DEVELOPMENT OF A MAP-ENABLED PLANNING DOCUMENT

By

ASHWINI WAKCHAURE

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To my Mom, Dad, Brother, and
Great teachers I have had throughout the years.

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LIST OF ABBREVIATIONS

CSV	Comma separated value file
DCA	Department of Community Affairs
ESRI	Environmental Systems Research Institute
EST	Environmental screening tool
ETDM	Efficient transportation decision making
FDOT	Florida Department of Transportation
FGDL	Florida Geographic Data Library
GIS	Geographical information systems
GUI	Graphical user interface
HTML	Hyper text markup language
JPEG	Joint photographic experts group
NOI	Notice of intent
ORC	Objection, recommendations and comments
PARSOL	Planning and Regulatory Services Online
PDF	Portable document format (Adobe)
RTCP	Rational theory of comprehensive planning
URL	Universal resource locator

Abstract of Dissertation Presented to the Graduate School
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Ashwini Wakchaure

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My study developed methods for creating a map-enabled planning document with mapping capabilities and tools for better integration between text and spatial elements in the context of comprehensive plan review. Urban planning is spatial in nature, and therefore maps are an integral part of most planning documents. If maps contained in a planning document are interactive, and if they can be accessed directly from the planning document, then planners can convey spatial information in a much better way. Therefore this study was focused on development of a map-enabled planning document containing interactive maps and associated mapping tools. This study was set in the context of comprehensive plan review, and functionality of the map-enabled planning document was derived from the mapping needs of comprehensive plan review process. The central research question of my study was whether a map-enabled planning document with interactive maps and mapping functionality could be created and whether such a document would be useful in the review process. As part of this study, a prototype of a map-enabled planning document was developed using embedded GIS technology, with the ArcEngine software and the Microsoft Word software. I was successful in implementing complete range of desired functionality derived from the perspective of comprehensive plan review process in the prototype. One of the important goals of this study was to bring about

tighter integration between text and maps, and that was achieved by creating links between text and maps, map features, and map layers. Moreover a search functionality that allowed for searching selected text in the map data was also implemented. The prototype was found useful for comprehensive plan review by the reviewing agencies that tested it. The prototype demonstrated that the presence of interactive maps in the planning document and the ability to link map data with text data can significantly extend descriptive power of planning documents and also incorporate transparency in the review process, by bringing out relevant spatial analysis clearly through interactive maps. Such a map-enabled planning document can be useful in other planning processes such as public participation sessions or inter-agency collaborative meetings.

CHAPTER 1
INTRODUCTION

My study developed methods for creating a map-enabled planning document with mapping capabilities and tools for better integration between text and spatial elements to aid the process of comprehensive plan review. Urban planning is spatial in nature and therefore, almost all planning documents include maps to describe spatial aspect of plans. Currently, maps included in a planning document are static images of maps; one cannot alter display of such maps or manipulate them in any way in the planning document for better understanding. However, in present times, maps are prepared digitally with computers and map related data is also present in a digital format. Considering availability of maps in a digital format, it was felt that it may be possible to integrate digital interactive maps in a planning document using current technologies.

Initially this study was oriented towards creating a digital framework for comprehensive plan review; however, an examination of comprehensive plan review process indicated that the main challenge of the digital framework lay in integrating map manipulation capability with planning documents. Therefore, focus of this study was shifted to development of a map-enabled planning document.

A planning document containing interactive maps and associated mapping tools has potential to enhance user's understanding of spatial issues highlighted by the included maps, by allowing a user to manipulate map display, query data, filter data and conduct spatial analysis (e.g. proximity analysis). It was felt that comprehensive plan review process could benefit from the use of a map-enabled planning document in two ways, reviewers could obtain a better understanding of spatial component of comprehensive plan proposals, by browsing included interactive maps, and reviewers could describe their comments pertaining to spatial elements by incorporating additional maps in the comments section. Thus interactive maps included in the review documents could potentially play a much larger role than the static maps, by clearly demonstrating spatial reasoning related to review, and by adding transparency to the review process. Central research question of this study was whether a map-enabled planning document with interactive maps and mapping functionality sufficient for the purposes of comprehensive plan review could be created and whether such a document would be useful in the review process? In this study, a prototype of a map-enabled planning document was developed and tested with two review agencies and mapping functionality included in the map-enabled planning document was derived from requirements of comprehensive plan review.

Background

Comprehensive planning is widely used in urban governance in the United States. It is a tool used by the communities to guide development in desired directions. A comprehensive plan outlines a community's vision and states goals, objectives and policies for required elements such as land use planning, public safety, health, transportation, conservation and so on. It also includes supporting documentation pertaining to data collection and analysis. Preparing comprehensive plans is not mandatory in all the states; however it is required in the State of Florida.

Rational Theory of Comprehensive Planning

The rational theory of comprehensive planning (RTCP) uses a rational decision-making process based on comprehensive analysis of the information. It is goal oriented, and advocates the means ends analysis, in which the ends (that is, the goals and objectives) are identified first, and then different methods are explored and evaluated in terms of their ability to achieve the desired ends. The RTCP relies on comprehensiveness of the analysis and therefore requires extensive information about the situation, methods and analysis. The analysis is objective in nature, and the goals and objectives may be translated into measurable quantities, so that different methods of achieving these goals may be evaluated based on their performance. The RTCP is often challenged over its ability to produce truly comprehensive analysis, on its "means for satisfying ends" approach and its presumption of single common public interest.

Comprehensiveness of the analysis

Lindblom (1959) while proposing an incremental approach to planning, systematically pointed out the shortcomings of the rational theory of planning. He questioned whether it was possible for human beings or organizations to be completely comprehensive especially in light of the practical limitations of time and money amongst other things. He further questioned the ability of planning organizations or planning professionals to handle large amount of information and stated that the limitation lied in the intelligence of the human being. Faludi (1973) cited an example of a person's short-term memory as a type of limitation, and further explained that such shortcomings could be overcome, in certain instances by using various strategies based on experience. Therefore, the criticism of the theory was that the decision-making could not be rational enough, if it was not possible for the analysis to be truly comprehensive.

Validity of the means-ends approach

The other criticism is of the theory's means-ends analysis approach. In the RTCP, the ends that is the goals and objectives are outlined first. However, Lindblom (1959) questioned whether it was possible to do so in all the cases. He further mentioned that in case of complex social problems having multiple objectives, there might be a disagreement over the importance of different objectives, and accordingly the choice of means would vary. Besides in some cases, different means would yield different combinations of objective satisfaction. Therefore, based on the desired combination of objectives, selection of means would vary in such a case. To demonstrate this point, Lindblom cited an example in which one alternative offered a better price at the risk of unemployment, whereas the other alternative offered lesser price stabilization, with a much lower risk of unemployment. Moreover there could be additional complexities in the situation, such as having conflicting objectives, and dealing with inherent difficulties in attributing different objectives with relative importance. Thus, Lindblom questioned the merits of clarifying objectives first. He also raised the issue of disagreement amongst different actors, such as citizens, congressmen, public officials, and proposed simultaneous means-ends analysis in his theory of incremental planning.

Presumption of single public interest

The RTCP neither considers disagreement issues in the formulation of its goals and objectives, nor does it address the possibility of having different views on what is termed as common public interest. These disagreements are one of the criticisms raised by Davidoff (1965) while emphasizing the necessity of plural plans. Davidoff pointed out that when only the government prepared plans representing majority's interests, minority interests might not be represented. He further commented that "being isolated as the only plan maker in the community, public agencies as well as public may have suffered from incomplete and shallow analysis of potential alternatives. Lively political dispute aided by plural plans could do much to improve the level of rationality in the process of preparing the public plan." The solution of plural plans brings about the issue of evaluating multiple plans, consideration of social costs and benefits and also finding sponsorship for preparing such plans. Davidoff suggested the route of advocacy planning, wherein plans could be prepared by organizations representing special interest groups.

Many researchers have pointed out that the RTCP may not be always successful in representing minority interests. Healey (1996) stressed upon the need for developing arenas of communication among different segments of the community. Krumholz (1982) in his article on equity planning cited conditions in Cleveland where interests of the poor and black population in the city were not well represented. Ritzdorf (1996) in her article on feminist thoughts on the theory and practice of planning, commented that planning theory has been male dominated and that feminist theorists do not approve of rationality in planning as the sole basis of action, and are interested in knowledge in terms of its applicability. Feminists support pluralistic thoughts, and they feel that a theory that offers flexibility in approach instead of a universally applicable approach is more suitable in planning decision making.

Criticisms on the RTCP do not challenge the concept of rational analysis, although Lindblom (1959), in his incremental approach, suggested marginal improvements and short term planning. Strategic planning (Kaufman & Jacobs, 1987) also tends to favor short term planning, abandoning long term planning implied in comprehensive planning.

Rational Theory of Comprehensive Planning in Contemporary Planning

Contemporary planning practice addresses some of the shortcomings of the RTCP. As far as the issues of public interest representation are concerned, now the plan making agencies consider public opinions through a series of public participation meetings in the plan preparation phase and identify goals and objectives for the comprehensive plan. Multiple public interests can also come to surface during such meetings. In such meetings, people can also comment on the means used to achieve goals and objectives of the comprehensive plans and contribute to the planning process. Planning agencies can also share their meetings with the people via television and internet media if possible, thus keeping people aware of the planning process.

Lindblom's (1959) criticisms regarding limitations on achieving complete comprehensive analysis still apply because the degree of comprehensiveness achieved is always limited by the available resources such as time, and money. However, at present planners have advanced tools available at their disposal compared to the decades of the 1960s and 1970s when these criticisms were raised and therefore they can certainly achieve a higher degree of comprehensiveness in their analysis than before. At least some of their time may be freed through the advent of technology in general. For instance, now planners can have all the planning documents, associated spatial data in a digital format, and can access such information almost from any place where the internet is available. They can create and modify maps (and documents) digitally without spending long hours on preparing paper maps, and they can conduct spatial analysis at a fast speed with the current GIS technology. In today's digital world, planners have access to sophisticated tools for obtaining data and information from a variety of sources, conducting data analysis, and comparing different scenarios. Thus, technology contributes to achieving higher degree of comprehensiveness in two ways, one by presenting tools for conducting sophisticated analysis of information, and another by generating time, and resource savings, through faster processing.

This study proposes a tool in the form of a map-enabled planning document having integrated mapping functionality, and if found useful for the purpose of comprehensive plan review, it may result in time savings and allow planners to focus on achieving higher degree of comprehensiveness in their work. RTCP recommends comprehensive analysis of situation and methods as the basis for rational planning, and improvements in technology and tools can help planners or planning agencies achieve higher degree of comprehensiveness. Achieving higher degree of comprehensiveness in the analysis may not directly lead to a better plan; however it provides a sound basis for decision making with the available information. A better plan may be viewed as the most efficient way in which a planning vision can be realized. Better plan cannot be assured just by reaching high degree of comprehensiveness in analysis, because planning is futuristic in nature, and there is always an element of uncertainty in the outcome of planning activities, due to unforeseen factors. Also, planning decision making necessarily has a component of guesstimation which could go wrong every now and then. However, comprehensiveness in analysis creates a stronger possibility that planning guesstimates could be more accurate.

Comprehensive Planning: Responsibility and Review

The necessity for a comprehensive plan review arises, when the prepared comprehensive plans have to adhere to certain specified criteria, and the review process is set up to ensure that the comprehensive plans are in compliance with the specified criteria. Normally, such a situation occurs, because, some states outline state goals, or define a comprehensive plan, and the local governments in their jurisdiction are expected to adhere to the state goals. One of the main reasons for state intervention in local planning is growth management, which presumes that the local governments do not possess adequate ability to manage growth, and state intervention is necessary. By defining growth management guidelines states aim to bring about consistent and coordinated development. However, the authority of state to intervene in local planning varies in different states.

Each state's choice of the legislative approach, adoption of the Dillion's Rule approach or the Home Rule approach, determines delegation of power between the state and local governments. The Dillion's rule originates from the concept that local governments are creatures of the state, and thus require explicit grant of powers by the state legislation to the local governments, and the rest of the powers stay with the state. The Home Rule approach originates from the belief that local governments have the right to self govern, and therefore this approach grants local governments all powers to take local decisions, unless some powers are taken away by the state through legislation. Thus in comparison, local governments from states adopting the Dillion's rule approach are weaker than the local governments from states following the Home rule approach. Critics of Dillion's rule argue that the local governments do not have enough powers to manage growth, whereas critics of the Home rule argue that resulting planning leads to a lack of uniformity among units of government (Richardson, 2003) and is not adequately coordinated at the regional level. However, legislative statutes, that can shift the balance of power between the state and local governments, can be passed. Oregon, a home rule state, has passed statutes that require local governments to ensure that their comprehensive plans are consistent with the state goals, and if not, the local governments are penalized for non-compliance.

Comprehensive planning in other states

Currently, 12 states (Bissey, 2002) engage in the state-wide planning, which may consist of setting state goals or formulating a state comprehensive plan that can guide local planning. Oregon initiated a strong state level planning program in 1973, and 11 other states followed suit later on. These include Florida, Georgia, Maine, Maryland, New Hampshire, New Jersey, Rhode Island, Tennessee, Vermont, Washington and Wisconsin. The list of the above mentioned 12 states which engage in state-wide planning, comprises of both, the Dillion's Rule states (Maryland) as well as Home Rule states (Oregon), though in some states, a mix of both these approaches can be found (Florida). Only a few of the above-mentioned states make local level comprehensive planning mandatory, though it is encouraged in rest of the states (e.g. Maine, New Hampshire, Tennessee, Vermont, New Jersey). Besides these states, Hawaii also has a state level comprehensive plan, but it is mandatory for only the state agencies.

Growth management has been a driving factor in bringing about state intervention in local level planning. Growth management concerns during the 60s and the 70s were limited to conservation of natural resources; however by the 90s, the focus of growth management broadened to encompass problems sprawl, haphazard growth and issues related to the quality of life (DeGrove & Metzger, 1993). In order to combat unwanted growth and ensure coordinated development, many states introduced growth management programs. Vermont in 1970 first established a regional growth management program with Act 250, followed by Florida in 1972, and Oregon in 1973; and other states followed suit eventually.

Oregon’s growth management program is the most comprehensive of all the state programs. It requires formulation of comprehensive plans in accordance with state goals, and includes an acknowledgment process, economic development goal, conservation of farm and forest land, establishment of urban growth boundaries, segregation of rural lands from urban lands, affordable housing program, and a strong citizen participation requirement (DeGrove, 1993). The programs adopted by other states vary and may not include all the features mentioned above. To ensure coordinated growth, many states introduced consistency and concurrency requirements on local planning. Consistency requirements make certain that local plans are not pursuing planning schemes that are in conflict with neighboring local plans (horizontal consistency), or regional plans or state plans (vertical consistency). Implementation of consistency requirements manifests in different forms, Florida makes it mandatory whereas Maine provides additional benefits if the consistency requirements are met through certification (DeGrove & Metzger, 1993). Most of the above mentioned states have state-wide planning goals, which address issues related to environment, economic development, housing, infrastructure, transportation and so on.

Not all states mandate compliance with state goals, for instance Vermont’s Act 250 specifies state goals, though the compliance is sought through incentives, and is not compulsory. In Florida however, compliance is ensured through comprehensive plan reviews and non-compliance may be penalized by withdrawing state funding. In Rhode Island, the state intervenes and prepares the local plan, if the community does not prepare a plan, that’s in compliance

(Innes, 1993). Conflict on the decision of compliance is handled in a variety of ways, by setting up special committees, through mediation or in court.

Comprehensive plan review systems

Comprehensive planning is not required in all the states, however, if a comprehensive plan is prepared, most states require that the plan be consistent with regional plans (Gale, 1992), and plans of neighboring local governments (Horizontal and vertical consistency). To ensure compliance with the state's guidelines, a review is necessary. A brief overview of the planning process in 12 states concerned with state level planning, indicates that usually the state land-planning agency (normally associated with the Department of Community Affairs or the Office of Smart Growth), is the agency reviewing comprehensive plans. While no state at this point in time, has an application that facilitates comprehensive plan review, almost all the states provide various related documents and other resources including spatial data on their web sites. The Department of Community Affairs from Georgia offered local governments an online planning support system, termed as the PlanBuilder, on their website when this research started. The PlanBuilder application included mapping tools, along with utilities for including tables, charts and text and facilitated making of a comprehensive plan.

However, currently this application has been discontinued. Among other states, the state of Vermont uses a state permit system instead of comprehensive plans to manage growth. The Environmental board and the district commissions in charge of the permit application review, maintain a searchable database of permit applications, their review status, and scanned application documents. It is unclear whether the entire review process is digital in nature. A brief overview of comprehensive plan review framework for all the 12 states is presented in the Table 1-1 for additional reference.

Table 1-1. States with comprehensive planning

State	Reviewing agency	Review process chart	Online review	Maps and data
Florida	State Land Planning Agency: Department of Community Affairs (Department of Community Affairs, State of Florida, 2008).	Yes, on the DCA Web site (Florida Statutes, 2008).	No	DCA on its website provides a database of comprehensive plan proposals, and ORC documents, also the regional planning councils provides ready maps on their websites, Data library comprising of state-wide GIS data is hosted by University of Florida on its website.
New Jersey	State Land Planning Agency: NJ Department of Community Affairs, Office of Smart Growth (Department of Community Affairs, State of New Jersey, 2008)	Yes, on the Office of Smart Growth Website, in the PDF documents on Guidelines for Plan Endorsement process	No, but electronic document submission encouraged, GIS data standards specified on website, a listing of current plan endorsement related petitions seen on the web site	Have State plan and policy map, provide ready maps in jpg and PDF format, provide GIS data in zipped format, as shape files (Office of Smart Growth, 2008).

Table 1-1. Continued

State	Reviewing agency	Review process chart	Online review	Maps and data
Oregon	Department of Land Conservation and Development : State's Land Conservation and Development Commission (Oregon Department of Land Conservation and Development, 2008)	Information available on the website of LCDC, under the menu item Rules (Oregon State Archives, 2008).	No	The Oregon Geospatial Enterprise Office manages GIS data (Oregon Geospatial Enterprise Office, 2008). The Oregon explorer tool maintained on the Oregon State University website, allows users to create their own maps of any area within Oregon using the explorer collection of geographic data layers.
Vermont	Act 250 is administered by the Environmental Board (Natural Resources board). Nine district commissions, each comprised of volunteer members with a paid staff, review applications and issue decisions and land use permits (Natural Resources Board, 2008).	Yes, Act 250, Vermont's Land use and Development Control law contains it.	Not exactly, but they have searchable permit database, have scanned application files on web in tiff format, so reviewers may be accessing online documents on case by case basis and processing those.	Vermont Center for Geographic Information manages GIS data. They have an inetractive map viewer, built using IMF 5.1. Other government agencies have their own interactive map viewers (Vermont Center for Geographic Information, 2008).

Table 1-1. Continued

State	Reviewing agency	Review process chart	Online review	Maps and data
Georgia	Department of Community Affairs	The process described in a PDF document at their website (Georgia Department of Community Affairs, 2008). Applicable law: Georgia Planning Act 1989. Comprehensive planning compulsory, the Planning Act also assigns local governments certain minimum responsibilities to maintain "Qualified Local Government" (QLG) status and, thus, be eligible to receive certain state funding.	No, but they had a Plan Builder operation in an online planning support system format for making comprehensive plans in 2005. It has been discontinued now.	They provide a word document template for the comprehensive plan, in which local agencies can fill out information. Also they provide county and city specific data tables, ready to use on their website.
Maine	Maine State Planning Office (Maine State Planning Office, 2008)	Beginning on September 20, 2008 all Plans will be reviewed under the new Comprehensive Plan Review Criteria Rule (Chapter 208). Review process information on their website (Executive Department, 2008). Planning criteria applied in review described in another PDF document on their website.	No	They present comprehensive planning resources for cities including GIS data, ArcExplorer, Interactive online map viewer.
Rhode Island	State Planning Council, state-wide planning program responsible for review (State Planning Council, 2008).	Have plan handbooks, goals information, process flow charts incorporated in the handbook. Under the Rhode Island Comprehensive Planning and Land Use Regulation Act, the Statewide Planning Program is responsible for coordinating the review and approval of local comprehensive plans, amendments, and updates.	No	Rhode Island Geographic Information System, a state level agency that maintains and distributes GIS data (Rhode Island Statewide Planning Program, 2008).

Table 1-1. Continued

State	Reviewing agency	Review process chart	Online review	Maps and data
Washington	Growth Management Services, Department of Community, Trade and Economic Development (Department of Community, Trade and Economic Development, 2008).	Have PDF documents containing planning resources, may have process chart, accept digital submission of comprehensive plan documents	No	Maps (adobe PDF) and environmental data (shapefiles) available on the website of Department of Ecology (Department of Ecology, 2008).
Maryland	Maryland Department of Planning, The Planning Commission (Economic Growth, Resource Protection, and Planning Commission, 2008).	Law: Planning Act of 1992. Maryland has online land use map viewer that uses ArcIMS, In their resource documents I couldn't locate the flow chart.	No	Maryland has online land use map viewer (Maryland Department of Planning, 2008).
New Hampshire	Office of Energy and Planning, Only State Development plan, requiring consistency with other state agencies (Office of State Planning, 2008).	State and regional planning agencies, prepare a comprehensive plan. Local communities prepare a master plan, and adopt it (Central New Hampshire Regional Planning Commission, 2008).	No	Regional agencies distribute GIS data, maps for free and ArcView projects $10 a map, didn't find process chart, might be there in interagency information, Have Granit Conservation lands map viewer, and substantial amount of GIS data can be downloaded from there (New Hampshire Office of Energy and Planning, 2008).

Table 1-1. Continued

State	Reviewing agency	Review process chart	Online review	Maps and data
Tennessee	Department of Economic and Community Development, Planning Commission (Department of Economic and Community Development, 2008).	Three star and five star review, certification for 3 star 5 star programs, additional incentives and grants upon certification.	No	State office of information resources provides GIS data, supports a map viewer and property tax viewer (State of Tennessee, 2008).
Wisconsin	Department of Administration, Division of Intergovernmental Relations (Division of Intergovernmental Relations, 2008).	Comprehensive planning law passed in 1999. Clicking on a county or a city feature (in the online map viewer) that has completed comprehensive plan brings up a web link that takes us to the comprehensive plan PDF document, which seems to have static maps, in 3 files that I have checked.	No	The University of Wisconsin's Applied Population Lab maintains an interactive map that includes features that showcase completed comprehensive plans. The interactive map can be used download census data, watersheds and basin boundaries by data frame or by political boundaries in shape file format and in excel spreadsheet format.

To summarize, there are some states that encourage comprehensive planning and review prepared comprehensive plans for compliance, primarily to bring about coordinated, consistent development across the state. From the compiled information about states with comprehensive planning, it is evident that at this time, the review process in these states does not use a dedicated application for conducting review. However, some states such as Vermont and Georgia employ some applications that aid the review process. None of these states including Florida, currently use technologies that offer the same functionality as that provided in a map-enabled planning document. Most states offer spatial data viewers, and data download functionality on the website of the land planning agency. In many states, regional planning agencies provide additional assistance with GIS data to the cities and towns in their jurisdiction.

Comprehensive Plan Review System in the State of Florida

The State of Florida exhibits the Top Down philosophy in planning, by exercising substantial control over local governments. In a move towards coordinated development in the state, in 1972, the Florida legislature enacted the Environmental Land and Management Act, which "established state planning programs to address development in more than one local jurisdiction" (Chapter 380, Florida Statute as cited in Pelham, 1987). In 1975, comprehensive planning was made mandatory for local governments, through the Local Government Comprehensive Planning and Land Development Regulation Act. Later in 1984, the comprehensive planning was made mandatory for the state and regional planning councils. Subsequently in 1985, and 1986, the Local Government Comprehensive Planning and Land Development Regulation Act was amended, and the amendments specified that the local government's comprehensive plans should be consistent with the State comprehensive plan and plans of other regional agencies, and that developments should be permitted only in areas with sufficient infrastructure. Thus consistency and concurrency requirements were introduced in the local level planning in 1986. The Local Government Comprehensive Planning and Land Development Regulation Act, further assigned the state land-planning agency; the Florida Department of Community Affairs (DCA), the task of checking compliance of the local government's plans using minimum criteria, and the act also required that local governments include measurable objectives and specific policies in the comprehensive plan to ensure implementation (Pelham, 1987).

Comprehensive plans prepared by different agencies and municipalities are reviewed by the Department of Community Affairs (DCA), jointly with related agencies (Department of Transportation, Water Management Agencies), and relevant regional planning councils. After review, comprehensive plans are either approved with a certificate of compliance, or modifications are recommended, to bring the plan in compliance.

In Florida non-compliance may be penalized with withdrawal of state funding. To ensure coordinated development, Florida imposes consistency requirements on local planning. Comprehensive plans are checked for consistency with neighboring local plans and regional and state plans. Florida also imposes additional concurrency requirements on local plans, to ensure that growth is concurrent with the infrastructure. Any conflicts related to the plan or its compliance can be resolved through an appeal process with the Division of Administrative Hearings. Comprehensive plan review process is addressed in the section 163.3184 of the Florida Statutes; main steps of the review process are outlined next.

