Avenue와 Visual basic 4.0을 이용하여 개발하였다. 이를 이용하여 NFS(Network File System)기반으로 서버의 데이터베이스를 타일 및 레이어 단위로 접근할 수 있고 조회 및 출력을 할 수 있도록 하였다.



<Figure 6> 민원인 소유지의 각종 등급근거를 쉽게 조회하고 출력할 수 있다.



<Figure7> 클라이언트인 PC의 응용프로그램을 이용하여 서버의 특정도엽에 대한 주제도를 조회 -출력함으로써 업무의 효율성을 높일 수 있다.

5.3 시스템의 관리

시스템의 보호와 데이터의 보안유지를 위하여 일반사용자, 자료관리자, 시스템관리자의 3개 등급으로 사용자를 구분하였다. 일반사용자는 데이터의 이용이 필요한 실무부서의 실무자를 대상으로하여 데이터의 조화 및 출력가능만 부여하도록 하였다. 자료관리자는 해당부서에서 주관하는 데이터에 대한 수정·갱신권한을 가지도록 하였다. 또한 시스템관리자는 데이터 전체에 대한 수정 및 삭제권한과 시스템 전체에 대한 수정보완 권한을 갖도록 하였다.

< 사용자 데이터 접근권한 >

구　　분	일반사용자	자료관리자	시스템관리자
데이터 조회 / 출력	○	○	○
데이터수정(해당부서)	×	○	○
데이터 삭제	×	×	○
시스템 수정	×	×	○

6. 결론 및 과제

제주도 중산간지역과 같이 개발과 보전의 필요성이 공존하는 지역의 경우 무엇보다도 중요한 것은 과학적인 분석결과를 바탕으로 한 합리적 토지이용계획의 수립이다. 제주도 GIS 구축은 우선 토지에 관한 각종 정보가 하나의 시스템 안에 통합되어 토지의 효율적인 관리가 가능하게 되며, 도면 및 각종 대장의 전산화로 인력 및 경비가 절감되며, 중산간지역의 개발 및 보전에 관한 합리적 정책의 수립이 가능하고, 향후 각종 계획업무를 지원할 수 있는 정보시스템 구축의 토대가 마련될 것으로 기대된다. 특히 GIS는 빠른 시간내에 다양한 시뮬레이션을 가능하게 하므로 환경을 고려한 토지이용계획 등 점점 복잡해져 가는 계획환경하에서 의사결정을 지원하는 필수 불가결한 도구로 자리잡을 것이다.

그러나 공간문제는 본질적으로 매우 복잡하고 애매모호하므로 본 연구에서처럼 단순한 논리에 의존할 경우 현실적으로 여러 가지 문제가 발생되기 때문에 다음과 같은 몇가지 문제점들이 우선적으로 해결되어야 할 것이다.

우선, 입력데이타의 정확성에 관한 문제를 들 수 있다. 환경보전을 위한 개발행위규제는 개인의 토지소유권 행사와 직결되어 있으므로 계획상의 경계선은 정확성이 보장되어야 한다. 그러나 분석과정에 이용되었던 주제도면은 원도면 자체가 종이의 신축 등으로 부정확하며, 트레이싱지에 재 작성하여 수치화하는 과정에서 많은 오차가 발생하므로 개략적인 토지이용계획 수립 목적으로 활용하는 데는 큰 무리가 없으나 사업시행계획의 단계까지 활용하는 데는 상당한 무리가 따른 것으로 예상된다.

둘째, 각 중첩분석에서는 가장 대축척인 주제도의 정밀도를 따르게 되므로 대축척의 자료가 토지이용 형태를 결정하는 주요요인으로 작용하나 각 주제도의 도면축적이 상이하기 때문에 그 신뢰도는 떨어지게 된다.

셋째, 현황조사 자료를 GIS로 구축하는 과정에서 항상 완벽한 자료의 구축은 불가능하므로 추가자료의 획득 또는 기존자료의 변경요인 발생시 계속적으로 자료의 갱신이 가능하고, 갱신된 자료에 의해서 보다 더 정확한 분석이 가능하도록 융통성있는 시스템이 구축되어야 한다.

환경과 자원에 대한 관심과 중요성이 점증하고 있는 추세에 비추어, 토지이용계획의 수립은 단순한 현황조건의 분석·판단에 의한 결과의 제시기능보다 한걸음 나아가, 각 계획대안의 장·단점에 대한 과학적 판단을 지원하는 공간의사결정지원 시스템(SDSS : Spatial Dicision Support Syetem)을 구축하여 보다 현실적이고 설득력있는 결과가 도출될 수 있도록 계속적인 노력이 있어야 할 것이다.

GIS Utilization for the Multi-purpose Cadastre: Development and benefits

Earl Epstein
Professor
Ohio State University

ABSTRACT

An automated geographic information system consists of data about the location and attributes of natural and cultural features on or near the earth's surface and the people, procedures, software and hardware needed to manage and use the data. A multipurpose cadastre is a geographic information system that emphasizes data about the location and extent of rights and interests in parcels. A system conceived and built with this emphasis is ideally designed to provide the information needed by those involved in decisions about land planning and development, environmental impacts and other land related activities. Recently, we have studied the development of these systems over their life cycle and in a community context rather than simply within an organization. This paper discusses the life cycle of a community multipurpose cadastre, called a community multipurpose land information system, focussing on the stages of development, forces for change in these stages, measurable indicators, and factors, and benefits. The community benefit, called equity, is described with attention to institutional incentives and barriers to the capture of this benefit.

요 지

GIS는 지표상의 자연, 인문환경에 대한 위치, 속성정보와 이러한 정보를 관리하고 사용하는데 필요한 인적자원, 하드웨어, 소프트웨어로 구성된다. 다목적 지적정보시스템은 필지의 위치와 소유권, 이해관계 등의 범위에 대한 자료에 주안점을 둔 지리정보시스템이다. 이러한 시스템은 토지이용계획 및 개발, 환경영향평가 등 토지이용관련 활동에 필요한 의사결정을 하는데 필요한 정보를 제공해줄 수 있다. 최근 우리는 단지 하나의 기구내에서가 아니라 지역사회 전체의 맥락에서 이러한 시스템 개발의 전과정에 관하여 연구했다. 이 글에서는 지역사회의 다목적 토지정보시스템의 life cycle에 대하여 논의하고자 한다. 특히 개발단계에 촛점을 맞추어 각 단계로 변하게 하는 원동력, 지표, 요인 및 혜택에 대하여 논의할 것이다. 제도적인 유인책과 평등성이라 할 수 있는 지역사회가 얻게되는 혜택을, 그 혜택을 얻기위한 제도적 유인책과 장애요소에 초점을 맞추어 설명하였다.

1. INTRODUCTION

Periodically the concepts of a multipurpose cadastre should be reviewed for veteran participants in the management of geographically referenced information system and introduced to new participants. Preoccupation with the development of information science technology and its application to the specific problems of spatial information management may result in overlooking the special role of data about property parcels. The property parcel is the focus of a cadastre and people, governments, and organizations care greatly about parcels. Often information system designers are removed from those who use information system products to manage land and its resources or from those affected by land management decisions influenced by these products. Therefore, it is important to describe the role of the cadastre within a spatial information system.

This paper summarizes the multipurpose cadastre and its role in a spatial information system and in land management. It also summarizes recent consideration of the development life cycle of the multipurpose cadastre in a community of users. The stages of system development and forces for change in these stages are identified and described, as are measurable parameters for these important characteristics. Finally, the benefits of investments in a multipurpose cadastre within the broad community context and over time are described. These benefits of these investments are seen to be considerable when the system products are opened to use by many community members rather than restricted to a narrow organizational context.

2. THE MULTIPURPOSE CADASTRE AND LAND MANAGEMENT

The demand for land information appears at all levels of government and inthe private sector. This demand reflects a critical need for better land information to improve land conveyance procedures, furnish a basis for land valuation, and provide much needed information for resource management and development.[National Academy Press, 1980 and 1983]

The concept of the multipurpose cadastre is that of a framework that supports continues, readily available and comprehensive land-related information at the parcel level. The components of the multipurpose cadastre are the following:

1. A reference frame, consisting of a geodetic network
2. A series of current, accurate large-scale maps
3. A cadastral overlay delineating all cadastral parcels
4. A unique identifying number assigned to each parcel
5. A series of land data files with indexes for purposes of information retrieval and linking with information in other data files.

The reference frame, consisting of a system of monuments having geodetically derived coordinates, permits defining the relative spatial location of all land-related data. Requirements for the geodetic reference framework for a cadastre are summarized as: First, it must permit correlation of real property boundary-line data with topographic, earth science, and other land and land-related data. Second, it must be permanently monumented on the ground so that lines on the map may be reproduced in the field.

The base map consists of a family of large-scale planimetric and topographic maps which permits the graphical representation of the land-related data. The base map is the primary medium by which cadastral parcels are related to the geodetic reference framework; to major natural and man-made features such as bodies of water, roads, buildings, and fences; to political boundaries; and to each other. The base map also provides the means by which all land-related information may be spatially referenced to cadastral parcels. It is the medium for determining and expressing locations in continuous space, so that shifts in the locations of the boundaries of cadastral parcels may be entered as necessary in the officials records. The map may be stored either in graphic form, on paper or Mylar, for example, or in digital form as a "virtual" map.

The cadastral overlay consists of a specialized series of maps delineating the current status of property ownership. The individual building block for the overlay will be the cadastral parcel. This is an unambiguously defined unit of land within which unique property interests are recognized.

Associated with each parcel will be a unique identification number. The cadastral overlay depicts positions of property boundaries in relation to the other features shown on the base map and shows the standard identifier of each parcel, the latter serving as the key to the many other parcel records that can then be based on the multipurpose cadastre. The cadastral overlay can be viewed as a property ownership map that adheres to standards for accuracy of plotting of property boundaries and completeness in display of parcel identifiers- including standards for timely updating to show boundaries and identifiers of newly created parcels. The cadastral overlay is the result of work by surveyors, abstractors, title attorneys, zoning organizations, and courts. This overlay represents the property parcels.

The unique parcel identification number will provide a key for linking each cadastral parcel to various land data files or registers. These records may contain information about land ownership, use, cover, assessment, and such other attributes as may be required in making decisions about the management of land resources. Other identifiers, either existing or to be introduced, may be used to assist in accessing in accessing and manipulating these land-information records.

In order to relate other land information to the basic components, linkage mechanisms are required. Essential elements of the linkage mechanism are standard definition of the parcel identifier, geographic location of the parcel, a parcel index map, a computerized index of parcels, and links to geographically-related data.

The basic components (reference frame, base map, and cadastral layer), if properly established and maintained, can provide the common framework for all land information systems. Exchange of land data between systems describing natural phenomena, on the one hand, and cultural phenomena, such as attributes of land parcels, on the other, is greatly facilitated when both are built upon the foundation of a multipurpose cadastre.

These basic components define the cadastre. A cadastre is a record of interests in land, encompassing both the nature and extent of these interests. An interest in land (a property right) may be narrowly construed as a legal right capable of ownership or more broadly interpreted to include any uniquely recognized relationship among people with regard to the acquisition and management of land.

The complete set of these relations in a community in regard to use of land and its resources is called land tenure. Land tenure encompasses all the many relationships that govern (1) control of and access to land resources,(2) the use of these resources, and (3) the claims on goods and services that flow from these relationships.

The importance of the cadastre rests upon the simple, fundamental idea that people, whether they are government officials, representatives of private organizations, or citizens, are interested in who has the right to decide about allocation and use of land and its resources and how these decisions impact them, their property, and the community. The term multipurpose applies when this broad community of cadastre product users is recognized and provision made for their convenient and consistent access to the data.

While concern about the quality of existing cadastral institutions has been voiced for some time, it is only in the last few decades that an awareness of the magnitude of the economic and social costs incurred by continued reliance on outmoded cadastral arrangements has surfaced. Although these costs have been incurred in many and varied areas of human activity, they are most apparent in the processes of land transfer, property assessment, and land use management, and in the quest for a better understanding of the land tenure institution itself. A multipurpose cadastre is designed to overcome difficulties with more limited systems by (1) providing in a continuous fashion a comprehensive record of land-related information and (2) presenting this information at the parcel level.

3. THE COMMUNITY MULTIPURPOSE LAND INFORMATION (CADASTRE) MODEL

The geographic and land information system (GIS/LIS) literature is considerable, both anecdotally and analytically. There are papers which develop a theory of the nature of GIS/LIS development in organizations. GIS/LIS development itself is part of the broader context of adoption and diffusion of technology in organizations for which there is a considerable theoretical and empirical literature. This knowledge and experience is the basis for models of GIS/LIS development that guide both data collection and analysis.

Efforts to extend knowledge about system development begins with review of the theoretical and experimental literature on adoption and diffusion of technology in organizations generally and the adoption and diffusion of GIS/LIS particularly. They also rely upon the theoretical and empirical literature on the land management process, the domain of activity where the products of GIS/LIS systems are used. The well developed land management literature reveals that the major venue for GIS/LIS development is often local government. It is at this level that the products of a GIS/LIS are used to make plans, policies, decisions and actions that determine people's rights and interests in land. This is where, collectively, the largest investments in land records management and systems development occur in North American venues.

Recently, these theories and observations were reviewed and extended to develop a model of a community Multipurpose Land Information System (MPLIS). [Tulloch et al, 1996] The name multipurpose land information system is used synonymously with that of multipurpose cadastre. The community MPLIS model provides the intellectual basis for (a) identifying the data to be collected, (b) data collection methods, and (c) analysis of the results. A brief review of the model's features is appropriate.

A major feature of this model is the distinction between STAGES of system development in a community and FORCES that drive change in that status.

The model identifies sets of observable parameters that characterize the stages and forces. These parameters are called INDICATORS for the stages and FACTORS for the forces.

The STAGES represent points along a life cycle of system development in a community. They define where a system is in the course of its development over time. The ability to describe the stages of a system promotes communication among people who work with systems in different organizations, places and times. The STAGES OF COMMUNITY MPLIS DEVELOPMENT are:

3.1 NO ACTIVITY

Activities are limited to manual processes and there are currently no planned modernization efforts.

3.2 SYSTEM INITIATION

Activities are directed toward establishing the prerequisites for such a system (i.e., database design, needs assessment, procurement)

3.3 DATABASE DEVELOPMENT

Building databases to support geographic or land information management (i.e., resource boundaries, parcel map construction or conversion)

3.4 RECORD KEEPING

Existing data are used in routine queries and selective information retrieval (i.e., tax assessment number of new building permits)

3.5 ANALYSIS

Existing data enable the performing of complex inquiries (i.e., 911 emergency routing , landfill siting)

3.6 DEMOCRATIZATION

Existing data enable agency decision makers and the public to conduct spatial analysis (i.e., alternative scenarios for future land and resource use or evaluation of social services)

The classes of measurable parameters called INDICATORS whose values determine the stages of a community MPLIS are:

Use of Technology
Transfer of Data
Improved Data Quality
Improved Agency Data Management
Education and Training
Change in Decision Making Process
Impacts of Land Related Decisions

FORCE for change represents a condition in a community that tends to promote change in the stage of development. Measurable parameters whose values define the force for change are called FACTORS. The classes of major FACTORS are:

Mandates or Standards
Incentives
Costs
Government Operations, Programs, Programs and Issues
Characteristics of the Technology
Characteristics of Data and Information
Beliefs
Leadership
Institutional Factors

Information about the data, equipment, and procedures that characterize a GIS/LIS are described as FOUNDATIONAL ELEMENTS. Classes of FOUNDATIONAL ELEMENTS are:

Base Mapping
Geodetic Reference Framework
Parcels Mapping
Zoning Mapping
Wetlands Mapping
Soils Mapping
Hydrography Mapping
Administrative Mapping
Institutional Arrangements
Communication, Education and Training
Public Access Arrangements

Another important feature of the model is that it extends the state of knowledge and description of the BENEFITS of these systems and develops a new category of benefits. The existence, recognition and measurement of benefits help characterize systems. The perceived ability to capture a benefit contributes to the force for change. The classes of BENEFITS are called the three Es and consist of:

EFFICIENCY results where GIS/LIS tools make it possible to perform traditional mapping activities at reducedcost, to generate more products, or to complete tasks more rapidly. Attention focusses on the activities of the agency's mapping subsection.

EFFECTIVENESS results when more or better information can be generated from traditional data because the new tools make possible digitally stored data and software for sophisticated analysis. Attention shifts to how well system products support agencies' mandated functions.

EQUITY results from the perceived or real benefits that are made possible by an increase in participation by citizens and organizations in decisions about land and resources. Attention shifts to land management activities throughout the community.

Traditionally, attention to system benefits has focussed on efficiency and effectiveness. Efficiency is a common measure of benefits because it is easily expressed in monetary terms, reflecting the amount of money saved through system implementation in the information management section of an organization. Effectiveness is somewhat more difficult to determine.

However, estimates of the monetary values of these benefits can be made based upon the savings associated with activities made possible by the additional information generated from the traditional data.These are also popular measures of benefits because they relate closely to the internal needs of organizations and are easily understood by non-technicians and decision makers in those organizations. [Epstein, et al, 1997]

Recently, attention has turned to the benefits associated with the broader use of system products beyond the organization and throughout the community. These outcomes are characterized as societal benefits, equity, decision making, and democratization. As a general trend, this attention is evidenced by the amount of interest in community issues such as public access and liability and concerns about the outcomes associated with the growing relationships between GIS and society. Here the set of product users is potentially greater in number and type than those users in the organizations that initiate and develop the system. The perspective encompasses the whole community of public and private organizations and people interested in the value to them in their land related work which depends upon decisions made with the products of an information system.

The benefits from use of system products by increased numbers of community members are labeled equity benefits. This label is appropriate because land related decisions made by a more representative segment of the community means that GIS/LIS becomes democratized.

This democratization represents an important advance in MPLIS development, holding out the potential for increased community awareness, utilization and support for the system based on a sense of increased participation in the allocation of land and its resources.

There is also another reason for describing these benefits as equity benefits. Their achievement depends upon wide distribution and easy access to system products, This fundamental characteristic of dissemination and access has always been a standard for public data and information and a subject of policy controversy. The long-term democratic interest in the dissemination of records and information used by governments to execute their legislative and legal mandates is exhibited by the open records and freedom of information laws which are built upon the democratic principle that access to information used by governments for their public business is essential in a society where people need to know what their governments are doing. A negative view of broad, convenient access by many to GIS/LIS data restricts the full development of systems and to garnering the large, unrealized potential for equity benefits.

4. SUMMARY

The multipurpose cadastre traditionally emphasizes the importance of data and information about the nature and extent of rights and interests in land parcels. Much of this material is held by government agencies who use it to execute their mandated land management functions. Modern technology now makes it possible to reasonably acquire and use data and information about parcels at great accuracy. The technology also makes it possible to disseminate that data and information so that many people in the community can obtain and use that material. Widespread, convenient access to publicly held cadastral data makes it possible to achieve considerable economic and democratic benefits from system investments.

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Using Spatial Information Systems to Support Australia's Sustainable Development

Philip Tickle
Manager
Bureau of Resource Sciences

ABSTRACT

The Bureau of Resource Sciences is one of three professionally independent specialist bureaus within the Commonwealth of Australia's Department of Primary Industries and Energy. The Bureau's mission is to enhance the sustainable development of Australia's agricultural, fisheries, forestry, mineral and petroleum resources and their industries, by providing high quality scientific and technical advice to government, industry and the community.

In a country the size of Australia, the task of providing timely, high-level advice on sustainable development issues requires large volumes of data and the ability to integrate and display it in ways that can be understood by policymakers and land managers. To support this core business, the Bureau maintains a wide range of national GIS databases including the National Forest Inventory, National Plantations Inventory, Digital Atlas of Australian Soils and the Geology of Australia, and a range of climate and terrain databases. The Bureau is also involved in a variety of nationally significant, multi-disciplinary projects in collaboration with State land management agencies.

These projects include: the National Greenhouse Gas Inventory, which

is mapping forest cover change across the continent using satellite information and modelling changes in biomass; Comprehensive Regional Assessments of Australia's commercial forests, that involve the spatial modelling of forest growth and yield, and landuse allocation; the Sustainable landuse Information System, that is developing techniques to predict and monitor drought cross the Continent, and ASSESS (A System for SElecting Suitable Sites) which is a GIS-based Decision Support System developed to identify suitable areas for radioactive waste disposal and now being used for a range of other purposes.

In order to integrate, analyse and display these datasets, the Bureau has installed the most advanced computing facility dedicated to natural resource assessment in Australia.

The facility includes an integrated network of multi-processor servers, a massively parallel CM5 supercomputer, a Cray vector supercomputer and a range of software systems.

Through a number of case studies, this paper will discuss a range of experiences and issues faced by the BRS in recent years including: the development of national spatial databases, data standards and metadata, applications development and the adoption of leading-edge technology in support of ecologically sustainable development.

요 지

자원과학국은 호주연방의 1차산업과 에너지부 내에 설치되어 있는 세 개의 전문기관중 하나이다. 자원과학국의 목적은 양질의 과학적, 기술적 조언을 정부기관과 업계 그리고 지역사회에 제공함으로써 호주의 농업, 어업, 산림, 광물과 석유자원의 지속가능한 개발을 지원하는 것이다.

호주와 같은 나라의 규모에서 지속가능한 개발에 대한 보다 높은 수준의 정보를 제공하기 위해서는 많은 양의 데이터와 그것을 정책결정자와 토지관리자가 이해할 수 있도록 적절하게 통합하고 표현할 수 있는 능력이 필요하다.

이러한 중심업무를 지지하기 위해서 자원과학청은 국립산림일람표와 국립식생일람표, 호주토양수치지도, 호주의 지질도를 포함한 많은 양의 국가GIS데이터와 기후, 지형데이터를 가지고 있다. 또한 국가적으로 중요한 다양한 프로

젝트에 주립토지관리위원회와 함께 연구하고 있다.

그 프로젝트들 중에는 다음과 같은 것들이 포함된다: 위성정보를 이용하여 호주대륙전역의 산림변화를 지도화 하고 생태계의 변화를 모델링하는 온난화 가스(greenhouse gas), 산림성장과 양, 토지이용 등을 공간적으로 모델링하는 호주상업산림의 통합적인 지역영향평가, 호주의 가뭄을 예측하고 모니터링하는 기법을 개발하는 지속가능한 토지정보시스템, 방사능폐기물에 대한 지속가능한 지역을 선정하기 위해 GIS를 기초로 한 의사결정시스템인 입지선정시스템(A System for SElecting Suitable Sites, ASSESS)등 이다. 이러한 데이터들을 통합하고 분석하고 디스플레이하기 위해 자원관리국은 호주의 자연자원평가에 전용되는 가장 발달된 전산시설을 설치하였다.

이 시설은 복수연산장치 서버의 통합 네트워크, 병렬 연산 CM5 슈퍼컴퓨터, Cray 슈퍼컴퓨터, 그리고 다양한 종류의 소프트웨어 시스템등을 포함한다. 이 발표에서는 많은 사례연구를 통해서 최근의 자원관리국의 경험과 이슈들을 소개하고자 한다. 특히, 국가공간데이터의 개발, 데이터표준화와 메타데이터, 생태적으로 지속가능한 개발을 지지할 수 있는 첨단기술기법의 적용과 응용프로그램 개발 등이 논의될 것이다.

1. INTRODUCTION

In 1987 the World Commission on Environment and Development released a report entitled "Our Common Future" which today, is usually referred to as the Brundtland Report. The report recognised that sustainable development meant that the global community must adopt lifestyles within the planet's means. Australia's response has been to adopt and further refine the concept of sustainable development, and to adapt it to Australia's unique biophysical, social and economic environment. The result of this response was the development of a National Strategy for Ecologically Sustainable Development (ESD).

Australia's three tiers of Government, Commonwealth, State and local adopted the strategy and identified 5 guiding principles of ESD: integrating economic and environmental goals into policies and activities ensuring that environmental assets are properly valued providing for equity within and between generations dealing cautiously with risk and irreversibility, and recognising the global dimension

If decision-makers are going to apply these evolving principles of ESD to complex economic and environmental issues it is clear that they must have access to high quality information in a timely manner.

A number of significant programs have spawned in Australia to support the principles of ESD, one of which is the Bureau of Resource Sciences (BRS). The BRS is one of three professionally independent specialist bureaus within the Commonwealth Department of Primary Industries and Energy. The Bureau's mission is to enhance the sustainable development of Australia's agricultural, fisheries, forestry, minerals and petroleum resources and their industries by providing high quality advice to government, industry and the community.

In a country the size of Australia, the task of providing timely, high-level advice on sustainable development requires extensive amounts (volumes and themes) of information. It also requires the ability to integrate them in a variety of ways to ensure that effective policies are implemented. In order to identify relevant issues and explore options the information required often spans the breadth of biophysical and socio-economic realms. More often than not, there is no single answer to an ESD problem which requires the capacity to explore the implications of particular policies. In order to cope with such demands the BRS has installed, applied and developed a range of expertise and technologies. These include: The most advanced computing facility dedicated to natural resource assessment in Australia; the use of an integrated suite of software solutions including Geographic Information Systems (GIS), Exploratory Data Analysis (EDA) systems and Decision Support Systems DSS, and using multidisciplinary scientists in a team-based approach to solving ESD problems.

The aim of this paper is firstly to describe a number of more or less discrete stages that occur as you move from primary data to information, and the range of technologies that support these stages. Then, through a number of case studies the paper will discuss a range of experiences and issues faced by the BRS in recent years including:

The development of national spatial databases, data standards, metadata, applications development, and the adoption of leading edge technology in support of evidence-based policy development.

2. STAGES IN THE ESD INFORMATION FLOW

2.1 Data Access

In Australia the majority of information is collected by state agencies. Information relating to ESD issues can be widely scattered. It may exist in a range of formats (it may or may not be in digital form) and scales, and be of varying levels of currency. It may have been collected using a number of different standards.

As a spatial data user wanting to compile a national overview relating to complex problems, there are some simple pieces of data about the data (metadata) which will allow the user to decide whether a dataset is suitable or whether new information needs to be collected. This need was recognised by the Bureau of Rural Resources (now the BRS) almost a decade ago, and lead to the development of a highly complex computer-based directory which attempted to collect very detailed information about a dataset and store it on dedicated nodes connected to a central database.

The initial system was only partially successful, and has as a result, taught us a great deal about the core requirements of a metadata system for Australia. These requirements and lessons are dealt with in the case study "Data About the Data".

2.2 Inventory

Australia has a number of programs which, for several decades have been undertaking socio-economic statistical surveys and population censuses. Since 1990 Australia has also had continental scale GIS databases of soils, vegetation and geology, land ownership and topographic information such as roads and streams. These biophysical datasets where created at scales ranging from 1:1,000,000 to 1:5,000,000. For a short period of time these datasets allowed simplified reporting to be carried out, but as coarse scale, one-off datasets they are of limited value in the complex world of ESD.

There is no doubt that if we really want to understand ESD we need enormous amounts of spatially organised data. It needs to be up to date, of high spatial resolution (usually equal to or better than 1:100,000 scale) and have a high degree accuracy and precision.

Given the enormous cost of collecting high resolution biophysical and socio-economic data across an entire continent, effort is currently being put into coordinating the development of an National Spatial Data Infrastructure (NSDI) through initiatives such as the Australia, New Zealand Land Information Council. The aim of this ANZLIC is to:

- Identify the national priorities for fundamental datasets
- Encourage all 3 spheres of Australian government to integrate their management strategies into a national model
- Promote coordination between disciplines, and
- Adopt national standards for data collection, classification and interpretation.

The BRS is also involved, along with a number of other Commonwealth agencies in coordinating national base-line inventory programs such as those outlined in the case studies which will be made available to the NSDI.

The dynamic nature of most problems relating to ESD require many themes to be monitored through time in order to indicate the success or failure of management strategies and implementation. Many of these issues also occur at very small scales which makes high temporal resolution monitoring very costly.

To cope with a need to monitor a large number of themes at local scales and generate regular national reports, a great deal of work is currently be done in Australia to develop indicators of ESD. The most advanced of these are the Indicators of Sustainable Forest Management. The BRS and other Commonwealth and State agencies are currently developing a comprehensive suite of indicators that will allow nationally standardised monitoring of Australia's commercial forests.

In the long-term these indicators, when coupled with satellite and other national mapping and survey programs will provide a far greater understanding of the interactions and complexities of ESD issues.

2.3 Data Management

Only 5 years ago the idea of compiling over 100 different datasets into a standard data structure in order to generate a seamless 100 metre resolution forest cover grid for the entire Australian continent would have been thought impossible. As would the idea of bringing a 500 megabyte satellite scene back from tape and to your image processing display within a couple of minutes. Even 2 years ago the notion of modelling terrain and horizon corrected radiation across 30 million cells as input into a monthly growth model which created 20 gigabytes of output seemed like a pipe dream. But there are solutions available now that make databases of this size createable, storable and retrievable.

New RAID disk arrays allow disks to be "strapped" together to produce 50 gigabyte and more disks. Hierarchical data management systems combine terabyte robotic tape storage systems with the disk arrays to produce the effect of one enormous disk.

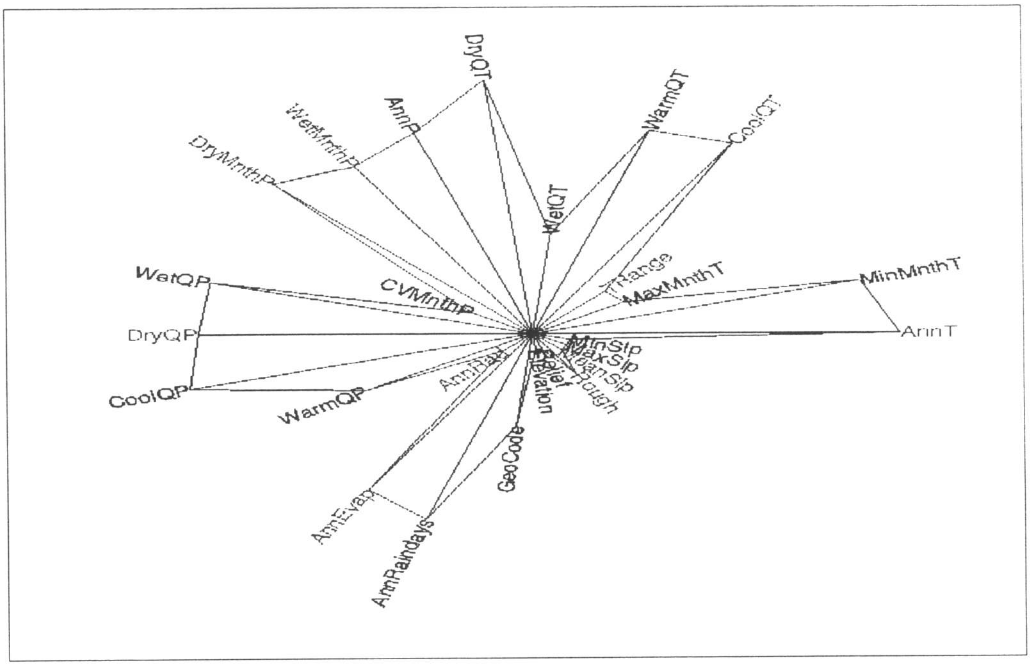
This is however, far more to data management than fitting more and more data onto your organisation computing system. How do you keep track of what you have on the system? How do you update such immense databases and ensure that the version being used is actually the correct one? What responsibility does a data creator or custodian have to maintain information? How does a user decide whether the information is appropriate for a particular use.

2.4 Data Integration

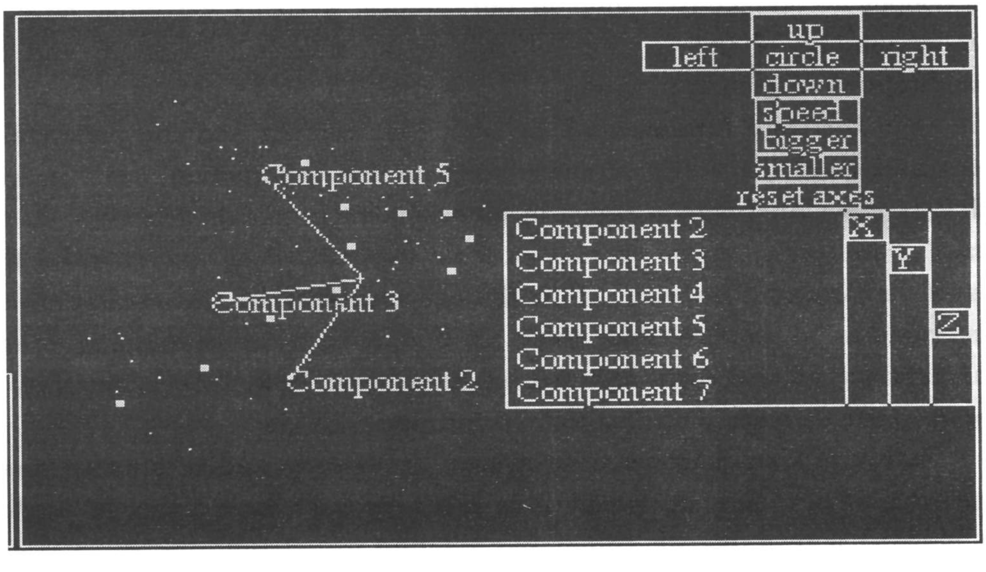
Data integration has been the bread and butter of Geographic Information Systems for over a decade. Such systems have allowed the cartographic profession to improve the efficiencies of map production, and indeed, allowed the non-cartographic scientist to produce reasonable looking maps. GIS has also replaced the need for scientists to peer through multiple map-overlays on light tables, with the capacity to intersect any combination of environmental and socio economic layers. This capacity to undertake complex Boolean operations involving a number of data themes matured more than 5 years ago. When coupled with incredible increases in computing performance it has provided us with the capacity integrate and summmarise volumes of data probably 2 orders of magnitude greater than a decade ago. We have also seen GIS move from the specialist laboratory onto the desktops of policy makers and part-time GIS users.

Unfortunately, as we delved into the dynamics of ESD, we have found the need to start asking more complex questions like how are particular themes related or correlated. Are there causal links between them? Can you use one to predict the other? Can you reduce the number of variables your dealing with. The key to answering these types of questions is having the capacity to develop an understanding of the underlying dynamics of your spatial data. Although GIS allows us to integrate a variety of datasets, it is not necessarily the most appropriate tool for understanding the structure in the data.

Modern Exploratory Data Analysis (EDA) and Data Mining (DM) tools allow us manipulate, analyse and visual our information in traditional statistical and highly visual ways to allow underlying structures and processes to be identified. A simple example of this is shown in figure 1. where a starplot was being used to represent the relative importance of a range of environmental variables in defining a particular forest ecosystem. The 3 dimensional scattergram in figure 2. was also used to assist in identifying unique ecosystems following Principle Components Analysis (PCA). These types of tools not only allow a scientist to better understand underlying processes involved but also assist in the communicating these findings to decision makers.



<Fig.1> A starplot showing the significance of each variable in defining the class



<Fig.2> An interactive 3 dimensional scattergram

Once we think we have an understanding of the driving processes and interrelationships of a system (i.e. they can be modelled) we can then start asking questions about how we think the system may respond to various management decisions. And so a Decision Support System (DSS) is born. DSS may take on a variety of forms. It could be a simple tool for applying Multi Criteria Analysis (MCA) to back to your spatial data, or as outlined later in this paper, the application of a processed-based plant growth model within a GIS to assess the effectiveness of a range of tree planting scenarios. Alternatively, the DSS may provide the scope to consider trends through time, address "whatif" questions, and through a gaming approach, explore opportunities for raising a regions environmental and economic performance through changes in landuse or management practices.

2.5 Risk Assessment

One of the major principles behind ESD is dealing cautiously with risk and irreversibility. In dealing with the tensions of economic development and conservation of our natural systems we must have an understanding of the chances of making an incorrect decision, and the implications of getting it wrong.

It is therefore fundamental for both the scientist and the policymaker to understand the levels of uncertainty in the information, and the risk that is associated with a range of management or policy decisions. In the case of the policy maker, it may only be the sum of all uncertainties that is of importance. However, it is the responsibility of the creator of the information to ensure that there is a thorough understanding of the uncertainty within each information layer, and how that uncertainty is propagated through data integration and presentation.

With the spatial information system technology and computing power we have at our disposal today it is relatively easy for a users to produce a detailed map and data summaries relating to a large number of spatial themes, irrespective of their quality. There is nothing to stop an ill-informed user integrating 1:25,000 scale information with 1:500,000 scale, even though the results might be meaningless. It is also possible to apply the same information to sophisticated models and DSS which then propagate a range of errors through space and time.

Errors exist in all forms of spatial data at all scales, particularly in environmental data where interpretation is required. Take the mapping of forest types from aerial photography for example. Mapping errors might occur due to:

- miss-interpretation of a vegetation boundaries;
- spatial errors in the rectification of the photography
- spatial errors in the tracing of overlays prior to scanning
- spatial errors in the registration of the data to a basemap
- miss-labelling of polygons due to human error
- inappropriate scale or poor photography
- inappropriate minimum mapping unit size and a host of other reasons.

If random locations were selected in the field, and compared to the GIS layer, it would not be uncommon to have less than 50 percent agreement in areas of complex vegetation. If this dataset is then overlayed with another dataset of similar reliability, the combined probability of correct attribution for all attributes in some polygons could be only 25 percent.

A sophisticated predictive model may have been generated using highly accurate plot information which can accurately predict the productivity of a forest stand. In addition to this, a Decision Support System (DSS) might have been developed which allows a forest manager to predict how a forest stand responds to particular management with a very high level of confidence. This manager cannot however, extrapolate using the DSS across the forest estate without the mapping described above. In some areas, the reliability of the mapping may render the model useless. It is therefore imperative for him or her to understand the probability of a decision being wrong.

Estimating the risks of making a poor decision can be undertaken in a number of ways. Two common methods used include sensitivity analysis and statistical probability analysis. An example of how the BRS has dealt with risk is discussed in several of the case studies.

Case Study 1.

3. Data About The Data

This case study discusses the importance of metadata and meta-databases in providing decision makers with timely access to appropriate data, and the lessons learnt by the BRS in developing a national Meta-database for Australia

3.1 The Past

In 1989 the then Bureau of Rural Resources (now the BRS) initiated the development of a spatial data directory system to support natural resource management and policy development. The national scope of this directory required the active participation and cooperation of federal and state governments as the Commonwealth government is charged with formulating national policies while state governments have the constitutional responsibility to manage the land.

As no commercial system existed at the time, the Bureau developed the FINDAR software to collect, maintain and provide access to the National Directory of Australian Resources (NDAR). FINDAR stood for the Facility for Interrogating NDAR. The aim was to have all leading state and federal agencies using FINDAR to manage their own metadata and to upload the information (or subsets of it) to NDAR which would be the primary point of contact.

This approach was only partially successful due to the complexity and overhead costs of the software at the time (each agency required an ORACLE relational database) and a lack of commitment from many state agencies, who at the time, did not see the value in putting resources into metadata collation and management. The limited success of this method demonstrated how important cooperation and participation was to successfully implementing a national metadata system. It demonstrated how important it is for individuals and agencies to understand the purposes for which metadata area used; the importance of people and organisational issues in the collection and maintenance of metadata; the importance of identifying data custodians (lead agencies) who have the responsibility for managing and maintaining datasets, and the importance distilling the culture of metadata exchange within agencies through to the individual.

3.2 Developing National Metadata Standards

In 1995 the Australia New Zealand Land Information Committee (ANZLIC) Metadata Working Group was formed consisting of representatives of State and Commonwealth governments and a number of stakeholders. Through a series of workshops involving the Australian spatial data community the Working Group developed a minimum set of core metadata elements required to adequately describe data for national directory purposes.

In developing these standards reference was made to other metadata initiatives such as the US Federal Government Data Committee (FGDC), the NASA Global Change Master Directory (GCMD) and International Directory Network, and the development of the Dublin Core Metadata Element Set .

Having learnt from experience that there is a negative relationship between the level of complexity and probability of success, initiatives such as the FGDC were regarded as being too complex and created an unnecessary compliance burden on data custodians. The FGDC was however, used as a framework for developing the ANZLIC guidelines.

To support these guidelines a PC-based application has been developed which allows agencies to collect and manage their own metadata. The Bureau has also developed an Arc/Info AML (Arc Macro Language) application which allows the metadata to be directly linked to the GIS databases in accordance with the guidelines. An SGML standard is also currently being finalised to allow the interchange of metadata between agencies

3.3 The Future

The concept of an Australian Spatial Data Directory has been endorsed by ANZLIC, with the BRS having the responsibility to manage and coordinate the development of, and access to the directory. Due to a recognition of the importance of metadata, there has also been a commitment from agencies throughout Australia to collect and provide access to ANZLIC compliant metadata through the ASDD.

The ASDD will allow the metadata user to have a single point of access to a distributed metadata management network. This will mean that a data custodian will only have to manage a single occurrence of each metadata description, and the user will simply access the information through WEB-based tools.

There will also be a seamless integration between the metadata and the datasets themselves. Users will be able to navigate through increasing levels of metadata to the point of the actual dataset which might be then downloaded or ordered from the custodian.

In the Australian context, the key to the success of such a system relies on the establishment of standards for describing a minimum set of core attributes to meet the needs of multi-disciplinary users. The system must also have the potential to be expanded in a hierarchical fashion as data custodians become accustomed to creating and managing metadata as part of their routine work. Any system that is highly prescriptive and complex is destined for failure.

Case Study 2.

4. Developing a National Forest and Woodlands Database for Australia

This case study describes the metadata, inventory standards, data management and integration philosophies used in developing Australia's most sophisticated national database on forest information.

4.1 Introduction

One of the major programs managed by the BRS is the National Forest Inventory. The aim of this program is to: assist governments in their sphere of responsibility to plan and manage for the conservation and use of Australia's forests by facilitating the collection and availability of contemporary, valid and standardise data through a Commonwealth and State government partnership.

Since 1992, the NFI Project Team and its State partners have been undertaking regional and local scale inventories on a range of forest values with the aim of integrating these datasets to produce a new Continental Inventory that is capable of supporting regional and national level planning. The type of mapping ranges from 1:25,000 scale visual interpretation of aerial photographs, to classification of Landsat TM, and AVHRR imagery. The products from such mapping then range from very detailed floristic and structural vector information, to 25m resolution mapping of forest density to simple forest non-forest mapping using 1km resolution AVHRR.

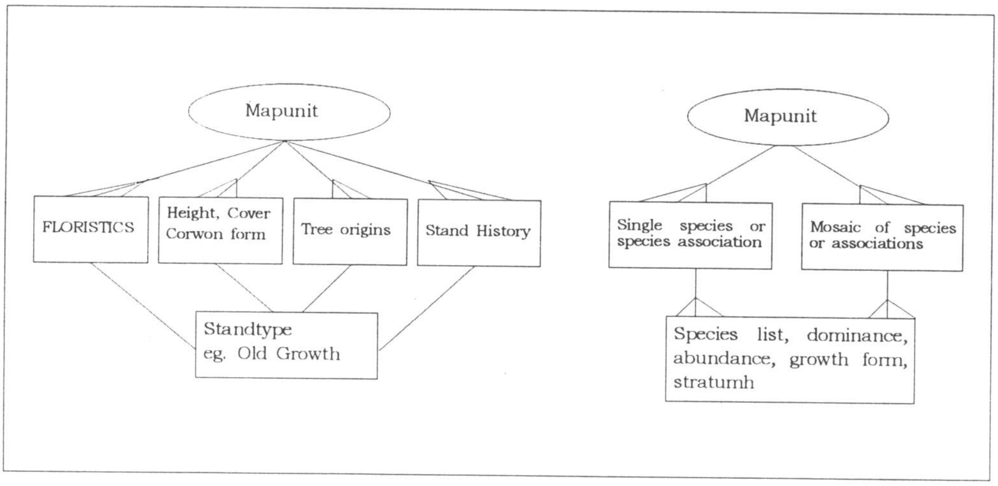
The inventory of Australia's forests has been undertaken using a bottom up and auditing approach to digital database management. This approach works on the principles that:

- The lowest common denominator should not be used in developing a national database;
- The most current, finest scale and most highly attributed information should be used in any one area;
- There should be one definitive dataset stored in a corporate database, rather than independent datasets of different scales and currencies for any one area;
- feature level metadata should be used to attribute differences in logical consistency;
- A corporate database should play an auditing role to identify gaps in information as well as providing the user with quantitative information on reliability, and
- both raster and vector data structures can be used in the one corporate database.

4.2 Data Integration

The NFI's database consists of over 50 core attributes (figure 3.) covering information on:

- Floristics (vegetation species)
- Height
- Tree cover
- Tree age and growth stage
- Stand history
- Wood resources
- Land and ownership and
- Metadata



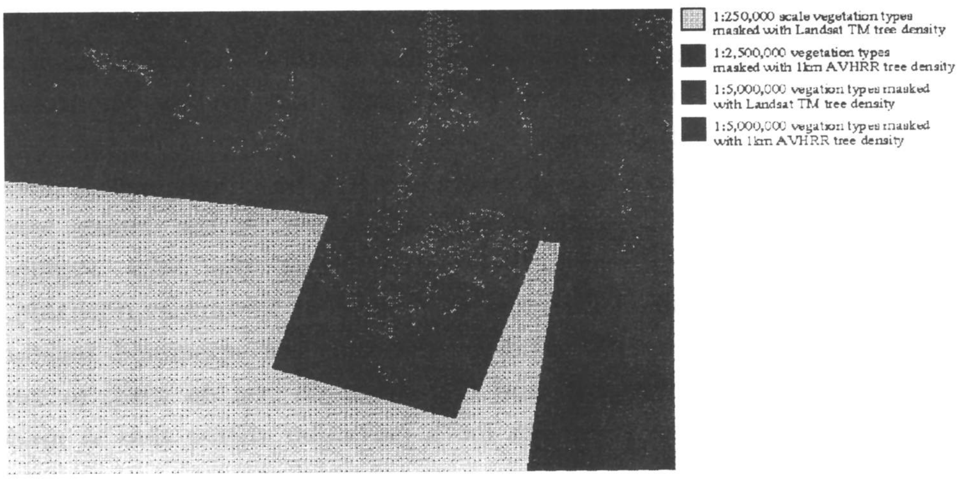
<Fig.3> The NFI database structure

As the NFI has been involved in both the collection of new data and the collation of existing information, a database structure is required that is flexible enough to enable the integration of data with a range of attribute and spatial complexities.

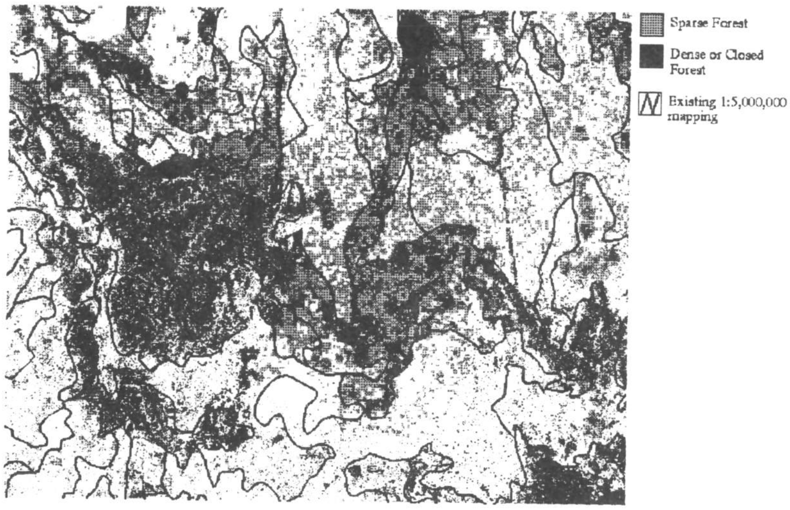
To achieve this, a the Relational Database Management System (RDBMS) is used to generate a unique mapunit number for each unique combination of attributes in the original dataset. These attributes, along with their mapunit number are placed into a lookup table which has also been given the NFI attributes. The NFI attributes are populated with data (in many cases transformed) from the original attributes. Where attributes require codes to be generated, central (definitive) lookup tables are used. Every vegetation dataset that is incorporated into the database (raster or vector) is populated with the same level of attributing and every attribute with missing data is filled with a null value (e.g. -9999 or NODATA).

Each original dataset is also given a unique number (referenced to a central table) and placed into a date-stamped archive area. A central reference table is then used to record the location of the dataset, along with the name of the custodian and data use restrictions. The final dataset (coverage or grid) is then placed into a reference area with only the mapunit attached to the polygon attribute table (PAT) or raster value attribute table (VAT) and a relational table for storage of the NFI attributes. The resultant coverages or grids refer to the same centralized RDBMS tables

Users can immediately integrate data of any scale and with any level of attributing. They can also undertake a gap analysis by querying fields for NODATA values, and they can relate back to the archive and track down the primary datasets used in the final dataset if an update is to occur. (see figure 4. and 5.).



<Fig.4> A map of data sources



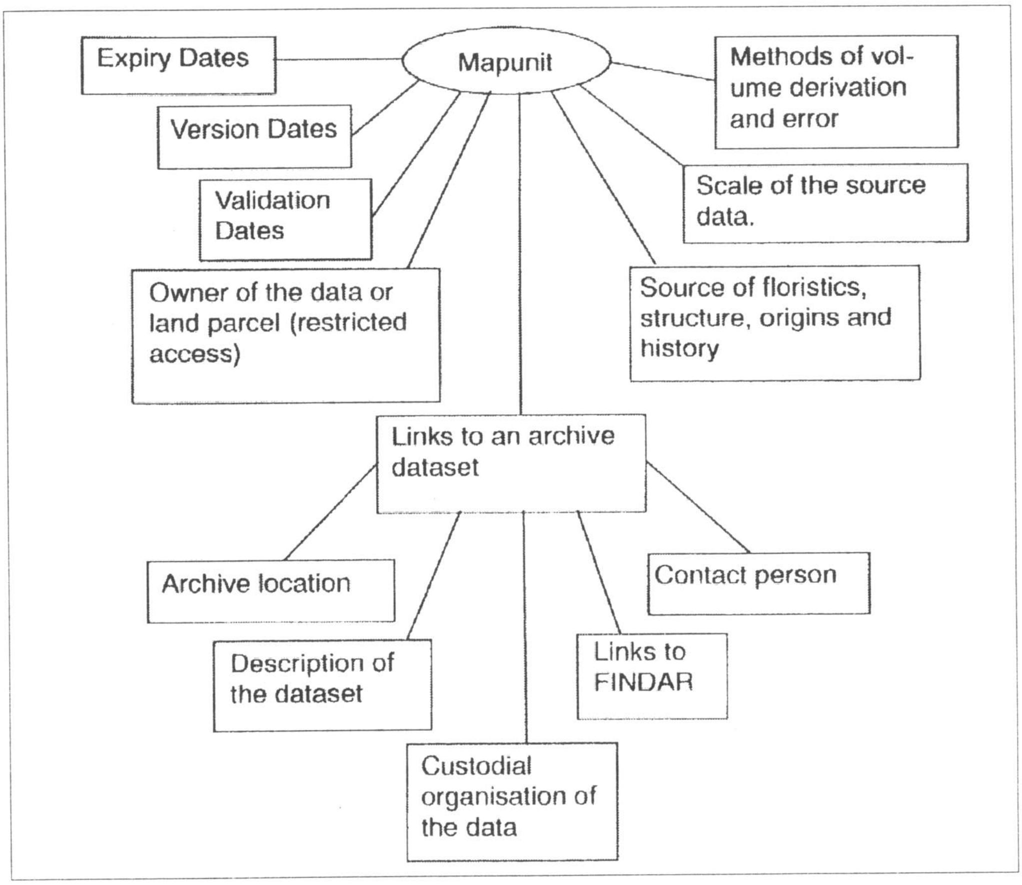
<Fig.5> Forest cover map generated from the data in figure 4

4.3 Data Management

A great deal of effort has been spent internationally on metadata standards for use in meta-databases (directories) and to aid in data transfer (e.g. Spatial Data Transfer Standard (SDTS)). However, most of the information contained within such metadata relates to the dataset as a whole and any variations in a dataset are only recorded as logical consistency text fields. The problem is that most of this information starts to disappear when users begin to integrate and overlay information to produce "value added" datasets.