1. Local governments submit comprehensive plan documents to the DCA and other review agencies.

2. If the submission is complete, then the DCA informs the local government that the submission is complete (Within 5 working days of receipt of documents).

3. Review agencies send their comments on comprehensive plan documents to the DCA (Within 30 days of receipt of documents).

4. Relevant regional planning council (or the affected person or local government) submits a request to review to DCA.

5. The DCA notifies the local government of its decision to review (Within 35 days of receipt of documents).

6. DCA does not review for compliance adopted small scale amendments. Small scale amendments relate to a parcel of ten acres or less and do not involve a text change to the local comprehensive plan or amendment to the future land-use map. If the DCA has decided to review plan documents, then they issue Objections, Recommendations and Comments (ORC) within 60 days of receipt of plan documents.

7. Local government then adopts plan amendments within 60 days of receipt of ORC and 120 days of receipt of ORC for amendments that are based on the Evaluation and Appraisal Report (Evaluation and appraisal report is generated by a local government after an evaluation of its comprehensive plan to determine deficiencies and necessary updates. Following completion of the evaluation and appraisal report, the local government submits related amendments to the DCA reflecting the necessary changes). Local government submits copies of adopted plan documents to the DCA and review agencies.

8. The DCA then issues a Notice of Intent (NOI) within 45 days of receipt of the adopted plan documents, which could declare that the adopted plan amendment is in compliance or not in compliance.

Affected persons can challenge the DCA's decision regarding compliance, with the Division of Administrative Hearings, where upon hearing negotiations may lead to a compliance agreement and remedial plan amendment. The DCA or Administrative Commission issues a final order regarding that. An affected person under Florida law includes:

- One who owns property, resides, or owns or operates a business within the boundaries of the local government that adopted the plan or plan amendment.

- In the case of future land-use map amendments, one who owns property outside the local government jurisdiction, and which property abuts the property affected by the future land use map amendment.

- The local government that adopted the plan or plan amendment.

- An adjoining local government that can demonstrate substantial impacts.

The current process of comprehensive plan review is described in the form of a flow chart by the DCA, presented in Appendix A, for easy reference.

Application for Comprehensive Plan Review

In Florida, there are about 417 municipalities, 67 counties, 11 regional planning councils and a number of other regional agencies, all of which prepare comprehensive plans, and are required to prepare a comprehensive plan once every 7 years. Thus the task of comprehensive plan review is substantial and repetitive. The Department of Community Affairs presents substantial information about the comprehensive plan review process, including examples of comprehensive plans prepared by some cities, on their website. However, presently, no digital application for comprehensive plan review exists. Apart from the State of Florida, other states that review comprehensive plans for compliance also do not have an application targeted towards comprehensive plan review at this time. I speculate that an application geared towards comprehensive plan review will be useful for the agencies involved in the review process. Such an application may also advance the e-Government agenda.

E-Government initiative

The U.S. Government in 2002 enacted the E-Government act, which intends to bring about a citizen-centric, result-oriented, and a market-based government, through the use of information technologies (Bush, 2002). Some of the benefits that are possible through the implementation of e-Government include increased efficiency in terms of cost and time, improved quality of service, transparency in processing, increased opportunities for public participation and consistency in outcome (Bonham, Seifert, and Thorson, 2003). A digital application for comprehensive plan review not only has the potential to acquire most of the benefits stated above, but it may also help streamline the review process. The Gartner Group has described e-Government as follows:

"E-Government as a continuous optimization of service delivery, constituency participation and governance by transforming internal and external relationships through technology, the Internet and new media" (Bonham et al. 2003). E-Governments can be categorized into G2G (Government to Government), G2B (Government to Business) and G2C (Government to Citizens) sectors. A digital framework for the comprehensive plan review process would essentially be a government to government (G2G) as well as a government to citizen (G2C) type of service.

Progressive stages of e-Government

E-government does not mean simple conversion of government processes into digital processes, but a transformation of government services and processes to gain from the rapid technological developments. Bonham et al. (2003) have classified E-Government services into 4 categories, based on the technology used in providing various services. These categories are presence, interaction, transaction and transformation.

Presence refers to the static dissemination of information, a basic stage of evolution of E-Government, akin to having an informative but non interactive website. Interaction is the second step in which the government may have an interactive web site, though interactions have a limited ability. In this case users may be able to download forms or email contact persons. Transaction, the third stage of e-Government, refers to having a service that facilitates completion of an entire task online, for example, at the IRS website; users can pay their taxes by downloading appropriate forms and by submitting those after completion. In this case, services are standardized and result in consistent outcomes. Transformation, the fourth stage of e-Government, refers to the complete transformation of a governmental service, right from the conception stage to organization and execution stage. This stage can result in customer-centric solutions by eliminating agency-centric organizational barriers.

Many governmental agencies and city governments in the U.S. currently have websites, through which they offer information and various services, and thus based upon the technology utilized, they could fall into either the interaction phase or the transaction phase of E-Government services.

Layne and Lee (2001) also use a four-stage model to describe development of a fully functional e-government model, the stages being cataloguing, transaction, vertical integration and horizontal integration. Cataloguing refers to the display of non-transactional information from government such as having web presence and forms for download. The transaction stage is communicative in that citizens communicate with the government and can complete transactions online. The vertical integration stage refers to merging / connecting different levels of the government and their databases, an example would be of a driving license database that can be cross-referenced across state and national levels. The horizontal integration stage refers to the integration between different services of the government. Layne and Lee state "since the discrepancy between different services of government is larger than the discrepancy between levels of government, vertical integration will be attained first before horizontal integration".

Challenges for e-Government

Layne and Lee (2001) also identify challenges in achieving successive stages of the e-government. Initial challenges include resources for creating online presence, responsibility for coordination and planning of services, maintenance of information, addressing issues of privacy, development of a one stop information portal and reorganization of information by services, actions or events. As the e-government proceeds to the stages of integration, the agencies face numerous challenges such as authentication; inter agency format compatibility, database compatibility, exposure level of legacy systems to outside, increasing numbers of automated transactions, issues of confidentiality and privacy. In these stages services may transcend departmental boundaries, and in order to achieve integration, governments may have to make permanent changes to their processes. Layne and Lee mention difficulties in evaluating responsiveness and quality of services of online systems vs. offline systems.

Although the e-Government initiative faces some concerns arising from security-related issues (protecting data, privacy, confidentiality of information, viruses and such), heavy IT investments and the digital divide (unequal access to computing resources within the community members), the benefits accrued therein are numerous. Some of the distinct advantages of e-Government include 24x7 access to online services and information, increased public participation, increased efficiency in terms of cost and time-saving, improved quality of service, transparency in processing, and consistency in outcome (Bonham et al. 2003). Local governments and reviewing agencies can thus certainly benefit from the application of e-government initiative to the comprehensive planning processes.

Performance measurement of e-Government

Stowers's (2004) report on measuring the performance of e-Government identifies 3 levels of measures for comparison, namely input measures, output measures and outcome measures. These have been further categorized in two classes, web measures and service-oriented measures. Input measures consist of items such as staff costs, development costs, staff time for application, other development time, vendor time for application development as well maintenance. Output measures include number of hits, number of downloads, number of completed transactions, and time spent by user on the website. Outcome measures comprise of items such as number of emails responded to, number of permits processed, number of times maps accessed and so on. The output measures include accountability of services in terms of accuracy, ease of use, adequacy of information, service quality, efficiency in costs, and overall cost and time savings for the e-government.

The Planning and Regulatory Services Online (PARSOL) is an e-Government project in the United Kingdom that is developing a variety of service delivery standards, benchmarks, and toolkits for facilitating online delivery of planning services (Planning and Regulatory Services Online, 2008). PARSOL standards related to planning processes are quite detailed; they are based on each step of the planning process and the services meeting these standards are evaluated on a scale of three levels namely minimum, progressing and excellent. While minimum level of standards deals with parts of the planning services being accessible online, progressive and excellent levels address substantial progress in the task of service delivery. The standards themselves are classified into three categories, namely customer focused, organizational and corporate standards. For example, Customer focused standards related to seeking pre-application planning advice are measured on provision of service online and aims for reduction, in office, telephone and email queries and reduction in the need for advice from qualified planners. Organizational standards address issues related to inter-organizational communication and corporate standards address issues such as sharing of land and property information effectively. These standards provide an example of some of the criteria that may be used to measure performance of digital framework.

E-Government characteristics applicable to this study

The literature on e-Government centers on using latest technologies to improve government related processes and outlines problems and benefits associated with it. While e-government efforts are not just about presenting information online, presenting information online is often the first stage of such efforts. Therefore, quite a few of the e-Government benefits mentioned in the literature such as 24x7 access to online information and services, increased opportunity for public participation (better medium for communication such as forums, online comments) derive from online presence. Some of the problems associated with the internet media also follow such as security, virus threats and related issues. However, other benefits such as time and cost efficiencies, improved quality of service, consistency in outcome, and transparency in processing may be accrued as a result of transforming government services with newer technologies.

The comprehensive plan review process may certainly benefit from using a map-enabled planning document, due to integrated mapping functionality, if effectively implemented. If the proposed map-enabled planning document employs web based technologies then it may have potential to obtain most of the e-Government benefits. Even if the map-enabled planning document does not employ web based technologies, by integrating additional mapping functionality within the planning document it may be able to generate cost and time efficiencies, since at present reviewers may require a dedicated mapping application as well as a document processing application to analyze comprehensive plan proposals. The map-enabled planning document may indirectly result in improved quality of service if it is found useful for the review process, and results in faster processing, and accurate reviews. A map-enabled planning document is more like a tool and therefore the extent of benefits accrued from it will be dependent upon effective usage of its functionality.

The performance measurement studies related to e-Government provide information about the criteria that may be used for performance measurement. Time, costs (inclusive of software costs, staff costs, maintenance costs), ease of use, adequacy of information, accuracy, reduction in queries are some of the measures suggested in the literature. Considering the scope of this study, it may not be possible to undertake rigorous performance evaluation of the map-enabled planning document based on these criteria.

Components of the Application for Comprehensive Plan Review

Initially my study was oriented towards developing an application for the comprehensive plan review, considering the importance of the comprehensive plan review process, its repetitive nature, and the immensity of the task. A digital application for comprehensive plan review will have to support two main functions:

1. Facilitate exchange of documents and comments among review agencies, and
2. Provide necessary tools for conducting a review of comprehensive plan

The exchange of documents and comments among all the agencies can be done, via internet media with email, and email attachments, provided all the materials to be exchanged are in a digital format. As far as the tools for conducting a review are concerned, it is essential to provide tools to analyze the spatial component of the comprehensive plan document that is the maps. Urban planning has a strong spatial component associated with it, and many times, we need to know, where something is, how it interacts with other features, whether it is suitably located, and if it is present in sufficient quantities. For instance, if we were to look at roads in a city, we would like to know, where the main roads are, if they are appropriately located, if the roads within the city serve all the areas of the city, or if the city lacks in meeting the appropriate level of service standards for the road network. The spatial aspect of such information cannot be conveyed easily without maps. Therefore, maps are an integral component of most planning documents and also the comprehensive plan documents. Thus, to analyze information conveyed through maps in a comprehensive plan document, it is necessary to have tools that can handle spatial data, and manipulate maps. Some other tools that may be useful for the review are the ability to add comments, and display tracking information.

Research

Initially, my study was geared towards creating a digital framework for comprehensive plan review. However, from an examination of comprehensive plan review process it was clear that the main challenge of the digital framework lay in integrating map manipulation capability with the planning documents. Therefore, focus of study was shifted to creating a map-enabled planning document that could support mapping capabilities.

Research Statement

My study developed methods for creating a map-enabled planning document with mapping capabilities and tools for better integration between text and spatial elements (in the context of a comprehensive plan review).

Currently planning documents use static images of maps to describe the spatial component of the document subject. I felt that with the help of current technologies, it would be possible to integrate interactive maps within planning documents, provide mapping tools, and further link related text and map portions within the document. Almost all planning documents have maps in them, due to the spatial nature of urban planning, and therefore a facility to have access to interactive maps instead of map images can be quite handy, to better understand the spatial component. Planning documents may be different; some may be just descriptive documents (e.g. a document describing the state of a road network within the city), while others may seek to convey a plan proposal for future development (e.g. a document describing a proposal for addition of roads in a city to relieve the road network congestion). Based upon individual planning documents, the purpose of maps included within the planning documents may vary.

When a map is used to explain a city road network, mapping tools related to map display (zoom, pan) and layer state manipulation (turn layer visible or invisible) may be sufficient to describe the city road network. When a map is used to convey the specific locations in a city, where new roads have to be added in order to relieve network congestion, then mapping tools for displaying numerical information, or enabling selection of features will be necessary, as one would like to show numerical analysis associated with different roads such as peak time of traffic on roads, and the capacity of roads. One may also want to show the roads which are over capacity and experience traffic jams. Thus the purpose of the planning document, and the maps included within defines the nature of mapping tools, necessary to best convey the spatial information within the documents. I speculated that if the comprehensive plan documents were map-enabled planning documents with access to maps, mapping tools, and linked features, then various plan review agencies' task of comprehensive plan review would be simplified. It was felt that interactive maps in review documents would be useful in clearly conveying spatial information in the document and adding transparency to the review process. Therefore the main objective of this study was to create a map-enabled planning document with mapping functionality. Central research question of this study was whether a map-enabled planning document with interactive maps and mapping functionality sufficient for the purposes of comprehensive plan review could be created and whether such a document would be useful in the review process. Another important objective of this study was to bring about tighter integration between text and map data in a planning document.

Objectives

- **Objective 1:** To outline desired functionality of a map-enabled planning document.
- **Objective 2:** To examine candidate technologies that can satisfy functional requirements of a dynamic planning document and to develop a prototype.
- **Objective 3:** To create links between relevant portions of map and text, thereby enabling a tighter integration between text and maps in the dynamic planning document.
- **Objective 4:** To evaluate performance of the previously developed prototype through one or more reviewing agencies, and to incorporate suggested improvements in the prototype if possible.

A map-enabled planning document may have many uses, but in this study, the purpose behind the development of a map-enabled planning document was to help the comprehensive plan review process. Thus the functionality of the map-enabled planning document was determined by the requirements of the comprehensive plan review process.

A map-enabled planning document may be developed with different technological approaches such as using completely web based technologies, or using a mixture of web based and desktop based technologies, or using embedded technologies. Word processing functionality is essential to most software, and therefore reasonable word processing functionality is available with web based technologies, as well as the desktop based technologies. However, all approaches do not offer similar mapping functionality. For instance, dedicated desktop based mapping technologies offer a wide range of mapping and analysis tools as compared to many web based technologies. Among web based technologies, mapping software choices include open source mapping software as well as proprietary mapping software. Open source software often has limited functionality in comparison with proprietary software. On the whole, it was necessary to understand the limitations of different approaches, and choose appropriate technology based on desired functionality of the map-enabled planning document.

A typical planning document has multiple references to maps, and currently planning documents contain static images of maps. In a map-enabled planning document, it would be useful to be able to link not only map images with the relevant text portions of the document, but also to link features with text. In this study, various opportunities for bringing about tighter integration of maps and text were explored.

A prototype of a map-enabled planning document was evaluated through one or more reviewing agencies, and wherever possible, suggested improvements were incorporated in the prototype. Complex improvements to the prototype that were hard to implement in the time frame of this study were outlined in the future scope of work.

Methods

Study methods were as follows:

1. Gather information about map related aspects of the map-enabled planning document. This included an overview of available geographical information systems (GIS) technologies, their characteristics, implementation details of these technologies and information about any real life examples that demonstrated linking capabilities between text and spatial data.

2. Gather information about the comprehensive plan review process, to subsequently understand possible mapping needs of the comprehensive plan documents. This included gathering information from the database of the comprehensive planning documents, comments, and objections, recommendations and comments (ORC) documents kept on the state of Florida website (in an effort to create paperless records).

3. Based on steps 1 & 2, identify a range of mapping functionality desired in the map-enabled planning document, and further identify a suitable GIS technology to implement the map-enabled planning document.

4. Develop a prototype using selected GIS technology and implement the desired mapping functionality. Also explore ways in which linking between text and spatial data can be achieved.

5. Seek comments on the prototype through a review by one or more planning agencies.

The first step of the methodology refers to collecting information about various GIS technologies and its implementations. This step was covered in the literature review. In the second step, information about comprehensive plan review was collected to find out the requirements of the review process in terms of the mapping functionality, so as to understand what kind of mapping functionality was necessary in the map-enabled planning document. In the third step, based on the identification of the desired functionality in the map-enabled planning document, a suitable GIS technology was chosen for implementation of the prototype. Next a prototype was developed, and apart from inclusion of the desired functionality, advanced functionality related to linking between maps and text was developed as far as possible. Finally comments were sought on the usefulness of the prototype from one or more reviewing agencies.

Regarding the development of a prototype based on selected technology, it is possible that different implementations of these technologies can be developed and that the prototype formed in this study may not be the best possible implementation. However, this study pointed out appropriate technologies in view of the functional requirements of the digital framework, since selection of the technologies is based on their functionality, as gathered from the current literature or prevalent applications of these technologies currently in use.

Performance of a mapping technology at a particular scale of data can vary. Some technologies are more suitable for handling small amounts of data. Feature datasets tend to get large with larger number of features. Therefore datasets covering an entire state tend to be much larger than the datasets of a city. Spatial analysis of large datasets, having large number of features, or having many complex features, can be time-consuming, if the analysis involves feature by feature operation such as computing intersections, or features within. Desktop based tools may be faster in mapping performance, based upon the computer hosting the application. Web based tools sometimes may take longer, because of concurrent processing, and thus for some users, there may be a wait time involved. Some technologies may process analysis in raster format, which tends to be faster over larger areas, when compared with vector analysis. Thus the performance of any technology can vary in different situations, and it may happen that the technology chosen for development of the prototype is suitable at the scale tested, but not suitable at other scales larger, or smaller.

Relevance of the Study

Comprehensive plan documents are seldom without maps, and if these documents contain interactive digital maps instead of static images, then the planning concepts in these documents may be understood in a much better way. Therefore, this study aimed to create a map-enabled planning document, and developed a prototype to show what is possible. Having maps without any mapping tools is not of much use, and thus mapping functionality necessary for conducting the comprehensive plan review was integrated in the prototype of the map-enabled planning document.

Such a map-enabled planning document has potential of becoming a useful tool for planners, since much of planning activity requires discussion and communication of planning ideas between multiple agencies, interest groups, citizens and politicians. If planning documents are map-enabled, then it will be easy to demonstrate the spatial reasoning behind certain planning activities, for instance planners can open a document and alter the maps within, to show various layers, and relevant analysis. Moreover, suggestions from collaborators or the public can be implemented within the maps ad hoc, and results may be examined in real time. It may also be useful in public participation sessions, wherein planners can demonstrate the where and why questions, related to location attributes, by manipulating enclosed maps or by allowing people to explore maps at kiosks or similar facilities. A map-enabled planning document may be an additional tool for planners, and the extent of its usefulness will depend upon circumstances in which it is used. The current state of technology has potential to support development of such a tool and this study explored the usefulness of just such a tool for comprehensive plan review.

GIS Technologies

Since this study developed methods for creating a map-enabled planning document with mapping tools, it was necessary to gather information about various mapping technologies and study their examples to understand their functionality and implementation requirements. Therefore a broad overview of different GIS technologies was obtained.

The origin of GIS can be traced back to the 60s, to Canada, where it was initially used for natural resource management (Burrough and McDonnell, 1998). Development of GIS has great significance, since it provides us with a systematic approach of dealing with spatial data. GIS is extensively used in the planning field, primarily because almost all planning related information has a spatial dimension associated with it. Mapping applications also are more commonly used in recent times than before, due to availability of digital mapping data. Many government agencies now publish spatial data via the internet in the public domain, thus enabling anyone interested with an opportunity to browse through spatial data or conduct spatial analysis. Government as a part of an e-Government effort has created a one stop GIS data portal geodata.gov which links to spatial data from multiple agencies for all the states in the United States.

Aside from planning professionals, people as such are also more exposed to mapping data and applications now days, due to much common use of GPS systems for route navigation, access to location based services from cell phones, computers and PDAs, and access to web based free applications like Google maps, Google earth and other map viewers. Since we wanted to tightly integrate mapping functionality with the planning documents, here an overview of different GIS technologies was obtained to find out their salient features, and range of functionality.

GIS Technology Alternatives

Various GIS technologies were considered during the literature review, to understand the range of mapping functionality offered by different GIS technologies. Also examples of each GIS technology were reviewed to find out more about their implementation requirements and their ability to support linking between text and map data.

Standalone GIS technology

Standalone GIS technology refers to the dedicated GIS applications that are commonly desktop based. They are dedicated GIS applications, and aim to provide full GIS functionality including GIS data creation, editing, manipulation and GIS analysis. They also support advanced functionality in the form of add-ons that is targeted towards a particular purpose, or is built around a field of study. One example of a common standalone GIS application is the ArcGIS application developed by ESRI (Environmental Systems Research Institute, Inc., 2008). The ArcGIS application supports various spatial data formats, provides tools for map making, map display, general map analysis, comprehensive query functionality, and also offers tools for map export and printing. Advanced functionality is available for this application in the form of various extensions such as 3D Analyst (supports 3d analysis, 3d viewing of maps, walkthrough creation), Business Analyst (supports business location related functionality), Network Analyst (supports network building, manipulating and related analysis functionality) and so on. Prominent GIS software providers include companies like ESRI, MapInfo, Intergraph, AutoDesk, and GE (GE small world). These companies now support different types of GIS software that are designed for desktop use, enterprise wide use, Internet use and more recently, wireless use. Most of these software can be customized using programming languages such as Visual Basic, C++ or Java to integrate additional functionality.

Web GIS technology

Web GIS technology allows users to access GIS functionality through a web browser. Web GIS applications typically follow a distributed architecture that divides processing between a client machine (user's machine) and a server machine, and these applications use the Internet media to provide access to GIS functionality to users. The website providing Web GIS functionality transports user's GIS commands from the browser to the server machine (web server) and sends the output back to the browser, where user sees the results. All of the GIS processing is completed on the server machine, and the internet browser just acts like a screen which accepts input and displays output. Some web GIS applications allow some mapping commands to be processed on the user's machine. However, this requires that some sort of mini application mostly in the form of an ActiveX control or a JAVA plug-in be installed on the user's machine, that can execute required GIS commands on the user's machine. When minimal processing is handled by the user's machine it is referred to as a thin client. When partial processing is handled by the user's machine, it is referred to as a thick client. One of the issues with the usage of a thick client is that the users are weary of installing a plug-in or similar stuff on their machines, due to security concerns and virus, spyware threats.

The biggest advantage of the web GIS technology is that it does not require users to have any particular GIS software installed on their machine. Since processing is mainly handled by the server machine, the user's computer requires no CPU time, consumes no memory space for storing data, or handling analysis routines, and thus a very basic computer that connects to the internet and has an internet browser application can suffice for accessing functionality offered by a web GIS application. This characteristic of the web GIS applications has empowered a large section of population that has internet connectivity, with GIS tools; thereby slowly eroding the criticism that GIS is an elitist technology (Curry, 1994; Pickles, 1995).

One of the limitations of the web GIS technology is that the range of functionality offered is often limited as compared to the dedicated GIS applications. Most web GIS applications support multiple users at the same time, and thus server machine has to process various requests concurrently, and this puts a limit on server side processing. Besides, there may be wait time on the user side, when server is busy processing users' requests. Another issue is that the output provided to the user may be in an image format (raster) instead of vector format. Quite a few web GIS applications are purpose oriented in the sense that they satisfy a particular mapping need. For instance, there may be an application that allows viewers to locate wildfire occurrences within a county. In such a case, dataset required is fixed, the base map is preset, and users then either need to query the current wildfires, or view some in greater detail or add a new location. Required datasets can be located on the server and server can maintain different maps related to that. In such cases, web GIS application is appropriate because specific and limited functionality is required. Full range GIS analysis functionality is not necessary. Moreover, real time information can be quickly available to multiple users simultaneously. Another type of web GIS applications may provide a map viewer type of functionality. In such applications users can browse spatial data using these viewers and create maps, or manipulate some data. Such applications may or may not support query functionality. In the discussion of state planning, I discussed 12 states that carry out comprehensive planning. Many of these states offer map browsing and data download capabilities with a map viewer implemented using web GIS technologies.

Embedded GIS systems

As the name Embedded GIS suggests, in embedded GIS applications, GIS functionality is programmatically incorporated in other applications. Usually embedded GIS applications are developed when users are familiar with other non-GIS applications, and only need specific GIS functionality, so embedding it in another application is feasible. Embedded GIS is possible because some software makers of the GIS software expose their core programmed objects to developers in a toolkit, which can then be used to custom build required GIS functionality. Since base objects are already available, developers do not have to build everything from scratch. An additional benefit of using embedded GIS is that sometimes out of box functionality provided by a GIS application may not include required functionality; however it can be programmed using base objects. While the base objects can be used to model most GIS functionality, it is not meant to be used for complete GIS application development, as that requires much more objects than the base objects, and the effort and time required to build a complete GIS application from base objects may make it uneconomical. Some of the benefits of using embedded GIS applications include relatively low cost, as compared to that of owning stand-alone GIS software, ease of learning (since users do not have to learn complete GIS software to use a limited range of functions), and user friendliness, since the required GIS functionality is available within the interface of a familiar application. Embedded GIS applications can also be web based, if the GIS functionality is embedded in a web-based application. Currently ESRI offers embedded GIS functionality in its ArcEngine software package. Other software makers such as Bentley (Microstation is one of the Bentley products) also offer facility to embed their core software objects.