In order to overcome this problem the NFI has implemented metadata management at both the dataset and feature level. At the dataset level the SDTS compatible information is stored using the BRS Facility for Interrogating the National Directory of Australian Resources (FINDAR). But what do you do when 50 different datasets are appended together to produce a state wide dataset, and then what do you do when to improve these data you overlay a dataset for a particular theme that is made up of several other datasets?

The only way to keep track of this information is to store metadata at the feature level. A feature can be a single polygon or group of polygons with the same value for all attributes. As outlined previously, a unique code is given to every unique combination of attribute values within a dataset. This unique code also records 18 metadata attributes that include information on everything from scale and sources of linework, to methods of wood volume derivation and data expiry dates (figure 6). This ultimately means that the source of attribute values for each of the core attributes can immediately be identified, and that at any time an entire dataset can be extracted from an integrated dataset when updating is required.



<Fig.6> Meta-database structure

4.4 Summary

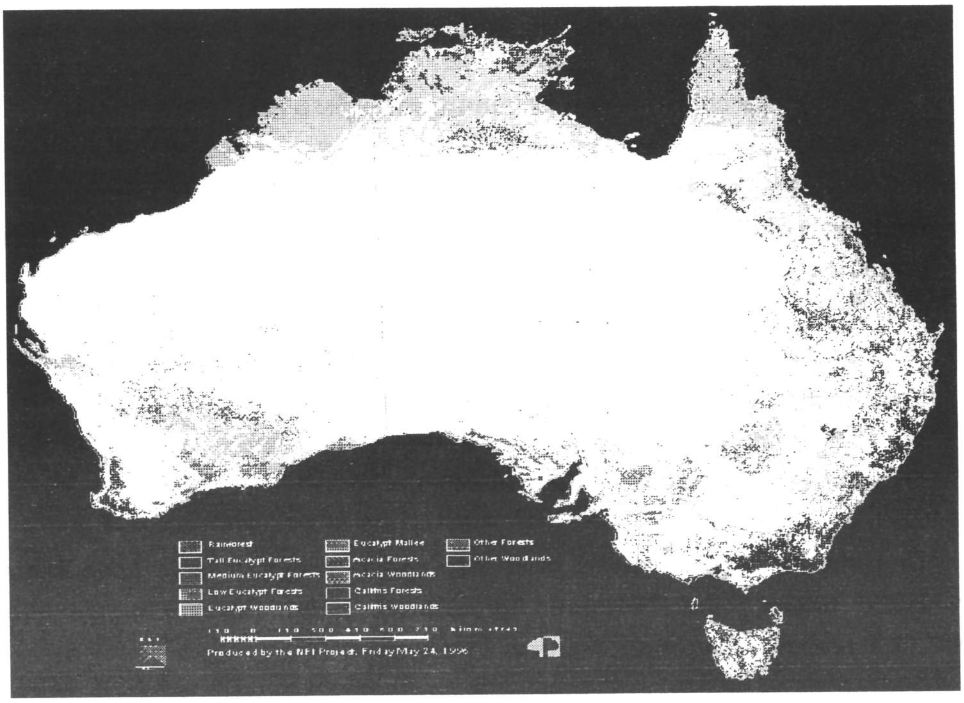
The development of a multi-scale national database describing Australia's forests has required the complete integration of both raster and vector technologies. This has allowed us to maintain definitive, multi-scale databases with the flexibility to produce data-reduced raster or vector products for various purposes, while also maintaining the integrity of area statements by using imbedded metadata to link back to primary data.

The level of integration has also allowed us to maintain centralized relational databases that can be used by both raster and vector datasets. By taking advantage of improved software and computing performance, and integrating feature level metadata, a user no longer has to be limited by the lowest common denominator in terms of scale and level of attribution.

Since the completion of this version of the National Forest and Woodlands Database there has been wide government use of the information, with this, and a similarly structured land tenure database providing the basis for Australia's first National State of the Forests Report and the first Montreal Process Report on Criteria and Indicators for the conservation and sustainable management of forests. The database is also providing the basis for forest biomass estimates as part of Australia's National Greenhouse Gas Inventory.

The NFI database has provided:

- An international reference for policy-makers in the formulation of national policies;
- Improved the quality of information available to decision-makers and the public;
- Better informed the forest policy debate at regional, national and international levels, and
- provided a framework for data standards and reporting that will provide a clearer picture of forest management performance in the future.



<Fig.7> Forest cover in Australia

Case Study 3.

5. National Greenhouse Gas Inventory

This case study describes 2 initiatives addressing greenhouse gas missions in Australia. Both projects are involve all 5 aspects of the ESD information flow using a variety of techniques.

5.1 Introduction

In 1994, Australia released its first National Greenhouse Gas Inventory (NGGI) for the years 1988 and 1990, as required by the United Nations Framework Convention on Climate Change (UNFCCC). In this inventory it was revealed that the forestry and landuse change sectors may account for 25% of all emissions. However, the emission estimates from these sectors were also the most uncertain due mainly to the limited data on the quantity of carbon lost through land clearance and the carbon gained through growth of managed forests and plantations.

The uncertainty of emissions from the forestry and agricultural sectors needed to be addressed to give confidence in the formulation of government policies and decisions relating to climate change. In order to achieve this a better understanding of the following was required:

- The quantity of above and below ground biomass (and carbon) lost though land clearance and forest harvesting.
- The rates of biomass accumulation (and hence carbon uptake) by managed forests and natural regeneration

In order to achieve these goals two major projects have been initiated by BRS, namely the National Agricultural Land Cover Change Project (NALCC) and the National Biomass Inventory (NBI).

6. National Agricultural Land Cover Change Project

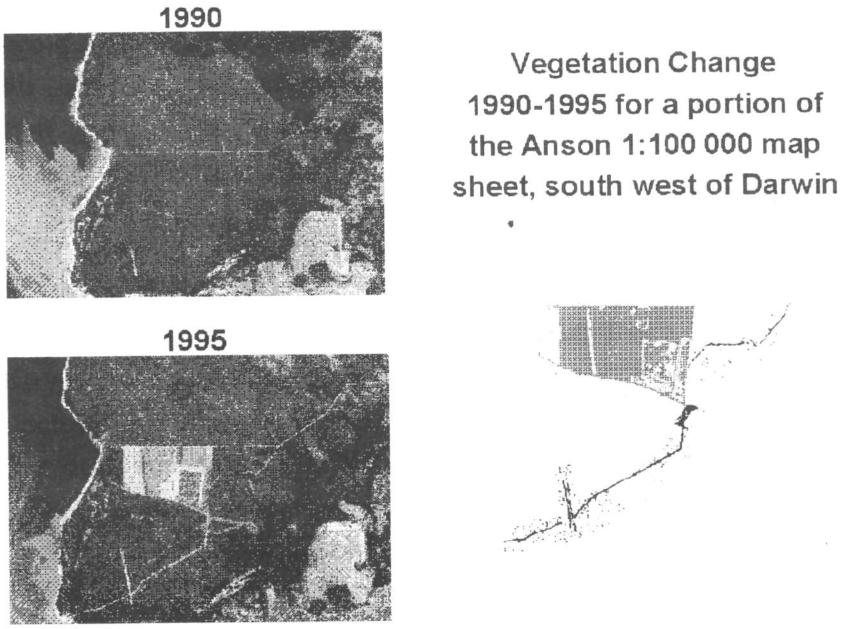
6.1 Introduction

Agricultural lands occupy almost 3 million square kilometres or about 40 percent of the Australian continent. During the 1960s and 1970s vast areas of land were cleared for agricultural development. So extensive was the clearing, even coarse 1 kilometre resolution AVHRR data would have accurately documented it. In the last 15 years, however, the rates and patterns of land clearance have changed. Although still significant in total area, most single instances of clearing are occurring as patches less than 100 hectares. In order to quantify the greenhouse gas emissions from such land clearing, a cost effective remote sensing data source, and method of mapping was required that could be cover the entire agricultural zone.

6.2 Mapping Forest Cover Change

Work undertaken for the state of Victoria suggested the mapping had to be done at less than 1 hectare minimum resolution if the type of clearing taking place there was to be reliably monitored. This work also suggested that the most appropriate scale was 1:100,000 and that the most suitable remote sensing information was Landsat Thematic Mapper data.

165 Landsat TM scene pairs were purchased to undertake the project, with processing being undertaken by BRS and the individual state agencies. Following the completion of image processing to detect changes in woody vegetation cover, the Bureau will be compiling the information into a seamless GIS database to quantify the losses and gains in woody vegetation cover over the 5 year period between 1990 and 1995. In addition to this, a structural vegetation dataset will be compiled along with information on vegetation biomass at a coarser resolution(and hence carbon values) which have been lost or gained through land clearance or management.



<Fig.8> Mapping forest cover change

6.3 Inventory Standards

All of the collection of new data for this project has been undertaken under strict standards of processing, vegetation attribute structuring and metadata management consistent with the National Forest Inventory databases. This will enable other databases to be easily updated and as well a providing valuable baseline information for a range of other projects.

7. National Biomass Inventory

7.1 Introduction

Apart from a small proportion of commercial forest areas, very little information is currently available relating to standing biomass and growth rates. Given the uncertainty surrounding the estimates of carbon sources and sinks from managed forests there was a need to compliment the NALCC project by generating a spatial estimate of standing biomass and assessing the potential of modelling biomass accumulation using high resolution topographic, climatic and soils data.

7.2 Modelling Forest Growth

The ability to transfer traditional forestry growth models to other regions is also limited due to their constrained statistical nature. In most cases these growth models are based on statistically derived growth curves which relate stem volumes through time to particular sites. In most cases the site relates to an index which reflects local soil fertility and microclimate impacts on a particular species.

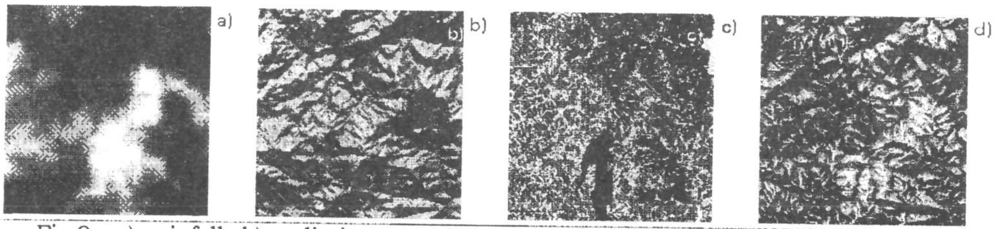
To be effective, these empirical models also require monitoring of large numbers of permanent growth plots over long periods to establish reliable growth curves. A process-based model, on the other hand, attempts to simulate growth in terms of the underlying physiological processes that determine growth and the way the stands are affected by the physical conditions to which the trees are subject and with which they interact (Landsberg, 1997).

In order to demonstrate the utility of processed-based models the BRS is currently undertaking a pilot study to assess the potential of using the 3PG (Physiological Principles Predicting Growth) model of Landsberg and Waring (in press) to predict forest and woodland biomass accumulation for any point in Australia using GIS-based information on climate, topography and soils and vegetation type.

The 3PG model has been developed to make use of a number of generalised relationships which have become apparent from several decades of research which are soundly based on biophysical processes relating to plant growth. The system also allows process-based calculations to be integrated with allometric regressions and other empirical relationships to produce monthly estimates of biomass production partitioned into roots, stems and leaves.

The basis of the model is that forest growth can be described in terms of radiation interception, transpiration, photosynthesis and carbon allocation, rather than statistical equations made from measuring stands of trees (although field calibration obviously has to be undertaken). To run the model in a GIS environment, BRS has converted the system to run within Arc/Info GRID which allows direct predictions be made on a pixel by pixel basis using the following input data:

- Monthly minimum and maximum temperature
- Monthly rainfall
- Monthly absorbed photosynthetically active radiation (APAR)
- Monthly Net Radiation
- Monthly frost days
- Slope
- Aspect
- Soil nutrient status
- Soil water holding capacity



<Fig.9> a) rainfall. b) radiation. c) soil water capacity. d) modelled forest growth

7.3 Outcomes to Date

Results to date in comparing the 3PG model to forest inventory data from around Australia have shown a very good relationship between actual and predicted volumes. In order to further test and calibrate the model an intensive destructive sampling program is currently being carried out in collaboration with state agencies which involves destructively sampling a number of representative trees from particular forest communities around the country. The use of Radar and Laser Altimetry is also being assessed.

This project is going to provide a revised spatial estimate of standing biomass for the entire forested area of Australia and when integrated with the NALCC project will refine estimates of biomass losses and gains.

The application of process-based models will not only allow the Bureau to inform policy-makers on the carbon sequestration rates of particular landuses relating to forests, but it will also allow us to evaluate the consequences of climate change and the potential effectiveness of greenhouse gas reduction strategies.

Case Study 4.

8. A System for SElecting Suitable Sites (ASSESS)

This case study describes a GIS application developed specifically to provide an interactive mechanism for data integration in support of environmental decision making.

8.1 Introduction

One of the most common types of spatial inquiry is that of locating areas with a specific combination of attributes. In many instances, the queries support a search for areas that are suitable for a particular landuse. The suitability of an area for a particular landuse can, however, mean different things to different people. The disparity arises because:

- people have different viewpoints on how an area should be used, for example conservation as opposed to development;
- there is poor consensus on which environmental and socio-economic themes should be influential in the site selection process; and
- suitability is a continuum, that is, more complex than the binary extremes of suitable and unsuitable.

These issues were addressed by the Bureau of Resource Sciences in a project requiring the identification of potential sites for a national low-level radioactive waste repository for Australia.

Many of the environmental attributes could not be attributed to suitability categories with full consensus. Nor was there agreement on the relative importance of the themes, or consistency in the reliability of the available datasets. It became apparent that a GIS tool was required that could display the full range of information available, and enable the user to modify both the categorisation of the environmental datasets and their relative importance. This would enable all participants to develop scenarios that supported their own particular viewpoint, which could then be compared with others to assess 'tensions' between viewpoints. The tool was developed using Arc/Info GRID and is called ASSESS.

8.2 The Development of ASSESS

The Radwaste project had two analytical requirements that influenced the modelling environment. First, the site selection process had to be conducted at a suitable scale to represent all of continental Australia. Second, the spatial analysis environment needed to be interactive, allowing the overlay of multiple environmental themes as a single operation and providing the results within a single session. These requirements were met in the grid-modelling environment of Arc/Info. All of the continental datasets were converted to grids with a five by five kilometre cell size, which was determined as the minimum resolution of the least reliable input vector coverage. Each grid consisted of approximately 300,000 data cells.

A numerical rating approach was adopted for converting the descriptive attributes of vector coverages to the cell values of environmental suitability grids. The descriptive attributes were allocated to one of five suitability classes, namely, suitable, mainly suitable, intermediate /indeterminate, mainly unsuitable and unsuitable. These classes have associated ratings of 1 for suitable though to 5 for unsuitable, which, for analysis, are the grid cell values. The rating approach was sensitive to the nature of the descriptive attributes and did not require that every theme had a complete set of ratings. For example, some themes required only an indication of presence or absence of a feature, such as surficial water features or major fault lines, hence it was appropriate to use only two values representing either suitable (1) or unsuitable (5) cells.

The ASSESS interface was developed using the Arc Macro Language (AML) to assemble a series of functional menus that frame an ArcPlot display window (figure 10.). The primary purpose of the interface was to provide the user with an interactive set of tools for viewing, modifying and overlaying environmental suitability grids, such that the resulting scenario reflects the conditions of the clients specific application. The sequence to develop a scenario is as follows:

1. Determine the rankings to be attached to attribute groups for each theme. Using the mouse, the client simply moves the slider to change the rank to an appropriate value.

2. Preview or apply the rankings.

3. Weight the theme grids relative to each other. For this purpose each theme grid has a slider bar associated with it. The slider

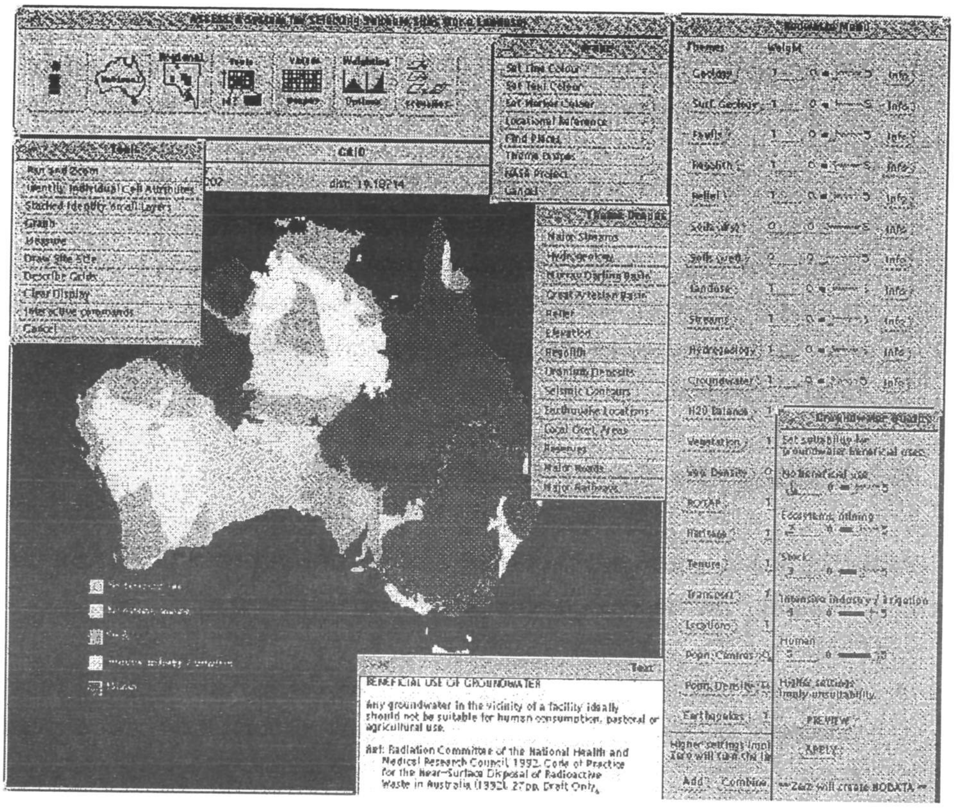
value ranges from 0 to 5. Placing the slider on 0 will exclude the layer from subsequent modelling. A value of 5 will weight the layer 5 times more than the normal setting of the layer which is 1.

4. Overlay the activated grids. This is performed in GRID using arithmetic operators. Each of the activated theme grids are multiplied by their weighting and then added together. The summed rating values are then reallocated to five summed suitability categories using an equal-interval slice. The scenario is then displayed.

8.3 Making the Best Use of ASSESS

ASSESS has become a successful tool in the support of environmental decision making. Its success stems from three elements:

- Provision of quick viewing access to 30 environmental resource datasets at the continental scale and a further 7 at a regional scale;
- An interface between GIS capabilities and environmental managers, with no requirement for a prior knowledge of Arc/Info; and
- A simple, quick and repeatable method for developing land use scenarios.



<Fig.10> The ASSESS interface

8.4 The future of ASSESS

The primary role of ASSESS in the BRS will remain as a decision support tool. It continues to be popular with clients and it has been applicable to several projects since. Examples are:

- Establishing a framework for assessing priority regions for funding under the Rural Partnership Program
- Potential for Changing Rural Land Uses - converting marginal wool-production lands to softwood or native hardwood plantations.
- Market Analysis for Termite Control
- Selecting Landing Sites for an Assured Crew Return Vehicle (ACRV)

It is also the Bureau's intention to link ASSESS with other key software packages such as Whatif? so that we have an integrated decision support platform.

Case Study 5.

9. Irrigation Futures

This case study describes a Decision Support System being developed to integrate environmental, social, landuse and economic information into a framework which allows the policymaker to anticipate and understand risk and to discover new options for action.

9.1 Introduction

The Murray-Darling Basin (MDB) in Australia occupies more than one million square kilometres approximately 14 per cent of Australia's land area. It is the nation's most important agricultural region, accounting for about 50% (A$10 billion/year) of gross agricultural production (MDBC, 1991). Irrigated agriculture in the MDB is facing a number of challenges including salinisation and waterlogging, low commodity prices and water policy reforms.

There are major concerns for the long-term viability of many irrigated farms, particularly small farms and those engaged in traditional grazing and mixed cropping activities. Resource managers and regional communities must make urgent policy decisions to provide a framework for the future of irrigated farming in these regions. Issues include the sustainability of irrigated agriculture, alternative land use, land retirement, structural adjustment, irrigation infrastructure replacement, water pricing and allocation, and nature conservation. Soundly based information on the implications of these decisions is fundamental to the development of successful policies and programs, and to the allocation and effective use of government and community funds.

The major constraint to regional and central policymaking is the lack of information describing biophysical futures for irrigation districts, though there is a wealth of information describing the biophysical and socio-economic conditions of the irrigated regions. To significantly improve the application of such information an accessible, user-friendly decision support system (DSS) methodology is being developed that will provide the scope to consider trends, address 'whatif' questions and, through a gaming approach, explore opportunities for raising the region's economic and environmental performance (Fordham and Malafant, 1995).

9.2 Design approach and software

The decision support framework is being developed using WhatIf?, an object-oriented decision support system and scenario analysis package that allows the future to be explored by examining the driving processes in the system and their interrelationships rather than trying to forecast the future by extrapolating data measured from past activities. The WhatIf? decision support tools developed by ROBBERT Associates, Ottawa, follow the design approach outlined by Gault et al. (1987). WhatIf? tools have three main components: TOOL (Tool On Object Language), an interactive coding language for manipulating data objects; SAMM (Scenario And Model Manager), which provides the interface linking sets of models; and Documenter, a text and graphics system for preparing structural and relationship diagrams and for preparing framework documentation.

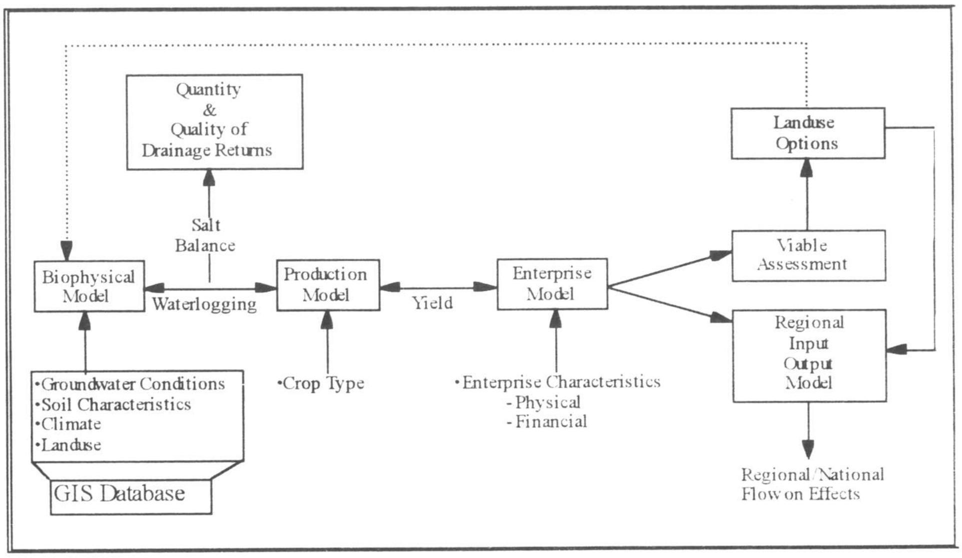
Decision scenarios allow the policymaker to anticipate and understand risk and to discover new options for action. Well-documented scenarios provide a way of exploring alternative futures, and can support informed debate about the policy decisions built into the scenarios and the resolution of their tensions (Malafant and Fordham, 1997).

9.3 The application framework

The DSS framework represents relationships using biophysical, production, enterprise and regional/national flow-on effects components (Figure 11.). The framework is being developed initially for the Cohuna catchment in the Barr Creek irrigation area of Victoria. Cohuna, a 3000 hectare catchment, has shallow watertables of variable salinity; land use is predominantly dairying on summer-irrigated perennial pastures, with some annual pastures (Fordham and Malafant, 1997).

Spatial information is compiled is a GIS and transferred to WhatIf? using automatic data conversion routines. Although WhatIf? does have mapping functionality, results can be easily transferred back into Arc/Info for map display and querying. The biophysical component consists of two hydrological modules, which study surface and subsurface water and salt movement in detail to evaluate salinity and waterlogging values. Linked to the biophysical component is a production component that determines the detrimental effects of salinisation and waterlogging on agricultural production.

The enterprise component quantifies the financial performance of farms in the region using the Farm Management Analysis Models described by Young and Dowell (1992). The flow-on effects of irrigated agriculture to the rest of the economy. i.e. those generated by the use of purchased inputs, labour, capital and research in irrigated agriculture and the marketing and handling of the production from irrigation can be estimated using Input-Output (I/O) analysis (Powell, Jensen and Gibson, 1985).



<Fig.11> The DSS framework diagram showing the four main components, linkages, feedback, outputs and data requirements

9.4 Extending the DSS into the Forests

Recently the functionality of WhatIf has been extended to include the LUPIS (Landuse Planning and Information System) spatial DSS developed by CSIRO Division of Wildlife and Ecology (Ive etal, 1988). The aim of this work is to assist in the identification of preferred plans of management or landuses within forest areas as part of Regional Forest Agreements being carried out by the Bureau.