Open source GIS technology

Open source software refers to the software that is freely available in the public domain along with its source code, and may allow developers to modify the code and redistribute. Some examples of open source GIS software include UMN map server, GRASS GIS, Quantum GIS, MapWindow GIS and so on. Some of these programs are web based, and others are desktop applications, and the functionality offered by each varies. Many people contribute to the open source GIS projects, especially since the code and algorithms are available for modifications and reference. Therefore the functionality offered by open source projects is constantly evolving. These projects also offer support over multiple operating systems, and some may cater to those operating systems, that may not be used widely.

GRASS GIS, (GRASS GIS website) developed by the U.S. Army and many academicians, presents a wide range of GIS functionality to the users. It supports raster and vector data formats, image processing capabilities and tools for data visualization, and analysis. GRASS GIS is multi platform, but supports user interaction with the X windows system. However Quantum GIS (Quantum GIS website), another open source application, has plug-ins for GRASS GIS that allow users to use GRASS GIS with the Quantum GIS graphical user interface (GUI), on multiple platforms including windows. Quantum GIS supports spatial data in many formats, and also works with PostgreSQL layers. PostgreSQL (PostgreSQL website) is relational database management software, that is free, and therefore a combination of Quantum GIS, with GRASS GIS and PostgreSQL presents users with a strong GIS and database capability. Such applications can be considered for the development of a map-enabled planning document. Amongst web based GIS applications, University of Minnesota's UMN map server is open source software that can be used to serve maps on the internet. Besides, the applications mentioned here, there are many other open source GIS utilities available on the internet, however quite a few applications are more like map viewers presenting basic map display functionality.

GIS web services

Besides the above-mentioned GIS applications, another category of applications exist, namely the GIS web services. These GIS web services are software components designed to provide specific GIS functionality, and can be accessed by other applications through the Internet. Web Services are reusable components and a developer does not need to understand the logic behind the design of a web service to use it in his/her application. Developers of web services adhere to the web based data transfer standards such as Simple Object Access Protocol (SOAP) or Web Service Definition Language (WSDL), established by organizations such as the Open GIS Consortium (OGC) and they can be then integrated with web applications conforming to those standards (Tang & Selwood, 2003). Web services can be used to host data and distribute it, or they can be used to perform a specific task such as a distance calculator, or place finder.

Spatial databases

GIS dataset consists of various records, each of which is associated with a shape, which is a geometrical representation of features on ground, and also has a number of attributes. Attribute data are stored in a table, and can be queried like any other tabular data. GIS software can make use of different database management systems (DBMS) such as MS Access (for small scale data), Oracle, SQL Server to store the attribute tables associated with data layers, and then use Structured Query Language (SQL), to execute queries. Linking GIS software to standard database management software for data storage and querying is advantageous, because users can benefit from sophisticated query capabilities, optimization, indexing, performance tuning and other tools present in such database management software. However, the advantages of using a standard DBMS do not extend to spatial queries, the primary reason being that the structure of current database software is not suited to store geometrical shapes such as polylines, which may have multiple parts such as segments and their vertices. Besides, standard SQL does not have any spatial query operators and even spatial data types do not exist. As a result, spatial queries can be handled only by current GIS software; however the GIS software does not offer capabilities of spatial indexing or query optimization. Spatial databases is an emerging area of research, which focuses on development of spatial databases, appropriate storage structure, design of queries, development of efficient algorithms for spatial operations, and query optimization (Rigaux, Scholl, & Voisard, 2001). Oracle has already incorporated some of the spatial functionality into their databases, through spatial extension called as Oracle Spatial, since their 8i release. Oracle spatial has spatial data types, and supports the use of spatial operators in their SQL queries. Oracle spatial also has a map viewer that renders maps, if a dataset is developed using Oracle's native data types. In the 10g release of Oracle Spatial, Oracle has incorporated the ability of storing raster data with GeoRaster tools. Oracle Spatial comes with Oracle Locator, which provides tools for supporting location based services (Oracle Technology Network, 2008).

Summary of GIS technologies

In the literature on GIS technologies, various GIS technologies such as standalone GIS software, web GIS, web services, embedded GIS, open source GIS and spatial databases were examined, to understand differences in between them, and to identify possible range of GIS functionality available with each technology.

Standalone GIS software provides comprehensive GIS functionality, and proprietary software of this category is probably the most expensive of the all the technologies covered here. Standalone GIS software can be linked via customization to other word processing software, to bring about close integration with text and spatial data.

Web GIS technology offers unique benefits of concurrent use, storage of maps and associated data on the server, and freely accessible GIS functionality on the client machines. Hyperlinks can be used to bring about integration between text and spatial data. Planning documents may have to be stored on the server, for hyper linking with maps. The GIS functionality offered with the proprietary web GIS applications, is limited, although opportunities for customization exist. Open source GIS applications that are web based also offer limited GIS functionality in comparison with the standalone GIS software. With open source applications technical support may be an issue. Some of the disadvantages associated with the web GIS technologies are slow (depending upon network congestion) delivery of information, map rendering and so on.

Open source GIS applications that are desktop based, may offer complete range of GIS functionality but linking those functions with text processing software for bringing about tight integration between text and spatial data can be difficult. Embedded GIS applications that are based on proprietary software expose core GIS objects with basic functionality in built in them, to the developers. This allows the developers to build any type of GIS functionality using the core objects. However, embedded GIS technology is suitable for developing limited functionality because it may be time consuming and uneconomical to build complete GIS functionality using the core objects. One important benefit of using the embedded GIS technology is that GIS tools can be embedded in different software. In terms of bringing about text and spatial data integration, it is useful, because GIS functionality can be embedded in the text processing software. Spatial databases technologies are database centric, and since planning documents may not have any substantial need for storing text information in a database, they are not relevant for this study.

Examples of Different GIS Technologies

Some examples of different GIS technologies mentioned earlier were selected for review to get an idea about their functionality, and implementation. Also, some examples were chosen for review, because they demonstrated text and map linking in their applications. Achieving text and map integration is one of the objectives in my study.

Bureau of Land Management's ePlanning application

The Bureau of Land Management (BLM) has developed ePlanning application for land use planning projects. This application displays web based (HTML format pages) land use planning documents containing links to maps in one window, and maps associated with links in the document are displayed in another window. In this application (current version 2.0), data layers used in a map are referred to as map services. Users can choose data from map services permitted by the ePlanning application to make maps. Users cannot modify legend of the map services but they can alter each service's transparency value, and they can also change the order of map services in the table of contents of the map viewer. Some of the commands present in the map viewer are add service, remove service, refresh map, pan, zoom, full extent and identify.

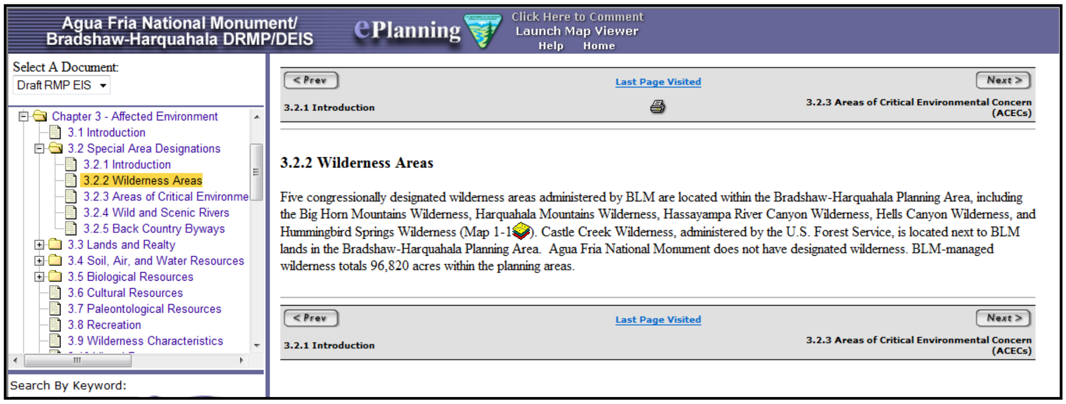


Figure 1-1. Web document view: ePlanning application (Source: Bureau of Land Management, Denver, CO. ePlanning project about Aqua Fria National Monument. Retrieved Nov 21, 2004 from https://www.blm.gov/eplanning/az_pn/builds/build217/index.htm)

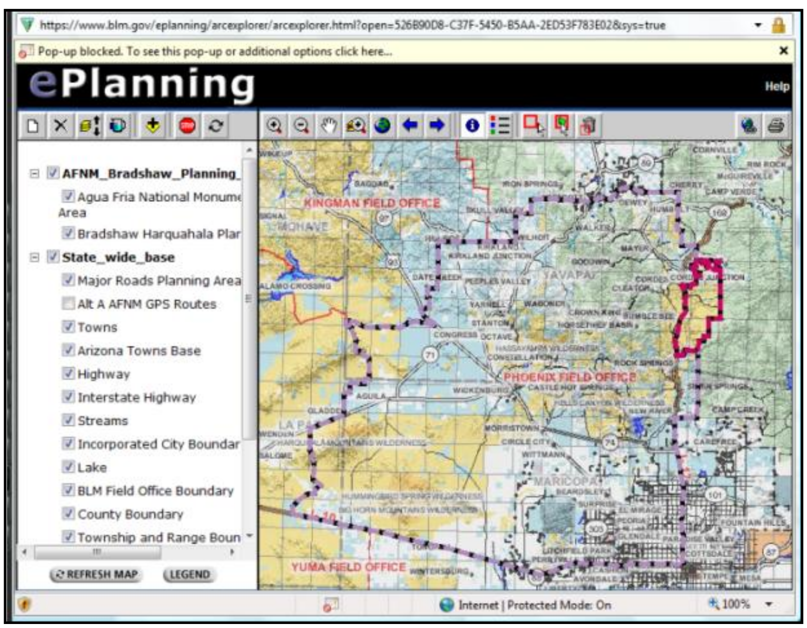


Figure 1-2. Map view: ePlanning application (Source: Bureau of Land Management, Denver, CO. Map viewer. Retrieved Dec 14, 2008, from https://www.blm.gov/arcexplorer/arcexplorer.html?open=526B90D8-C37F-5450-B5AA-2ED53F783E02&sys=true)

The ePlanning application also supports select by feature, and select by rectangle commands which let users select a single feature or a rectangular portion of a map. Users can link selection on the map with their document by obtaining a web link for the map. A web link is a URL (universal resource locator) associated with the user's selection that can be specified as a hyperlink in the planning document at a desired location.

Thus this application allows users to link selection on a map with relevant text in a document. It is a web based application, and users have limitations on choosing map services (data layers) for their maps, but the text and map linking functionality is similar to the kind of functionality desired in the map-enabled document. Users can also comment on already hosted planning documents on the eplanning project website, by selecting some text within the document and adding a comment to it through comment submission form.

The ePlanning application is still being developed. In this application ArcIMS is used to enable web-based GIS, and ArcSDE is used to make a connection to the underlying database. In the version 1of this application (Bureau of Land Management, 2004), users could select a feature on the map and view linked portion of the text, and also, they could click on a map link included in the text to view linked map.

Figure 1-3. Creation of a link to map (Source: Bureau of Land Management, Denver, CO. Introduction to the ePlanning map viewer. Retrieved Dec 14, 2008, from http://www.blm.gov/eplanning/help/Help_Project/Introduction_to_the_ePlanningMapViewer.pdf)

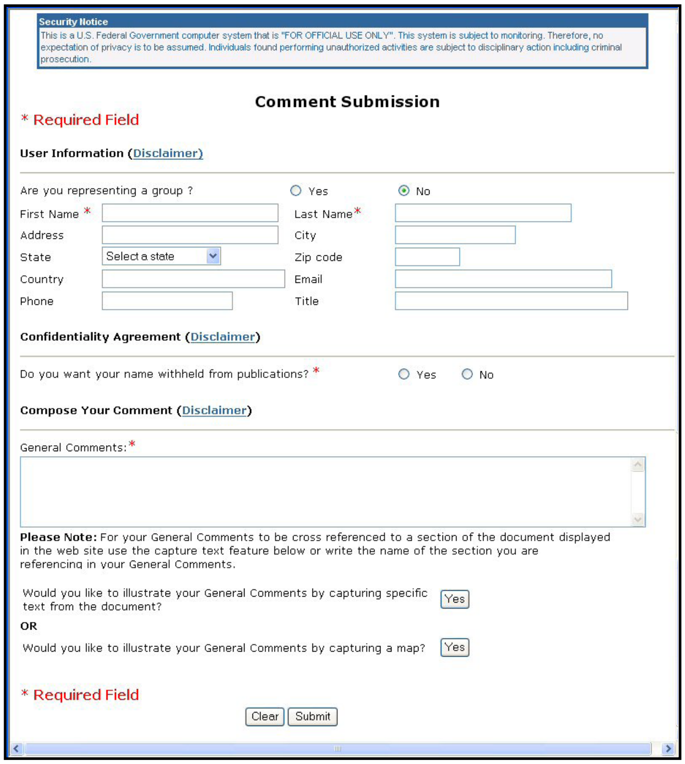


Figure 1-4. Comment submission form (Source: Bureau of Land Management, Denver, CO. Introduction to the ePlanning map viewer. Retrieved Dec 14, 2008, from http://www.blm.gov/eplanning/help/Help_Project/Introduction_to_the_ePlanningMapViewer.pdf)

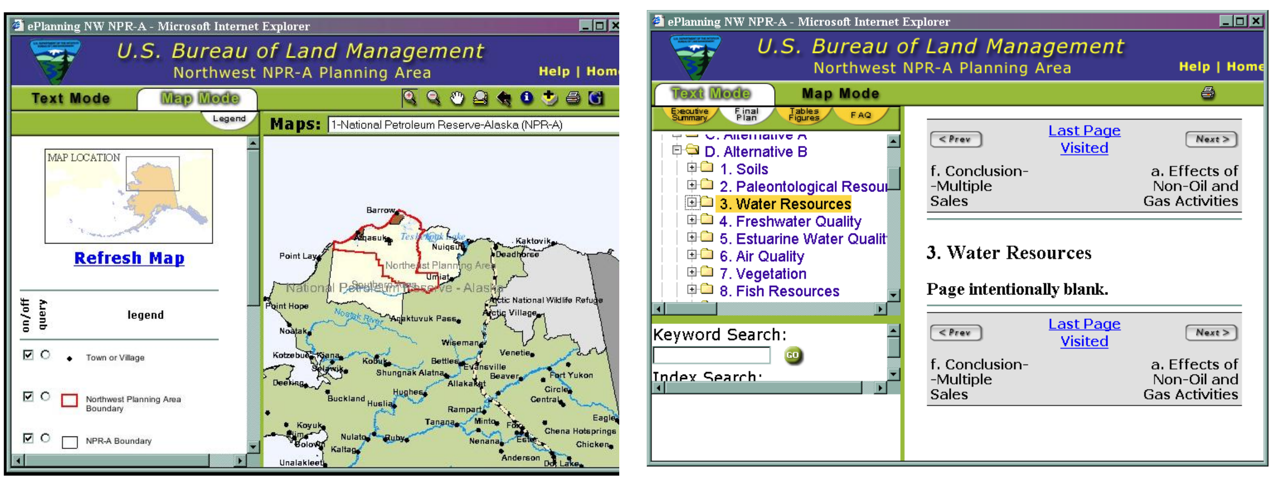


Figure 1-5. Linked text and map (Source: Bureau of Land Management, Denver, CO. Plans related to northwest NPR-A planning area. Retrieved Nov. 21, 2004, from www.blm.gov/planning/tools_egov.htm)

Recently (2007) version 2 of the ePlanning application has been released. In the current version ESRI GIS technology is used to create maps, and maps are distributed to the public in the form of GeoPDF documents. GeoPDFs are created using an extension developed by TerraGo Technologies. With GeoPDFs users can view maps in PDF documents, and also perform attribute queries on map data, alter layer visibility and obtain coordinates for a particular location. Other technologies used in the ePlanning application are Documentum software for content management and record management services, Arbortext tools for web development and digital media publisher, and CommentWorks software for comment processing and analysis (Bureau of Land Management, 2007). The ePlanning application also takes into account workflows related to documents and document transfer amongst different participants. This application facilitates collaboration between multiple participants, allows for submission of comments and also offers interlinking capability between text and maps. Thus it is an important example that shows what is possible with the web GIS technology and how text and map data in a planning document can be linked.

WebServices: SiteToDoBusinessOnline company's services

SiteToDoBusinessOnline (STDBonline) is an online service and comprehensive website that serves members of the Certified Commercial Investment Network (CCIN), which is a commercial real estate network. The STDBonline makes use of ESRI's Business Analyst Online web service based solution, to cater to its clientele. At the STDBonline website users can identify their area of interest interactively in a map viewer, and for their area of interest they can generate various reports according to their needs. Such reports may include information related to demographic information, consumer spending in the selected area, flooding information, travel time from a particular road and so on.

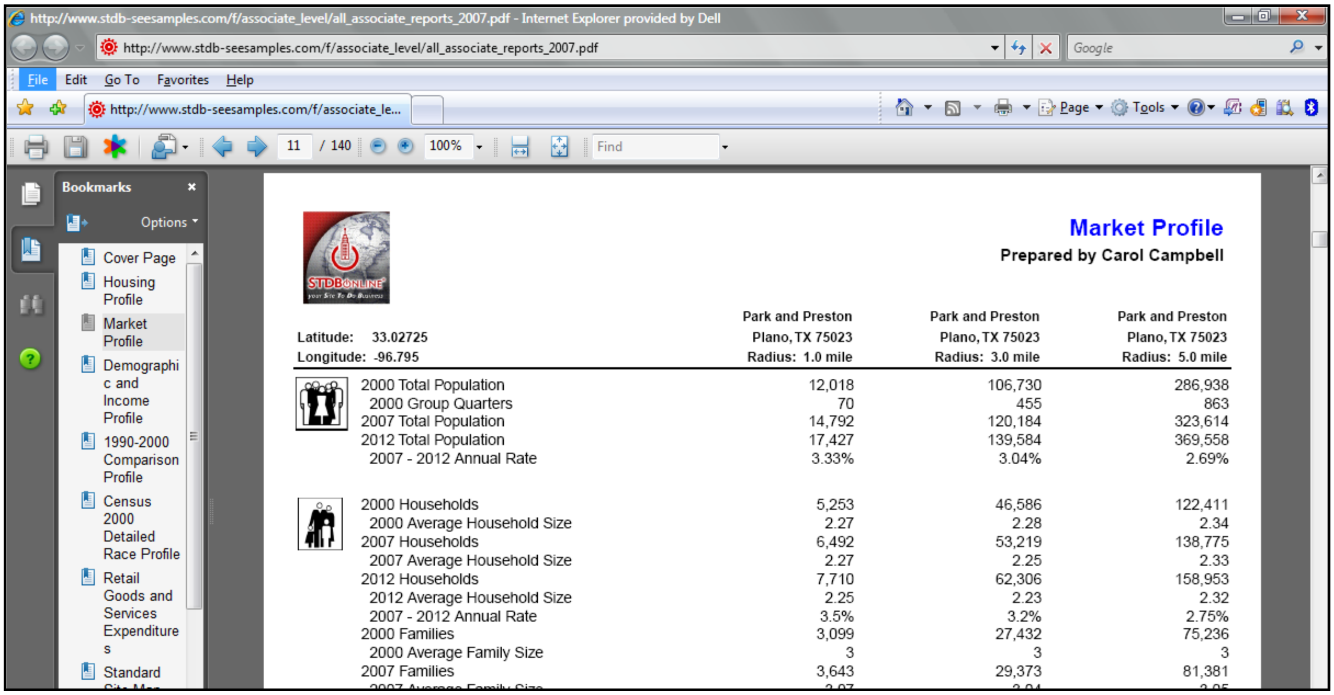


Figure 1-6. Report generation using web services (Source: SiteToDoBusinessOnline Inc., Chicago, IL. Sample report. Retrieved on Nov 21, 2007 from http://www.stdb-seesamples.com/f/associate_level/all_associate_reports_2007.pdf)

Users can also develop a property profile and compare various properties. STDBonline offers wide variety of services on their website, including quick maps, 3d view of structures, and various real estate related reports. STDBonline makes use of pre-programmed Business Analyst Online web services, and therefore does not need to invest in any mapping software, or host data required for mapping and analysis. Data is served by web services, and logic required for conducting spatial analysis is predefined; therefore STDBonline can focus on report generation related to site analysis and market potential (Environmental Systems Research Institute, Inc., 2007).

Environmental Systems Research Institute (ESRI) provides Business Analyst Online service that uses similar web service technology and supports map definition and report generation. ESRI's demonstrative example of the business analyst service can support creation of census reports instantaneously for any area selected on a map.

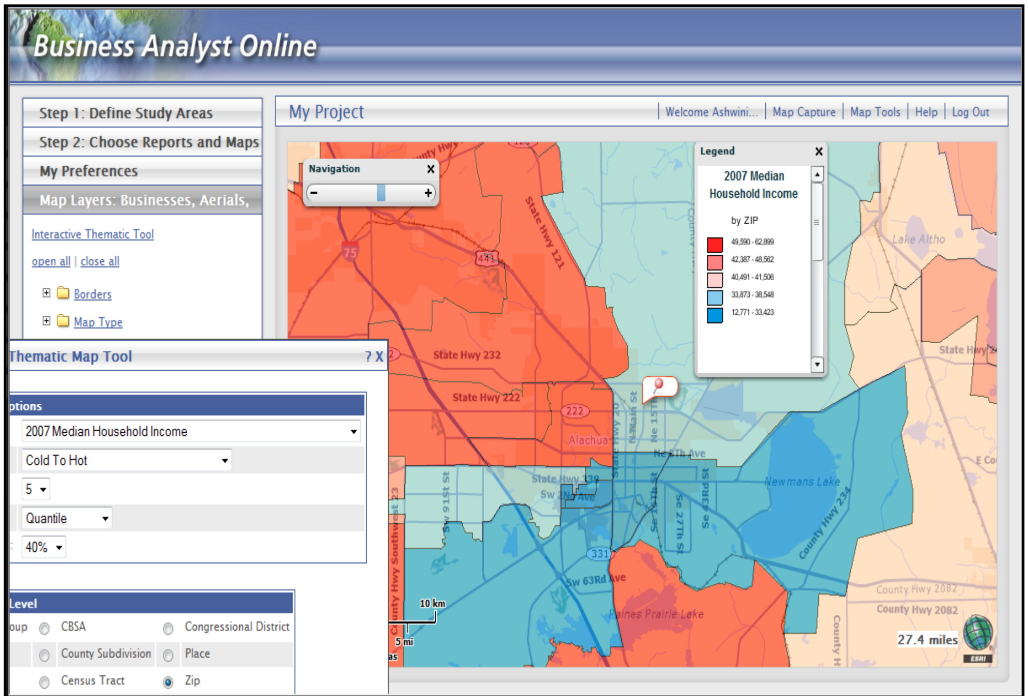


Figure 1-7. Census report generation with business analyst online web service (Source: Environmental Systems Research Institute, Inc., Redlands, CA. Retrieved on Nov 21, 2007 from http://www.esri.com/software/bao/index.html)

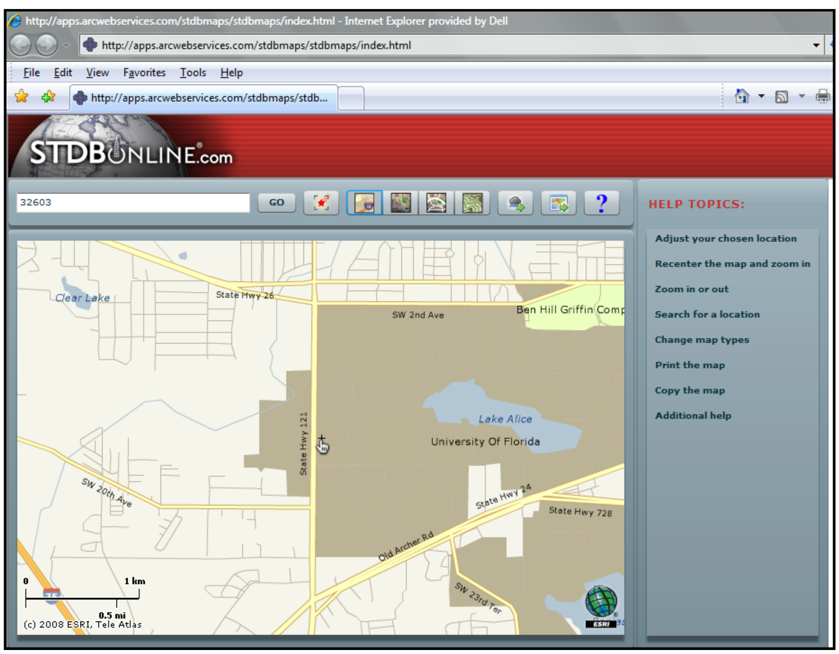


Figure 1-8. Quick maps application (Source: SiteToDoBusinessOnline Inc., Chicago, IL. Quick maps. Retrieved on Nov 21, 2007 from http://apps.arcwebservices.com/stdbmaps/stdbmaps/index.html)

Open source GIS example

One of the biggest advantages of open source GIS software is huge savings in cost. Open source software is freely available for development, thus making it attractive to agencies that cannot afford to purchase and maintain a proprietary GIS. Bill & Korduan (2004) have developed internet-GIS for municipalities and counties, based on open source software. This internet GIS solution uses HTML and JavaScript for web page development. The UMN map server, developed by the University of Minnesota's Department of Natural Resources, is used for serving maps on the internet. Other software associated with development of this application is Microsoft Windows (operating system), Apache (server), MySQL (database software), and PHP (front end for MySQL). With these tools, Bill & Korduan (2004) have developed a Web GIS supporting map navigation tools, layer management tools, scale bar, base reference map and thematic data queries. Currently raster data is being served in demonstrated examples, though the application is capable of handling vector data. Open source software is quite dynamic in the sense that developers are always adding functionality to it; at the same time, it needs to be explored further to see if it can present interesting and better alternatives to text and maps integration.