The WhatIf/LUPIS DSS will assist in the formulation of ideas and policies and landuses through the development of stakeholder driven guidelines. Also various scenarios will be developed to explore the range of possible planning solutions, by allocating weights (votes) to favour some landuses over others. The weightings are derived by allowing stakeholders to vote for particular landuse outcomes. An example of this might be to favour timber production over cattle grazing within a particular map unit. The DSS then allows the generation of regional statistics which summerise the extent to which each guideline has been achieved under each scenario. The DSS can then be used to either allocate a mapunit to a particular land tenure or forest management regime. In order to improve the flexibility of the system of the system, programs are currently being written to create real-time links with the ARCVIEW 3 GIS.

Case Study 6.

10. Modelling the Distribution of Rare Species

This case study describes some Exploratory Data Analysis and Visualisation techniques used to prioritise inventories and provide managers with an understanding of the reliability of information (level of risk) being used to make decisions.

10.1 Introduction

The Koala is known throughout the world as one of Australia's icons. It also inhabits many commercial forest regions, and through legislation, logging must not occur within areas containing koalas. Koalas can also occupy large home ranges, and to systematically survey all likely habitat across millions of hectares of forest is impossible. As part of a formal Environmental Impact Assessment undertaken in south east Australia, a solution was required to: assess the quality of existing data; identify likely logging compartments that may contain this and other rare species, prioritise field surveys and provide forest managers with estimates of certainty in their decisions.

10.2 Traditional Modelling

Predicting the distribution of flora an fauna using a range of environmental layers such as topography, climate and vegetation has become quite common in Australia. In most cases the locations of sites have been simply intersected with the environmental layers within the GIS and then the attributes transferred to external statistical packages. The statistical model is then build using a range of regression techniques which produces an equation that is simply applied to the spatial layers back in the GIS. A map is then generating showing the predicted distribution of the species. It is however, a method fraught with danger.

At best, predictive modelling has a significant level of uncertainty even when using large volumes of reliable data. The levels of uncertainty must therefore rise significantly when modelling rare fauna which by definition have very few data points to analyse. It is therefore very difficult for a manager to use a map of the predicted distribution of a rare species without some knowledge of the chances of being wrong.

10.3 Visualising Error in Models

Using traditional modelling techniques, the best a manager might hope for is an interpretation of statistical summaries from the scientist, and a qualitative assessment as to what it means in terms of reliability on the map. Given the non-linear nature of many of these models there is a very high probability that the interpretation is wrong.

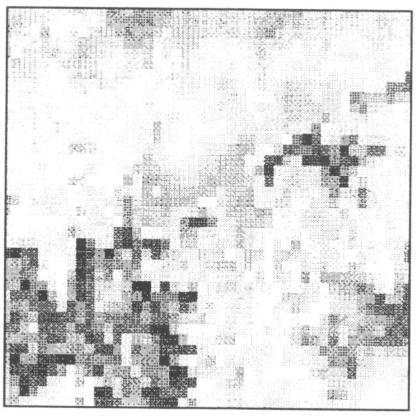
The BRS solved this problem by integrating an advanced statistical package with the GIS, and then applying tools from Remote Sensing sciences (Tickle, 1993).

Integrating the statistical package through a range of scripts allowed us to generate not only modelled predictions for every 200 metre cell in the raster GIS, but also the upper and lower 95 percent confidence limits of each prediction. Then using a knowledge of colour models all three surfaces could be displayed as a colour composite image, just as a three band satellite image is displayed. This method allowed the reliability of predictions in every cell to be assessed as well as providing the capacity to visualise interactions between species. An example of such output is shown in figure 12.

10.4 Summary

For a manager or policymaker to make informed decisions within the guiding principles of ESD and precautionary management, they must have an understanding of the reliability of the information and the chances of making the wrong decision.

Using innovative visualisation techniques the BRS: identified the most likely areas for finding a particular species; identified regions where more field work should be undertaken, and provided the forest manages with a tool for assessing the potential reliability of their decisions.



<Fig.12> Model output showing: high probability and high confidence in green; high probability and low confidence in white; low confidence and unknown probability in purple

11. CONCLUSIONS

The task of providing timely, high quality advice to inform resource use decisions compatible with the principles of Ecologically Sustainable development is an achievable one, as demonstrated by the studies undertaken by the Bureau of Resource Sciences.

There is no one technology that is capable of efficiently supporting all 5 stages of the information flow described in this paper, which are all of equal importance. There are currently hardware and software solutions which will allow each stage in the value adding process to be dealt with effectively and efficiently. However, there are still bottlenecks which may constrain an organisation in moving from one stage of the information flow to the next.

There are two main reasons for this. The first being a technical problem in developing graceful solutions for making one software or hardware package talk to another. An organisation must look strategically at its information needs and dedicate resources to maintaining links between the various technologies. If done successfully, an organisation can build a Spatial Information System that will transparently and efficiently cope with the complexities of Ecologically Sustainable Development.

The second is a human resources issue. The range of issues that have to be dealt with in any comprehensive application of ESD principles will always span a range of disciplines greater than a single individual can grasp. There is a need for two types of scientists. A "multidisciplinary technical specialist" i.e. someone that who has technical competence in a number of stages of the information flow and supporting technology, and general experience in a range of scientific disciplines. The second type are "specialists" in either scientific or technological disciplines.

It is the "multidisciplinary technical specialist" who provides the glue to the ESD Spatial Information System. This type of scientist is not trained by Universities. They develop by agencies providing graduates with a wide range of experience, and fostering individuals who appear to have talents in both the science and the technology. Even the most sophisticated Spatial Information System, will fail the test of Ecologically Sustainable Development without a talented multidisciplinary team of scientists behind it.

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GIS의 교통부문 활용을 위한 ITS와 연계 추진 방안

Integration of GIS Implementation Program with ITS for Application to Transportation

강 호 익

제일건설교통연구원 원장

ABSTRACT

Recently Korea has been facing serious surface transportation prob lems. Meanwhile, surface transportation systems are moving into the i nformation age, merging with computer, electronic and communication technologies that make travel faster, safer, easier and more intelligent. Intelligent Transport Systems(ITS) envisage the application of many ad vanced technologies including GIS to enhance the integrated performa nce. Great emphasis is being given to the development of GIS and IT S all over the world to take full advantage of those systems for intellig ent use.

Korean government launched research and development programs on GIS and ITS separately, pursuing those two systems as the nation al projects. The objective is to implement the programs across all conc erned organizations in a partnership process that includes governmen t, institute, academia and private sector.

The paper presents a broad overview of recent developments in Ko rea, and tries to figure out common causes which bind GIS and ITS t ogether in a commitment to improve the efficiency of the implementati on programs.

요 지

최근 우리나라는 심각한 교통문제에 직면하고 있다. 한편, 육상 교통 시스템은 컴퓨터, 전자, 통신등의 첨단기술을 접목하여 보다 빠르고 안전하며, 보다 쉽게 지능적으로 여행할 수 있는 정보화 시대로 접어 들고 있다. 지능형 교통 시스템(ITS)은 복합적인 성능을 높이기 위하여 GIS를 포함한 많은 첨단기술을 적용하게 된다. 많은 나라들이 GIS와 ITS의 지능화 이점을 최대한 살리기 위하여 이들 시스템 개발에 심혈을 기울이고 있다.

정부에서는 GIS와 ITS 연구개발 사업을 별개의 국가 기본계획으로 추진하고 있다. 이들 계획은 산,학,연,관 각 분야의 모든 관계기관간 협동과정을 통하여 추진하는 것을 목표로 하고 있다.

이 논문에서는 우리나라의 최근 동향을 개괄적으로 소개하고, 시행계획의 효율성을 높이기 위한 시도로 GIS와 ITS을 함께 추진할 수 있는 공통 요인을 찾아 내고자 한다.

문 제 제 기

정보화 사회가 급격히 진전되고 있다. 정보기술은 토목, 건축 기술에 비하여 훨씬 빨리 발전되고 있다. 정보화만 빨리 뛰는 게 아니다. 우리나라의 자동차 증가는 세계 어느 나라에도 유례가 없을 정도로 급증하여 금년 7월에 천만 대를 돌파하였다. 다양한 도시 문제 중에서도 교통문제는 가장 심각한 상태로서 출・퇴근 상황을 "전쟁"에 비유하는 상황에까지 이르게 되었다.

교통현상이란 '지리적 공간 위에서 교통수단을 이용해 각자의 교통목적을 이루기 위해 최적의 수단과 노선을 선택하는 과정에서 벌어지는 일련의 현상'이다. 그렇다면 정확한 지리 공간정보와 속성정보를 통해 현상을 정확히 인지, 분석하여 교통 계획 단계부터 운행, 관리 단계까지 체계적으로 대응한다면 해결의 실마리가 되지 않을까?

빨리 뛰는 놈은 더 빨리 뛸 수 있는 놈으로 잡아야 한다. 거북이가 토끼를 이긴 것은 동화속에서나 가능한 이야기다. 모든 것이 공개되고 관전자가 이해관계자인 정보사회에서는 상상하기 어려운 게임이다. 아니면 빨리 뛰는 자동차 안에 주력이 좋은 정보화(ITS,GIS)를 동승시키면 교통의 움직임을 일거수 일

투족 까지 놓치지 않고 알 수 있고 항상 쫓아갈 수 있다.

이를 위해 교통계에서 대표로 내세운 정보화가 ITS이다. ITS(Intelligent Transportation System)란 기존의 교통체계를 정보통신, 전자제어, 컴퓨터 등의 첨단 기술을 이용, 지능화 하여 교통의 이동성, 안전성, 효율성, 대기 오염 등을 혁신적으로 개선하는 새로운 교통체계이다. 완전한 준비가 되면 ITS가 운전대를 잡는 것이 보다 믿음직하고 효율적일 것이다.

GIS는 지구에 관한 공간 정보와 속성 정보를 분석하고 관리하는 시스템으로 정보를 한눈에 가시적으로 보여주며 변화를 쉽게 첨삭할 수 있다. 또한 GIS는 CAD, IP(Image Processing), DBMS, GPS, Multi-media, SCADA등의 통합 기술이며 컴퓨터 하드웨어, 소프트웨어, 네트워크, 인터넷등 다양한 기술을 기반 기술로 하고 통합성이 강한 기술이다.

운전석 옆자리는 항법사 자리이다. ITS가 운전을 할 때 GIS가 옆자리에서 항법사 역할을 한다면 가상 이상적일 것이다.

GIS와 ITS는 다르게 생겼지만 공통점이 너무나 많다. 주변의 친구들도 서로 잘아는 사이이다. 이들 둘을 맺어줄 방법은 없을까?

자동차 정보화시대
● 경로안내 시스템(RGS) ● 비상사태 통보시스템(ENS) ● 실시간 교통정보 ● 첨단 안전차량 시스템(ASVS)

자동차와 그 이용환경을 지능화 함으로써 사람과 자동차와 도로를 일체화하여 안전하고 쾌적하게 운전할 수 있는 자동차 사회를 실현하고자 하는 것이 ITS의 목표이다. 궁극적으로는 손과발, 눈을 운전으로부터 해방하고 음성으로 자동운전할 수 있는 것을 목표로 하지만, 현재는 눈을 외부의 표지판이나 종이 지도로부터 해방하여 차량내에서 최적의 교통정보를 받아 볼 수 있는 단계에 도달하였다. 1996년 4월 차량 정보 통신 시스템(VICS)이 일본에서 실용화되면서 자동차 정보화 시대는 새로운 전환점을 향하여 가고 있다.

경로안내 시스템은 고유의 동적경로안내 외에 다른 서비스의 기반역할을 한다.

- 달리는 사무실/계기판 위의 데스크톱

- 음성메일/E-mail
- 사무실이나 인터넷으로부터의 문서 접수
- 상거래 수행
- Fax 송수신
- 원격 차량 진단
- 외부 자료원이나 외부 서비스에 접속

비상사태 통보시스템은 다음과 같은 기능을 갖게 된다.

- 충돌 감지기를 이용한 자동발신
- 도로 DB를 이용한 정확한 위치확인
- 자동차 고장진단 등의 추가자료 제공
- 위성을 이용한 대체 통신수단으로 보다 광역에 신속한 응답 가능
- 여행정보 등을 위한 센터와의 개별 접속
- 도난 차량 추적

실시간 교통정보는 다음과 같은 기능을 갖게 된다.

- 차량탑재항법장치
- 자동위치 추적
- 전자데이터 교환(EDI)
- 음성인식을 통한 정보요구 및 제공
- 교통 및 도로상황에 대한 실시간 정보
- 이동전화, 라디오, 위성기술을 이용한 종합운전자 정보시스템(IDIS)으로 발전

첨단안전 차량 시스템의 주요 기능은 다음과 같다.

- 위험상황 사전제거
- 위험상황 조기경고 및 회피지원
- 운전자 시계 증진
- 차선유도 시스템
- 충돌경고 및 충돌 회피

이와 같이 자동차가 정보화 되고 그 자체가 정보통신수단으로 발전되어 궁극적으로는 첨단차량도로시스템(AVHS)으로 발전하여 자동운전도 가능한 시대

를 향하여 가고 있다.

교통제어의 방법으로 과거에는 교통상황판이나 라디오와 같은 매체를 사용하여 공통 정보를 제공 하였으나 근래에 와서는 개개인의 요구에 맞는 정보를 운전자들이 얻기를 원한다. 이 요구를 충족시키기 위하여 차량정보통신시스템(Vehicle Information and Communication System)이 개발되어 현재 실용단계에 와 있다. 이 시스템은 차량안의 단말장치를 통하여 운전자가 필요로 하는 실시간 정보를 분석하여 알려주는 것으로, 그 시간에 가장 빠른 경로 또는 사용가능한 주차정보등이다. 이 시스템이 제대로 작동하면 혼잡이 심한 도로에 교통량이 집중되는 것을 완화할 수 있으며 혼잡으로 인한 운전자의 스트레스를 감소시키고 안전도도 향상시킬 수 있다.

이 시스템의 구성은 정보수집, 정보처리 및 편집, 정보제공, 정보활용 등으로 분류된다. 정보수집은 고속도로와 도시간선도로상의 교통정보를 수집하는 기존의 교통관제센터로부터 유선을 통하여 차량정보시스템센터로 전송된다. 이때 전송되는 교통정보는 혼잡도, 구간별 통과시간, 사고 및 도로공사의 유무, 주차정보 등이다. 기존의 교통관제센터로부터 차량정보시스템센터로 전송된 정보들은 분석과정을 통하여 혼잡도를 상중하 세단계로 표시하며, 주차공간 유무 및 위치 등이 종합분석되어 중간단계인 미디어센터로 전송되며 이 정보는 즉시 차량안에 설치된 정보단말장치에 보내진다.

차량정보시스템은 적외선비콘, 전파비콘, FM 다중전송 등의 세가지 매체

를 통하여 분석결과를 이용자에게 제공한다. 각 매체는 매체센터에 의하여 제어되고 있으며 각 매체의 관할 구역도 각각 다르다. 각 매체의 담당구역이 다르지만 비콘장치가 고정되어 있기 때문에 움직이는 차량에 필요한 정보를 제공하는데 문제가 없다.

차량안의 단말기 모니터를 통하여 정보를 표현하는 방법에는 전자화된 지도를 보여주는 방법, 도형을 보여주는 방법과 문자를 보여주는 방법이 있다. 차량안 장치의 특성에 따라 위의 방법은 혼용될 수도 있다.

일본에서 가장 먼저 실용화된 차량정보통신시스템(VICS)의 특징은 이 시스템의 설립과 운영이 민관 합작으로 이루어졌으며 초기에는 각각의 기능과 시스템에 따른 차이가 무척 컸으나 VICS센터에서는 최소한의 규격만 설정하고 도로변과 차량안의 장치에 대해서는 제작사에 최대한의 재량을 보장하였다. 1996년 4월에 간또지역 부터 서비스를 시작하였다.

시스템구축과정에서는 정보전송방법의 표준화 및 정보의 규격화 등이 필수적이므로 민관의 협력이 필요하며 차량내 장치의 개발에는 제작사간의 기술경쟁을 통하여 긍정적인 효과를 얻을 수 있었다.

차량 정보 통신 시스템의 편익

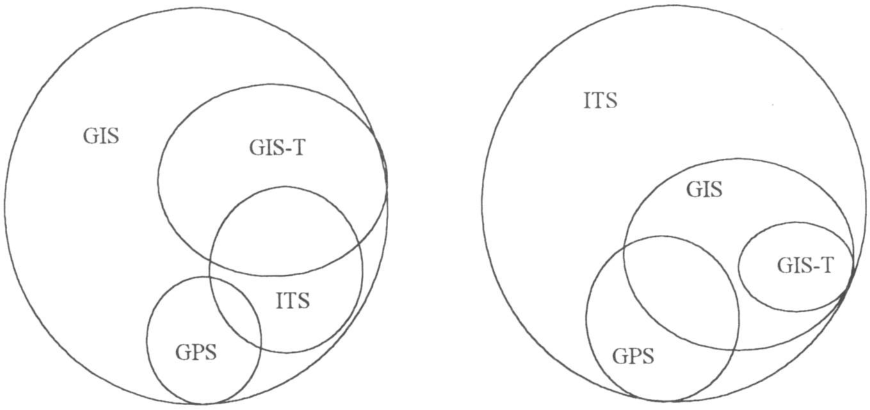
1) 효율성

- 목적지까지 빠르고 확실하게 유도
- 각종 유효정보 제공
- 생산성 향상(총 여행시간 및 거리 감소)

2) 안전성

- 경로 이탈 방지
- 운전자의 집중도 향상(종이 지도나 도로표지에서 해방)

GIS, ITS, GPS



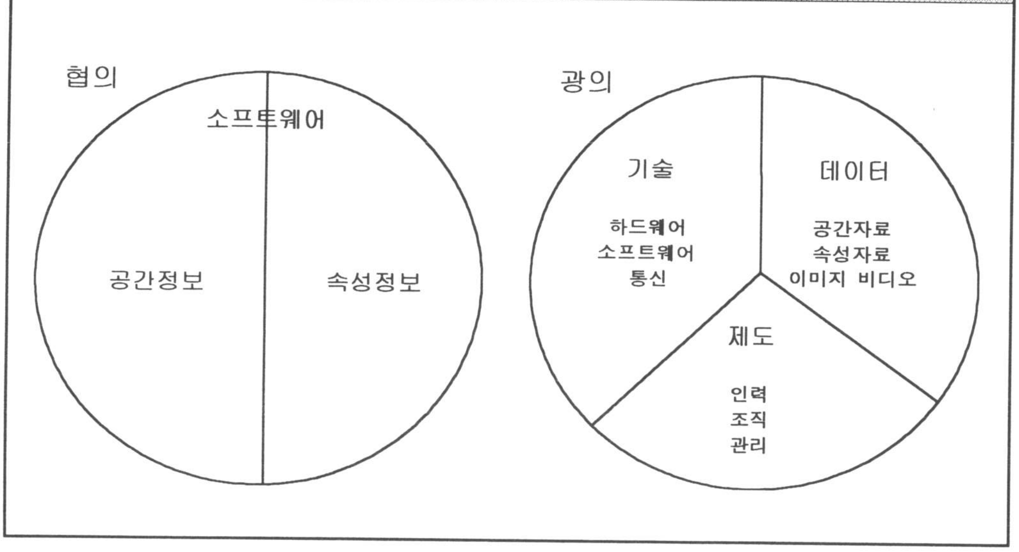
GIS는 공간정보와 속성정보를 효율적으로 결합하여 주어진 문제의 해결 및 의사결정에 최대의 효과를 얻기 위해 결합된 정보체계를 말한다. 도로나 철도 등 교통시설의 관련 데이터, 즉 차로수, 차로폭, 운행 속도, 통과교통량, 도로 포장상황, 열차운행 횟수 등 정확한 데이터를 가시적으로 한눈에 보여줄 수 있고, 또 새로운 시설물의 변화를 쉽게 첨가, 삭제할 수 있으며, 또 도로망, 철도망, 버스노선망 등을 중첩시켜 원하는 도면을 필요할 때마다 만들 수 있으며 각종 교통계획 등 공간분석을 할 수 있는 시스템이다.

GPS는 GPS위성을 통하여 임의의 지점이나 이동체의 순간 위치를 측정하여 표현하는 시스템으로서 이 시스템을 이용하여 임의지점에 대한 위치좌표값 측정이 가능하고 실시간적이고 주기적으로 임의 지점에 대한 위치 좌표 값을 확보할 경우 디지털 전자지도위에 이동체의 움직임을 표현하는 것도 가능하다.

따라서 GIS의 정보(공간정보, 속성정보)와 이를 이용한 GPS의 기술을 통하여 지능형교통시스템(ITS)과 이들 기술간의 연결점을 찾을 수 있다.

현시점에서 곧 실현되리라 예상되는 것은 자동차의 인터넷(The Internet on Wheels)연결이며 모든 차량이 Website를 갖는 것이다.

GIS의 영역



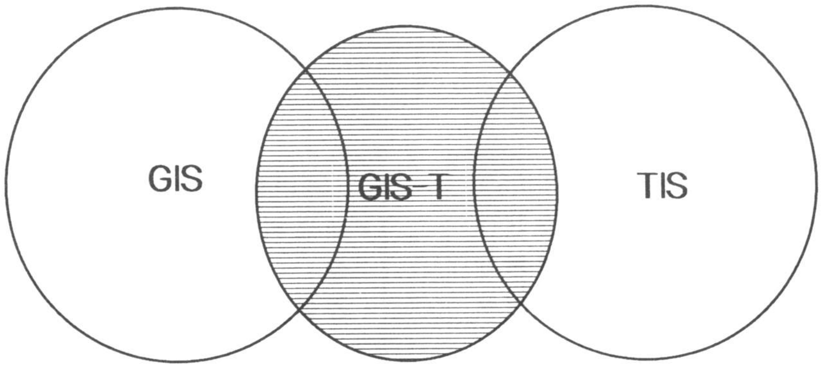
이러한 자동차의 정보화를 실현하기 위하여 GIS, ITS, GPS 등이 어떻게 활용될 수 있는가? 어떻게 상호유기적으로 결합되어야 하는가? 현재 우리나라는 이 분야에서 어디까지 발전해 왔고 발전해 가고 있는가를 검토해 보고자 한다.

GIS는 공간 정보와 속정정보를 결합한 정보체계로서 GIS의 속성정보를 통하여 교통부문 특히 ITS와의 연결점을 찾을수 있다. GIS는 자료의 분석뿐만 아니라 관리자와 사용자, 또한 그 구성 조직과 이를 관리하고 정보를 이용하는데 관련된 제도적 규제까지 포함된다. 따라서, GIS기술은 실제로 제도적 규제, 관리체계, 인력자원과 연결되어 있으며 GIS의 설계와 수행계획은 서로 연결되어 있는 것이다.

또한 기술, 데이터, 조직 이라는 세가지 요소는 GIS와 ITS가 공통으로 공유할 수 있는 체계이므로 광의의 GIS 영역은 그대로 ITS 체계와 같다고 할 수 있다. GIS는 자료를 처리하기 위한 데이터베이스 관리체계(DBMS)로도 생각할수 있다. 즉 GIS는 특별한 자료형식을 갖추고 있으며 보다 발전된 GIS는 다양한 공간 분석을 위해 복잡한 자료의 처리기능을 제공한다.

GIS는 처음에는 지도의 관리·이용에 관련된 다양하고 방대한 자료를 저장, 활용할 목적으로 시작되어 현재에는 교통분야는 물론이고 측량, 통신, 환경, 도시계획, 토목, 조경, 지적 등 많은 분야에서 활용되고 있으며, 전문가 시스템을 이용하여 의사결정 지원 시스템으로도 활용하게 되었다.

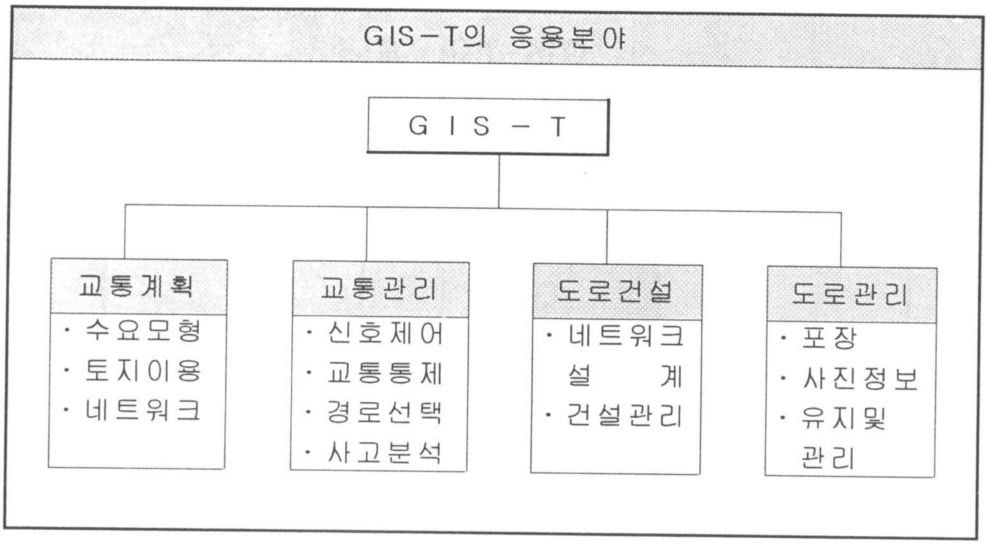
GIS-T의 개념



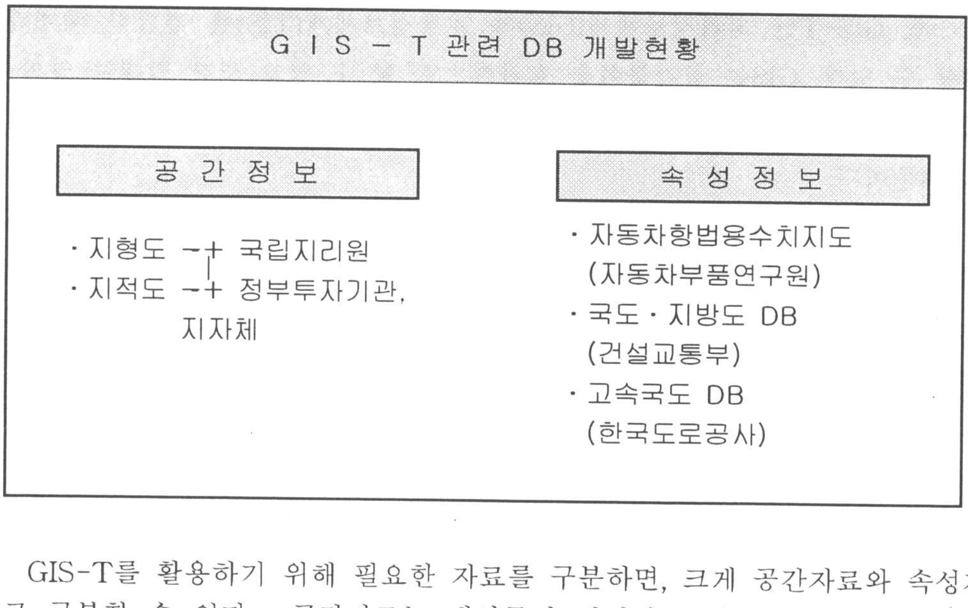
교통계획은 대부분 공간정보를 수반하기 때문에 공간정보의 처리와 지도를 결합하는 GIS의 기능이 필요하다. GIS-T란, GIS를 교통의 목적에 적합하게 변형한 것으로 교통관련 공간정보의 분석·관리, 즉 네트워크의 관리와 처리, 네트워크 속성의 갱신과 가시화, 공간분석, 경로분석, 다른 적용분야와의 연계 등을 위한 하부구조라 할 수 있다.