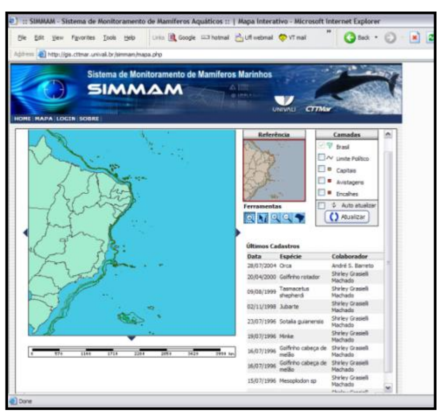


Figure 1-9. Example of open source GIS technology (Source: University of Minnesota's map server project gallery. Retrieved on Nov, 2004 from http://mapserver.gis.umn.edu/gallery)

Participatory GIS using Java based DITO and CommonGIS applications

Voss et al. (2004) developed a participatory GIS application to facilitate collaborative decision making with involvement from citizens. This application comprises of two separate applications, Dito and CommonGIS. Dito carries out collaborative decision making, and CommonGIS conducts GIS analysis, and supports result visualization. The Dito application sets up online discussion sessions and allows interaction among various participants. Linking between maps and discussion sessions is achieved with annotations present in a map. Annotations in a map are linked to relevant discussion sessions, and a user can activate a map by clicking on the annotation icon next to a linked discussion session, or the user can query a map feature to display all the discussions associated with it. The CommonGIS application supports temporal analysis, time series analysis and visualization of results. In the participatory GIS application, it is possible to visualize progress of comments related to a feature in the map since linked discussions can be ordered by date.

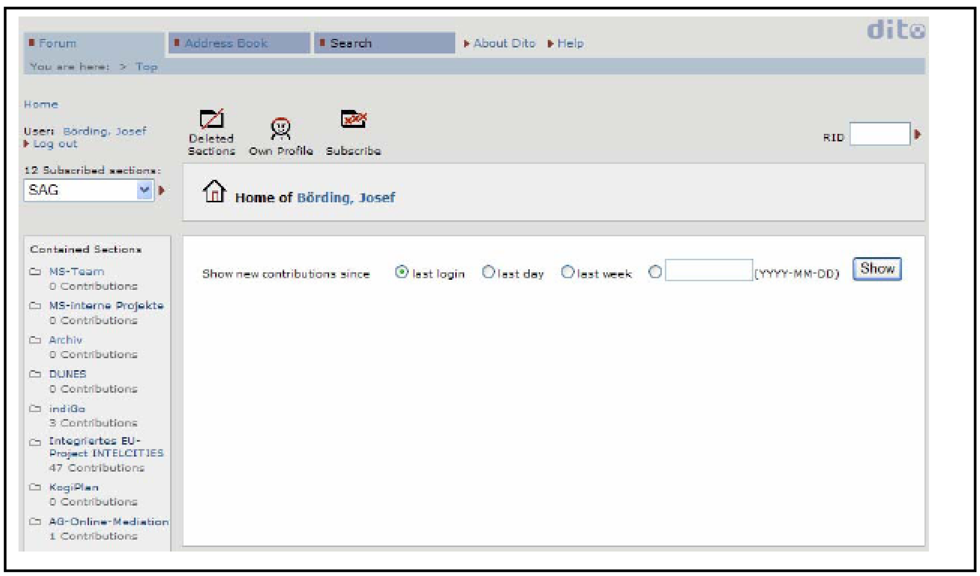


Figure 1-10. Dito application interface (Source: Fraunhofer Institute for Intelligent Analysis and Information Systems, Sankt Augustin, Germany. Retrieved Nov 21, 2004 from http://alex.ais.fraunhofer.de/zeno/forum/Dito-Users-Manual-v01.pdf?action=subscription)

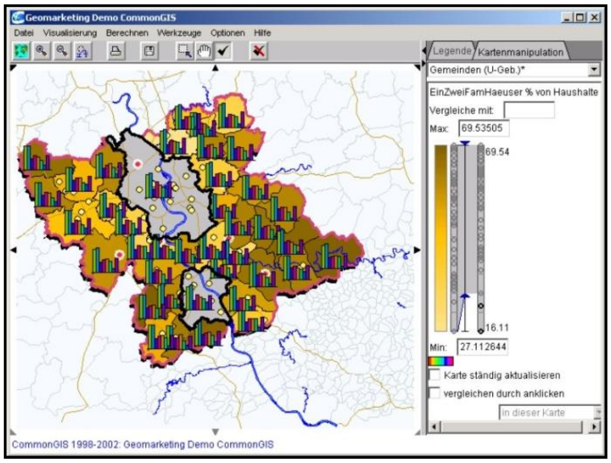


Figure 1-11. CommonGIS application interface (Source: Fraunhofer Institute for Intelligent Analysis and Information Systems, Sankt Augustin, Germany. Retrieved Nov 21, 2004 from http://alex.ais.fraunhofer.de/zeno/web?action=content&journal=15182&rootid=15093)

This application is developed using Java. The CommonGIS application is a Java applet that takes care of the GIS functionality offered in the application. It stores map data on client machines. The Dito application is also implemented in Java, and it is a web based application. It stores discussion sessions and map annotations on a web server, and retrieves that information on demand. Both applications allow a selective user access based on login information.

This application is relevant to this study, because of its capability of searchable comments and association of GIS maps with different discussion sessions. This application is developed and implemented in Germany by the Fraunhofer Institute for Intelligent Analysis and Information Systems and the websites for Dito and CommonGIS are also in German language; however information about the application and its implementation is obtained from a paper published by Voss et al. (2004).

Spatial database example

Relational database management systems with spatial data management capabilities are relatively newer advancements in the GIS field. Oracle, with its spatial data storage capabilities now offers advanced locator services, and geo-processing utilities such as buffer, union, and coordinate transformation. Creaform, an Italian company, has developed a complete e-Government solution for the city of Bolzano in Italy. Bolzono is a city of about 100,000 residents.

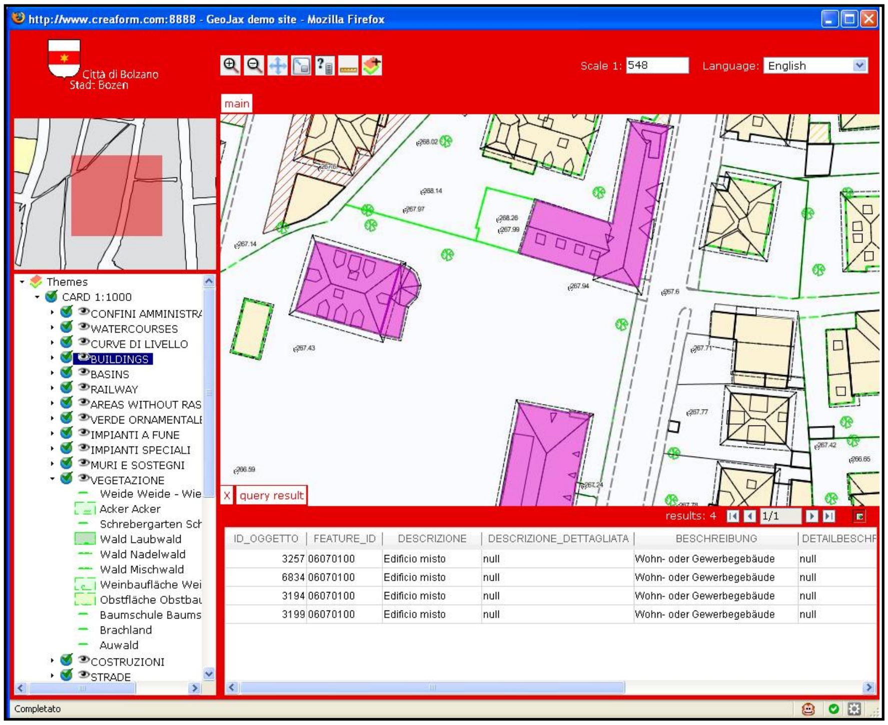


Figure 1-12. Spatial database mapping application (Source: Oracle Corporation, Redwood Shores, CA. *Complete e-Government Solution at City of Bolzano.* Presentation in the Oracle Spatial User Conference, 2008. Retrieved Dec 14, 2008, from http://download.oracle.com/otndocs/products/spatial/pdf/osuc2008_presentations/osuc2008_bolzano.pdf)

This application is made using three components; an AJAX (asynchronous JavaScript and XML) based web browser, a GeoJax webservice, and the Oracle Spatial database. The web service interacts with the Oracle Spatial database using Java database connectivity, and it also interacts with a browser to retrieve user specific information such as predefined themes in a map or functions available to that user. The GeoJax web service makes use of the Oracle application server and map viewer (11G version). This application is used by citizens, as well as variety of administrative offices of the city, including office of land registrar, office of territorial information and so on. In the application, access to the various offices related functions is available with a login, citizens do not need any login, and can access only standard functions (Borella & Lavoriero, 2008).

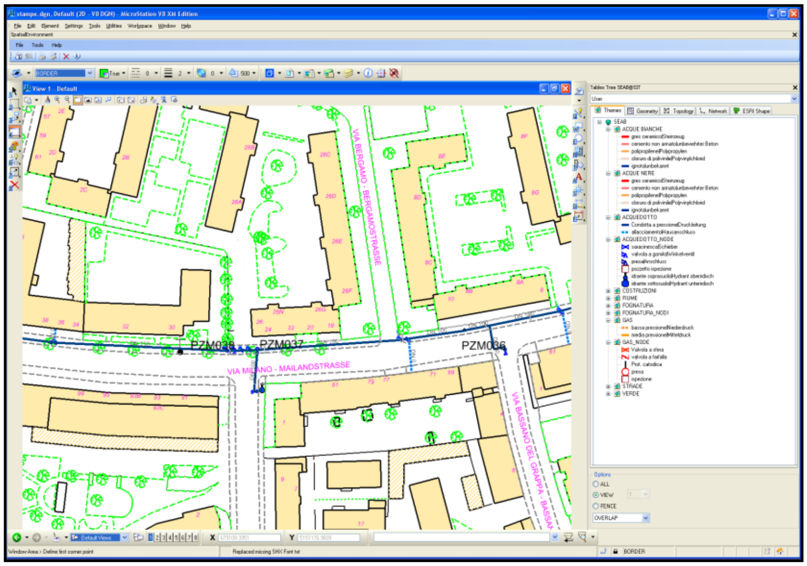


Figure 1-13. Editing environment to manage spatial data (Source: Oracle Corporation, Redwood Shores, CA. *Complete e-Government solution at city of Bolzano.* Presentation at the Oracle Spatial User Conference, 2008. Retrieved Dec 14, 2008, from http://download.oracle.com/otndocs/products/spatial/pdf/osuc2008_presentations/osuc2008_bolzano.pdf)

In this application editing of geometrical data and network data is handled by the Bentley Microstation XM, SpEn Enterprise editing environment, and therefore it offers precise editing tools available with the CAD (computer aided design) applications for editing data. This application, implemented using spatial database and related technologies, seems as complete as other applications powered by proprietary GIS software.

Embedded GIS in command, control and communication (c3) operations of ambulance services

In the United Kingdom, and Ireland, MIS Emergency Systems, Ltd. has developed an application, Alert c3, which deals with ambulance services. This application is implemented with embedded GIS functionality in the form of an eGIS module built with Cadcorp SIS Map Modeler application tools developed by Computer Aided Development Corporation (Cadcorp). The Cadcorp SIS Map Modeler application provides map-making, editing, modeling and analysis capability along with 3d modeling functions.

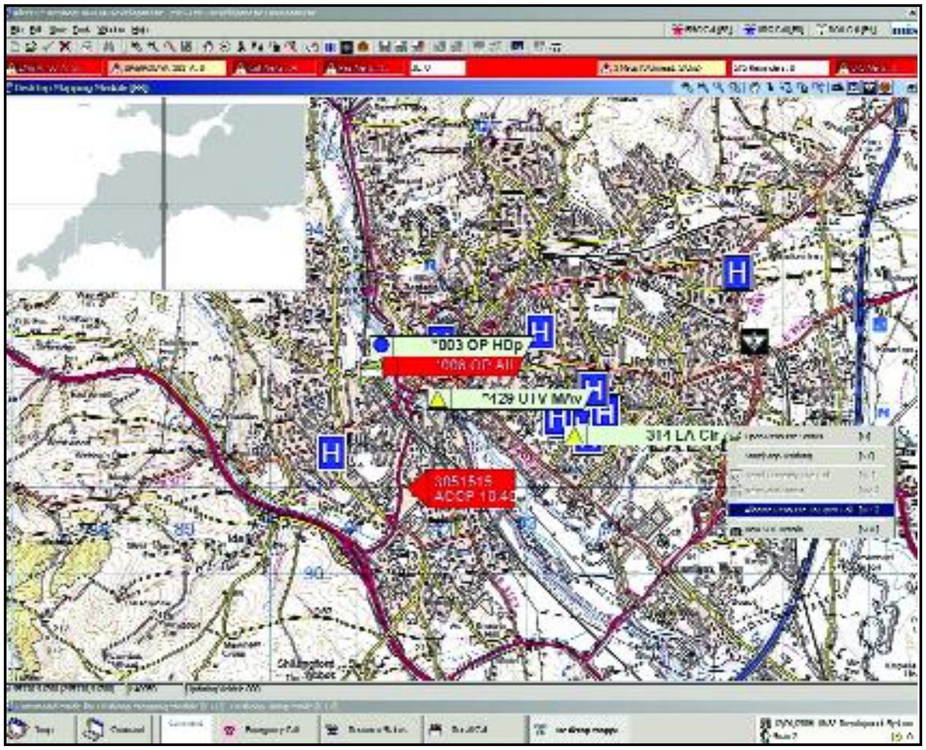


Figure 1-14. Alert c3 application (Source: Computer Aided Development Corporation, Stevenage, England. Case studies, emergency services. Retrieved Nov 21, 2007 from http://www.cadcorp.com/pdf_downloads/CS_Cadcorp_C3_ambulance_systems.pdf)

In the alert c3 application, interactive digital mapping capabilities are integrated, and maps are not just a backdrop used to show locations of calls, and ambulance resources. For instance, when a call is received, the system's critical location search facility identifies the caller's location, and a small eGIS window opens as part of the address match. The call taker can then confirm the caller's location or further narrow it down in case of multiple address results using the map displayed in the eGIS window, offer pre-arrival advice, and also locate relevant resources (such as ambulance or facilities) in the map and inform the caller of the exact ambulance location. When the location is within a certain distance, the eGIS window can respond by automatically zooming out to display a bird's eye view containing location of the resource and the destination.

In this application embedded GIS is used for various purposes including location searching, vehicle tracking, incident replay and investigation and predictive analysis and deployment profiling (Computer Aided Development Corporation, 2006). The system developers find that using embedded GIS within their C3 application removed limitations from trying to interface their software with other third party GIS products. They also find that the interactive GIS helped respond to commands faster, and dispatch resources sooner. The embedded GIS technology is very useful, when limited GIS functionality is required, and when more than one software is required for completion of a task.

Efficient transportation decision making process

Florida Department of Transportation (FDOT) created the Efficient Transportation Decision Making (ETDM) process as a response to the concerns expressed by citizens about long implementation time of transportation projects, and issues of substantial time gaps between environmental reviews of the project corridor and implementation of the project. At times when the time gaps were of the amount of 5-10 years, the project corridor underwent significant changes, which happened after the initial environmental reviews, thus rendering the environmental reviews obsolete (Florida Department of Transportation, 2008). The revamped process seeks early agency participation, provides access to standard and current datasets for decision-making, displays maps with a web based mapping tool, and presents information on various summary reports, GIS analysis reports and status of agency reviews about projects in the public domain.

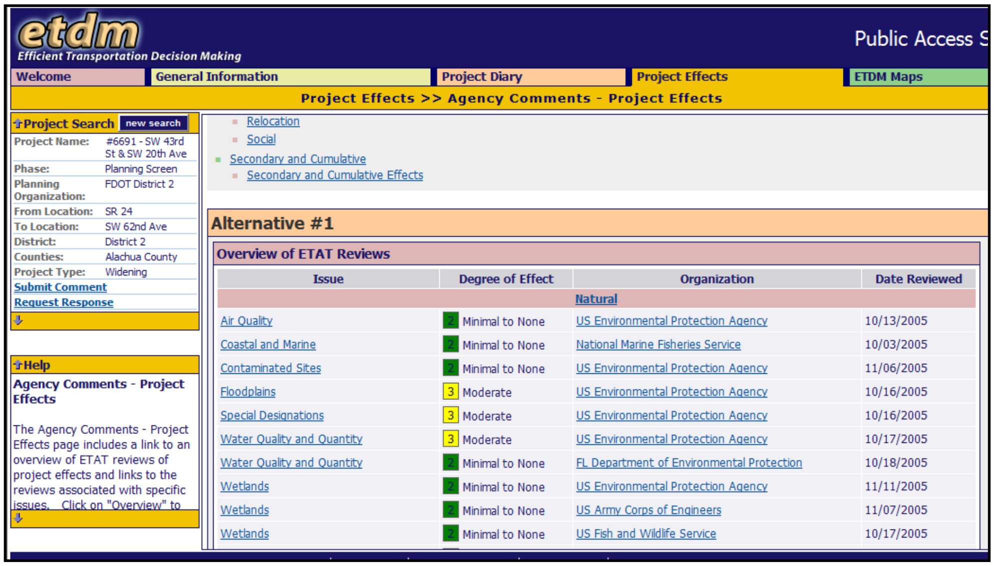


Figure 1-15. Agency reviews (Source: Florida Department of Transportation Environmental Management Office, Tallahassee, Florida. Retrieved Dec 14, 2008 from http://etdmpub.fla-etat.org/est/#)

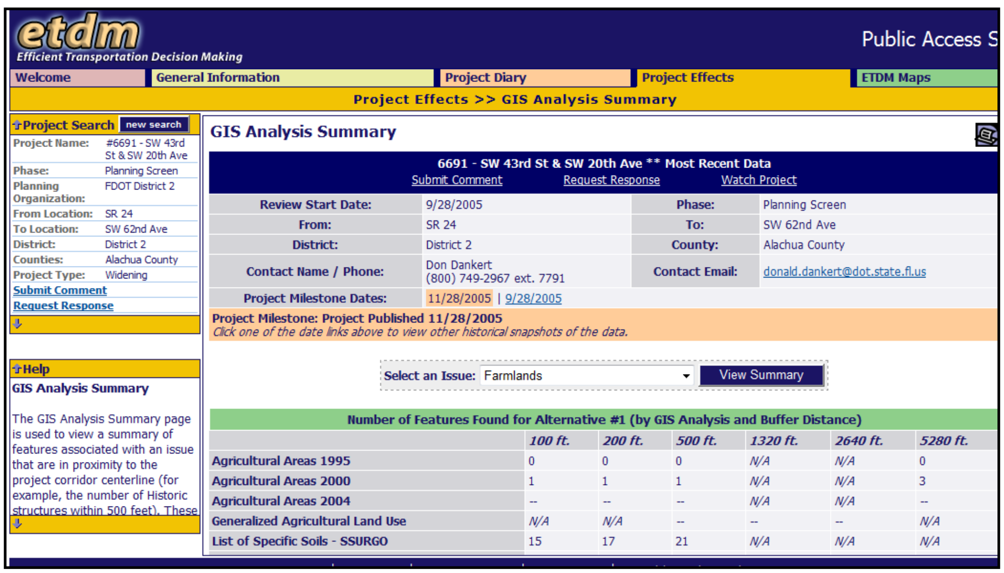


Figure 1-16. Project analysis (Source: Florida Department of Transportation Environmental Management Office, Tallahassee, Florida. Retrieved Dec 14, 2008 from http://etdmpub.fla-etat.org/est/#)

Early agency participation at the project planning level enables the project planning agency to determine possible impacts of the project and cost feasibility of the project due to adverse effects. Depending on the feedback of relevant regulatory and resource agencies, projects may be accepted for final design stage, altered, or rejected. The Environmental Screening Tool (EST) is a web based mapping application integrated in the ETDM process. The EST uses current datasets to display maps and provides quick analysis of the effects of the proposed project on natural and human resources. The tool also facilitates communication between all the interested agencies and people and maintains a record of communications. EST is implemented using ESRI's ArcIMS and ArcSDE technologies, and Oracle's database management system. FDOT developed the EST tool with in-house staff, consultants and the University of Florida GeoPlan Center. Associated data for the application is obtained from the Florida Geographic Data Library (FGDL), a repository of GIS data gathered from federal, state, and local government. The application and FGDL data is maintained by the University of Florida GeoPlan Center (University of Florida GeoPlan Center, 2008).

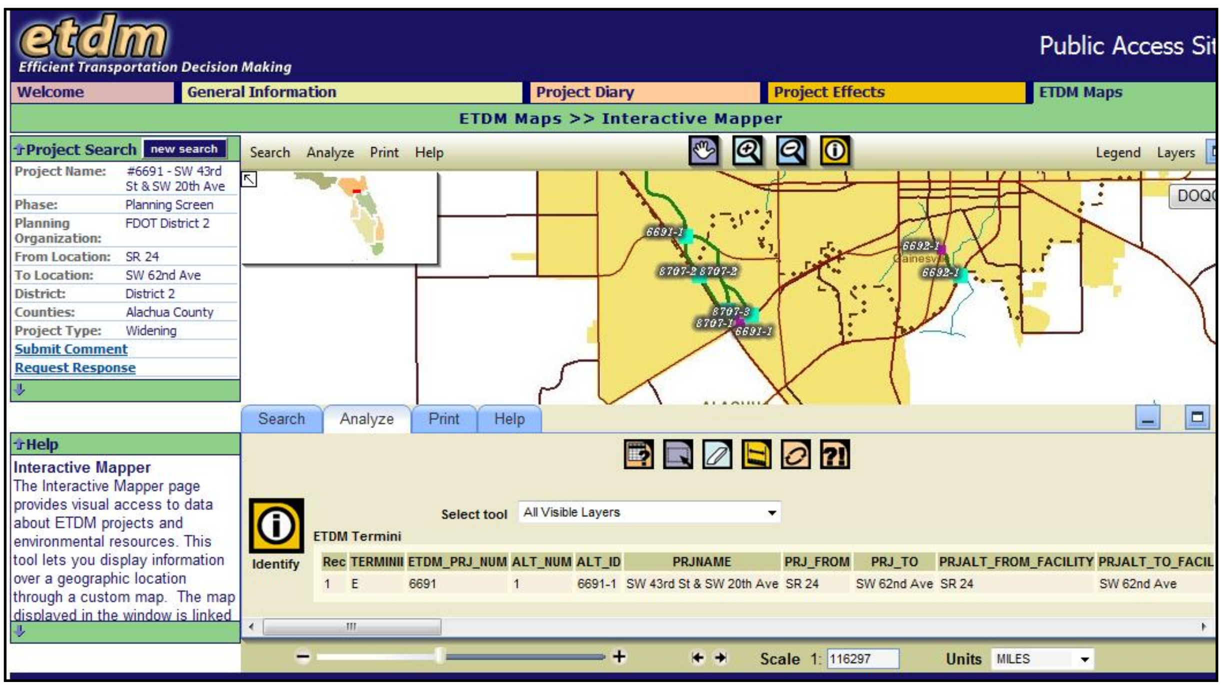


Figure 1-17. Environmental screening tool (Source: Florida Department of Transportation Environmental Management Office, Tallahassee, Florida. Retrieved Dec 14, 2008 from http://etdmpub.fla-etat.org/est/#)

Availability of standard and current data and ability to perform sophisticated analysis with diverse datasets based on preprogrammed logic has increased utility of the EST tool beyond the transportation projects; it was found to be useful by the Federal Emergency Management Agency during hurricane season in 2004. The ETDM example is interesting because, it demonstrates how web GIS and associated mapping tools can be integrated in a review-oriented application and how preprogrammed GIS analysis methods can be built in a web GIS application thus extending the capabilities of web based mapping technologies.