즉, GIS-T란 지리정보체계(GIS)와 교통정보체계(TIS)를 결합한 체계라고 말할 수 있다. GIS는 공간분석을 효과적으로 할 수 있고 또한 막대한 양의 자료를 수집·관리·표현할 수 있으며 TIS는 네트워크를 가장 잘 표현할 수 있기 때문이다.

이를 위해 TIS측면에서는 일관성 있는 공간자료를 제공할 수 있도록 GIS에서 이용 가능한 형태로 속성자료를 구축하는 것이며, GIS측면에서는 교통분야에 적용하기 위해 필요한 형태로 지리정보를 표현·처리할 수 있도록 여러 교통기관에서 수집·관리되어 온 도로 및 교통정보를 이용하고 연결할 수 있도록 하는 것이다.



GIS는 주로 공간정보를 다루어 왔으며 교통문제에 GIS를 이용하는 것은 새로운 시도로서 초보적인 단계이다. GIS-T의 데이터베이스에는 포장관리, 사고관리, 교통관리, 재고조사, 신호와 신호관리, 사진청보, 교통 네트워크가 포함된다. 교통자료가 기본적으로 선형의 교통 네트워크를 다루기 때문에 GIS-T는 면보다는 선을 기본으로 하는 네트워크를 중요시한다.



GIS-T를 활용하기 위해 필요한 자료를 구분하면, 크게 공간자료와 속성자료로 구분할 수 있다. 공간자료는 대상물의 지리적 특성을 나타내는 정보로

서, 즉 지구상에 점이나 선 혹은 면의 형태로 존재하는 개별 대상물들의 형태나 위치 등에 관한 정보를 말한다. 이러한 공간정보는 대상물의 공간적 해석이 가능하게 해 준다.

교통에서 반드시 필요로 하는 공간정보로는 교통시설을 나타낼 수 있는 지형도와 토지이용관련 정보를 나타낼 수 있는 지적도가 있다. 이러한 종이지도를 디지털화해 전자지도로 만드는 수치지도화 작업을 공간정보 구축이라 할수 있다.

반면, 속성자료는 대상물의 개별특징을 나타내 주는 정보로서 대상물의 존재형태나 사용목적 등에 따라 정보구축의 내용이나 방식 등이 달라지게 된다. 이러한 속성자료는 공간적 분석이 가능하도록 공간자료와 필히 연계되어야 한다.

속성자료는 일반적으로 문자로 표시하는 것이 보통이나 필요나 목적에 따라 이미지나 사진 등이 이용되기도 한다. 교통시설 · 도로의 위계 · 차로수 · 교통량 · 통행속도 · 신호체계 · 도로의 연장 등에 관련된 정보를 나타낸다. 현재 우리나라에서는 개별 관련기관들이 필요나 목적에 따라 수치지도와는 무관하게 제각기 다른 형태로 속성정보를 구축하여 사용하고 있는 실정으로 표준화가 시급하다.

현재 GIS 관련 데이터베이스는 국립지리원을 비롯하여 다수의 관련기관에서 추진되고 있으나 GIS-T를 목적으로 데이터 베이스를 구축한 것은 자동차부품개발연구원(KATECH)에서 실시했던 “자동차 항법용 수치지도 개발” 프로젝트가 첫 시도이다.

이 사업은 정부에서 특정기술분야에 자금을 지원하는 이른바 G7프로젝트의 일환으로 시행되었다. 이 사업의 세부분야중에 ‘자동차 항법시스템 제작기술’이 포함되어 있는데 그 기초 작업으로써 수치도로지도 제작 및 데이터베이스 구축사업을 시행한 것이다.

각 기관에서 시행한 기존 자료들을 분석하여 그 내용을 살펴보면 다음과 같다.

수치지형도(국립지리원)

1) 응용분야에 따른 정확도 Level화 미흡
   - 도면제작용, GIS용, Route Guidance용, 시설물 관리용

2) GIS 분석정보 관련 업무별 전문가 지침 부족

3) Layer Table 분류상의 문제

- 국가수치지형도는 지도제작에는 문제가 없으나 지리정보 활용시 별도의 작업이 필요
- 각 Layer는 서로 독립적으로 구성되어 있고 Layer의 특성(line, polygon, point)을 구분하기 힘듬
- 모든 Text정보는 대분류 9로 입력되어 있으며, 각 Layer(대분류 1~8)와 사실상 연계성이 없음
- 건물등의 폐곡선 처리시 별도의 입력작업이 필요함

고속국도DB (한국도로공사)

1) 준공도를 기초로 작성된 평면도는 800m 단위로 구성되어 있으나 좌표가 없음

2) 도로중심선을 기준으로 양측 25m 간격으로 입력되어 있고, 대부분의 속성이 평면도면상에 도형정보처럼 표시되어 있어 속성정보로서 사용할 수 없음

3) 도로대장조서가 속성정보로서 구축되어 있으나, 평면도 단위로 작성되어 있지 않고, IC간의 집계된 내용을 기록한 조서자료로서 도면과 속성정보를 연계시킬 수 없음

국도 및 지방도DB (건설교통부)

1) 도로대장을 기초자료로 작성된 도면을 수치화한 자료이며, 좌표체계가 없고 도로 중심선을 따라 양측 15m 간격 표시된 평면도임

2) 도로대장조서가 구축되어 있으나 노선별로 작성된 도로대장 전체의 집계 내용으로 도면과 연계성이 없음

지자체

1) 지적도 불부합 문제 발생

- 국가수치지형도(1/5,000)와 지적도(1/500) 통합시 불일치

ITS의 기능
• 교통관리(Traffic Management) • 교통제어(Traffic Control) • 운전자정보(Driver Information) • 경로안내(Route Guidance) • 차량위치확인(Vehicle Location) • 차량안전(Vehicle Safety)

자동차 항법용 수치지도(자동차 부품 연구원)

1) 도형 및 비도형 자료의 교환 Format을 지원해 주지 않음

최근 선진각국이 의욕적으로 추진하고 있는 지능형교통시스템(ITS:Intelligent Transportation System)은 당면하고 있는 교통문제를 해결할 수 있는 최적의 시스템으로 인정되고 있다. 이러한 선진각국의 ITS 도입 추세는 우리나라에도 예외가 아니어서 일부 정부투자기관과 지방자치단체가 이미 첨단정보통신 등을 접목하여 시험적으로 운영하고 있을 정도로 빠르게 ITS 도입이 추진되고 있다. ITS 구축을 위해서는 종합교통정보시스템개발, 교통정보구축기술개발, 교통정보데이터뱅크관리기술, 교통정보표출기술, 교통정보서비스기술 등 최첨단의 전기, 전자, 통신, 제어기술 들이 접목되어야만 가능하다. 이러한 기술분야 중에서 교통정보의 구축과 교통정보표출분야에서 GIS-T는 교통정보의 취득, 저장, 관리 및 분석과 효율적인 시각적 표출을 위해 매우 중요한 역할을 수행하게 된다.

따라서 현재 우리나라의 ITS 추진현황을 검토해 보고 장래 GIS-T와 ITS의 결합을 실현하기 위한 연계방안이 적극적으로 검토되어야 한다.

한국 ITS 국가기본계획

정부는 날로 심화돼 가고 있는 교통문제(교통혼잡, 교통지체, 교통사고, 주차난, 공해, 환경악화 등)를 해결하고 만성적인 SOC 부족현상에 대처하며, 체계적으로 교통정보 흐름과 관리운영을 개선하기 위하여 1994년부터 2년여에 걸쳐 ITS국가기본계획을 수립하였다.

정부는 5개 체계의 사용자 서비스를 선정하였다

- 첨단교통관리시스템 (ATMS:Advanced Traffic Management System)
- 첨단 여행자정보 시스템 (ATIS:Advanced Traveler Information System)
- 첨단 대중교통 시스템 (APTS:Advanced Public Transportation System)
- 첨단 물류 관리시스템 (CVO:Commercial Vehicle Operation)
- 첨단차량 및 도로시스템 (AVHS:Advanced Vehicle and Highway System)

국내 ITS 추진현황 및 시범사업

한국의 ITS 추진현황을 분야별 · 관련기관별로 구분하여 정리해 보면 다음의 표와 같다.

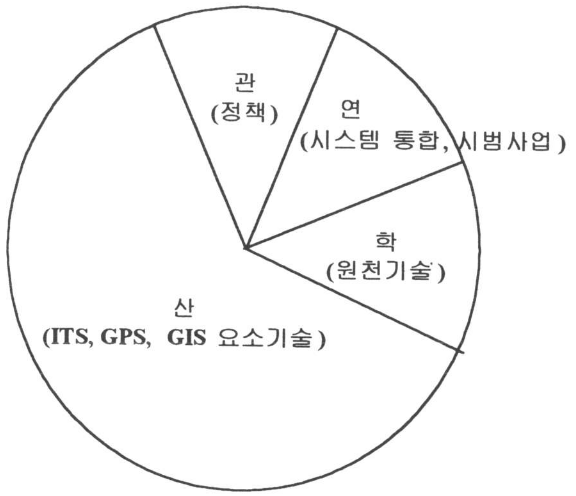
< 한국의 ITS 분야별 추진현황 >

분야	대상지역	시스템 구축	추진계획
국도 교통 관리시스템	전국 국도 (1단계 수도권 국도)	· 정보수집:도로교통상황 및 교통사고현황 등 · 정보분석:국도교통관리센터 · 정보활용:실시간 신호제어, 가변정보판 운영	· 2000년 운영목표 -96년 기본설계(10억) -97년 실시설계(30억)
수도권 교통정보 시스템	서울 생활권 중심의 수도권 지역	· 정보수집:도로교통상황 및 교통사고 현황 등 · 정보분석:종합교통정보센터 · 정보제공:도로정보판, 라디오 문자송신, 전화ARS, 차내 주행안내장비 등	· 2000년 운영목표 -96년 기본설계(5억) -97년 실시설계(30억)
신신호 시스템	서울특별시	· 기존 전자식 신호시스템을 신신호시스템으로 교체 · 교통관리센터 통제	- 97년 : 운영계획 - 지자체도 도입추진
버스도착 안내시스템	서울특별시 종로구	· 대중교통종합정보센터 · 운행관리, 운행상태정보 · 정보의 관리(운수회사)	- 대상구간 확대운영
첨단 교통 관리시스템	올림픽대로,강변북로내부순환고속도로	· 정보수집:도로교통상황 및 돌발상황정보 · 정보제공:가변안내 정보판	- 제공서비스 추가
물 류 관리체계		- 화물위치추적 시스템 - 화물차량위치추적 시스템	- 종합물류정보망 구축 계획 - 97년: 본격적 운영
고속버스 정보시스템 시범사업	· 소요예산 (10억) -건교부:5억 -도로공사/민간: 5억	-버스도착안내,소요시간 안내 등 -과학적 차량 운행관리	- 96.12~97.8 :기본설계 - 97.9~98.8 : 서울-대전구간 시범사업
과천지역 시범사업	· 소요예산 (112억) -건교부:26억 -과천시:7억 -민간:79억	- 교통량 감응 신호 - 버스도착안내 및 주행안내 - 과적차량 자동계중 - 통행료 자동징수	- 96.6~96.9:설계 - 97.2~97.12 : 설치, 운영 및 평가
연구개발	· 필요성 -시스템구축S/W 및 H/W개발공급 -국제경쟁대비 -관련산업기술 개발촉진	· 개발대상 기술 - 교통정보수집, 가공, S/W, 통신기술 - 시스템 통합, 전자지도 표준화 - 자동 요금징수 시스템, 자동운전도로 시스템	- 관련부처, 산학연 공동 개발 - 선진국과 공동개발 등 다양한 기술 확보전략구상

그동안 개발단계나 일부 시범운영에 들어갔던 다양한 기능의 ITS사업들이 97년 하반기부터 본격적인 시행에 들어갈 계획이어서 1997년이 ITS 실용화의 분기점이 될 것으로 보인다.

특히 올가을 시행되는 과천시의 ITS 시범운영은 그 성과의 정도에 따라 향후 한국 ITS추진에 큰 영향을 미칠것으로 보인다.

국내 ITS 관련 기술개발 현황



1991년부터 3년간에 걸쳐 첨단 신호제어 시스템이 서울시 일부 구간에서 시범운영 되었으며 1997년부터 설치 운영중이다.

고속도로 교통 관리시스템(Freeway Traffic Management System)도 1992년부터 3년간에 걸쳐 서울-대전간 고속도로에 설치되어 운영중이며 확대 계획을 추진 중에 있다.

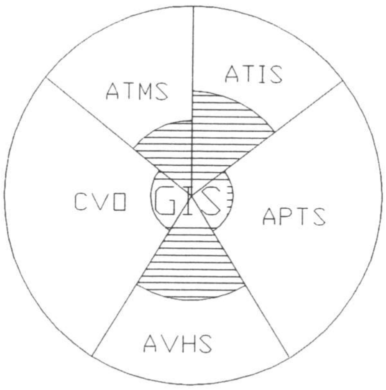
건설교통부가 주도하는 지능형교통시스템(ITS)시범사업이 기본계획 및 실시설계를 끝내고 과천지역에 시스템 구축후 1997년 가을부터 시범운영을 한다.

민간에서 개발중인 시스템으로는 GPS(Global Positioning System)를 이용한 차량항법체계, 차량의 고유번호를 인식하는 자동 차량인식 시스템, 화상정보검지 시스템 등이 있다.

< 국내 ITS 관련 기술개발 현황 >

구 분		개 발 내 용
정부	정보통신부 통상산업부 과학기술처	▪ ITS 핵심기술 개발을 위한 지원과제 선정 ▪ 산 · 학 · 연 등의 연구개발사업 지원 강화
	건교부	▪ ITS 추진전담부서 ▪ ITS 연구개발 및 기반기술 확보
연구기관	국토개발연구원	▪ 국가 ITS 구축 기반기술 연구 개발 총괄 ▪ 공통 주제도 수치지도 표준화
	교통개발연구원	▪ 경기도 과천 ITS시범사업 시스템 설계 및 구축사업 전담 ▪ 개별 ITS의 통합화 기술개발에 주력 ▪ 교통제어 알고리즘 및 동적경로 탐색 알고리즘 개발 등 교통운영 · 관리부문과 분야별 개별시스템의 통합 등 연구성과의 현장적용 추진중
	광주과학기술원	▪ 차량간 통신, 차량간격 자동제어, 자동조향 등 자동주행이 가능한 첨단도로와 지능형차량에 대한 연구를 중점 수행중 ▪ 지형형 차량의 핵심 요소기술인 충돌방지장치, 차량위치추적 및 주행안내장치, 도로상황인식장치 등 연구
	도로교통안전협회	▪ 신신호시스템의 개발부터 설치작업까지 전담 ▪ 첨단 교통관리 및 자체적으로 구축중인 교통정보센터등의 구축경험을 바탕으로 교통정보시스템과 실시간 교통신호제어부문의 기술개발에 주력
	건설기술연구원	▪ 수도권 교통정보시스템 구축을 통한 교통정보시스템 구축기술개발
	한국도로공사	▪ 고속도로 교통관리시스템 시범 설치완료
	자동차부품연구원	▪ 자동차업체들과 공동으로 차량항법장치 · 졸음운전방지시스템 ▪ 충돌방지시스템 등 첨단지능형 차량부문의 기술개발 추진
학계	고려대	▪ 무인자동차 시스템 개발 ▪ GPS를 이용한 Navigation System 개발완료
	서울대	▪ 전자통행료 징수시스템과 통신시스템 연구 진행중
	아주대	▪ 교통알고리즘과 교통관리부문의 연구 진행중
업계	현대전자	▪ GPS를 이용한 Navigation System 개발완료
	기아정보시스템	▪ 교통정보센터의 DB구축 및 교통정보 안내분야 ▪ 올림픽대로 교통종합관제시스템, 무인감시시스템등 교통관제부문 개발
	LG산전	▪ 도로교통안전협회 및 경찰청 등과 공동으로 신신호시스템을 개발완료하고 중앙연구소를 중심으로 무인단속시스템 개발
	삼성전자 대우전자	▪ 전자통행료징수시스템, 신신호시스템, 차량간 통신시스템, 교통정보 전송기술 등 첨단교통관제분야의 기술개발
	쌍용정보통신	▪ ITS 통합기술 개발
	인포뱅크	▪ 시내버스 주행안내시스템 개발
	해태전자	▪ 고속버스 안내시스템 개발
	인테크	▪ 버스도착안내시스템 개발 ▪ 자동통행료 징수 시스템(ETC) 개발
	제일엔지니어링	▪ 서울시 내부순환 고속도로 교통관리시스템 개발

ITS 와 GIS 관계



분야	제공서비스		개요
ATMS	실시간 교통제어		통행시간 측정, 사고규제상황 등 실시간 도로교통상황의 파악을 통해 효율적인 도로교통관리를 도모
	돌발상황관리		
	자동교통단속		
	자동요금징수		
	중차량관리		
ATIS	도로교통정보		교통여건, 교통규제상황등 교통관련정보를 운전자에게 제공하여 안전, 원활, 쾌적한 이동을 지원
	부가정보	종합여행정보안내	
		실시간최적경로안내	
APTS	대중교통정보제공		대중교통수단의 운행스케쥴, 차량의 현위치 등 관련정보를 취합, 이용자와 관리자에게 제공함으로서 대중교통수단의 효율적 이용을 도모
	대중교통관리		
CVO	화물 및 화물차량 관리		사용차량의 위치파악 및 본부와의 상호교신을 통해 신속하고 경제적인 운송을 실현
	위험물차량 최적경로 유도		
AVHS	첨단차량시스템		차량 및 도로에 설치하는 첨단 전자 정보통신기기를 통해 자동적으로 차량운행을 제어함으로서 궁극적으로 자동운전지향
	첨단도로시스템		

긴급배차시스템

시스템 구성요소	버튼 작동시
• GPS 수신기 • 이동 무선 통신 • 차내 작동버튼	중앙관제소에 비상 ⇓ GPS에 의한 위치확인 ⇓ 구급차 급파

국내기술수준은 전자, 통신 등 지능형 교통체계 구축에 필요한 세부기술 개발능력은 부분적으로 갖고 있으나 전체적인 시스템 통합기술, 알고리즘 기술, 자동차 제어기술 등은 아직도 미흡한 편이다. 그러나 기 개발 또는 설치 완료된 첨단교통신호체계와 고속도로 교통관리체계를 근간으로 ITS의 구축과 이와 관련된 요소기술의 제품화가 가속될 전망이다.

새로운 수치지도제작 기술발전은 차량 관리시스템에 막대한 영향을 미치고 있다. 앰브란스, 소방서, 경찰, 판매 서비스센타, 택배회사나 리무진 서비스 같은 다양한 조직들은 수치지도 기술발전으로 획기적인 운영향상을 가져오고 있다. 이러한 조직들은 수치지도와 여러 GIS 소프트웨어를 사용한 컴퓨터로 운영되는 차량급파 시스템을 이용하여 대응시간을 크게 단축시킬 수 있다.

차량관리 기술을 채택한 조직과 계획에는 다음과 같은 것이 있다.

- 사고발생시 가장 중요한 초기 대응시간 몇 분간을 단축한 앰블란스 서비스
- 차량내부에 수치지도를 장착하는 ITS 개발 계획
- 차량추적이 필요한 조직이나 회사로 하여금 혁신적이고 비용 효과적인 차량위치 안내 서비스

응급차량 운영센터 컴퓨터와 지도는 응급차량에게 도로망과 지리정보를 가시적으로 보여주며 모든 응급차량의 위치정보를 정확하게 알 수 있게 한다. 각각의 차량은 색상으로 코드화 되어 각 차량의 현상황을 알 수 있다. 예를 들면, 청색은 대기상태, 노란색은 출동중, 붉은색은 현장, 녹색은 응급환자 이송중 등을 나타낸다.

응급센터의 전광판은 차량으로부터 계속적인 정보로 상황의 변동내역을 표시한다. 각각의 차량은 현재위치와 응급센터로부터 전송된 목적지가 동적으로

표시되는 전자지도와 차량안내 시스템이 장착된 컴퓨터를 탑재하고 있다. 매 100m마다 차량안내 시스템은 장착된 무선모뎀을 이용하여 자동적으로 차량의 좌표를 본부의 메인시스템에 전송한다. 본부에서는 모든 응급차량의 정확한 위치를 파악하고 있기 때문에 가장 근접한 위치에 있는 차량을 선택해서 가능한 신속하게 급파할 수 있다.

이러한 차량안내 시스템의 도입전에는 계속적으로 차량위치를 묻고 어떤 차량이 가장 근접해 있는 지를 파악하고 그 차량을 호출하는데 너무나 많은 불필요한 시간을 낭비하였다. 이런 응급상황을 다루는 경우 몇분, 몇초의 시간이 생명을 구하는데 아주 중요한 시간이 될 수 있다.

컴퓨터를 사용한 차량급파 시스템은 모든 응급차량의 위치를 파악하는 것 뿐만 아니라 자동적으로 가장 근접한 차량을 파견할 수 있다. 이 시스템은 본부의 차량 통제소에서 모든 차량의 위치를 파악하는 상황에서도 응급호출 40초 내에 차량파견이 이루어지지 않는다면 자동적으로 가장 근접한 위치의 차량을 찾아내어 파견하도록 되어 있다.

장래의 긴급 구난 시스템
● 자동화 향상 – 충돌 감지기를 이용한 자동 발신 – 도로 DB를 이용한 정확한 위치확인 (경로 안내 시스템과 연계) – 자동차 고장진단 등의 추가 자료 제공 – 대체 통신수단(위성통신)

지난 몇 년동안의 기술발전은 차량을 관리해야 하는 회사나 조직으로 하여금 사업양태를 기초부터 바꿔 놓았다. 실제 차량위치의 파악이 곤란 하여 차량 파견의 비효율을 유발하는 양방향 Radio 송수신 시대는 가고, 현재는 자동화된 수치지도와 컴퓨터를 이용한 차량 급파 시스템 혹은 정교한 통신 기반시설 등을 이용하여 획기적인 효율성 향상을 현실화 시켜 시간과 비용을 단축하고 있다.

국내 GPS 개발 현황
● 차량항법장치(CNS) ● 차량위치 추적 시스템(AVLS) ● 열차위치 측정 시스템 ● GPS Simulator ● GPS 택시 미터기 ● GPS 수신기 이용 차량운행 기록장치

GIS구축사업을 수행하는데 소요되는 비용중에서 데이터베이스 구축비용이 전체 비용의 약 2/3 (65~75%) 정도를 차지한다. 다시 말해서 GIS-T구축의 성패는 데이터베이스 구축에 좌우된다는 의미이다. 따라서 데이터베이스 구축을 얼마나 효율적으로, 체계적으로, 그리고 정확하게 구축하느냐가 그만큼 중요하다고 할 수 있다.

초기 자료수집 및 기존 자료의 갱신시에 범지구측위시스템(GPS:Global Positioning System)을 활용한다면 자료의 정확성은 물론이고 비용 및 시간을 크게 줄일 수 있을 것이며, 더 나아가 GIS-T와 GPS의 통합서비스 구현방안을 강구하여 교통부문에 적용한다면 현 교통문제해결에 커다란 실마리가 될 수 있을 것이다.

GPS 개요 및 측위 방법

GPS는 미국정부가 1970년대 초 군사목적으로 개발한 항법지원시스템이었는데 GPS의 일부가 민간에 개방되면서 여러 가지 응용분야에서 사용하게 되었다. GPS위성에서 방송하는 C/A코드를 이용하면 전세계 어디서나, 언제라도 원하는 지점의 측위가 가능하며 그 정확도는 ±100m 정도이다. GPS는 위성, 위성을 관제하는 지상관제설비, 사용자가 이용하는 GPS수신기를 포함하는 시스템이다.

GPS는 GPS위성을 통하여 임의의 지점이나 이동체의 순간 위치를 측정하여 표현하는 시스템으로서 위치측정 방법은 기본적으로 위성을 기준점으로 하는 삼각측량원리를 이용한다. 즉 삼각측량의 기준점을 위성으로 하고 지구상에 설치되어 있는 수신기까지의 거리를 측정하여 수신기의 위치를 결정하는

방식이다. 이동체의 실시간 위치를 주기적으로 확보하여 디지털 전자지도에 표현하는 것이 현재 국내외적으로 활발히 개발되어 상용화 단계에 있는 CNS(Car Navigation System), ITS(Intelligent Transportation System), AVL(Automatic Vehicle Location) 등의 시스템들이 적용하고 있는 GPS의 측위 원리이다.