Summary of GIS technology related examples

In the literature review, different examples of various GIS technologies were examined to find out if related GIS technologies were suitable in terms of the GIS functionality necessary to develop a map-enabled document, and to understand their implementation requirements. The ePlanning application developed by the BLM was very interesting because it demonstrated how web based text matter could be linked with a map. In ePlanning version 1, hyperlinks are used to connect text with map elements. The application presented users with a unique link to a web based map as a way of associating spatial references in user's comments or documents. This application showed how links between text and maps could be created with web GIS technology, and it was directly relevant to the map-enabled document's goal of bringing about tight integration between text and maps. Mapping functionality available in this application includes map navigation tools, changing map data, and querying the layer attributes. With this application, users cannot add local data to maps, but they can choose a map service from available options and use data associated with that map service.

The example of STDBonline company's site specific services demonstrated use of preprocessed mapping logic to create reports based on user's selection of a location. While the quick generation of reports was quite impressive, this technology was not found much useful for the map-enabled document, because reviewers might want to process map data in different ways to conduct comprehensive plan review, and therefore it was not possible to predefine spatial analysis logic necessary for comprehensive plan review.

Open source GIS example demonstrated use of UMN map server (open source map server developed at the University of Minnesota) to create a web GIS application. There are a variety of open source GIS applications available, and range of functionality available with each application varies, and also their functionality improves over time as developers add to it. Open source GIS software could be used for implementing a map-enabled document however linking GIS functionality with text data was found to be somewhat difficult considering that the open source GIS software would have to be customized to build necessary functionality, and normally documentation available with such applications is not very detailed.

The example of participatory GIS, implemented using two applications DITO and CommonGIS was very interesting, since these applications when used together facilitated use of GIS in a collaborative setting. With this application, users could select features in a map and link discussions to the selected features, using annotations associated with features. Moreover, it was possible to query discussions using a feature, or its annotation, and because the discussions were saved in a forum like format, it was possible to view a progression of comments associated with the selected feature. This application stored map data on client machines and stored discussions on a server, normally most web GIS applications keep map data on a server, therefore compared to the norm this approach was novel. This application displayed one way in which links could be created between text and maps.

The embedded GIS example related to the ambulance services demonstrated integration of custom built mapping functionality with an already existing application. Here, maps were used for address matching, navigation, for displaying location of ambulance resources, and for displaying the destination of the ambulance. Maps were also useful in incident replay and investigation later on. Such functionality specifically geared to the needs of ambulance services is not available directly with any GIS technology including standalone GIS technologies, and therefore the embedded GIS technology was a good choice of technology to implement custom built functionality. Besides, use of embedded GIS technology allowed for integration of mapping tools within another application.

The EST tool integrated in the ETDM example is different than a standard ESRI based web GIS solution because of its ability to provide detailed reports involving GIS analysis, however the logic behind GIS analysis is preprogrammed, and as in most ESRI based web GIS solutions (based on ArcIMS technology), users cannot execute spatial queries, save selection sets or use maps developed in the EST tool in other mapping applications.

It was clear from the examination of different technologies and their examples, that development of a map-enabled planning document could be supported by a number of GIS technologies including web GIS, embedded GIS, and also it was possible to create links between map data and text data using different technologies.

CHAPTER 2
STUDY OF METHODS

My study developed methods for creating a map-enabled planning document with mapping capabilities and tools for better integration between text and spatial elements (in the context of a comprehensive plan review). Currently planning documents use static images of maps to describe the spatial component of the document subject. However, with the help of current technologies, it is possible to integrate interactive maps within the planning documents, provide mapping tools, and further link related text and map portions within the document. The purpose of the planning document and the maps included within, defines the nature of mapping tools necessary to best convey the spatial information within the documents. In this study, the goal was to work towards creating a map-enabled planning document for the purpose of comprehensive plan review, for use with various state and regional planning agencies. Study methods are as follows:

1. Gather information about map related aspects of the map-enabled planning document. This includes an overview of the available GIS technologies, their characteristics, implementation details of these technologies and information about any real life examples that may demonstrate linking capabilities between text and spatial data.

2. Gather information about the comprehensive plan review process, to subsequently understand possible mapping needs of the comprehensive plan documents. This includes gathering information from the database comprising of comprehensive plan documents, and objections, recommendations and suggestions (ORC) documents kept on the state of Florida website.

3. Identify a range of mapping functionality desired in the map-enabled planning document, based on the above two steps, and further identify a suitable GIS technology to implement the map-enabled planning document.

4. Design a prototype using the selected GIS technology and implement the desired mapping functionality. Also explore ways in which linking between text and spatial data can be achieved.

5. Seek comments on the prototype through a review by one or more planning agencies.

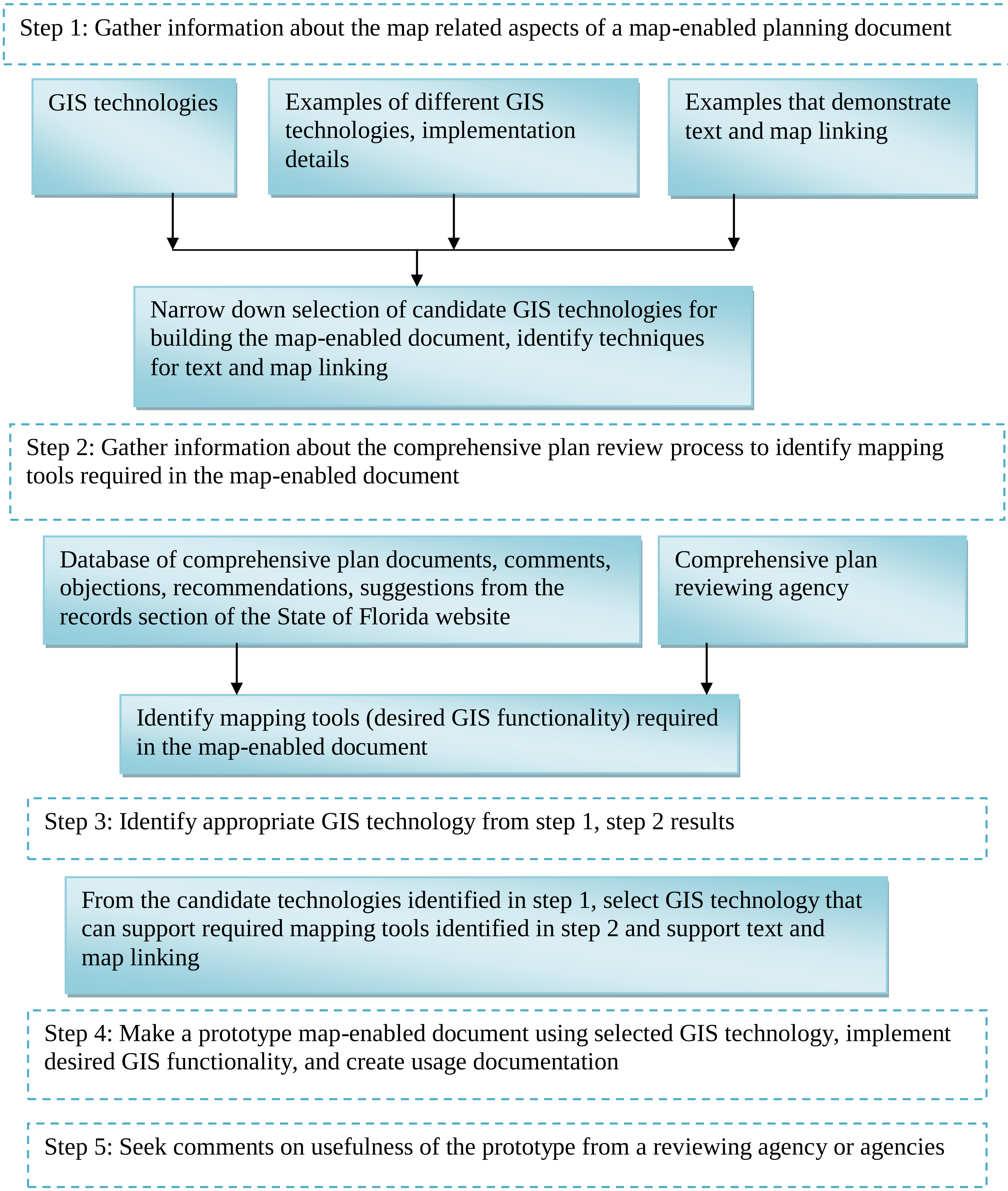


Figure 2-1. Methods diagram

Step 1: Information Collection about Map Related Functions

In this step, information about various GIS technologies that can be used to incorporate mapping functionality in the map-enabled document is collected. Different GIS technologies may have different requirements of operating systems, use of web server, and they may offer varying level of GIS functionality. Also, some technologies support different programming languages for customization of the software, while others do not support the ability to customize their functionality. Therefore, it was necessary to gather information about the different GIS technologies, as well as their functionality. This information was obtained from GIS software companies and their demonstrative examples, from the journal articles mentioning technologies used for conducting GIS analysis, from popular books on GIS technologies, and from the educators and professionals working in the field.

The information collected about each GIS technology was used to determine if the technology was appropriate for developing a map-enabled planning document, whether it worked on popular operating systems, whether it supported linking between text and maps, and whether it was possible to customize the technology in order to support such linking. Accordingly, in this step, the candidate technologies that were fit to be used to create a map-enabled planning document were narrowed down.

Since the purpose behind creating a map-enabled planning document was to aid the comprehensive plan review process, the websites of planning agencies of various states carrying out comprehensive plan review were searched to find out if any digital applications for comprehensive plan review were developed by these agencies. Also their choice of GIS technologies was noted.

Step 2: Information Collection about Comprehensive Plan Review

In this step, information about the comprehensive plan review process followed in the state of Florida was obtained. The purpose of this step was to understand general mapping needs of reviewers, and to identify the range of GIS functionality needed to be included in the map-enabled planning document, so as to support the task of a comprehensive plan review. The sources for this information were actual reviewers from Alachua County online document records from the state of Florida's database of comprehensive plan proposals, online document records of objections, recommendations and comments (ORC) given on the comprehensive plan proposals by the DCA, and other procedural information about the review process presented at the DCA website. Substantial amount of information was available online, due to the paperless record keeping system. Alachua County is one of the plan reviewing agencies, and it is located in the City of Gainesville where the University of Florida is located. Therefore, it was preferred over other agencies for collection of information, about the review process and associated mapping needs.

Mapping functionality required during a comprehensive plan review can vary case by case and in some cases one may just need to verify some data, in other cases one may need to conduct some additional analysis. Therefore, based on the information gathered from the review process and from reviewers at the Alachua County, some GIS functionality was identified as the minimum necessary functionality that should be there in a map-enabled planning document to aid the review process. Besides that, additional GIS functionality was identified as the GIS functionality that would be useful to have in a map-enabled planning document. The minimum GIS functionality along with the additional GIS functionality identified in this step, was used to determine the range of desired GIS functionality of a map-enabled planning document.

Step 3: Identification of Suitable GIS Technology

In step 1, some GIS technologies were identified as candidate technologies that could be used in preparing a map-enabled planning document. In step 2, the range of GIS functionality that was desired in a map-enabled planning document was determined. In this step, based on the desired GIS functionality determined in step 2, candidate technologies were reexamined in their ability to support such functionality, and a suitable technology was selected for implementing a map-enabled document's prototype. Other restrictions regarding operating system requirements, hard ware use requirements specific to each GIS technology were also taken into consideration while identifying a suitable technology for prototype development. Since considerable information about different GIS technologies was collected in the first step, additional information gathering requirements were minimal in this step.

Step 4: Development of a Prototype

In this step a prototype of a map-enabled document was developed. As far as the implementation of GIS functionality was concerned, primary goal was to implement all of the minimum necessary GIS functionality and as far as possible to implement all the desired GIS functionality in the prototype. Moreover, one objective of a map-enabled planning document was to bring about tighter integration between text and spatial content, and therefore different ways of achieving that were explored in this step. Integration between text and spatial content was considered important, because quite a few times, in the planning document there are references to specific locations, such as a particular road, or town or a land parcel, and many a times unless there is a direct map showing that location, there is no direct way of knowing where exactly that place is. However in this case, with the prototype referencing interactive maps in the document, the spatial data required to pinpoint a location in a document was available with the document. Through customization of the selected GIS technology desired linking functionality was implemented in this step. Besides, making the prototype, it was necessary to create usage documentation of the prototype so that the agency reviewing this prototype had some documentation to refer to regarding its usage. Therefore, that documentation was created in this step as well.

Step 5: Seek Comments on Usefulness of the Prototype

In this step, the prototype of a map-enabled planning document was given to willing agencies to try. Supporting documentation about using the prototype was supplied to them for ready reference, besides presenting direct demonstrations of the overall prototype usage. They were also given videos (screen cast links) of each command usage, as part of the documentation. Reviewing agency's comments were sought on the general usefulness of the prototype in the planning field, and in the review process. From their feedback, relatively simple suggestions were incorporated into the prototype according to the availability of time and rest of the complex suggestions were outlined as future work. In the conclusions, the prototype of a map-enabled planning document, and its advantages and disadvantages were discussed.

Methodological Issues

In this study a prototype of the map-enabled planning document was prepared, using selected GIS technology. The purpose of the prototype was to demonstrate that the making of a map-enabled planning document was possible, and the prototype illustrated one way of making it. Since different implementations of a prototype are possible, the prototype formed in this study might not be the best possible implementation with that technology. Also, the prototype might not have the look and feel and sophistication of the commercially available applications, primarily because commercial application developers often have more resources in terms of man power, time, availability of productivity software (custom tools that may improve programming practices, availability of code snippets from previous work), budget and so on.

The technological fields undergo rapid changes and newer applications and newer ways of doing stuff keep on emerging all the time. While this study was going on, new versions of ESRI GIS technology (9.2, 9.3) were released, and also new versions of development environment (Visual Studio 2005, 2008) were released. As a result some of the functionality integrated in the prototype was not necessary in the long run, because the new versions supported it directly. Also, the newer versions offered better tools for development, which were not available initially. Besides other technologies such as the open source GIS technologies evolved over duration of this study to support more functionality. However, even at present time no application exists for conducting comprehensive plan review, and no application directly similar to the map-enabled planning document has been prepared.

Willingness of the reviewing agencies to test the prototype was an issue, since they were already busy with their work, and interesting them in the task of testing the prototype was difficult. Moreover the task of testing the prototype of a map-enabled planning document involved learning the workings of prototype, and then testing it in order to offer comments, and thus imposed heavy burden of time on the reviewing agencies. Also, agencies were weary of installing unknown application on their computers due to security and incompatibility issues, and that might have been a deterrent in getting agencies to test the prototype.

Another issue in testing the prototype was satisfying licensing requirements. In the academic setup some software and hardware is available to the students, and the licensing requirements of the licensed software can be fulfilled. Therefore a prototype was developed with one of the technologies available with the university. However the same license could not be offered to the reviewing agencies for the purpose of testing.

It is important to note that the prototype of the map-enabled document is a tool, and ultimately its usefulness is determined by how it is put to use, and if all the functionality available with it is used in the best possible manner. For instance, if a map-enabled planning document's ability of accessible maps is not used at all, then it is like any other planning document, and does not contribute to additional usefulness. Therefore, it is possible that the reviewing agencies may find some functionality in the prototype more useful than other, depending on their usage of the prototype.

CHAPTER 3
FUNCTIONALITY IDENTIFICATION AND SELECTION OF TECHNOLOGY

The map-enabled planning document was developed to aid the comprehensive plan review process. Therefore, assessment of the desired functionality of the map-enabled planning document was based on the following:

- Understanding of the comprehensive plan review process in the State of Florida.
- Examination of the documents involved in review, especially comprehensive plan proposal documents submitted for review and comments received as a result of the review.
- Understanding of the comprehensive plan review process from the perspective of the Alachua County, which is one of the review agencies.

Comprehensive Plan Review Process and Related Documents

In the State of Florida, under the Local Government Comprehensive Planning and Land Development Regulation Act (1975, amendments in 1985, 1986), comprehensive planning is mandatory for all local governments, counties, regional planning agencies and the state planning authority, (once in every 7 years, maximum of two amendments in a year) and the law further specifies that comprehensive plans prepared by the local governments should be consistent with the state comprehensive plan and plans of other regional agencies. Besides consistency requirements, the State of Florida also imposes additional concurrency requirements, which ensure that growth is concurrent with the infrastructure, and thus emphasize on the pay-as-you-grow mandate.

In Florida, the primary responsibility of the comprehensive plan review lies with the Department of Community Affairs (DCA). Current comprehensive plan review process is outlined by DCA in a flowchart and it is presented in the Appendix A for reference. Additionally, an excerpt from the State of Florida's state comprehensive plan is presented for reference in the Appendix C. The DCA seeks comments from other regional agencies on the comprehensive plan proposals and amendments during the review process. Other regional agencies involved in the review process are as per the following:

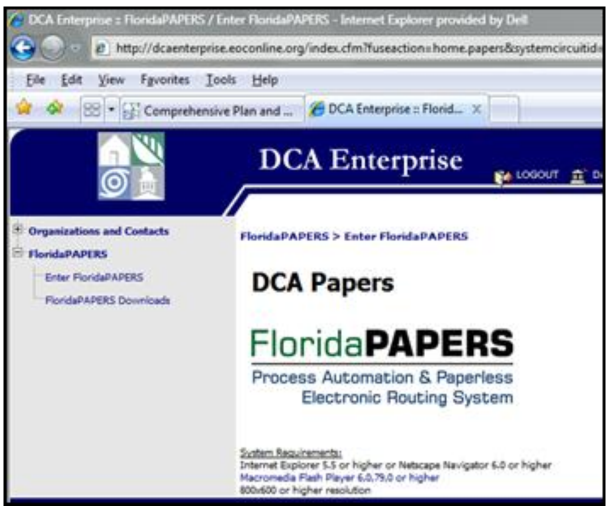
- Appropriate Regional Planning Council
- Appropriate Water Management District
- Department of Transportation
- Department of Environmental Protection
- Department of State
- Appropriate County (For municipal plan amendments)
- Florida Fish and Wildlife Conservation Commission
- Department of Agriculture and Consumer Services (For county plan amendments)
- Department of Education (For public educational facilities element)

During review, a plan preparing agency submits multiple copies of the comprehensive plan proposal or the comprehensive plan amendments to the DCA as well as all the applicable regional agencies. The regional agencies review the documents, and send their comments to the DCA. Upon receipt of the comments, the DCA notifies the local government (in 35 days of complete submission) of its intent to review, and issues Objection, Recommendations and Comments (ORC) on the proposed plan or amendments (in 60 days of complete submission). The DCA does not review for compliance adopted small scale amendments (less than 10 acres).

The local government adopts the plan amendments (within 60 days of receipt of ORC) with an effective date, and sends copies of the adopted documents (within 10 working days after adoption) to DCA as well as to the applicable regional agencies. The DCA issues Notice of Intent (NOI) within 45 days of the receipt of the complete adopted plan documents, declaring whether the plan is in compliance or not. If the plan is found not in compliance, then the negotiation may lead to a compliance agreement and a remedial plan amendment, otherwise, if the DCA's decision is challenged, then a hearing takes place before the Division of Administrative Hearings in the Department of Management Services and a final order is given.

Review Documents

The DCA maintains review related documents on its website. All the comprehensive plan and amendment proposals received in the current year are stored on the Florida Papers website (Department of Community Affairs Enterprise, 2008), and the database of the ORC documents is accessible via a link (Division of Community Planning, 2008) on the DCA website. This database also contains the Notice of Intent (NOI) documents, that specify whether the comprehensive plan is in compliance or not. All the documents are stored in the portable document format (PDF).



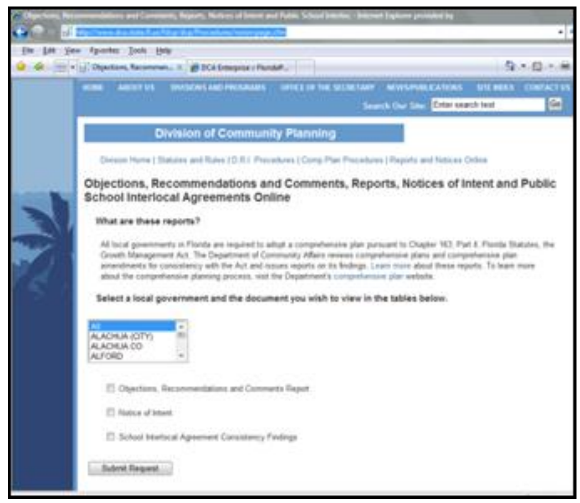


Figure 3-1. Review document databases (Source: Department of Community Affairs, Tallahassee, FL. Retrieved on Nov 21, 2007 from http://www.dca.state.fl.us/fdcp/dcp/Procedures/noiorcpage.cfm, http://dcaenterprise.eoconline.org/index.cfm?fuseaction=home.papers&systemcircuitid=18&navtitle=Enter%20FloridaPAPERS&navcircuit=FloridaPAPERS)

The DCA offers a description of rules about the document submission for the comprehensive plan review process on their website (Florida Department of State, 2008). The rules state that the review documents can be submitted in either paper or electronic format; the DCA requires that at least one paper copy be submitted. The proposal documents do not seem to include any GIS data or maps with the submission, and that is not a submission requirement.

Comprehensive plan proposals and plan amendment proposals often contain maps depicting property details and other related maps, as may be required by the data and analysis section supporting the proposed plan amendments or planning objectives. Each amendment is individually identified by an application number, which is later on used as a reference by the DCA and other review agencies while reviewing the application. In case of a plan amendment containing residential development, the data and analysis section include relevant maps, and various calculations, such as projected demand for residential units, potential water demand, and wastewater demand due to the development, possible trip generation, and current level of service standards wherever applicable. These calculations may be required for evaluating fulfillment of the concurrency requirements (Pay as you Grow mandate in Florida). The proposed plan amendments wherever applicable mention the property parcels by their tax parcel number, which can be used by the review agencies to identify these properties on the map.

A typical ORC document usually includes an overview of the proposed amendments, the corresponding objections, and at least one recommendation suggesting an approach that might be taken by the city to address the cited objection. An example of an ORC document is kept in the Appendix B. Objections raised in the example ORC document refer to the violation of consistency requirements wherever applicable and cite relevant rules or the state goals that the proposed amendment does not meet. In cases of land use change amendments, the DCA suggests that the local government should demonstrate the need for additional units (housing and commercial) proposed, with the land use analysis based on the projected population growth in accordance with the future land use plan. Some objections in the example document refer to issues of ground water recharge, obtaining access to the central sewer system, incorrect estimation of vehicle trips, and proposed developments encouraging urban sprawl.

The examination of various ORC documents indicated that in many cases objections were raised with respect to one of the following causes:

- Issues of data insufficiency when presenting data and analysis section, related to an item on the plan proposal or the plan amendment (for e.g. a residential land use change was proposed but no analysis was offered about its impact on adjacent roads, and their ability to absorb that impact).
- Issues of analysis incorrectness (For example, if additional residential land use change was proposed then it was necessary to correctly compute its impact on the infrastructure such as water, and show that sufficient quantity was available.)
- Issues of lack of analysis (For example, for a proposed residential land use change, it would be necessary to justify it with the additional residential demand based on population projections.)
- Issues of conflicting land uses (For example, if industrial development was proposed where surrounding land uses were residential, or conservation, then an objection might be taken on the basis of conflicting land uses.)
- Issues of conflicts with state goals, or local government goals or adjacent local government goals or regional goals (For example, local government had outlined a goal of conserving certain creeks in the comprehensive plan previously, but later in an amendment, they proposed a large scale development near one of the creeks, which was a violation of their own goal, and also the environment conservation related state and regional goals.)
- Issues of not satisfying concurrency requirements (For instance, in a proposal, all the data, analysis information was provided, but the development caused impacts that the current level of infrastructure was unable to absorb.)

Examples of the ORC documents indicated that they did not contain maps, and they referred to a particular map in a proposal with an identifying number. Comment documents sent by the reviewers that were present in the ORC documents, also did not contain any maps, and they too referenced the proposed amendments by their application numbers. In the examples of ORC documents, some objections raised were of such a nature that no references to a map were necessary, for instance when there was a lack of analysis. However some objections had a location component. In such cases, the ORC documents referred to maps submitted in the proposal documents with a map name or the exhibit name to discuss a spatial issue. The ORC documents used road intersections to refer to traffic situations at particular locations wherever applicable. Direct use of maps in the ORC documents was not seen in the examples browsed on the website; however the comprehensive plan and amendment proposals were seldom without maps.

Alachua County Review Process

To understand the comprehensive plan review process at a review agency, the Alachua County's growth management department was approached. Only the proposals that fall within the jurisdiction of a county are forwarded to the county for review. There are three reviewers that participate in a comprehensive plan review, one reviewer each from the environmental planning department, the public works department and the comprehensive planning department. They have a workload of about 15-20 review cases a year. The county receives a copy of the plan review proposal from the local government directly. During the review, if the county feels any need to have additional information about a case, besides the documents submitted by the local government, then they contact the local government directly to obtain the additional information. Documents may be submitted by the local government in paper or electronic format. Paper maps may be included in the paper submission, or static map images may be included in the digital submission. Submission of paper maps with the proposal is not an issue for the county, because, the county has satisfactory resources when it comes to data and maps, with their GIS department. The reviewers, during the review process, make use of the county's web based GeoGM Mapper application (Department of Growth Management, 2008) to look at the maps related to a case.

The GeoGM Mapper application is powered by an ArcIMS (ESRI's Web GIS related product) based map server that serves more than 70 layers. Data can be searched in the GeoGM Mapper on the basis of four criteria, the address, the tax parcel number, the tax parcel owner's name, and the section township range (STR). Reviewers can access area of interest on the map by querying for the parcel, based on one of the above four criteria, and can get to the appropriate area of interest and access the related data layers. If there are any mapping / analysis needs beyond the functionality offered by the GeoGM Mapper application, then the GIS department is involved for additional assistance. After all the reviewers have commented on a case, then final comments for the DCA are prepared and sent.

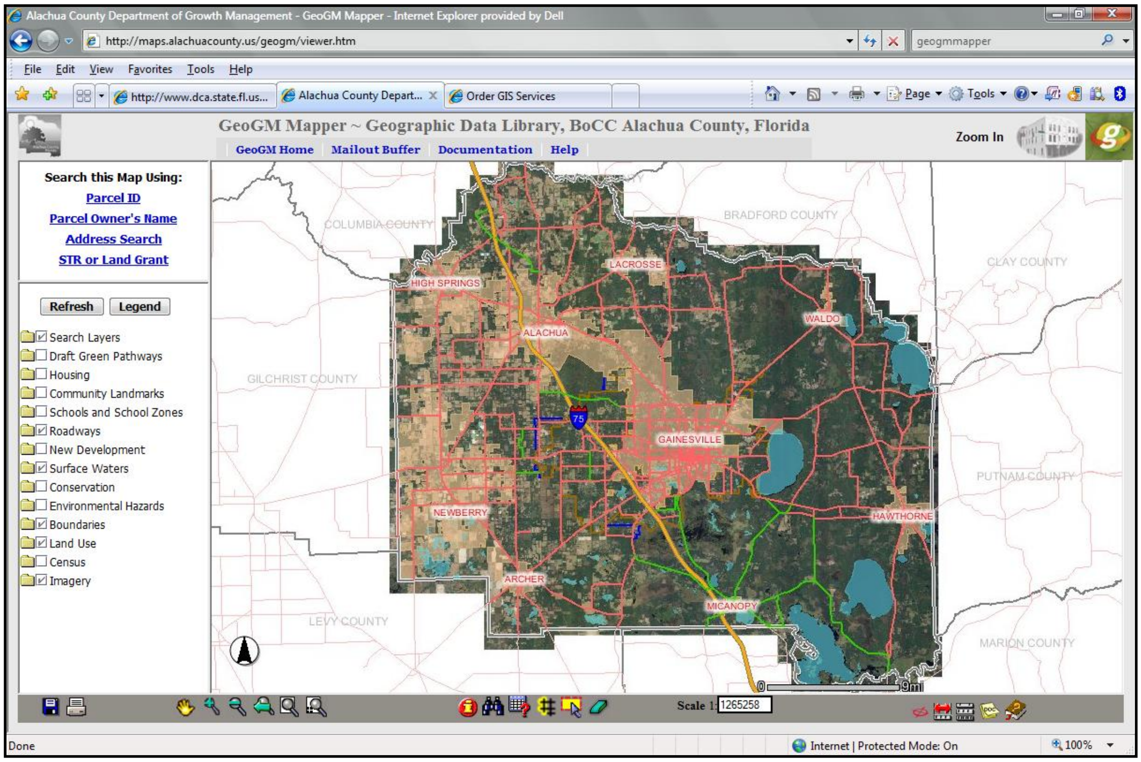


Figure 3-2. The GeoGM Mapper application (Source: Alachua county, FL. Retrieved on Dec 12, 2008 from http://maps.alachuacounty.us/geogm)

GeoGM Mapper Application

Since the GeoGM Mapper application was used by the reviewers at the Alachua County, it was examined in detail, to understand the functionality it offered. The functionality offered by the GeoGM Mapper application included following commands.

- **Display related**: Pan, Zoom in, Zoom to Selection, Zoom to Full Extent, Back to last extent, Zoom out
- **Layer related**: Layer display on, off, set active layer

- **Tools**: Measure, Identify (Information), Set map units, Scale, Data documentation
- **File related**: Print, Save map as an image (jpeg file)
- **Search related**: Find, Query
- **Selection tools**: Selection, Clear Selection (attribute table of selected features is displayed upon selection)
- **Buffer**: Graphic buffer by distance

The GeoGM Mapper application provided basic map display functionality related to map navigation and layer display. While the users could set layers visible or invisible, the order of the layers stayed fixed, and the legend of the layers was predetermined. The users could set a layer active, which was necessary for execution of the query functions, since the active layer's fields and unique values determined the query parameters. The application supported attribute query on its feature layers. The application's search by parcel, or by address, functionality was especially useful to the reviewers in identifying the exact location of the parcel of interest. The application did not support spatial query functionality. The users could buffer features in the active layer and specify the buffer distance. Users could also change the map units, and doing so was particularly useful to them in the buffer operation, since they could specify the buffer distance in miles instead of meters or vice versa. The application also allowed selection of features, and the ability to zoom to a selection. Upon selection the attribute information of the selected features, is displayed in another popup window, and then it could be downloaded in the csv format, or an excel spreadsheet format, or printed. With the application users could save the map as an image in a jpeg format and print it.

With this application, reviewers could choose which layers to view on a map (county layers, adjacent local government layers, data layers of interest such as water bodies, sinkholes), and obtain an understanding of the spatial location of features in relation to the proposed comprehensive plan development, such as where the features of interest were, and at what distance were they located from the proposed development (using the buffer command or the measure distance command). Reviewers could also query for features of interest, to find those quickly on the map and to get more information about their other attributes. Gaining such an understanding, reviewers were able to determine whether they needed further analysis of maps, whether impacts of the proposed development were positive, whether the nature of development was satisfactory, and if the proposed development was in accordance with the state goals, the county goals and the regional planning council plans.

Determination of Necessary Functionality in a Map-Enabled Planning Document

There were limits to GIS capabilities that could be implemented in a map-enabled planning document. It would not have been possible to include advanced GIS functionality due to various factors such as available choices of GIS technologies, cost of each technology, availability of resources, difficulty in implementation of the technologies and limited time for the prototype development process. Therefore, a range of functionality was identified, within which the minimum end of the range was defined from what the reviewers were currently using for comprehensive plan review, that is the GeoGM Mapper application and its functionality, and the maximum end of the desired functionality was defined as an extension of more advanced tools that were available with the GeoGM Mapper application.

Desired Range of Functionality in a Map-Enabled Planning Document

Finally, functionality of a map-enabled planning document was determined from the observed functionality of the GeoGM Mapper application, examination of review related documents and overall understanding of the review process.

Map manipulation: add data, save maps

The most important functionality for a map-enabled planning document was providing access to relevant data layers, especially since the vision of a map-enabled planning document included the ability to directly review maps associated with a planning document. In case of a comprehensive plan review document, it was important to include relevant datasets describing proposal under review, and to include additional data sets that were necessary to conduct the review. A plan preparing agency might not have access to other datasets used by different reviewing agencies and vice versa, therefore it was necessary to build functionality to add data layers to the maps included in a map-enabled planning document. Since the addition of data layers to a map would result in a new map, it was essential to include the ability to save maps as well.

With the GeoGM Mapper application, Alachua county reviewers could identify locations of interest on their maps via parcel information, but if the plan preparing agency had outlined a certain area of a parcel under review for single family units, or dedicated some area of the parcel for recreational activities, the county could only view these delineations on included paper map or on static image of a digital map, but the county could not overlay parcel delineations on their maps, unless digital data layers containing delineations were submitted by the plan preparing agency along with the application. The map-enabled planning document aimed to incorporate interactive maps instead of static map images, and therefore it was necessary to provide ability to save maps in a workable format (not as an image of a map), so that information about legend, order of layers, and other details was saved with each map.

Basic map display functionality

Since basic map display functionality is essential for browsing maps, it was necessary to incorporate zoom, pan and related functions in a map-enabled planning document.

Layer arrangement

The ability to change layer order, layer visibility, and legend is useful in effectively displaying a map, and therefore these functions were included in the desired functionality of a map-enabled planning document. However, not all mapping technologies would be able to support all these functions. If implementation of all the above mentioned functions was not possible then at the minimum end it was deemed necessary to have the ability to change the layer order, and alter the layer visibility.

Query, selection, buffer functions

Queries are vital in finding features of interest, therefore it was crucial to have this functionality in a map-enabled planning document, besides queries were also used by reviewers at the Alachua County to locate relevant property parcels and other features. There are two types of queries possible in standalone GIS software, namely attribute queries and spatial queries. Having a broad range of query functionality may offer users more choices in conducting spatial analysis, although not all technologies support all types of spatial queries. Therefore, in a map-enabled planning document, support for attribute queries was required as basic query functionality, and support for spatial queries was considered desirable as that could make the map-enabled planning document more powerful.

Selection of features in a map is quite important when a user wishes to examine in detail specific features, and therefore that functionality was desired in a map-enabled planning document. Buffering of features is also frequently used to find out if some feature is within a certain distance of another feature. For instance, residential development within a certain distance of roads is desirable, but residential development within the 100 year flood zone may be undesirable. Therefore buffering features was considered a necessary tool in a map-enabled planning document. Additionally saving buffers could help in executing queries on the buffered features, or in conducting additional spatial analysis if necessary, and hence that was added as a desired functionality in a map-enabled planning document.

Saving query results

One of the important aspects of both attribute and spatial queries was that a subset of dataset could be obtained based on some criterion. Attribute queries played a significant role, in understanding distribution of data. For instance a reviewer might want to know how many roads satisfied the level of service criterion of one. They could perform an attribute query on roads to find out which road features met the criterion and which road features did not meet that criterion. Such analysis, fueled by queries, might go into the review process. Therefore, it was considered useful to capture query results and save those in a suitable format. Alternatively modification of selections was also found useful, if one were able to add to or subtract from a selection. This was not considered a necessary feature in the minimum range of functionality, but it was considered useful if it could be incorporated in the advanced range of functionality.

Modification of datasets

Some functionality such as clipping of datasets, merging of datasets, or obtaining intersection of datasets is useful in GIS operations. This kind of functionality was not essential for the purposes of review, as reviewers would be working with already existing standard datasets. Also, capability to edit standard data is not always provided, as users might inadvertently delete part of the data, and affect data integrity. Therefore in light of these concerns, modifications of datasets functionality was considered useful but above the minimum range of functionality. Moreover, it was felt that instead of data modification, it would useful to have data extraction functionality that is the ability to export selected features from a dataset to create a subset for additional work. Ability to extract subsets of data could also serve as a way of saving a specific selection set. This kind of functionality was not available in the GeoGM Mapper application, and was desired in a map-enabled planning document.

Providing list of referenced datasets, and map files

To validate results of the review, or to replicate the results, it was necessary to know what actions were performed, and on which datasets. Sometimes, similar datasets may exist but at a different level of accuracy, and that may generate different results for the same action. The county review process did not need to keep tab of the data layers used in review, because data layers available for review were constant, since they were hosted on a web server and could not be altered. However, if a map-enabled document did not use a centralized data repository, then it would be necessary to know about the data layers referenced in a document. Therefore, ability to obtain a listing of map files and data layers accessed by a map-enabled planning document was considered a necessary functionality in the map-enabled planning document.

Non-Mapping Functionality

Non mapping functionality required in the map-enabled planning document was derived from examination of the review process.

Comments on the map and the text portions of the document

Since a map-enabled planning document was expected to be used in the context of comprehensive plan review, it was felt that it would be useful to have the ability to incorporate comments in a document that could be associated with a reviewer. Also, if comments could be linked with relevant portions of text, that would prove to be useful in understanding context of the comments. Therefore this functionality was added in the desired range of the functionality of a map-enabled planning document.

Ability to distribute the map-enabled planning document with maps and map data

If the map-enabled planning document was web based, and contained data that was hosted in a centralized repository accessible from multiple locations, then the issue of distribution of the map-enabled planning document might not arise. However, if that was not the case, then it would be necessary to package data files and map files referenced in the map-enabled planning document together with the text files, so that it could be distributed without any information loss. Since the review process involved an exchange of comments amongst agencies; it was considered necessary to have tools for distributing map and data files with the planning document.

Integration between text and map data

One of the goals behind development of a map-enabled planning document was to bring about tight integration of text and maps. This kind of functionality was not very commonly seen in examples, however the ePlanning example described in the literature review had implemented a similar kind of functionality. A typical planning document has multiple references to maps, and currently planning documents contain static images of maps. In a map-enabled planning document, since maps as well as mapping data would be included, functions related to linking between text and map data were desired. Also if possible, ability to search for presence of selected text within map data was desired as that would enable the user to locate items mentioned in the document using maps. Therefore these functions were added to the list of desired functionality of a map-enabled planning document.

Choice of Mapping Technology

After the range of desired functionality had been identified, next a comparative overview of different GIS technologies was obtained, in order to assess what might be possible with each technology. In the literature review, general description and examples of about six GIS technologies listed below were examined.

- Standalone GIS Technology
- Web GIS technology
- Embedded GIS systems
- Open source GIS technology
- GIS Web Services
- Spatial databases

Based on information gathered about these technologies standalone GIS technology, GIS web services, and spatial databases were found to be inappropriate choices for development of a map-enabled planning document. The reasoning behind this is explained next and it is also presented in the table 3-1.

Standalone GIS technology refers to dedicated GIS applications that are proprietary. These are primarily desktop applications, offering a wide range of GIS functionality, comprising of data creation, modification, analysis and visualization. For the sole purpose of review, a complete range of GIS functionality is not necessary, as reviewers do not need to edit datasets, merge datasets, or invoke specialized GIS functions such as creating a slope analysis, or network analysis. Standalone GIS applications are the most expensive of all the GIS technologies considered for the prototype development, because they are highly priced due to a wide range of GIS functionality and each machine having standalone GIS requires a license to run the application. Besides, to bring about integration of text and spatial data, customization of all the technologies considered is necessary. However, other technologies are cheaper than standalone GIS, and their limited range of functionality may be sufficient for the purpose of the review. Therefore, standalone GIS technology was eliminated from the consideration of candidate technologies for the prototype development.

Table 3-1. Technology comparison chart

Choice of GIS software	Server side	Client side	GIS functionality	Expense	Text and map integration
Standalone GIS (ESRI ArcGIS, Intergraph solutions)	Nil	Full	Complete	Most expensive	Through programming, linking with external text processing software possible.
GIS web services (Arc Web Services)	Full	Nil	Limited	Expense per install on server machine only, additional service subscription charges	Through hyper linking, some programming may be necessary
Spatial databases	Full to partial (varies)	Full to partial (varies)	Limited to higher	Database software cost, spatial technology cost	Customization will be required.
Web GIS (ArcIMS solution by ESRI)	Full to partial (varies)	None to partial (varies)	Limited	Expense per install on server machine only	Through hyper linking, some programming may be necessary
Embedded GIS (in desktop software, ESRI based ArcEngine implementations)	Nil	Full	Full range required functionality needs to be programmed	Relatively less expensive, run time license on each machine	Through programming, more opportunities through interfacing of text and GIS software
Open source desktop GIS	Nil	Full	Limited to higher (application specific)	Free	Through programming and hyper linking, interfacing with text software maybe complicated in a desktop setup, depending upon the programming language of the open source software
Open source Web GIS	Full to partial (varies)	None to partial (varies)	Limited to higher (application specific), can be enhanced	Free	Through programming and hyper linking

GIS web services are preprogrammed modules that provide GIS functionality and these are web based solutions. Examples of web service technologies demonstrated functionality related to data hosting services, map display tools, distance finding, and report generation based on preprogrammed queries. In comprehensive plan review, reviewers would need to work with their own data, apart from the maps included with each review case and execute case specific queries. Therefore using preprogramming analysis logic for the purpose of the review was not a valid option. Also, local data could not be added in the GIS web services. Besides, it was felt that building additional functionality in web services to create a tighter integration between text and maps might not yield any different results than what might be possible with the web GIS technology. Therefore there did not seem to be any advantage in using this technology over other web based technologies.

Spatial databases present a new way of implementing GIS functionality in that they work with the existing structure of relational database management systems, by building in a spatial awareness in the data records. The query facilities in spatial database management systems can support queries with standard query languages such as SQL (Sequential query language). However, since the map-enabled planning document did not require database management capability, it did not make sense to use spatial databases for /implementing the required GIS functionality. Elimination of these technologies resulted in three candidate technologies, namely the web GIS technology, the open source (web based or desktop based) GIS technology and the embedded GIS technology.

Candidate Technologies

Upon identification of candidate technologies, each technology was further examined in detail in terms of its functionality and implementation. Also each technology’s ability to support customization to develop tools for linking text and map data was considered when making final choice of the appropriate technology to implement a map-enabled planning document.

Web GIS technology, advantages and disadvantages

Web GIS technology has client server architecture and most of the GIS functionality offered by the application is handled by a server. The datasets involved are also stored on the server. As a result it costs nothing for the user, but a server machine requires a license for running the web GIS application, if it is proprietary software. This makes it very cost effective for the users, although the cost of running a proprietary web GIS application on the server machine is quite high. Web GIS works with internet media, and therefore can support concurrent users; at the same time, it is subject to network congestion, and has slow application delivery because the processing takes place on the server.

Additionally, the functionality offered by a web GIS application may be limited. Functionality of the GeoGM Mapper application has been discussed in detail previously. The GeoGM Mapper application is implemented using ESRI's ArcIMS solution. The ArcIMS software's latest (2008) version (9.3) has many improvements over its previous versions. It now supports feature streaming, allows for data extraction, and supports variety of data formats. However, previously that functionality was not there, and map output was always presented in a raster (image) format with feature data also rendered like raster data, this resulted in poor resolution when maps were zoomed in for closer viewing, this may have changed in the current version. Spatial queries are not yet supported in ArcIMS. ArcIMS based web GIS can be customized with ArcXML (ArcIMS programming language) to adjust its look and feel, but it is not clear if out of the box GIS functionality can be enhanced by programming to support functions like spatial queries or saving maps in a workable format and not as images.

Addition of local data to web based maps, and saving maps for additional work is a problem in web GIS, because once the browser is closed, it does not remember user's map configuration for future use. Moreover saved maps may still be in the image format, although feature streaming is currently supported. Integration with text and maps may be somewhat easier with web GIS, as there are some examples (ePlanning example) that have attempted to implement similar functionality. Additionally the internet media offers hyper linking capabilities, which can be easily used for linking text and maps, if the text is in a web based document format. On the whole, this option was found cost effective for users but expensive for running it on a server, and it offered limited GIS functionality (all the minimum functionality identified as necessary in the first part of this chapter could be implemented), compared to the embedded GIS technology, described later in this text.

Embedded GIS, advantages and disadvantages

Embedded GIS involves programmatically embedding GIS (Geographic Information Systems) functionality within another application such as Microsoft Word, or Excel. The greatest advantage with embedded GIS is that core GIS programming objects are exposed to developers, and that allows developers to build any required GIS functionality. Thus it is possible to build spatial queries, or define other custom GIS functionality. This means that for the map-enabled document's GIS functionality, all of the minimum GIS functionality and additional GIS functionality identified in the first part of this chapter can be implemented with this technology. Embedded GIS technology is offered by proprietary software makers. We are considering using ArcEngine, the embedded GIS technology by ESRI, software makers of the ArcGIS suite of software. Their software is highly popular (especially in Florida), there is a good set of examples to refer to, there are numerous books on its usage, and there is a strong user community to assist new users. Therefore, this software is a good choice for building the map-enabled prototype.

One disadvantage of this technology is that beyond the basic map display controls, and the map navigation tools (zoom, pan) there isn't much ready to use functionality with ArcEngine. The entire functionality has to be built in with programming, so this implementation requires more programming work. Adding local data and saving maps is possible with embedded GIS. The saved maps may be accessed in other related software, and one can work with the same maps again. ESRI's embedded GIS solution ArcEngine, is related to the ArcGIS software suite, and therefore maps saved with embedded GIS can be opened with any application in that software suite. The disadvantages of the embedded GIS technology in comparison with the web GIS technology are that it is a desktop based software, and it is not free to the users, although it is cheaper than the standalone GIS software, and it is much cheaper than the cost of running a proprietary web GIS application on a server. Thus, each computer hosting an embedded GIS application has to obtain a valid license at cost. On the other hand, if the computer running an embedded GIS application has a valid installation of another product of the ESRI's ArcGIS suite, then the embedded GIS application can use that application's license, and becomes free to the user. ESRI's ArcGIS software is used by almost all the counties, cities, government agencies, and numerous private sector organizations and non government organizations in Florida and in the U.S. To these users a map-enabled planning document prototype developed with ArcEngine would be free. This option may be useful for the agencies that do not provide access to standalone GIS software for all the plan reviewers, due to reasons of affordability, who may now be able to offer the embedded GIS option due to its lower cost.

Another advantage of using ArcEngine based embedded GIS is that it supports use of the Visual Basic or Visual Basic for Applications language for customization. This language is supported by the Microsoft Word software for purposes of customization. Microsoft Word is popular text processing software, and many planning agencies use Microsoft Word for text processing, therefore if GIS capabilities are embedded in Microsoft Word, then that may result in a user friendly application for the reviewers. The reviewers do not have to learn new software. Microsoft Word has sophisticated word processing tools, and has its own core object model that's available for use within the macro customization capability. With the Microsoft Word programming objects, and the embedded GIS programming objects, better opportunities exist for integrating text and map data as compared to the web GIS scenario. This is a highly positive point for the embedded GIS technology.

On the whole, embedded GIS technology can provide strong functionality set, and to the users of ESRI GIS software, it may be no more expensive than the open source GIS technology. Therefore this technology was considered quite favorably for the prototype development of the map-enabled planning document.

Open source GIS, advantages and disadvantages

Open source GIS applications are free, and their source code is exposed; therefore they can be modified as required. This is the cheapest option for making the map-enabled document. Some of the open source software is developed for use with other open source software, either to complement their functionality or because no open source software exists in that area. For instance some open source software is particularly developed for the Linux platform and not for Windows platform. Thus when considering open source software, it is necessary to ensure platform compatibility as well as system compatibility. Most agencies use windows based operating systems, and windows based software, therefore it is important to have software that is compatible with their systems. Open source software may either be web based, or desktop based. If it is web based, compatibility is not an issue for agencies, because then it is accessible via an internet browser. However, implementation of web based software may be possible through particular free or open source servers, and that is a restricting factor for development. Another factor is that open source alternatives are created by developers in their spare time, and therefore there may not be complete documentation available, development may be slow, and the software may be error prone. At times, development of the open source software may be abandoned as well, and in such a case there will be no support. Having mentioned all these problems, there is some powerful open source GIS software available, which has been previously mentioned in the literature review. Grass GIS, and QGIS software, when used in conjunction with each other provide an easy to use GUI, and support windows operating system. GIS functionality offered by this combination of software may be quite good, perhaps better than the web GIS option. However, in the map-enabled planning document, GIS technology is employed to integrate maps and mapping functionality in the planning document and to bring about text and map integration. The text and map integration may be difficult to work out when two or three different software are involved, as each software may impose different customization requirements and may not work well with the text processing software. Considering these aspects, while open source GIS technologies were a good choice, their implementation and customization was found to be difficult, and hence open source GIS technologies were not considered further for the development of a map-enabled planning document.

Selected Technology

Thus, after eliminating open source GIS technologies from the candidate technologies, the choice of GIS technology was limited to either the web GIS technology or the embedded GIS technology for prototype development of a map-enabled planning document. The web GIS technology was free to the users, but it could be expensive to install on the server if a proprietary web GIS technology was chosen. The functionality offered by web GIS technology was limited compared to the functionality offered by the ESRI based embedded GIS technology, namely the

ArcEngine software. ArcEngine was a desktop based technology that had to be purchased, however it was the cheapest technology amongst the ESRI's ArcGIS suite of software, and more importantly it was free to the users of ESRI's ArcGIS suite of software. Since considerable planning agencies in the state of Florida use ArcGIS software, the ArcEngine based prototype would be free of cost to these agencies.

Finally, the embedded GIS technology by ESRI was selected for developing a prototype of a map-enabled planning document, primarily because it presented the ability to build all the required GIS functionality. Another important reason for its selection was that it could work very well with popular word processing software, Microsoft Word, and with Visual Basic as the common customization language between the Microsoft Word software and the ArcEngine software, this technology offered more opportunities for linking text with map data.

CHAPTER 5
PROTOTYPE DEVELOPMENT

The embedded GIS technology was chosen for prototype development considering available technologies and the desired functionality of a map-enabled planning document identified previously. Following is a list of functionality desired in a map-enabled planning document.