국내 GPS 현황

국내에 처음 GPS가 소개된 것은 1990년대 초반으로 아직 국내의 GPS개발수준은 초기 단계에 있다. 현재 국내의 GPS보급은 항법의 일부, 측량, 그리고 GIS의 데이터 취득분야에 일부 활용되고 있는 실정이다. 업계에서 이미 개발 보급하고 있거나 추진중인 GPS 관련 기술들은 다음과 같다.

< 국내 GPS 관련 기술 개발현황 및 추진사례 >

관련업계	개발 및 추진기술	내 용
샬롬ENG (1997)	GPS시뮬레이터 사업착수	▪ 미국사와 공급계약 체결 ▪ GPS 소프트웨어 및 장비를 포함한 전체시스템 유무를 파악하는 장비
	열차위치자동 측정시스템	▪ 열차사고 발생시 열차위치 측정 시스템
신 화 (1997)	GPS택시미터기	▪ GPS수신기와 모뎀, 무선망 등 이용 ▪ 택시의 위치, 택시미터의 요금수입 등을 실시간으로 확인
현대전자 (1997)	CNS '항법 프로세서보드' 개발착수	▪ 일본 마쓰시다전기와 공동개발 ▪ 항로 자동안내시스템 적용 ▪ 위성으로부터 신호를 수신할 수 없는 지역도 차량에 장착된 자이로와 속도계를 이용, 자체적으로 차량의 주행궤적을 판단해 전자지도상에 현재 위치를 실시간으로 표시 ▪ 7인치 와이드비젼 제공 ▪ 20만건 이상의 교통종합정보수록 및 도로상교차점 화면확대, 음성안내 기능
아 이 텍 코 리 아 (1997)	12 Channel GPS Engine	▪ 실시간 다중처리 방식 채택 ▪ DGPS(Differencial GPS)어플리케이션 지원 가능 ▪ 위치차를 최소화, 고유 ID를 가진 수신기 이용 ▪ GPS수신기를 통해 교통정보 수신이 가능하고 기능버튼을 누름과 동시에 화면이 뜨는 모델개발중

관련업계	개발 및 추진기술	내 용
하이네텍 (1996)	GPS 수신기 이용 차량운행 기록장치	▪ 차량운행경로 및 일반 운행상황을 액정화면에 표시, 메모리에 기록, 프린터 및 PC와 연결하여 실시간 정보 검색가능 ▪ 차량항법장치(CNS)와 직접연결가능 ▪ 시스템 구성 – GPS 디지타이징시스템 및 편집 · 입력 시스템 – GPS 시스템설계분석 및 리시버 응용 하드웨어 – GUI를 지원하는 사용자 인터페이스 – 지도와 좌표를 연결한 타코미터 디스플레이시스템 및 관련 소프트웨어 – GPS 리시버 인터페이스용 소프트웨어 – 타코미터 기능을 갖는 GPS 소프트웨어 및 차량위치 제어표시 시스템
쌍용정보통신 (1997)	차량항법장치 (CNS) '인터로드'출시	▪ 무선호출등을 통해 송신하는 각 지역의 교통정보를 모니터에 문자형식으로 제공 ▪ Map Matching기능 내장 – GPS의 수신오차 자동수정기능 ▪ 주행시뮬레이션 기능 – 목적지 자동검색기능 – 최단경로 검색기능 ▪ 지도회전(Heading Up)기능 ▪ 레이어 선택기능 ▪ 5인치 컬러 TV, CDF, 무선호출기능 제공
	차량위치추적 시스템(AVLS) 사업착수	▪ GPS 위성과 차량용 단말기 및 무선망이용 ▪ 차량의 현위치, 이동상황을 전자지도에 실시간 표현 ▪ 중앙관제소의 통제내용을 차량단말기에 문자와 음성으로 전달 ▪ 택배, 택시, 운송, 시스템경비, 선박, 119응급체계 서비스등에 활용가능 ▪ AVL센터운영을 위한 소프트웨어 개발 ▪ GPS 수신기와 무선통신장치를 결합한 단말기개발 ▪ AVL센터 서버용 소프트웨어 개발

ITS와 국가 수치지도 추진계획

구 분		1996	2000	2005	2010
ITS	1단계(기반조성)	———	———		
	2단계(확산)			———	
	3단계(성숙,고도화)				———
수치지도	지형도	———	——— 97		
	공통주제도		——— 99		
	지하매설물도	———	———		

ITS 추진계획

구분	1단계(1996-2000)	2단계(2001-2005)	3단계(2006-2010)
서비스	• ATMS, ATIS, APTS, CVO의 기초서비스 제공 • AVHS중 차량단독 제어기술(AVS)개발 일부실용화 • 각 시스템별 지역 또는 단위센터 구축	• ATMS, ATIS, APTS, CVO의 고급서비스 추가 • AVHS 기초서비스 현장 시험 연구 • 시스템간 연계체제 구축	• 차세대 ATMS, ATIS, CVO의 개발 및 구축 • AVHS본격 구축
연구개발	• 핵심요소기술 및 교통응용기술 개발 • 시스템 운영방안, 추진기반조성을 위한 법제도 연구	• 국산화율 지속적 제고 및 해외진출 모색 • 기술 고급화/다양화	• 차세대 기술개발 유도 • 본격 해외시장 진출

국가 수치지도 추진계획

국가지리정보체계 구축사업의 일환으로 진행되고 있는 수치지도제작은 1/5,000축척이 97년말까지 전국적으로 제작되며 1/1,000 축척의 경우는 6대 도시를 포함한 주요도시에 대해 제작될 예정이고 결과물 중에 도로망 계층(layer)이 별도로 제작되도록 되어 있다.

그러나 수록되는 내용은 차로수와 국도, 고속도로, 지방도 등의 분류에 따른 도로형상자료와 주변의 지형지물 및 배경자료로 단순하게 구성되어 있고 구조화된 도로망자료나 교통안전시설물이나 교통규제자료 등 중요한 자료는 포함하지 않고, 또한 자료구조상 ITS용 전자도로 DB로 직접 사용할 수 없다는 점등 문제점은 있으나 귀중한 수치기본도로 이용할 수 있다.

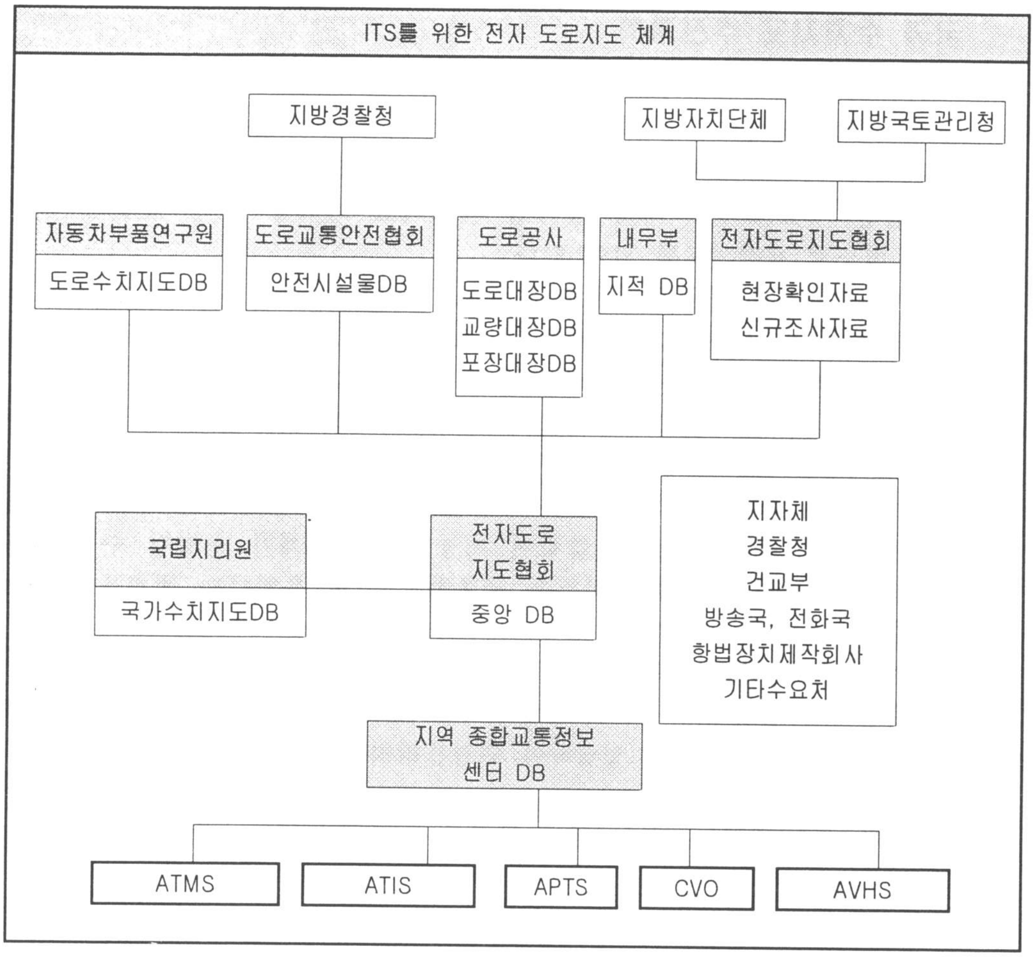
전자도로지도체계는 산재해 있는 복합적인 도로 및 교통관련 기초자료들을 물리적으로 또한 논리적으로 결합하여 지능형 교통체계가 운영될 수 있도록 전국적 규모의 공통 데이터 베이스를 구축하고 이를 운영하는 체계를 구축하는 것이다.

지역별 ITS가 필요로 하는 실시간 자료의 경우는 "지역종합교통정보센터"가 수집관리하며 전국적인 규모로 수집관리하여야 하는 비 실시간적 자료의 경우는 가칭 "전자도로지도협회"를 설립하여 수집관리하는 안을 고려하고 있다.

다음과 같은 자료는 해당기관과 협의하여 수집한다.

- 국가수치지도 DB : 국립지리원
- 도로수치지도 DB : 자동차 부품연구원
- 교통안전시설물 DB : 도로교통안전협회
- 도로대장 DB, 교량대장 DB, 포장대장 DB:지방국토관리청 및 도로공사
- 도로시설물 관리대장 : 지방자치단체
- 지적 DB : 내무부
- 교통규제자료 : 지방 경찰청

이들 전산자료를 효과적으로 합성하여 제작관리하는 방향으로 전자도로지도 DB 구축체계가 발전할 것이며, 이들 개별적인 전산체계가 확보되기 이전의 자료수집체계가 전자도로지도 체계 구축과 ITS 체계 전체에서 가장 중요한 요소가 될 것이다.



전자도로지도 DB 구축계획

구축내용	1997	1998	1999	2000	2001
전자도로지도협회설립 및 운영					
기초자료수집체계구축					
중앙 DB 설계 · 제작 · 갱신					
지역종합정보센타 DB표준설계					
지역종합교통정보센타와의 통신망 확보					

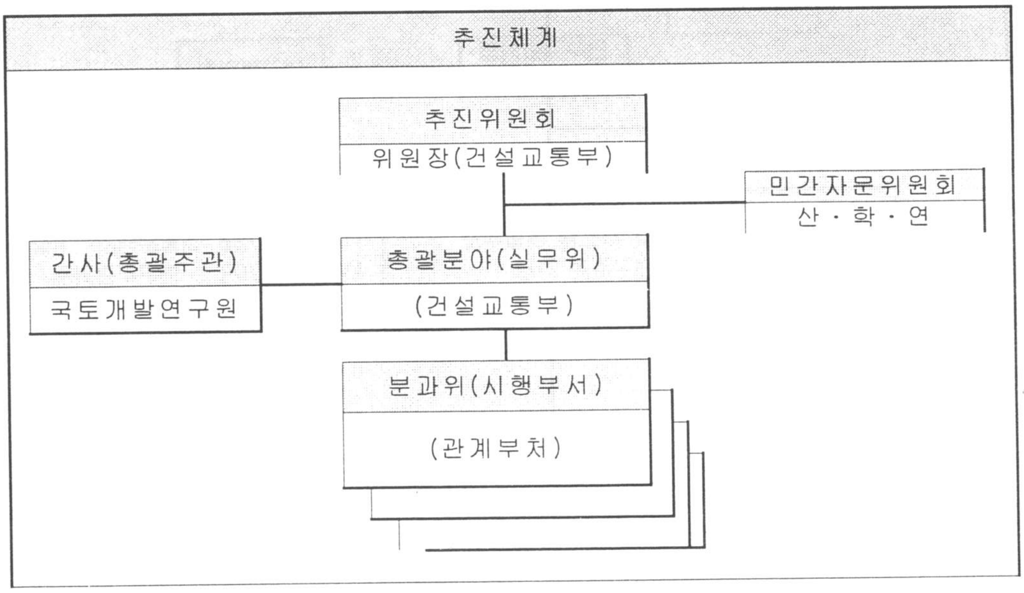
차량 항법장치(Car Navigation System)에서 항법을 가능케하는 도로관련 도형 및 비도형자료의 데이터베이스로서 전자도로지도(Digital Road Map)는 필수적이다. 전자도로지도의 개발은 선진외국의 기술습득단계에 있는 항법장치 관련 기술에 대한 국내연구의 시발점으로서 ITS 기반구축에 필수불가결한 요소이다.

이 계획은 다음과 같은 기능의 전자도로지도 제작을 목적으로 하고 있다.

- 자차 위치표시 기능
- 지도표시 기능(Map Display)
- 진로결정 기능(Path Finding)
- 경로안내 기능(Route Guidance)
- 자료검색 기능
- 주소·좌표 전환 기능

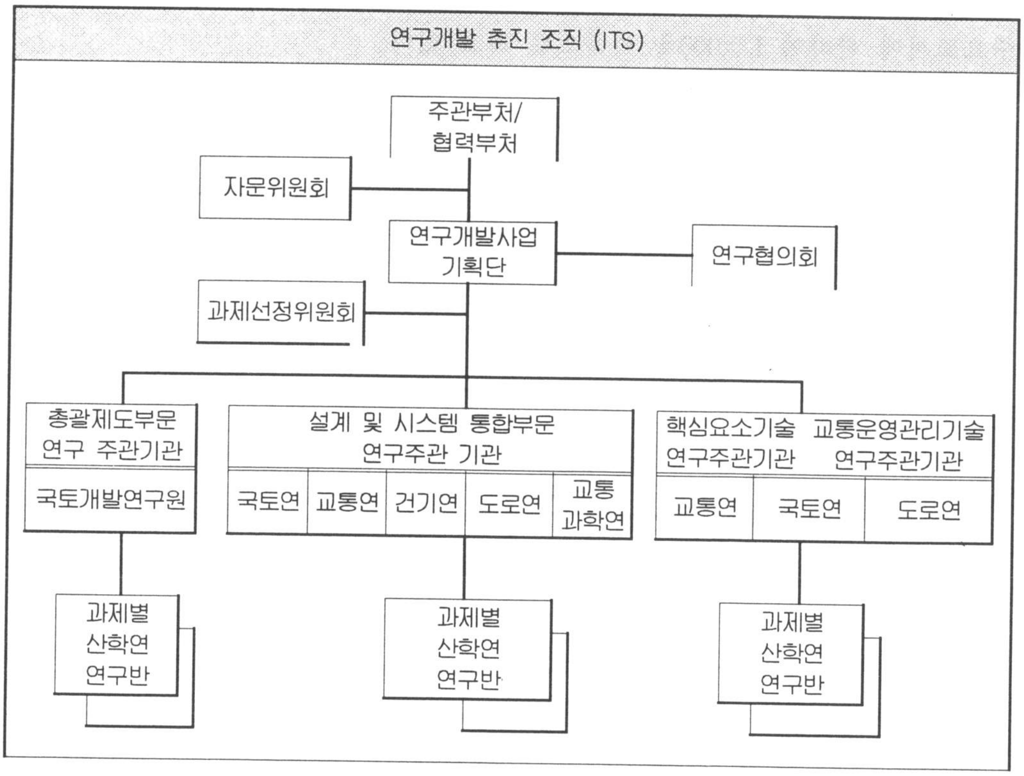
위치표시 기능은 주로 DGPS(Differential GPS)방식이나 D-R(Dead Reckoning)방식을 사용하는 것으로 상정하고 있다. 한국전역을 제작범위로 삼고 있으며 원도는 국립지리원 발행 1/25,000을 기본으로 하고 6대도시 수도권 주요도시에 한하여 1/5,000을 기준으로 하고 있다.

자료의 내용은 도로관련 자료, 교통정보자료, 행정구역자료, 지형지물 자료, 래스터 배경자료, 부가정보 자료로 구성되어 있다.



GIS와 ITS추진체계는 별도로 설립되어 있지만 조직의 형태는 유사하며 위의 추진체계는 GIS와 ITS에 공통으로 적용된다.

분야 / 부서	GIS	ITS
주관부서	건설교통부	건설교통부
관계부처	정보통신부	통상산업부
	과학기술처	정보통신부
	내무부	과학기술처
	통상산업부	
	재정경제원	
	농림수산부	
	환경부	
	총무처	
	통계청	경찰청
	산림청	

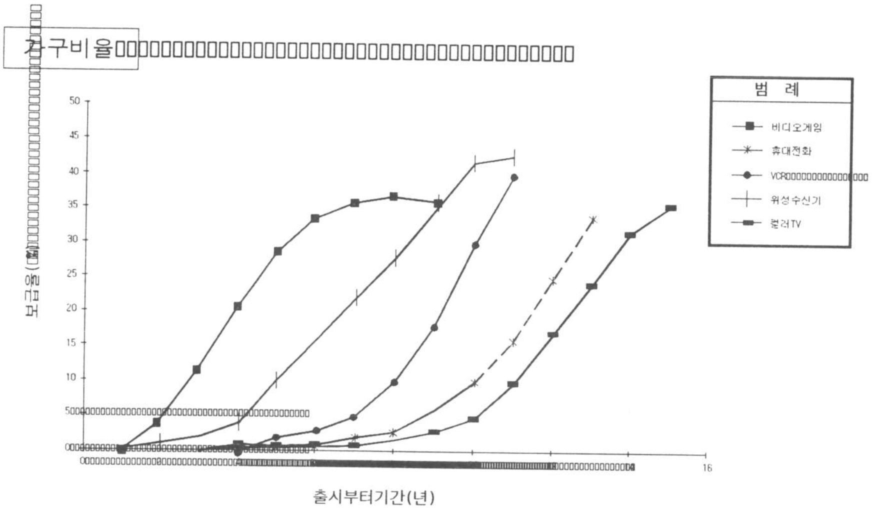


연구개발 사업계획

국가GIS사업	사업명	국가ITS구축기반
2,800억원	예 산	873억원
2단계(약10년)	추진단계	2단계(10년)
5	추진과제분담	4
29	연구과제	80
과천	시범사업	과천
96~97	(시행시기)	96~97

구 분	GIS	ITS
사업명	국가 GSI사업	국가ITS구축기반기술연구개발
예산(억원)	2,800 중앙, 지자체: 64% 민 간 : 36%	873 중앙, 투자기관 : 58% 민 간 : 42%
단계 1단계 2단계	1999년 까지 2000년 이후	1996 ~ 2000년 2001 ~ 2005년
추진과제	총 괄 기 술 개 발 지 리 정 보 토 지 정 보 표 준 화	총괄제도(12) 설계 및 시스템 통합 핵심요소기술(32) 교통운영관리기술(36)
연구과제	29과제	80과제
시범사업 (과천)	공공GIS활용체계의 일환으로 지하매설물 전산화 96.4 ~ 12 : 시범사업 97.~ : 평가 및 개발지침	98 ITS World Congress시범 기술개발촉진 및 ITS 홍보 96.6 ~ 10 : 실시설계 96.12 ~ 97.8 : 시스템 설치 97.9 ~ 12 : 시범운영, 평가

새로운 전자제품의 보급곡선

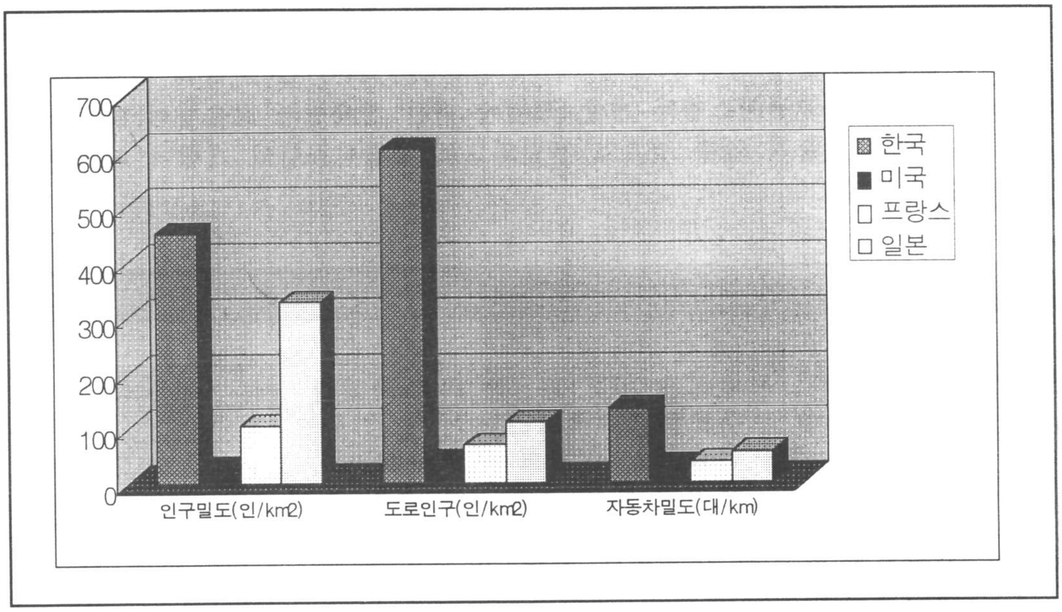


새로운 전자 · 통신장비들이 개발되어 소비자에게 소개된후 전 가구의 약 1/3에 보급되는 대중화 기간은 대체로 8~12년으로서, 차량정보통신 시스템(VICS)의 일부로 장착되는 경로안내 시스템이 대중화 되는 시기를 유추하는데 참고할 수 있다. 약 10년 정도로 가정할 때 ITS 2단계(확산단계)가 끝나는 기간과 대체로 일치한다.

앞에서 다룬바와 같이 GIS, ITS, GPS는 상호밀접히 연결되어 있으며 이외에도 많은 다른기술(위성통신, 인공지능, 첨단재료, 자동제어 등)의 발전과 흐름을 같이 해야할 것이다.

각 부문의 추진계획은 관련기술의 추진계획을 포함하여 서로 조정되어야 하며 관련부문간 정보교환과 조정창구가 확보되어야 한다. 어느 한 기술이 대중화되는 시기를 단축하기 위해서는 국민대중에게 제공되기전에 관련기술이 상호보완, 조정되어 시행착오를 최소화하므로서, 보다 효율적이고 사용하기 쉬운 시스템을 제공할 때 대중화기간은 짧아질 수 있을 것 이다.

선진국과 한국의 여건 비교



구 분	면적 (천km2)	인구 (백만명)	도로연장 (천km)	자동차보유대수 (백만대)	인구밀도(인/km2)	도로인구(인/km)	자동차밀도 (대/km)
한 국	99.4	44.9	74.2	10	452	605	135
미 국	9,809.4	263.3	6,277.8	195.4	28	42	31
프랑스	551.0	58.0	811.6	30	104	71	37
일 본	377.8	125.1	1,130.9	65	327	110	57

한국은 면적이 약 100,000km2 의 작은 나라이며 인구는 45백만명으로 인구밀도가 가장 높은 국가중의 하나이다. 도로망은 고속도로 1,840km를 포함하여 약 74,200km이며, 자동차는 1997년 7월에 10백만대를 넘어섰다. 도로는 국내 운송량중 여객의 80%, 화물의 경우에는 65%이상을 부담 처리하고 있다.

교통현황은 대도시부의 통행속도는 30km/시 내외(서울시의 경우 18km/시)이며 자동차시대의 도래로 대중교통 이용도가 점차 낮아지고 있고 전국적 교통정체 및 혼잡으로 인하여 년간 손실액은 12조원(GNP의 3.5%)으로 추산하고 있다.

또한 교통사고가 선진국에 비해 대단히 높으며(년간 사망자 10,000명, 년간 손실액 6조 6천억원) 대도시부의 대기오염은 상당히 심각한 상태에 이르고 있다. 이처럼 인구, 도로인구, 자동차 밀도가 선진국에 비하여 상대적으로 굉장히 높으므로 새로운 시스템의 도입에 의한 단위면적당, 단위 연장당 개선의 효과도 상대적으로 높게 나타날 것이다. 따라서 GIS, ITS, GPS 등의 결합에 의한 새로운 지능형 교통시스템의 개발, 도입에 따른 경제성과 효율성이 다른 선진국에 비하여 월등히 높을 것으로 판단되므로 통합시스템의 개발이 더욱 필요하다고 하겠다.

GIS와 ITS
개발주체 : 국가주도 주 수요자 : 정부기관, 지자체, 정부 투자기관 기술의 특성 : 주문형 (지역여건) 기술개발 전제로 구축사업 적기에 관련 요소기술 개발 공급 국내 시스템의 외국 기술종속 방지 기술경향 : 오픈 아키텍춰 지향 네트워크화 상호운영성 추구 GPS, DBMS와 통합 국제표준 : ISO TC211,204 연구개발 : 산·학·연·관 공동 시스템 구축절차 : 기본설계 - 상세설계 - 체계구축

GIS와 ITS는 국가 주도하에 각 주체들이 담당분야와 이용목적에 따라 구축하는 다양한 자료기반을 기초로 응용체계와 정보 제공체계로 구성된다. 이러한 체계가 제대로 운용되기 위해서는 여러 가지 표준과 관련기술을 상호 지원해야 한다는 것은 말할 필요도 없다. 오픈 아키텍춰는 당면하고 있는 현재의 최적 해결방안(Solution)으로서의 시스템 구축 뿐만 아니라 장래 확장성 및 타 분야와의 통합을 고려 하여야 한다.