- Add data
- Save maps
- Basic map display functionality such as pan, zoom and so on.
- Layer arrangement functions including change layer order, change layer visibility and modify layer symbology
- Query, selection, buffer functions including attribute queries, spatial queries, buffer features, selection of features
- Saving query results
- Modification of datasets especially extraction of selected features to form a subset, and clip and merge datasets
- Providing list of referenced datasets, and map files in the document
- Adding comments associated with map and text portions of the document
- Ability to distribute a map-enabled planning document with maps and referenced datasets
- Tools for interlinking text with maps, text with features, and finding text in maps

Technology

Two main technologies were used in making prototype map-enabled planning document.

- ArcEngine: ESRI's ArcEngine software contains a library of embeddable GIS components and tools packaged together for developers to build new or custom desktop applications.
- Microsoft Word: Microsoft Word is standard word processing software widely used at many universities and in the business world.

In the prototype, appropriate GIS technologies were embedded in the Microsoft Word processing software, primarily because most planning documents are prepared with the Microsoft Word software, and planning personnel are familiar with it. Also it was felt that the presence of mapping tools within the word processing software might help make a map-enabled planning document much more user-friendly.

The prototype was initially developed with the ArcEngine version 9.0 (current software at the time of development), Microsoft Word version 2000, and Microsoft XP as the operating system. However, later, the application was modified to make it compatible with ArcEngine 9.2 (ArcGIS 9.2 suite) and Microsoft Word 2003 on Microsoft XP operating system. The application also runs on ArcGIS 9.3 suite and Microsoft Word 2007(in the compatibility mode) on the Microsoft Vista operating system.

To summarize, the system requirements of the prototype are Microsoft Word software (2003-2007), ArcEngine Runtime license and installation, and Microsoft Vista, XP or Windows 2000 operating system. Systems that have the desktop installations of ArcMap, ArcEditor or ArcInfo (9.2/9.3), do not require additional installation of ArcEngine Runtime files or license. Therefore, the application can run directly on these systems, upon confirmation of a valid license check, with no additional cost. The entire prototype functionality is developed using the Visual Basic for Applications language exposed via macro functionality in the Microsoft Word software. In order to run this application, the following is necessary.

Macro content enabled: To do this, go to the Microsoft Word application’s main menu bar, and select Tools -> Macro -> Security. In the security dialog box, on the Security Level tab, select Medium security, this security level lets users choose whether or not to run potentially unsafe macros. In the security dialog box, on the Trusted Publishers tab, check the checkbox for item Trust Access to Visual Basic Project.

Upon opening a map-enabled prototype document, the Microsoft Word software may bring up a message box that states, This application is about to initialize ActiveX controls that might be unsafe. If you trust the source of this file, select Ok and the controls will be initialized using your current workspace settings. It is necessary to click Ok on this message box. ActiveX controls used in the document are related to mapping functionality controls, which comprise of built in controls available directly in the ArcEngine, such as a map control or a page layout control.

The prototype makes use of some standard references in the Microsoft Word VBA, and for complete functionality of the prototype it is necessary that there is no missing reference present. User may not have to do anything about this unless they encounter an error that reports a missing reference or some commands do not work.

Prototype Development

To demonstrate functionality of the prototype, a 20 page extract from the The Conservation, Open Space, and Groundwater Recharge Element of the City of Gainesville Comprehensive Plan document was used which is part of the Petition 175CPA-00 PB dated January 31, 2001 (City of Gainesville, 2001). This document was downloaded from website of the City of Gainesville, during the time of prototype development. It was obtained in a portable document format (PDF), and the 20 page excerpt was manually converted into a word document.

This document identifies various environmental resources of the city, and describes functions of these resources; it also identifies key community priorities for environmental conservation, and proposes strategies for the attainment of such conservation. There are four maps within the selected portion of the document. These maps were recreated in ArcGIS software, to use as interactive maps, for making a map-enabled planning document prototype. During map preparation, exact datasets used in static maps present in the original PDF document could not be obtained, however considering the demonstrative purpose of the document; similar datasets from the FGDL (Florida geographic data library) library were substituted for creating digital maps. For instance, one of the included maps depicting creeks identifies significant creeks in the legend. While a current dataset on creeks of the Gainesville was used from the FGDL data library, it did not contain all the creeks used in the original map with the document. However, for demonstration of the prototype it was not necessary that all datasets used in the reference maps match exactly with the original datasets, therefore the closest matching datasets were used.

The prototype functionality was also captured in a web page animation format using screen cast videos for most of the commands to demonstrate their usage, and links are provided to these web pages in a command reference document presented in the appendix E. A document containing a description of all the commands is provided in the appendix D.

Prototype Structure: Menus

Like other planning documents, the original document used for making the prototype included static images of maps. The prototype document however allows users to access maps associated with static images of maps in the document.

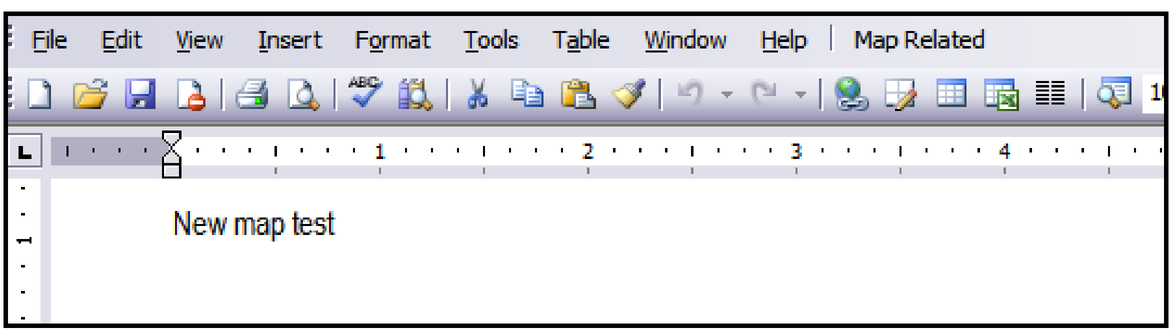


Figure 4-1. Map related menu item addition

In this prototype, GIS functionality is accessible via an additional item in the main menu bar in the Microsoft Word software; the additional menu item is titled Map Related. The Map Related menu item provides access to maps in the document, with commands like New Map, Open Map and Delete Map. Besides these commands the application also contains commands related to links between text and maps in the document, and other commands related to comments on maps or text.

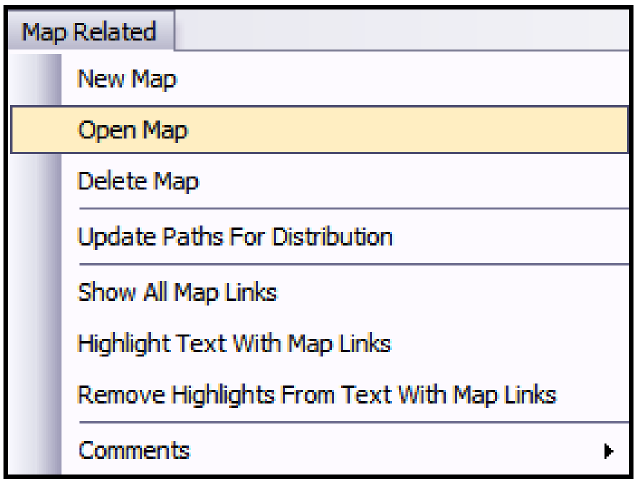


Figure 4-2. Map related commands

Some of the commands present in the Map Related menu item, are also available in some context sensitive menus that pop up when right-clicked. For instance, when a map image is selected in the document, the right-click popup menu shows the command Open Map.

Other map-specific commands are available in a windows form object that is used to display maps. The ArcEngine software provides developers with a number of form-based controls that are designed for displaying maps. These controls are used in a windows form, and this form, also referred in this document as a Map dialog box, is mainly used to display maps and perform any map-related tasks in the planning document. The map dialog box window has its own toolbar with map specific tools and related menu items.

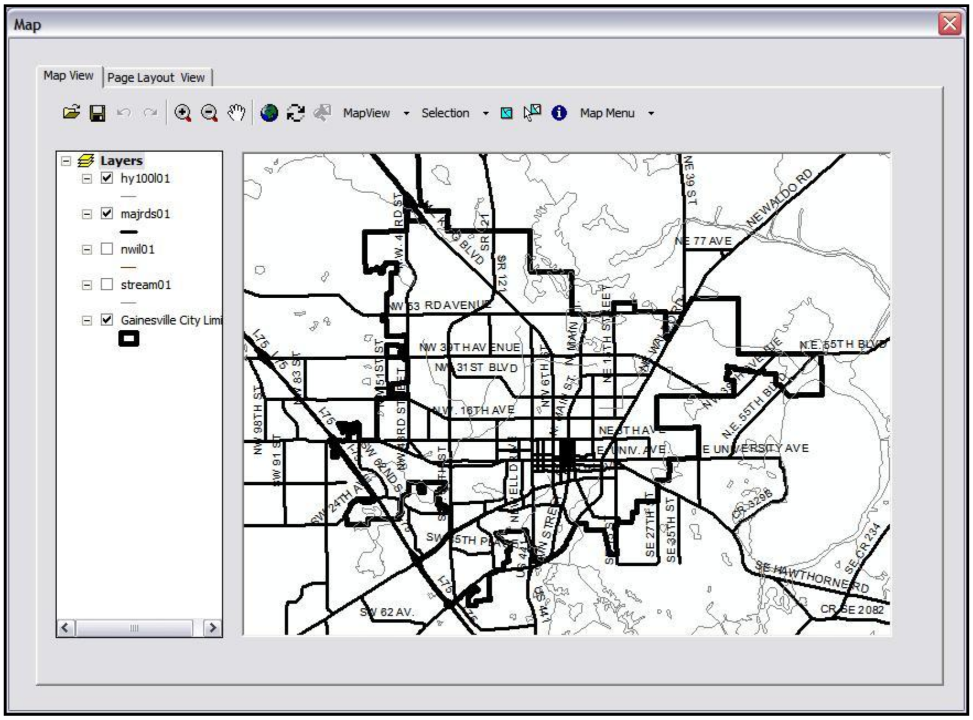


Figure 4-3. Map dialog box: Map view

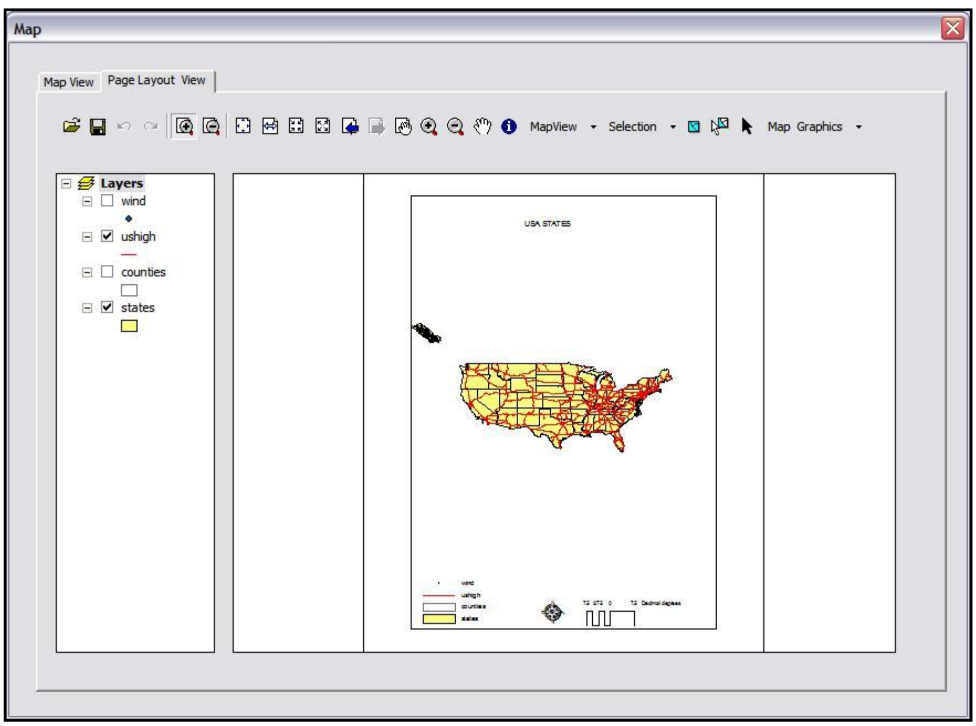


Figure 4-4. Map dialog box: Page layout view

Like the ArcMap (ESRI) software interface, the map dialog box supports two views, a map layout view and a page layout view. The page layout view defines a map in relation to the page, and allows users to add elements like legend, or text to the map, for printing or formatting purposes.

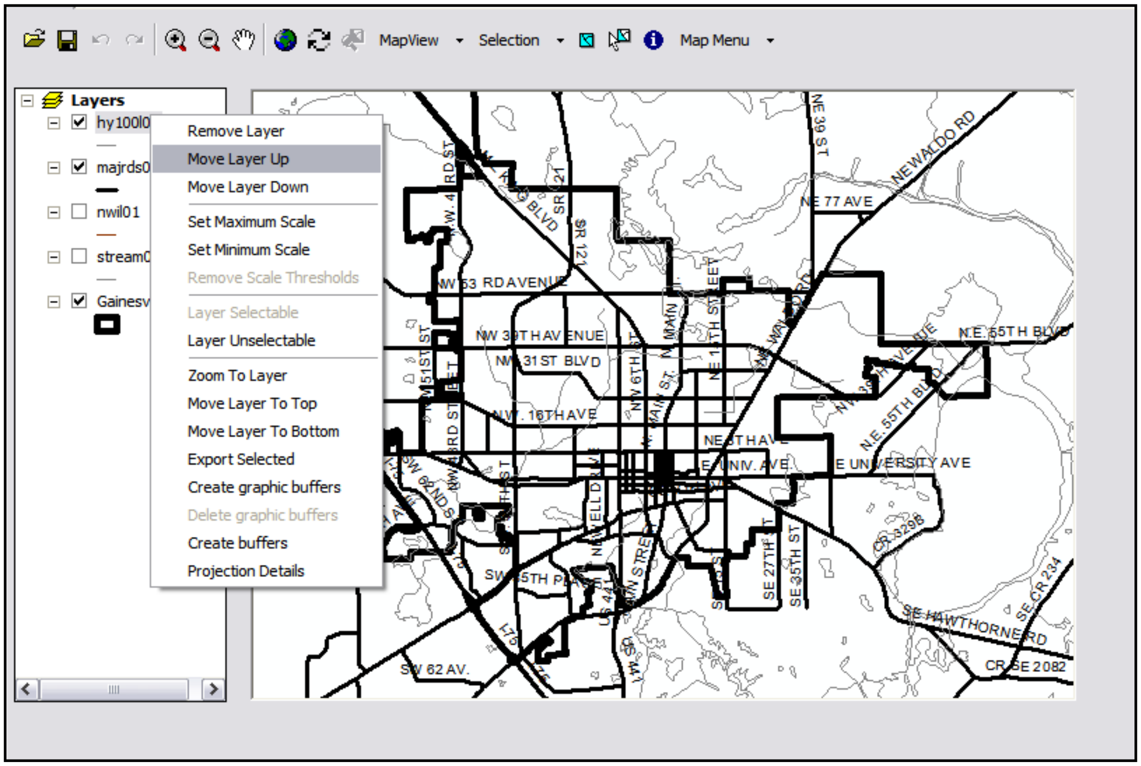


Figure 4-5. Right-click popup menu for layer

The map dialog box has a Table of Contents area on its left side that displays the contents of the map including a list of layers with layer symbols. The table of contents area is visible in the map view and the page layout view. The map toolbar varies in its tools and commands for each view. It is expected that most of the functions will be operated upon the map view, and the page layout view will be used basically to formulate the map image. Accordingly, some commands are view specific on the map toolbar. All the layer related commands are grouped in a right click popup menu that opens up when a user right clicks with a layer selection in the table of contents. The layer specific popup menu contains commands that deal with layer order, layer selection status, layer scale, zoom to the layer, buffers, and exporting selected features in that layer. Some common commands that can act on all layers are grouped in another right-click popup menu that pops up when the data frame name is right clicked.

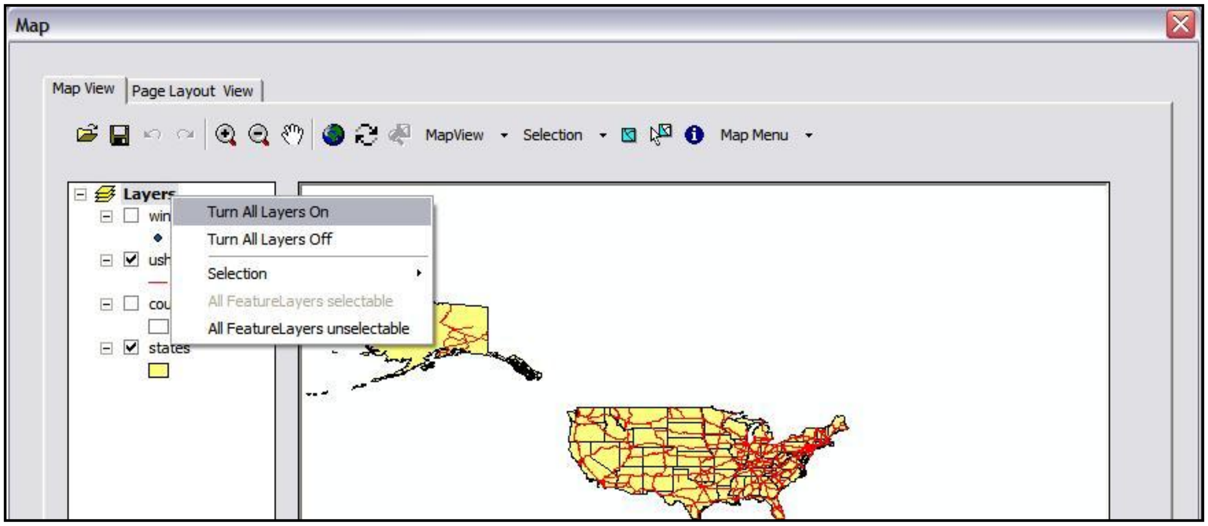


Figure 4-6. Right-click popup menu for data frame

For instance, in the following figure, the data frame name is Layers and right clicking on it opens up another popup menu, which contains commands that operate upon all layers at once, for instance, the All Featurelayers Selectable command sets all the layers to the selectable status. It is also possible to set all layers visible or invisible through this popup menu.

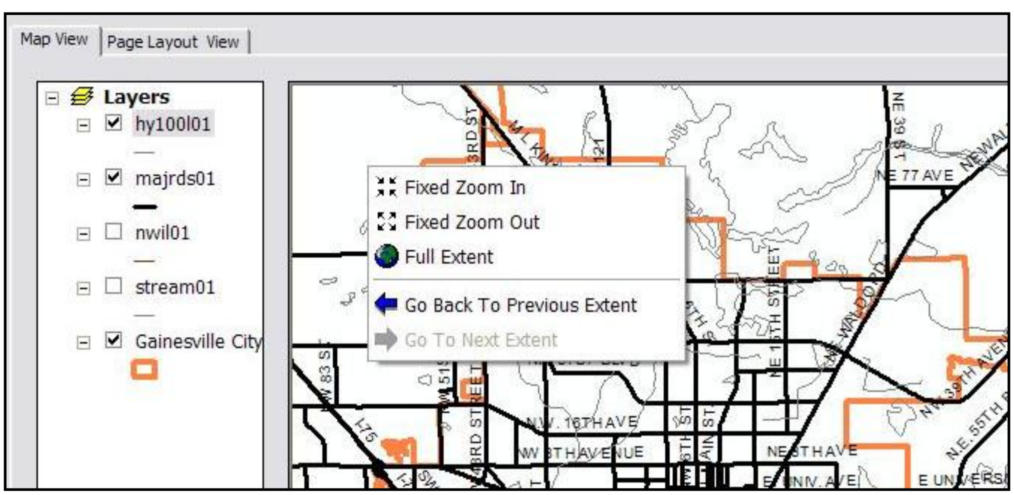


Figure 4-7. Right-click popup menu for the map view window

There is also a right-click context menu associated with the map view and it opens up when a user right clicks on the map area. This context menu primarily deals with the zoom in and the zoom out tools, and has commands to go to the previous extent or the next extent. The contents of this context menu are the same as the contents of the Map View menu item in the main toolbar present in the map view. Layer and map specific right-click context menus are not available in the page layout view, because it is assumed that most map related functions will be performed in the map view.

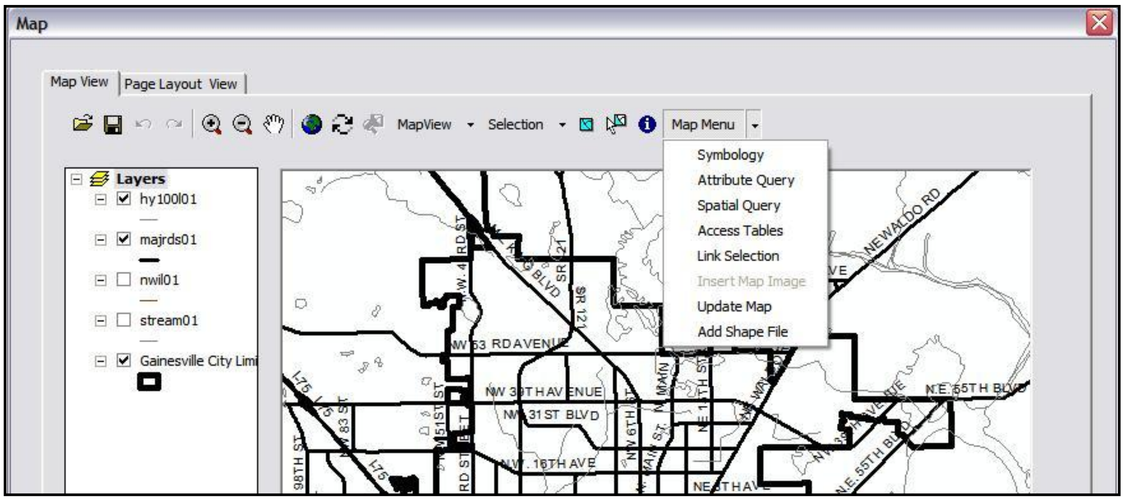


Figure 4-8. Customized menus specific to the map view

The toolbars present in the map view and the page layout view also vary. However, both toolbars contain the Selection menu item, that lets users select features, or clear the selection on the map. Zoom and pan tools in the map view, work on the actual map, whereas the zoom and pan tools in the page layout view work on the page. For instance when the zoom tool is clicked upon, in the page layout view, it zooms the page layout and it does not zoom in the extent the map visible in the data frame showing map. Commands for queries, and addition of a shape file to the map are only present in the map view. Commands Insert Map Image (in the document), Update Map and Symbology (layer related) are available in both the map view and the page layout view of the map.

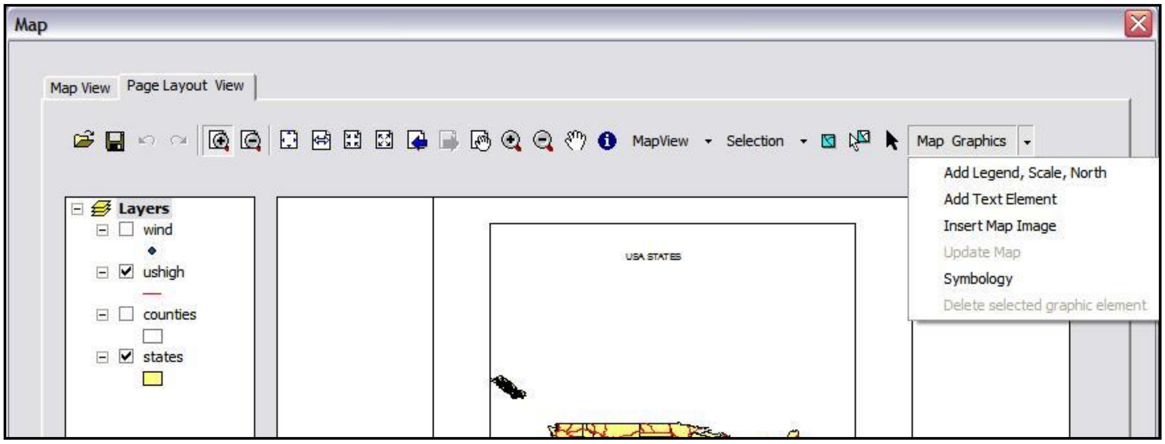


Figure 4-9. Customized menus specific to the page layout view

The page layout view contains page layout related commands for working the page layout. These include Add Legend, Scale, North and Add Text Element. These commands allow users to insert page layout elements on the page layout. Since eventually the page layout becomes a picture in the word document, users can add further details to the map picture with drawing tools available in the word document also.

Two other context sensitive menus in the Microsoft Word software are also modified to add map related commands. One of the context sensitive menus gets invoked when a user right clicks on a text portion of the document. This menu is modified to contain commands for linking selected text with maps, opening maps to show links, and finding text in the layer attribute tables.