GIS와 ITS는 공통점이 너무나 많고 닮은점도 많다. 이들을 둘러싸고 있는 제반여건을 공유하고 있으며 추진 주체는 더구나 한 몸이다.

한편으로는, GIS에서 바라보면 GIS-T는 이의 한부분이며 ITS는 하나의 응용분야이다. 반면, ITS에서 보면 GIS는 이를 구현하는데 필요한 하나의 요소기술이다. 그러나 한가지 분명한 것은 이 두 시스템이 밀접한 관련을 갖고

있으며 서로를 필요로 한다는 점이다.

이를 추진하기 위한 법과 제도도 이제부터 보다 체계적이고 구체적으로 연구하여 정립 하여야 한다. GIS(GIS-T)와 ITS는 원래 한몸으로서 처음부터 한뿌리에서 갈라져 나온 두 가지 일지도 모른다.

Cartographic Modeling Techniques for Highway Corridor Planning

C. Dana Tomlin
Professor
University of Pennsylvania

ABSTRACT

The United States' Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 calls for the use of digital tools and techniques for the siting of major highway corridors and the analysis of their anticipated impacts on surrounding regions. This has led to an increasing use of geographic information systems(GIS) in the field of transportation planning.

"Cartographic modeling" is a general methodology for the analytical use of GIS that shows particular promise for this kind of application. The distinctive feature of this methodology is its use of an algebra-like language to express a wide variety of geographic conditions and processes in clear and consistent terms. It does so by decomposing both data and data-processing tasks into elemental components that can then be recomposed with relative ease and with great flexibility. The result is what amounts to a "map algebraic" language in which cartographic layers for individual characteristics such as soil type, land value, or population are treated as variables that can be transformed or combined into new variables by way of specified operations.

In this presentation, cartographic modeling techniques are introduced and demonstrated by way of highway corridor allocation project involving the New Jersey Department of Transportation in the eastern United States. Notable among these are techniques to identify Nth-best alternative

routes and techniques to analyze and map the spatial influence of individual siting factors on optimal alignments.

요 지

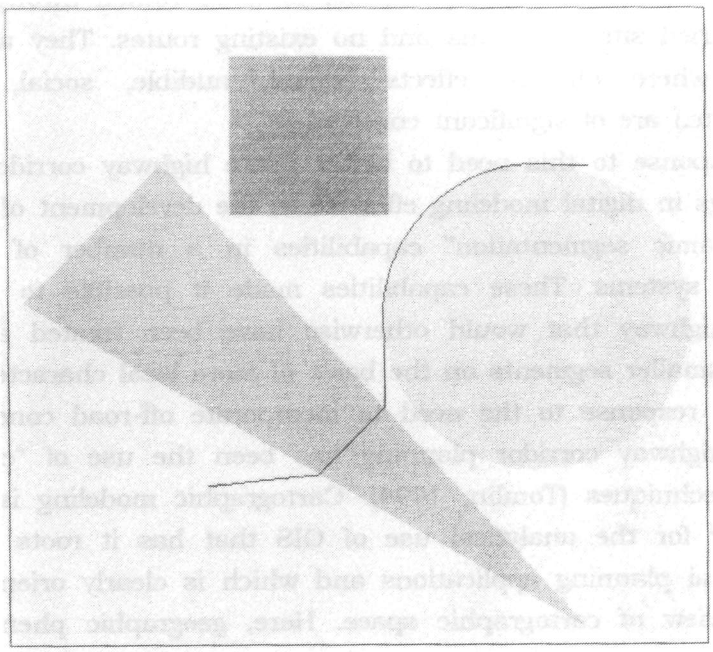
1991년 미국의 육상교통효율법(ISTEA)은 주요 고속도로회랑의 위치선정과 그것이 주변지역에 미치는 영향을 분석하기 위하여 전산도구와 기법을 이용할 것을 요구하고 있다. 이는 교통계획분야에서 GIS의 이용이 증대되는 결과를 가져왔다.

"지도모델링(Cartographic Modelling)"은 이 분야의 응용프로그램 개발에 큰 도움을 줄 수 있는 GIS의 분석적 이용의 일반적인 방법이다. 이 방법의 가장 큰 특징은 지리적인 현황과 프로세스를 명확하고 일관되게 표현할 수 있는 대수와 같은 언어를 이용하는 것이라고 할 수 있다. 이것은 데이터와 데이터처리작업을 그것을 구성하는 상대적으로 이해하기 쉽고 다양한 재결합이 가능한 기본요소로 분해함으로써 이루어진다. 그 결과 토양의 종류, 지가, 인구와 같은 개개의 특성들이 변수로 처리되어 주어진 작업에 맞추어 변환되거나 결합되어 사용될 수 있는 지도레이어를 만드는 데 필요한 "지도대수" 언어가 만들어 진다.

이 발표에서는 지도모델링기법을 미국동부의 뉴저지교통부에서 수행하고 있는 고속도로회랑배치 프로젝트(Highway Corridor Allocation Project)를 통해 소개하고자 한다. 이 중 가장 주목할 만한 것은 N번째 최적대안경로를 찾아내는 기법과 최적입지에 미치는 각각의 입지요소들의 공간적 영향을 분석하고 지도화하는 기법이다.

1. INTRODUCTION

Consider the map shown in Figure 1. It depicts the minimum-cost path from one point to another through a stylized landscape of varying transportation costs. Here, the path is drawn in black, while areas of increasing transportation cost are indicated by shades of grey. What appears as a circle is an area through which transportation is twice as costly as it is through the white background area. Similarly, the cost of transportation in the triangular area is twice as costly as it is the circle. And in the square, it is twice as costly as in the triangle. The optimal path extends from an upper right point down around the left edge of the circle and cuts across the triangle at precisely that width where the triangle becomes sufficiently narrow to justify this shortcut in order to avoid the greater cost of going all the way around. This simple and certainly contrived example is used here to illustrate a set of data-processing techniques that are neither simple nor contrived: techniques for the use of a digital geographic information system (GIS) in the planning of highway corridors.



<FIG.1>

In 1991, The United States' Intermodal Surface Transportation Efficiency Act (ISTEA) mandated the use of digital tools and techniques for the siting of major highway corridors and the analysis of their anticipated impacts on surrounding regions. This encouraged what, by that time, had already been an increasing use of computer-based geographic information systems to express highway siting criteria, to generate alternative highway alignments, and to evaluate their environmental impacts.

Early efforts to make use of digital capabilities in highway corridor planning were often limited to straightforward applications of general-purpose network optimization techniques that had been well known in this and other fields for a number of years. While these techniques remain quite useful in dealing with well-defined transportation networks, they are generally not as effective in dealing with situations where the network is not fully defined. These include situations, for example, where a new highway corridor is to be routed through a region of highly-varied site conditions and no existing routes. They also include situations where off-road effects (visual, audible, social, historical, biological, etc.) are of significant concern.

One response to this need to better relate highway corridors to their surroundings in digital modeling efforts was the development of what were called "dynamic segmentation" capabilities in a number of geographic information systems. These capabilities made it possible to partition a length of highway that would otherwise have been treated as a single entity into smaller segments on the basis of more local characteristics.

Another response to the need to incorporate off-road conditions and effects in highway corridor planning has been the use of "cartographic modeling" techniques (Tomlin, 1994). Cartographic modeling is a general methodology for the analytical use of GIS that has it roots in broader environmental planning applications and which is clearly oriented toward a broader view of cartographic space. Here, geographic phenomena are expressed not so much in terms of discrete entities in space but, rather, in terms of qualities of space: fields rather than objects.

A distinctive feature of the cartographic modeling methodology is its use of an algebra-like language to express a wide variety of geographic conditions and processes in clear and consistent terms. It does this by decomposing both data and data-processing tasks into elemental components that can then be recomposed with relative ease and with great flexibility. The result is what amounts to a "map algebraic" language in which cartographic layers for individual characteristics such as soil type, land value, or population are treated as variables that can be transformed or combined into new variables by way of specified operations.

This paper offers a brief introduction to the nature and use of cartographic modeling techniques for highway corridor planning. It does so by examining, and then extending, the "simple" example that has already been presented. While this example is clearly hypothetical, it is inspired by a real highway-siting project involving the New Jersey Department of Transportation and the University of Pennsylvania (Lee and Tomlin, 1997). The example is presented in three parts, respectively entitled

- specifying the problem
- generating solutions, and
- evaluating results.

2. SPECIFYING THE PROBLEM

Our first task is to efficiently organize and express this problem of determining the optimal route "from here to there" through a "friction field" of intervening costs that vary from one location to another. To do this in cartographic modeling terms requires that separate maps be created to depict "here," "there," and "friction." Each of these maps can be envisioned as a bounded plane area on which every location is associated with exactly one attribute. Each location is defined by a pair of X,Y coordinates (respectively indicating its position along horizontal and vertical axes in the cartographic plane) and a numerical Z value identifying its attribute.

Said more simply, a map called HERE is one on which every X,Y location within the rectangular study area—except one—is set to a Z value of 0. That one exceptional location (just to the upper right of the circle in Figure 1) is set to a Z value of 1. Similarly, THERE is a map on which the lower left path terminus (below the triangle in Figure 1) is likewise encoded. And FRICTION is a map on which locations lying in the background area, the circle, the triangle, and the square are set to values of 0, 2, 4, and 8, respectively.

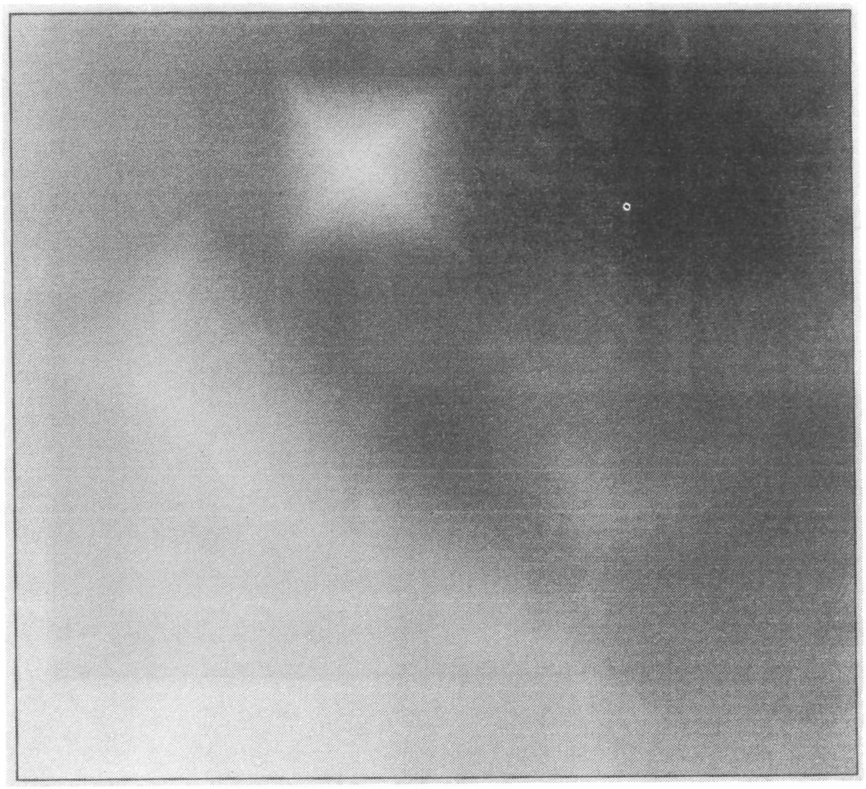
Given this initial data base of three maps, or three cartographic variables, map algebraic operations can be used to compute new variables (maps) much like conventional algebraic operations might be used, for example, to compute a new variable A from existing variables B and C through an operation given as A = B + C. In this case, however, the operations available are cartographic rather than merely mathematical in nature. Among them are operations to reassign Z values, to superimpose on map onto another (by adding or subtracting their Z values at coincident locations, for example), to measure distances or directions, to characterize sizes and shapes, to calculate travel times, to compute slopes and aspects, to simulate flows, and so on. Since each of these map algebraic operations accepts input and generates output in the same form (a map variable), the output of any one operation can be used as input to any other. It is this which makes it possible to address an open-ended range of applications with only a relatively small set of tools.

3. GENERATING SOLUTIONS

To illustrate the use of map algebra in the context of our simple example, consider the map shown in Figure 2. Entitled HOW-FAR- FROM -HERE, this is a map on which each location has been set to a Z value indicating its distance from that upper right point depicted on the map we chose to call HERE. This map was created in response to a map algebraic statement given as

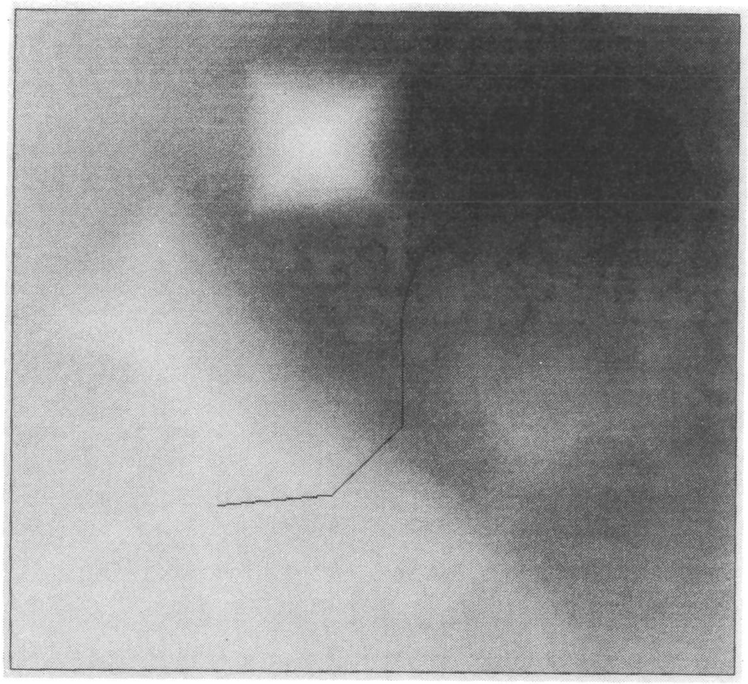
HOW-FAR-FROM-HERE = FocalProximity of HERE spreading in FRICTION

The higher values (greater distances) on HOW-FAR-FROM-HERE are represented in lighter shades of grey. If these distance values had been computed in terms of uniform transportation costs (i.e. without the impeding effect of FRICTION values) then this map would have appeared as a set of concentric, circular zones of increasing distance and lighter shades of grey. As it is, however, those zones are concentric but not at all circular. Rather, they tend to bend around and through the square, the circle, and the triangle much like (in fact, exactly like) waves that are subject to diffraction and refraction as the travel through media of varying density.



<Fig.2>

Given such a map, the task of determining the minimum-cost path between "here and there" is deceptively simple. It is merely a matter of simulating downstream flow (by using a map algebraic operation more typically associated with hydrological applications) from that lower left point depicted on THERE over the "topographic surface" of Z values on HOW-FAR-FROM-HERE. To illustrate this, consider the cartographic image presented in Figure 3. Here, HOW-FAR-FROM-HERE is depicted in discrete (rather than continuous) levels of grey in order to better suggest that this map is actually a field of Z values that comprise a three-dimensional surface: one that extends from a dark "basin" to lighter "ridges" in figurative, if not physical, terms. The black line on this image is not only one which represents the path of downstream flow from THERE over this three-dimensional surface, but also one which traces the path of minimum total FRICTION between HERE and THERE.



<Fig.3>

While this process does succeed in identifying optimal paths, it fails to give any indication of the location or cost of second-, third-, or nth-best alternative paths. In the practical context of highway corridor allocation, however, these sub-optimal alternatives can be quite important. It may be, for example, that FRICTION factors are sufficiently uncertain or politically contentious that alternative routes must be explored. And it could well be that minor variations in FRICTION result in entirely different results.

It is for this reason that another solution to this siting problem is well worth consideration: one that not only identifies the optimal path between HERE and THERE in terms of intervening FRICTION, but which also identifies and calculates the relative cost of all sub-optimal alternative paths as well. Like the first, this procedure is deceptively simple in both concept and execution.

If you examine the map shown in Figure 4, you will note that it is similar in appearance to the HOW-FAR-FROM-HERE map presented in

Figure 2. This, however, is a map entitled HOW-FAR-FROM-THERE on which lighter shades of grey indicate greater distance (in transportation cost) from the lower left point shown on THERE.

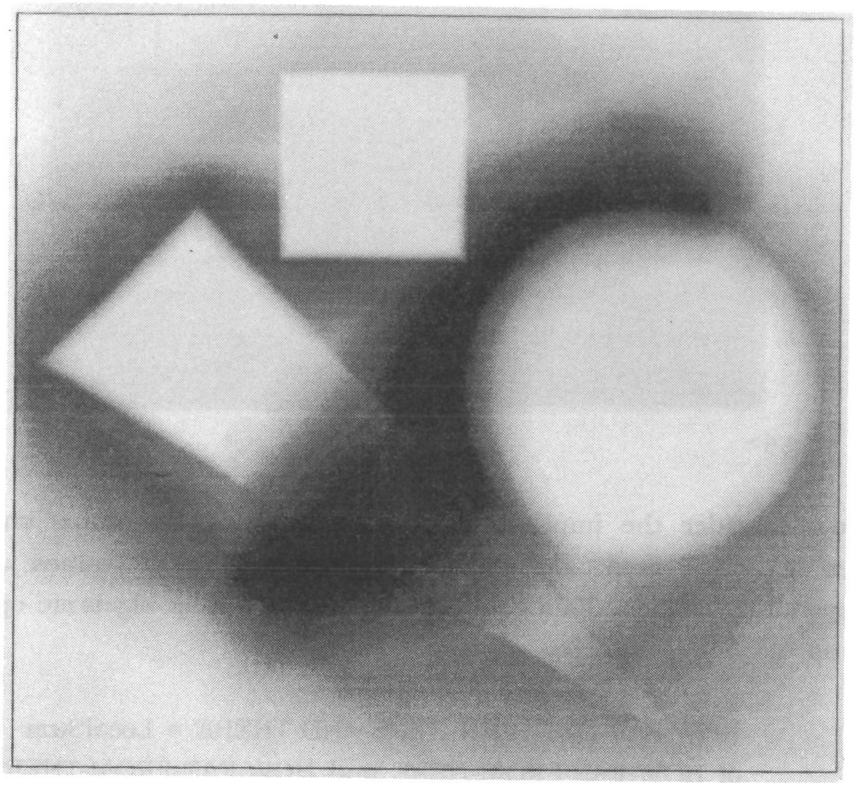
<Fig.4>

Now consider the implication of superimposing the maps shown in Figures 2 and 4 and adding their respective distance values at each corresponding location. This could be done with a map algebraic operation given as

HOW-FAR-BETWEEN-HERE-AND-THERE = LocalSum
of HOW-FAR-FROM-HERE and HOW-FAR-FROM-THERE

to generate a new map called HOW-FAR-BETWEEN-HERE-AND-THERE on which each location's Z value would indicate the sum of its minimum-cost distance from "here" and its minimum-cost distance from "there." Said differently, each location's value would indicate the total cost of the minimum-cost path that extend from "here" through that point to "there."

In Figure 5 is a rendition of HOW-FAR-BETWEEN-HERE-AND-THERE in which darker shades of grey indicate lower costs. Note that the optimal path shown in Figures 1 and 3 does indeed coincide with the darkest portions of this map but that this optimal route is now flanked by a swath of sub-optimal alternatives. Note too that, while no viable paths are evident above the square or below the circle, there does appear to be at least the suggestion of an alternative route extending below the square and to the left of the triangle.



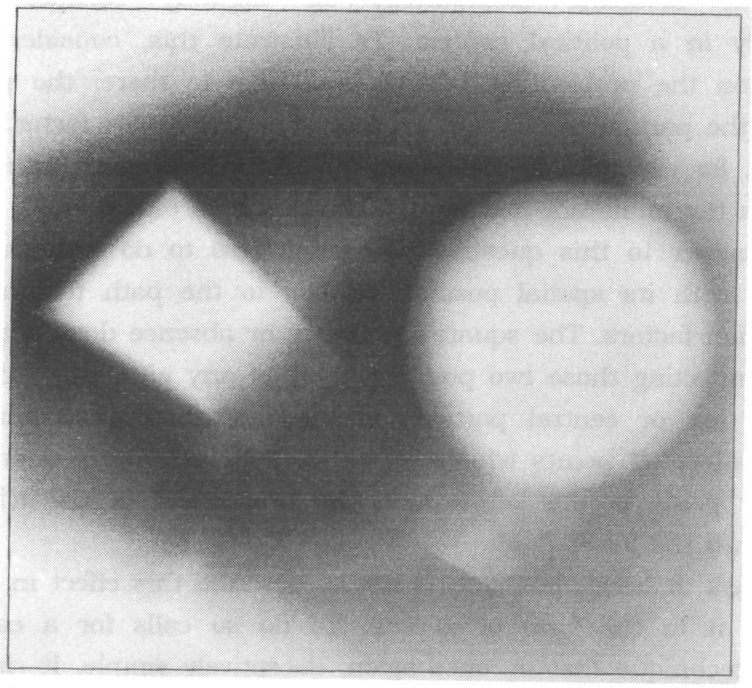
<Fig.5>

4. EVALUATING RESULTS

It is the ability to explore options and alternatives in this "fuzzy" manner that represents one of the more powerful features of the cartographic modeling methodology for highway corridor planning, particularly in a political context. To illustrate this, consider one final variation on the problem of getting from here to there: the problem of depicting the particular effect of an individual FRICTION factor. Just how important, for example, is that square? Exactly how much influence does it exert on the minimum-cost path(s) between here and there?

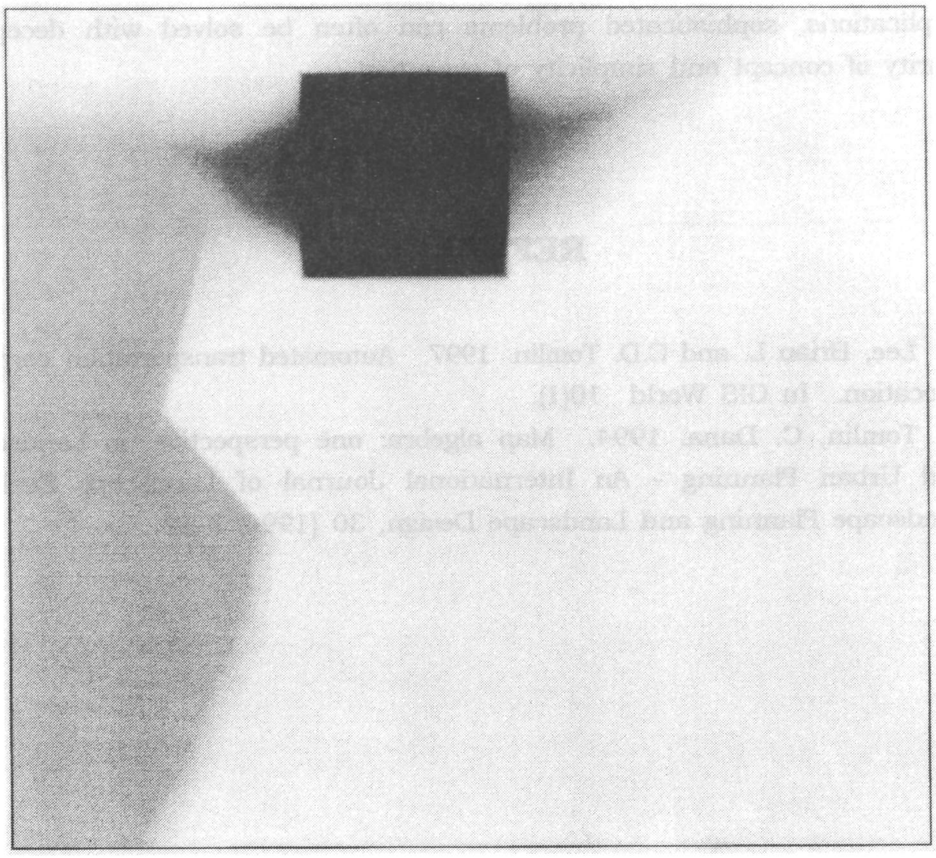
The answer to this question has much less to do with the square's cost than with its spatial position relative to the path termini and the other friction factors. The square's presence or absence does not affect the cost of connecting those two points by way of any path that extends over the lower left or central portions of this hypothetical terrain. It does, however, affect all points which lie within a broad swath extending from the upper point to the left around the broad end of the triangle and down toward the lower point.

The task at hand, however, is not to describe this effect in words but to convey it in the form of a map. To do so calls for a cartographic modeling technique that is, once again, deceptively simple. It is merely a matter of comparing HOW-FAR-BETWEEN-HERE-AND-THERE to the map shown in Figure 6. This is a version of HOW-FAR-BETWEEN-HERE-AND-THERE that was generated using a FRICTION map from which the square area of higher transportation cost had been removed.



<Fig.6>

By subtracting this version from the original, we generate the map shown in Figure 7. Here, each location has been set to a value indicating the amount by which its path cost decreases when the effect of the square is removed. The greatest effect (indicated by the darkest shades of grey) is within the square itself, while lesser effects are evident along those shadow-like zones that suggest the trend of would-be paths from here to there in the vicinity of the square.



<Fig.7>

CONCLUSION

In actual highway siting practice, the utility of this technique in particular and cartographic modeling methods in general ultimately relates to the flexibility with which problems can be formulated, solutions conceived, and implications explored. By expressing the variety of geographic data associated with these problems—from highly tangible site conditions to more abstract qualities of space—in similar cartographic terms, all can be better integrated into effective siting models. And by expressing data-processing capabilities in terms that transcend specific applications, sophisticated problems can often be solved with deceptive clarity of concept and simplicity of execution.

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The Utility of Geomatics in Emergency Planning and Management

P. Chagarlamudi
Manager
Geomatics Canada

ABSTRACT

Emergency planners and managers are routinely confronted with a maze of complex decisions that require reliable information extracted from accurate and often current spatial data. Emergency management is a comprehensive system set up by governments, private sector agencies and individuals to address natural and human-induced hazards. Prevention, Preparedness, Response and Recovery Programs are the four parts or components of this system. Canada, like other countries, has an obligation to protect its peoples and the environment from hazards.

Geomatics is an information technology sector focusing on the acquisition, storage, analysis, dissemination and management of geographically referenced information. Positioning and control surveys, topographic and thematic mapping, land and cadastral surveys, hydrographic surveys, remote sensing, and geographic information systems (GIS) are some of the principal domains of geomatics. Geomatics Canada, the principal mapping agency of the Government of Canada, maintains in its databases a variety of geographic information that is critical in responding to a majority of emergencies. Global Positioning Systems (GPS)

and remote sensing are some of the newer sources for creating the spatial data layers that can then be manipulated using a GIS to aid in decision making.

The significance of the spatial databases and the utility of geomatics technologies to efficient emergency management are discussed through specific Canadian examples. Particular focus is placed on integrating remote sensing data products with a GIS to provide managers with new tools to enhance support in planning and managing emergency operations related to earthquakes, forest fires and floods. The examples presented are from projects initiated in part within the Canadian framework for International Decade for Natural Disaster Reduction (IDNDR).

요 지

위기관리자나 계획가는 정확하고 가장 최신의 신빙성있는 정보를 이용하여 복잡한 정책결정을 해야한다. 위기관리는 자연재해와 인공재해를 처리하기 위해 정부, 사조직, 개인에 의해 만들어진 통합시스템이다. 이 시스템은 예방, 대책, 대응과 재해복구프로그램의 네가지 구성요소로 이루어진다. 다른 나라들과 마찬가지로 캐나다는 재해로부터 인간과 환경을 보호해야할 의무가 있다. 위기관리자나 계획가는 종종 정확하고 최신의 공간자료에서 추출된 신빙성 있는 정보를 필요로 하는 복잡한 정책결정을 해야한다.

지오매틱스는 지리관련정보의 수집, 저장, 분석, 보급, 관리에 초점을 맞추고 있는 정보기술분야이다. 위치측량, 지형도와 주제도, 토지와 지적조사, 수문조사, 원격탐사와 GIS는 지오매틱스의 주요영역이다.

지오메틱스 캐나다는 캐나다 정부의 주지도제작기관으로써 대부분의 위기에 대처하는데 꼭 필요한 광범한 지리정보를 데이터베이스로 유지관리하고 있다. GPS와 원격탐사는 의사결정에 도움을 주기 위해 GIS를 이용해 공간정보 데이터를 창출해내는 새로운 자료 공급원이 되고 있다.

이 발표에서는 공간 데이터베이스의 중요성과 효과적인 위기관리를 위한 지오메틱스 기법의 효용성을 구체적인 캐나다의 예를 들어 논의할 것이다. 특히 지진, 산불, 홍수 등과 관련된 구난작업의 계획과 관리를 효과적으로 지원할 수 있는 새로운 도구를 개발하기 위한 원격탐사자료와 GIS간의 통합에 초점을 맞추고 있다.

이 발표의 사례로는 국제 자연재해 감소의 10년을 위한 캐나다내의 프로젝트들이 사용되었다.

캐나다 국가지형데이터베이스(National Topographic Data Base, NTDB)는 사용자에게 수치화된 지형데이터를 제공하고 캐나다정부의 지리정보요구에 부응하여 만들어졌다. NTDB는 중요한 응급상황에 대처하기 위한 캐나다 도로망을 포함하여 112개의 엔터티와 14개의 주제도와 관련된 정보로 구성되어 있다.

특히 논점은 캐나다의 Manitoba에서 최근에 발생한 홍수기간동안 대중에게 많은 보조를 주기위한 새로운 도구로서 위기관리자에게 제공한 GIS에 캐나다의 RADARSAT 위성자료와 같은 원격탐사데이터를 통합시킨 점에 둘 것이다.

1. INTRODUCTION

All governments have an obligation to protect their peoples and the environment from hazards. Its geography, demography, social systems and institutions, political system and foreign policy dictate the manner in which emergency management is conducted and organized in a country.

Natural and human-induced hazards such as earthquakes, floods and forest fires, kill thousands of people and destroy billions of dollars of property each year. These losses will increase as world population increases and more people reside in areas that are subject to these hazards. Timely and accurate geographic information is essential for carrying out rescue, relief and rehabilitation efforts thus minimizing effects of these hazards1.

The Government of Canada has identified about 60 types of emergencies that might affect Canadians2. They range from forest fires, large floods, transportation and industrial accidents to severe earthquakes. Cooperation among government and other organizations and people is a trademark of Canadas emergency planning and management practice. Three levels of government - local, provincial and federal - cooperate and share resources and information in this practice, although the responsibility for meeting emergency situation rests with the level of government most directly affected.

Each of the three levels of governments maintains spatial information relevant to management operations in the geographic region of its jurisdiction. The national mapping agency, Geomatics Canada, provides geographic information covering the Canadian landmass.

2. EMERGENCY PLANNING AND MANAGEMENT IN THE CANADIAN CONTEXT

Canada is a vast landmass. From North to South it stretches over 4,600 kilometres of mostly wilderness and wildlife, and the greatest east-west distance extends over 5,500 kilometres spreading across 4 and one-half time zones. With shores on three oceans, the Pacific, Atlantic and Arctic, Canada has the worlds longest coastline of almost 245,000 kilometres. That coastline, and the border with the United States encompass 10 million square kilometres of severeign territory comprising virtually every geological and ecological feature found on the earth. Living within this huge landmass are roughly 29 million people, a relatively small population that makes Canada one of the least densely populated countries in the world.

The great diversity of Canadian geography, environment and economic activity contribute to a variety of potential threats that must be considered within the emergency spectrum. Emergency Preparedness Canada (EPC), a federal government organization, plays a key role in the development and maintenance of an appropriate level of civil emergency preparedness across Canada.

Canadas emergency management is based on the following principles2. First it is up to the individual to know what to do in an emergency. If the individual is unable to cope, the different orders of government are expected to get involved and to respond progressively, as their capabilities and resources are needed. Local emergency response organizations are normally the first on the scene. If they are overwhelmed, they may seek assistance from the province or territory, which in turn, will ask the federal government for help if necessary. In practice, emergency response management is based upon an active and cooperative partnership between all levels of government, public and private organizations, and the population at large.

Emergency management in Canada is a comprehensive system set up by governments, private sector agencies and individuals to address natural and human-induced hazards. It has four parts:

- Prevention programs are designed to prevent or mitigate the effects of emergencies and include measures such as building codes, zoning and land use management, public education, legislation, and tax and insurance incentives and disincentives.
- Preparedness programs are designed to ensure that individuals and agencies will be ready to react effectively once emergencies have occurred, and include measures such as emergency plans, mutual aid agreements, resource inventories, warning procedures, training exercises and emergency communications systems.
- Response programs are designed to combat emergencies when they have occurred, and include measures such as the implementation of emergency plans, activation of emergency operations centres, mobilization of resources, issuance of warnings and directions, provision of medical and social services assistance, and declaration of emergencies as enabled by appropriate legislation.
- Recovery programs are designed to help restore the environment or communities to their pre-emergency condition, and include measures such as physical restoration and reconstruction, economic impact studies, counselling, financial assistance programs, temporary housing and health and safety information.

3. GEOMATICS

Improved emergency planning and management is a concern as well as a priority in Canada and in many other countries. It involves several aspects ranging from monitoring, risk assessment and planning to coping with an event and evaluating its consequences. Decision making in emergency management requires reliable information extracted from accurate and current spatial data. This is precisely where geomatics technologies, encompassing the business of geographic or spatial information management, come in to play.

Geomatics may be defined as the science and technologies involved in management of geographically referenced information, including its acquisition, storage, analysis and dissemination. Geomatics is an "umbrella term" which has been adopted in Canada to encompass the disciplines of surveying, mapping, hydrographic surveys and nautical charting, cartography, remote sensing, and Geographic Information Systems (GIS) including associated systems, products and services.

The great diversity of Canadian geography that poses a variety of threats to emergency management also has led to the development of innovative approaches to spatial information collection and management. The Canadian geomatics community, that is the private and public sectors, recognizes the benefits of working together in planning and implementing various programs, whether it is simple mapping or complex technological innovation. It is through cooperation and jointly coordinated projects that the community has built its strength.

4. GEOGRAPHIC INFORMATION ON CANADAS LANDMASS

Geomatics Canada is the national agency responsible for surveying, mapping, remote sensing and geographic information systems in the Canadian federal government. It maintains and provides a variety of geographic information products on Canadas landmass for use in emergency management applications3. Specific categories of products include aeronautical charts, cadastral surveys, geodetic survey, remote sensing, thematic maps and topographic information. These are available both as digital and conventional products except for the products of the geodetic survey which are in digital domain. These data are crucial both for assisting the emergency services to make assessments about resources that they need to deploy in such events and for high quality estimates to be made of risk.

4.1 Geodetic Survey Products

The geodetic survey products are required for precise positioning, tracking and navigation. Specific products routinely supplied consist of Vertical and Horizontal Control Networks Products, Canadian Active Control System (CACS) Observational Data, GPS Satellite Clock Corrections, and Precise GPS Satellite Ephemerides3.

The Vertical and Horizontal Control Networks are comprised of physically marked survey stations across Canada for which horizontal coordinates and vertical elevations are accurately determined. Elevations issued are those based on the 1928 adjustment of the national levelling networks. Coordinates for horizontal networks are based on the North American Datum 1983 (NAD83) which is compatible with the World Geodetic System 1984 (WGS84), the terrestrial reference frame associated with the NAVSTAR Global Positioning System (GPS) now used extensively for navigation and surveying.

CACS observational data consist of dual-frequency calibrated satellite code and carrier phase observations from continuous tracking of GPS satellites at 30-second intervals. The precise GPS satellite ephemerides are computed from the data collected at the Canadian stations augmented by up to 24 globally distributed stations of the International GPS Service for Geodynamics. GPS satellite clock corrections with respect to the CACS reference clock are computed from observational data and precise GPS satellite ephemerides and are typically available 3 to 6 days after the observations. The clock corrections can be applied to pseudorange (code) measurements from a single receiver to mitigate the effects of selective availability and obtain positioning accuracy at the 1 to 10 meter level depending on the GPS receiver characteristics.

4.2 Topographic Information

Products on topographic information consist of the National

Topographic DataBase (NTDB), the Canadian Road Network (CRN), the Canadian Digital Elevation Data (CDED) and the Digital Terrain Elevation Data (DTED).

NTDB covers the entire Canadian landmass and contains the features normally found on topographic maps at the scale of 1:50,000 and 1:250,000. These features consist of hydrography, hypsography (contours), vegetation, the road network, roads, the rail network, the electric power network, designated area, land form, wetlands, and human-made features3.

CRN is the name of the national digital information base of Canadas road infrastructure. Extracting and reclassifying road infrastructure data from the NTDB created the CRN. The CRN only contains structured data relating to roads, which means it omits the topographic details normally seen on maps. Additional attributes, such as road numbers and highway exit numbers, have been added. Each data set corresponds to one National Topographic System (NTS) map sheet at the 1:50,000 or 1:250,000 scale.

The CRN product includes three levels of accuracy:

1. Stereo-digitized 1:50 000 data that meet 6 m for 68% of all data;
2. Scanned 1:50 000 NTDB data that meet 25 to 50 m for 68% of all data; and
3. Scanned 1:250 000 NTDB data that meet 125 to 250 m for 68% of all data.

CDED consists of an ordered array of ground elevations at regularly spaced intervals. It is based on NTS maps at the 1:250 000 scale. The coverage of every CDED file corresponds to half an NTS map sheet. The grid spacing is based on geographic coordinates at a minimum resolution of 3 arc seconds and a 12 arc seconds depending on latitude. It consists of elevation data in units of meters relative to mean sea level based on the NAD83 horizontal reference datum.

Geomatics Canadas DTED constitute a uniform, continuous matrix of altimetric data. However, Canadian coverage of DTED is incomplete.

Price for topographic data sets depends on the quantity of vector data in the file or theme, and is established by counting the number of kilometres of lines and the number of points delivered per order. A line is defined as being a linear entity or the delineation of an area measured in kilometres. A point is defined as being a punctual entity. Data sets are provided according to the subdivision requested by users and are available by pre-assembled geographic regions. Data are made available in the geographic coordinates and UTM systems, although other projections may be available on request.

Digital data files are delivered in the CCOGIF (Canadian Council on Geomatics), DXF (AutoCAD), And SIF (Standard Interchange Format) formats. Files can also be delivered in the following system formats: MID/MIF (MapInfo) and DGN (Micro-Station). Files are delivered for the DOS, UNIX, and VMS operating systems. PKZIP and TAR compression software are used to reduce file size. Files are delivered on 4-mm, 8-mm, and DC1650 cassettes; 3.5-inch diskettes; and compact disk (CD). Files can also be delivered via electronic transfer (FTP).

4.3 Remote Sensing Products

Satellite and airborne imagery covering the Canadian landmass are available from the Centre for Remote Sensing (CCRS) 3. These include ERS-1 Canadian Images, AVHRR Canadian Images, Sample Synthetic Aperture Radar (SAR) Data, SPOT PLA/MLA, Landsat MSS/TM, MOS MESSR, MSR & VTIR, ERS-1 SAR, JERS-1, NOAA AVHRR, Airborne C/X SAR, Airborne Data and SEASAT SAR. With RADARSAT's launch on Nov. 4, 1995, Canada and the world now have access to the first radar satellite system capable of large scale production and timely delivery of data.

RADARSAT is an advanced Earth observation satellite, equipped with a SAR, developed by Canada to monitor environmental change and to support resource sustainability. The SAR is a powerful microwave instrument that can transmit and receive signals to "see" through clouds, haze, smoke, and darkness, and obtain high quality images of the Earth in all weather at any time. Using a single frequency, C-Band, the RADARSAT SAR has the unique ability to shape and steer its radar beam over a 500-kilometre range. Users will have access to a variety of beam selections that can image swaths from 35 kilometres to 500 kilometres with resolutions from 10 metres to 100 metres respectively. Incidence angles range from less than 20 degrees to more than 50 degrees.

A private corporation, RADARSAT International, Inc. (RSI), was established in 1989 to process, market and distribute RADARSAT data to Canadian commercial users and to international users. In cooperation with CCRS and the Canadian Space Agency, RSI will help research and develop commercial applications, and will negotiate foreign reception and distribution agreements for RADARSAT data.

5. EXAMPLES OF EMERGENCY PLANNING AND MANAGEMENT

5.1 Earthquakes: A Focus on British Columbia

Earthquakes are caused by the abrupt release of strain that has built up in the earths crust. They are generally regarded as the most destructive of the various forces of nature. The overall loss in 1990 caused by a major earthquake occurring in California was estimated at approximately $100 billion, in Tokyo at as much as $300 billion4.

Seismologists predict that an earthquake of truly catastrophic dimensions will take place on the West Coast of Canada. A national earthquake support plan for British Columbia has been developed, in cooperation with federal government departments and agencies, provincial governments and non-governmental organizations, in order to respond to such an event2.

GIS is often used for efficient integration of information about natural hazards such as earthquakes. Schematic in Figure 1 describes perhaps the most widely used GIS operation, the electronic overlay of individual features, each representing a specific risk factor. By registering several features to a common grid or coordinate system, a GIS can generate meaningful maps based on a combination of factors5. For example, a planner could construct a three-factor map highlighting residential areas with either five metres or more of unconsolidated fill or a slope angle exceeding 15 degrees, populated areas vulnerable to shaking or landslides. To examine the impact of an earthquake along a particular fault, one might overlay a fourth feature showing all areas within 100 metres of a fault line. The GIS not only computes slopes and buffer zone but facilitates the analyst to experiment with different thresholds and combination of factors, that is simulations can be done.

Simulations of hypothetical earthquakes have been applied to predict geographic variations in ground shaking. Seismic energy and shaking susceptibility are the usual input to determine the intensity of ground shaking. A shaking susceptibility category may be assigned to each grid cell based on soils, geology and surface vulnerability to seismic pressure waves. Seismologists can provide computations of energy transmitted through bedrock from the hypothetical rupture of a plausible earthquake. Although earthquake modeling involves complex mathematics, the schematic of Figure 2 illustrates the utility of a GIS to manage massive amounts of data for tens of thousands of small cells5.

The EPC has undertaken the development of a Natural Hazards Electronic Map and Assessment Tools Information System (NHEMATIS) for Canada6. The NHEMATIS is a centralized, automated facility for the collection, representation, and analysis of natural hazard information. It is intended that NHEMATIS will be combined with characterizations of population and infrastructure to allow diverse risk and vulnerability analyses, with subsequent impact on both policy-making and readiness. In supporting risk assessment, NHEMATIS will, in the long term, provide complex analysis and modelling capabilities to address the Canadian situation, including neighbourhood analysis, network analysis, topological analysis, and visibility analysis. Custom development will be required to address a substantial portion of these requirements and is being implemented by the industry. The envisioned risk assessment application is intended to provide a number of significant benefits, including shared knowledge between hazard experts and national, provincial, and local organizations who have a vested interest in supporting emergency preparedness for various geographic locations in Canada. NHEMATIS will also provide a means of integrating the knowledge base of professionals from complementary disciplines, to provide a valuable source of data for research purposes.

It is envisioned that the NHEMATIS System will be built over a four-year period2. At the present time it is in its third year of development, with prototype v0.2 successfully completed March 31, 1997. Within the federal government, Environment Canada, Natural Resources Canada, and Public Works and Government Services Canada are providing scientific expertise and data.

The System employs an application shell that integrates an expert system-driven rulebase, GIS functionality (using ESRI's ArcView product), relational database(s) and quantitative models. It will demonstrate the ability to integrate information on all natural hazard types, capture location-specific information, provide drill-down capabilities and provide hazard impact assessment modelling capabilities on selected areas of interest and hazard types.

The first version of NHEMATIS (prototype v0.1) demonstrated the feasibility of the overall concept including basic analytical and forecasting functionality and showed its applicability as an emergency-planning tool. It was based on ArcView 2.1 for its GIS capabilities. Phase 2 (prototype v0.2) integrates the new enhanced ArcView 3.0 functionality which gives more advanced analytical capabilities to provide greater quantitative abilities to NHEMATIS. Some of the features incorporated into Phase 2 of the NHEMATIS system include:

- Advanced models and algorithms used to predict earthquake damage from shaking, liquefaction, landslides, and fire.
- Development of a general algorithmic approach to the estimation of building damage from earthquakes and other hazards.
- Development of basic algorithms for floods and landslides as separate hazards.

- Incorporation of polygon clipping into the inference process to give more accurate and realistic damage predictions for all hazards but particularly for tornadoes.
- Enhancement of the system to produce useful map output based on the impacts of the hazards on combinations of different components.
- Compilation of extensive geographic databases for five main study areas (Vancouver, Regional Municipality of Ottawa-Carleton, Edmonton, Montreal and Fredericton) and, in addition, development of a British Columbia regional study area to demonstrate the use of NHEMATIS at this scale.
- Enhancement of the user interface through the production of wizards for selecting and managing study areas, specifying hazards, and creating map outputs.
- Incorporation of new features of ArcView 3.0 including polygon operators to allow polygon clipping and raster map operators for enhanced map production.

The third phase of development will focus more intensively on working with potential end users and further refining both the system and the understanding of how it can best be packaged and used7. This phase of development will bring NHEMATIS to a stage to begin operationalizing the system in the fourth year of the project. During Phase 3, private sector will continue to work with domain experts from Environment Canada, Natural Resources Canada, Public Works and Government Services Canada, as well as U.S. agencies, to refine, review, and further develop hazards knowledge.

5.2 Canadas Fire Management Systems

Forest fires are a regular and serious concern in Canada. The number of forest fires in Canada ranged from about 6,000 to 12,000 a year during the 1970-95 period (Figure 3). Roughly half of the fires were caused by human activities while the remaining were attributed to lightning or unknown causes. The area burned varied from a low of 0.4

million hectares in 1978 to a high of almost 8 million hectares in 1990 amounting to $15 million and $275 million, respectively in fire fighting costs8.

There are 417.6 million hectares of forestland in Canada. The forest sector and forest resources are vitally important to Canada, in terms of their contribution both to the national economy and to the environment. Canadians want relevant, timely, and authoritative information about the state of their national resource. Geomatics technologies and products are employed in the data acquisition and in managing the forest resource including fires.

Fire management systems provide tools to personnel responsible for fire control and suppression. These tools range from simple charts and nomograms to sophisticated computer programs and physical models. GIS can combine fuel (vegetation), terrain and weather data needed to run fire growth models. Long-term fire growth can be predicted using probability and climatology.

Through the Canadian Forest Service, Natural Resources Canada is developing a Canadian Wildland Fire Information System (CWFIS). The Goal here is "to develop information and decision-support systems to monitor and predict wildland fire activity in Canada and to enhance fire management efficiency and effectiveness"9. The program consists of four major components:

1. National monitoring and forecasting reports on fire weather, behavior, severity, and on fire management Criteria and Indicators.
2. Decision support tools and models for fire occurrence prediction, resource allocation, meso-scale fire weather forecasting, and landscape level fire simulations.
3. Long-term fire growth models using probability and climatology.
4. Collaboration in the development of a national fire economic analysis system.

The CWFIS is an example of a hazard-specific national system envisioned by the G7 Information Society, Global Emergency Management

Information Network Initiative (GEMINI). It is also a prototype generic system that is adaptable to fire management agencies or to other countries. Establishing and linking a number of compatible national systems could provide the nucleus of a global fire information network10.

Canadian experience has shown that exchanging information among fire agencies is the first step to developing mutual understanding. This, in turn, fosters bi-lateral and multi-lateral agreements to exchange resources as no agency or nation can be an island unto itself where fire management is concerned; a point demonstrated once again through the recent situation in Southeast Asia. Prior interagency and intergovernmental agreements are the key to avoiding bureaucratic delays that can preclude effective resource exchanges. The process begins slowly and increases gradually as mutual trust develops among agencies. Implementing resource exchanges also fosters common standards for equipment and training; exchanging people fosters technology transfer. The overall effect is enhancement of fire management effectiveness and efficiency among all participants.

5.3 Floods: A Focus on the Red River, Manitoba

Flooded areas are typically cloud covered and are rarely recorded on images acquired form optical sensors. However, radar, with its cloud penetration capability, is well suited to monitor floods providing information for damage assessment and reclamation work. Spatial information provided by RADARSAT coupled with data in existing databases was a contributory factor in the success of the 1997 relief operations of the Red River flood in Manitoba.

The Red River originates in North-Central United States and drains into Lake Winnipeg. The Red is prone to floods in part because its headwaters, located in the south, thaw in the spring before its northern Manitoba reaches are free from ice. The Red River overflowed its banks during the spring runoff at least sixteen times this Century. The flood of 1950 was considered the second worst flood in the City of Winnipegs history with nearly two-thirds of the city impacted by floodwaters11. In

1997, some 2,000 square kilometres of the river were under water mocking the modest dimensions of the riverbed itself12. Higher than normal winter precipitation helped set the stage for this springs floods, along with cool temperatures and the still frozen northern reaches of the Red River.

Major flood-control projects have provided increased protection against the rising Red. With 28,000 Manitobans evacuated, the damages of this years flood are pegged at $150 million, compared to the 1950 flood that cost $606 million and forced 100,000 people from their homes. More than 8,500 soldiers from across Canada participated in Operation Assistance. Their equipment included more than 2,500 military vehicles, 58 vessels and 33 aircraft, which logged more than 1,500 flight hours12.

Figure 4 is a colour composite created using the May 9, April 25 and March 23, 1996 RADARSAT images3. Colour composites generated from multi-temporal data is a common method used to identify changes between dates of imagery. The image shows the evolution of the flood during a two-week period. For reference the city of Winnipeg and the town of Morris are noted. The dark blue tones (A) are classified as the common flood area on the two later dates. The red surfaces (B) located on the West Side of the Red River are flooded areas on April 25 only. The blue/green surfaces (D) north of the town of Morris are flooded are only on May 9. The yellow rectangle (E) is the levee protected town of Morris, located approximately 60 kilometres south of Winnipeg. This example demonstrates the strong potential of RADARSAT for flood extent mapping, damage assessment and flood monitoring 13.

6. INTERNATIONAL COOPERATION

In December 1989, Canada co-sponsored a Resolution in the United Nations which declared the 1990s to be the International Decade for Natural Disaster Reduction (IDNDR). The objective of the IDNDR is to reduce, through concerted international action, the loss of life, property damage and social and economic disruption caused by natural disasters.

Canada's participation in the IDNDR was predicated upon the following2:

- The mutual benefits to be gained by cooperative ventures with other countries;
- Canada's tradition of providing humanitarian aid to disaster victims;
- The contribution of Canadian engineering expertise, products and technology to disaster mitigation;
- Canadian developed remote sensing techniques for the monitoring of floods and forest fires; and,
- Canadian skills in training and education in the field of emergency preparedness.

A Canadian National Committee has been established to develop a program of action to mitigate the effects of natural disasters in Canada and abroad. The National Committee provides leadership, development and coordination of the Canadian IDNDR program.

The targets for the Decade adopted by the UN General Assembly are that by the year 2000 all countries, as part of their plan to achieve sustainable development should have in place:

- Comprehensive national risk assessments;
- Mitigation plans at national and local levels, including long term prevention, preparedness and community awareness; and,
- Ready access to global, regional, national and local warning systems and broad dissemination of warnings.

Within the Canadian framework for IDNDR, a series of projects have been undertaken to be completed by the end of this decade. Examples from some of these projects that employ GIS and other geomatics technologies were presented.

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