The Inline Shape context menu is also modified to add the Open Map command to it. The map pictures inserted in the document are of a particular type of shape defined in the Microsoft Word objects, termed as Inline Shape. Therefore the modification to the Inline Shape context menu enables users to right-click on the map picture, and presents the Open Map command, which then brings up the map dialog box with the selected map.

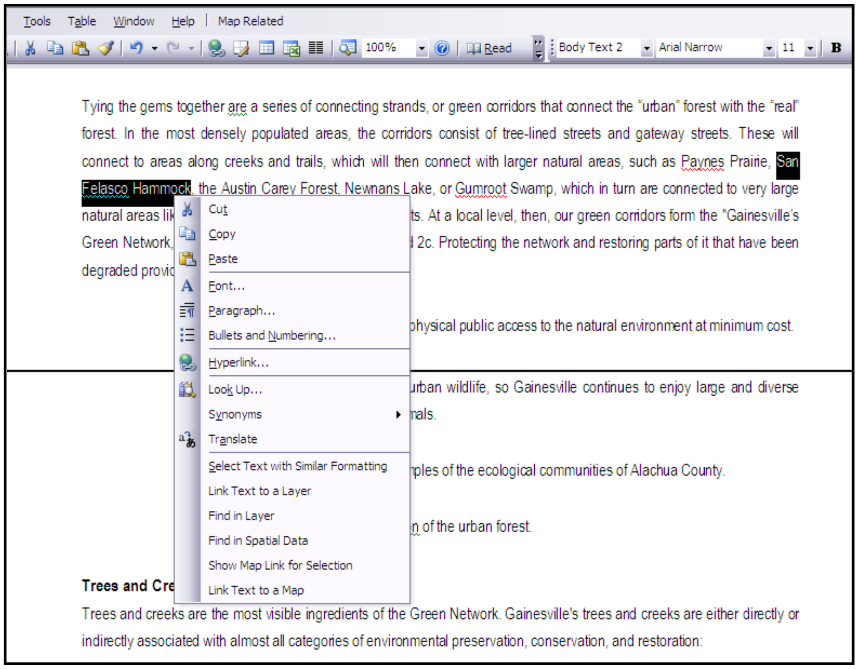


Figure 4-10. Modified right-click context menu for text selection

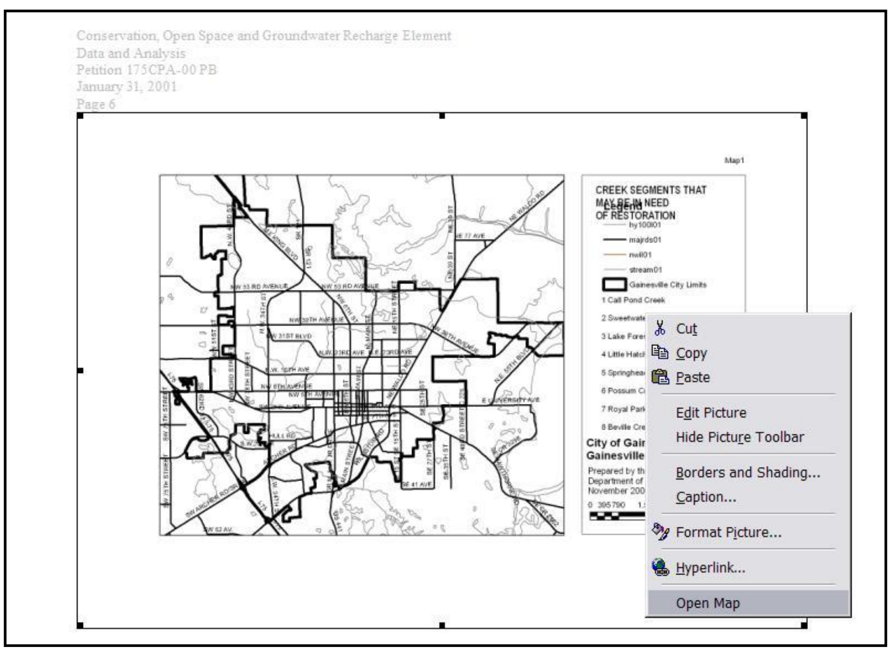


Figure 4-11. Open map menu item addition to the inline shape context menu

Prototype Structure: Preparing Interactive Maps

According to the main idea behind the map-enabled planning document, the document contains functionality to bring up a map when necessary from the picture of the map included in the document. There are two elements associated with a map in the planning document prototype, one being an image of the map, and the other being the actual map behind it, complete with data sets associated with the map. An image of a map could be a formatted map image complete with legend, scale and north arrow, or it could be just a snapshot of some feature in the map. In order to bring up a map by clicking upon its image, map information has to be associated with the document. To store all the information related to a map means referencing all the datasets associated with it, then referencing the arrangement of datasets, their legend, scale and display parameters, and obtaining the formatting information of the map image, that is information such as its title, presence of legend, and use of scale bar.

New map

In the map-enabled planning document, there are two ways in which a new map and an associated interactive map image can be specified. An interactive map can be inserted in the planning document by specifying either the individual datasets (currently only shape files and .lyr files are supported) or by specifying an .mxd document (mxd is a native ESRI format to store map documents). Also a map image name (no spaces are allowed in the name, has to be unique) has to be supplied to uniquely identify the map picture in the document. Other optional information such as comments about the map picture and the name of the map creator if supplied is stored along with the map details within the document. Users could choose to just specify a map picture and proceed to the map dialog box, and add data there with the Add Shape File command present in the Map Menu on the map view. After manipulating map display, users can save the map formed in an .mxd format, update the map details, and then the update operation will create a new map picture and insert it in the document.

A map image can be prepared and inserted in the document, by just specifying relevant datasets without saving map in an mxd format; however, in such a case, no information about the map scale, or layer symbology will be retained, and thus the map that comes up after clicking upon its image may not be an exact reproduction of the image in terms of legend, layer order, visibility and scale. Therefore, ideally, it is good to have each map image in the document associated with unique mxd format map file, although the datasets used in the map documents may be same. The Collect Map Related Details dialog accepts selection of layers (shape files or layer files *.shp , *.lyr) with the browse button, accepts input of a map document .mxd file, and can have information about the map creator and the comments related to the map picture.

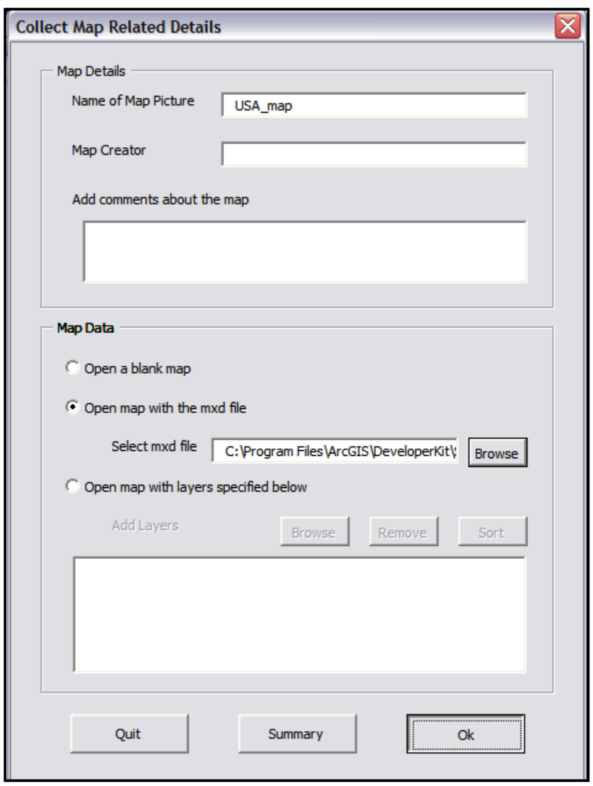


Figure 4-12. Dialog box associated with the new map command

Once all the required information related to the new map is specified by the user, a map dialog box opens and displays the map. If no layer or mxd information is specified it could be a blank map, in the map dialog box. After the user is satisfied with the map manipulation (adding datasets, setting symbology, scale), the user can choose to insert the map image in the document from the map menu present in the map view of the map dialog box. The Insert Map Image command exports the map (it could be a map view, or page layout view, whichever is active at the time of insertion) in a .jpg format and then inserts the .jpg file at the current cursor location in the word document.

Open map

Once an interactive map image is inserted in the document, the map behind it can be accessed by either right-clicking on the image, and choosing the open map menu item from the context menu or the map could also be accessed by navigating to the Map Related menu on the Microsoft Word menu bar, and selecting the Open Map menu item.

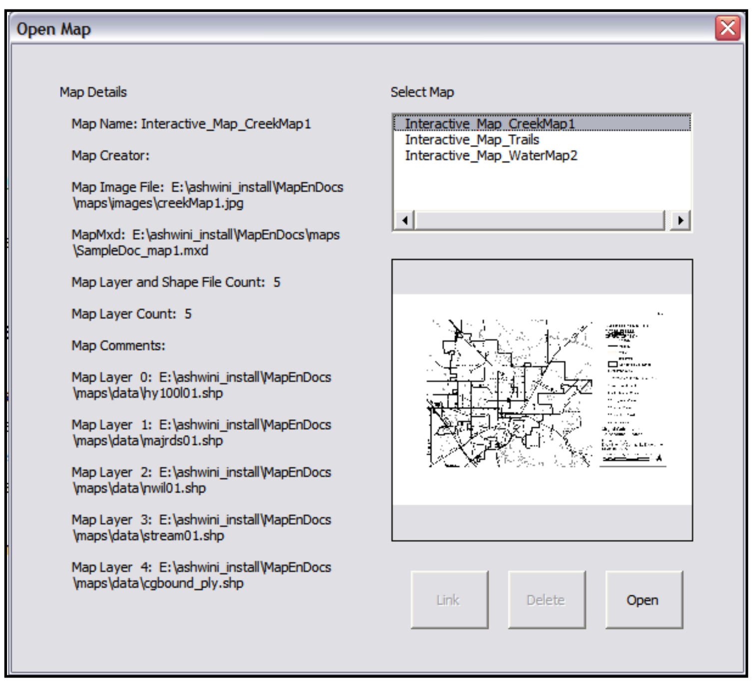


Figure 4-13. Open map dialog box

The Open Map menu item brings up a list of existing interactive map images in the document; it identifies each map image by the unique name assigned while creating the interactive map and the user can choose map of their interest in order to open it. Users can also delete a map, by selecting the Delete Map command from the Map Related menu item present in the Microsoft Word menu bar.

Update paths

Once all the interactive map images are inserted in the planning document, users should once execute the command Update Paths for Distribution from the Map Related menu, and this command arranges all the datasets, map images, and .mxd files associated with the interactive maps in a hierarchical folder arrangement with the planning document's path as the root folder. For instance, after updating the paths, new sub folders named maps, data and images are created, in the folder containing the planning document, and relevant files associated with the interactive maps are copied there. The conceptual folder arrangement resulting after updating paths is shown below.

..\DocumentPath\planning document.doc
..\DocumentPath\Maps\
..\DocumentPath\Maps\Data
..\DocumentPath\Maps\Images

The maps folder stores .mxd files, the data folder stores .shp files and the images folder stores .jpg files used in the maps associated with the document. If users are interested in moving the map-enabled planning document at another location, user needs to copy the document file at the desired destination, and again execute the command Update Paths for Distribution from the copied document's Map Related menu, and it will then copy the relevant data in appropriate folders, in the destination folder of the document.

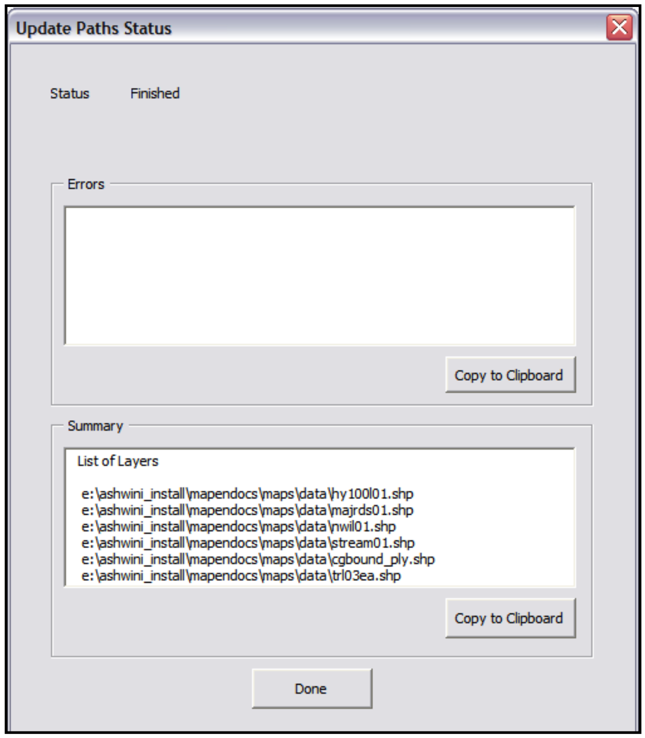


Figure 4-14. Update paths for distribution

The update paths status form also presents information about all the maps contained in the document, including associated layer files, and map image files. This information can be copied to the clipboard and stored in the document or somewhere else for reference. This completes the description regarding insertion of interactive maps in the planning document.

Prototype Structure: Map Manipulation Functionality

Functionality related to manipulation of maps is accessible from the map dialog box. The main toolbar in the map dialog box handles zoom, pan, change map extent and similar map display related functionality. Also the map view specific context menu offers some zoom related functionality. Layer management functions such as move layers up or down, set them visible or selectable are available with layer specific context menu in the table of contents window of the map view. Both the map views and page layout views, support selection functionality via a selection menu present on the toolbar, and it supports selection related commands such as interactive selection, zoom to selected features and clear selection. Besides these commands, the map-enabled planning document presents partial layer symbology modification support, and ability to execute spatial queries and attribute queries, creating of graphic or feature buffers. These functions are described below.

Export tabular data

The prototype allows users to export tabular data associated with different layers used in a map through this command. Tables can be exported in a csv file format, or selected fields from the layer attribute tables can be inserted in the word document itself in a tabular format.

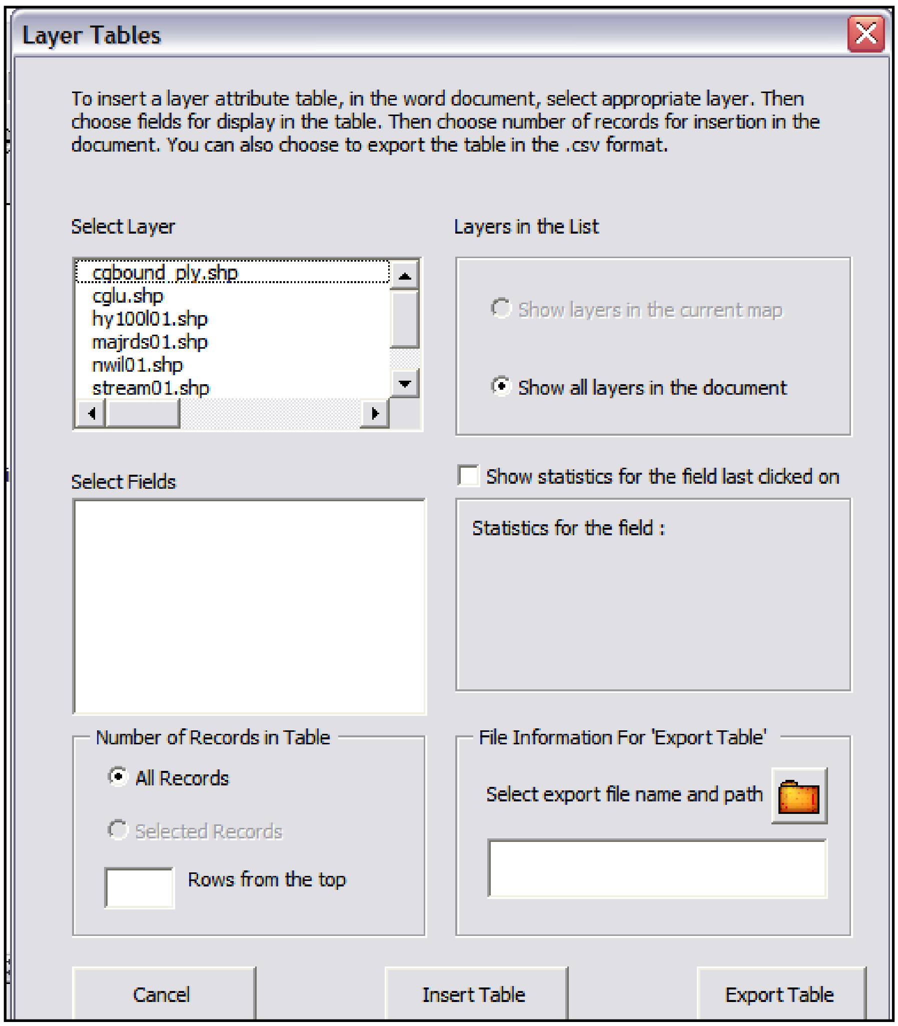


Figure 4-15. Access tables

The form used for this command does not show the actual table, but it can display data statistics for a numerical field. However, layer attribute tables are displayed in the attribute query form, so the user could open it up and browse through the tabular data, before exporting rows from it.

Modify layer symbology

The prototype provides some functionality to alter symbols used to display layers. The symbology dialog box lets a user modify symbology of one layer at a time, and five options are available to the user regarding symbology.

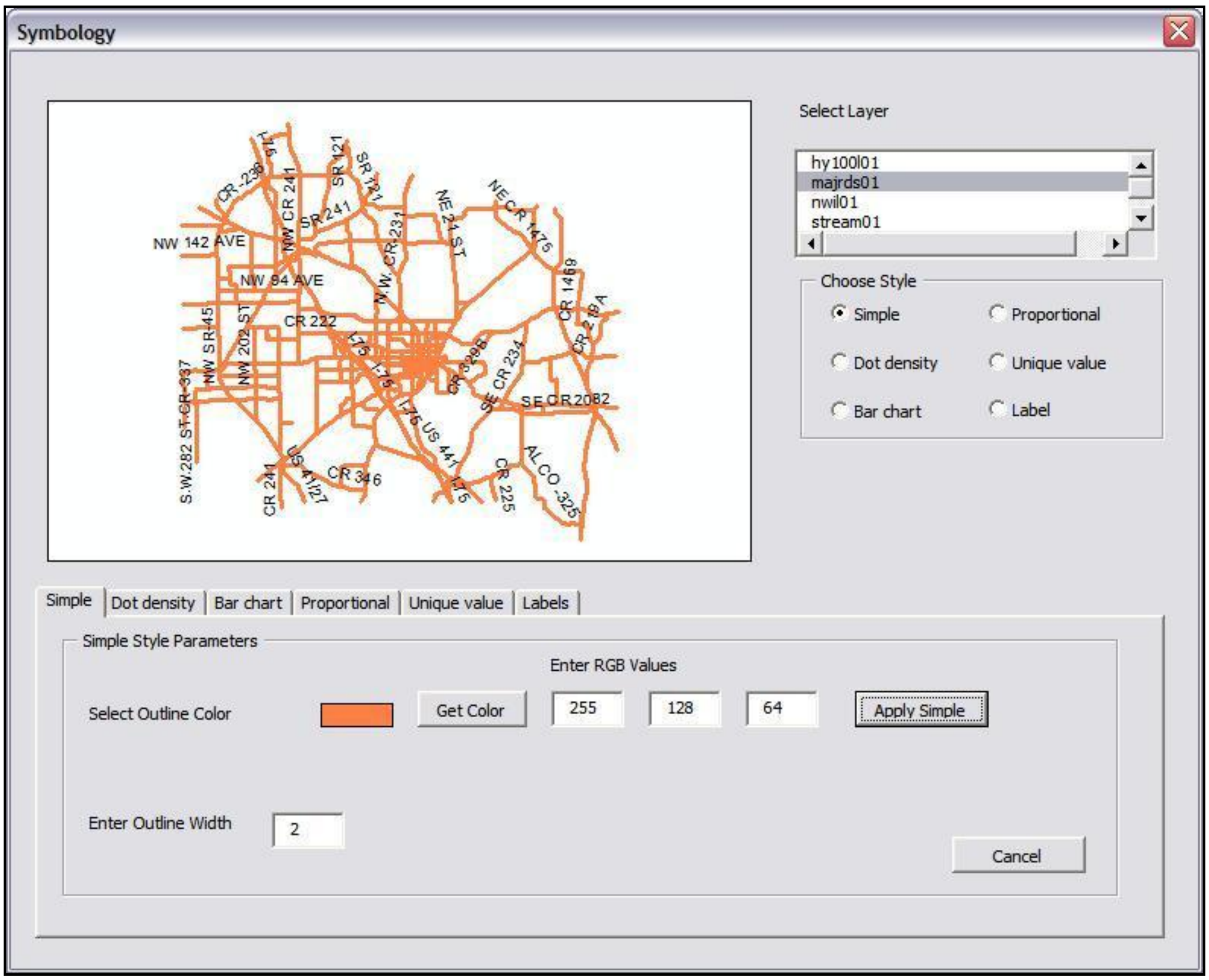


Figure 4-16. Symbology dialog box

These are simple rendering with a unique symbol, attribute value-based rendering in the form of dot density, or proportional symbols, comparative attribute value rendering based on two fields in the form of bar charts and unique value rendering. The symbology dialog box also lets users select options related to labeling features in a map.

Queries in the map

The prototype supports attribute queries and spatial queries. It works with a layer selection, and query expression can be formed by selecting appropriate field and associated values. Tabular windows in the attribute query dialog box show file attribute tables associated with the selected shape file layer and they can also display records selected by the query.

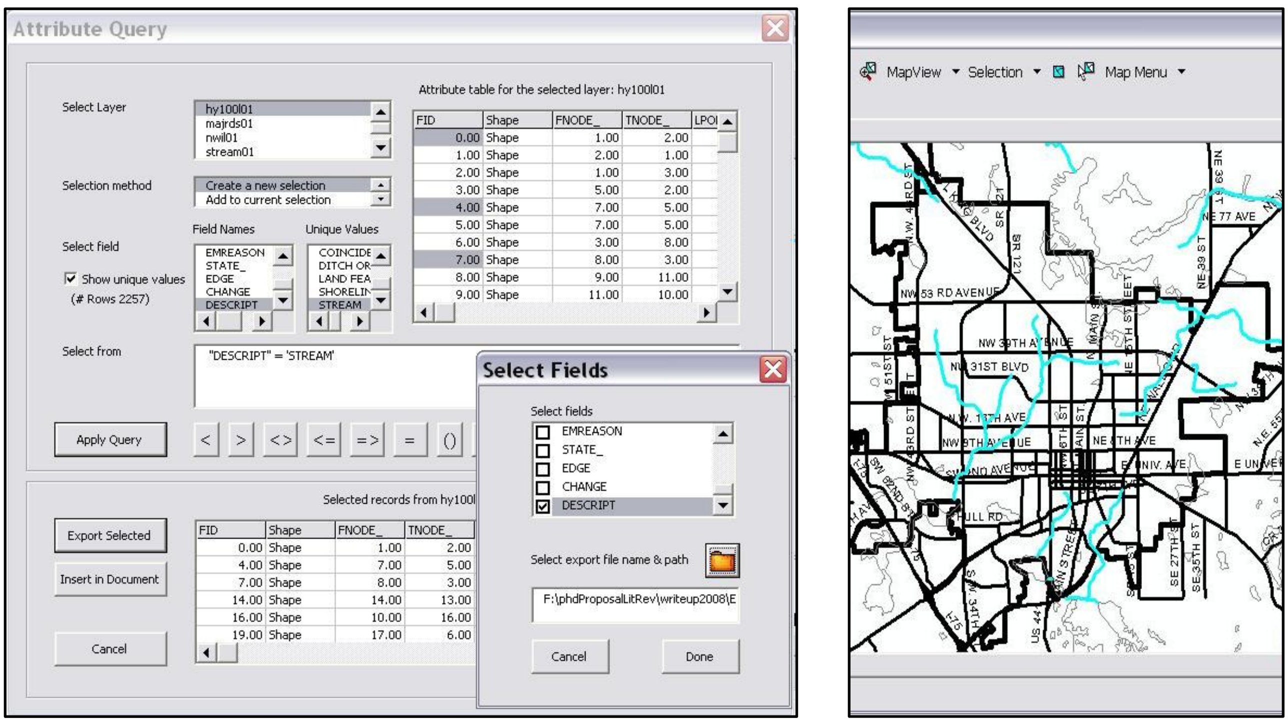


Figure 4-17. Attribute query dialog box and output

It is possible to export selected records as a table in the comma delimited value file format (.csv) which can then be opened in spread-sheet software like Microsoft Excel or any other standard database software. Selected records can also be inserted into a word document.

Spatial queries

The spatial query dialog box is modeled after the spatial query dialog box in the ArcMAP software, and the output of one spatial query can be seen in the figure. One of the most important aspects of spatial query execution is that spatial queries deal with shapes of the features, and therefore all the datasets involved in the spatial query operation need to have projection information associated with them. This can be ensured by checking existence of the .prj files having the same name as the .shp file.

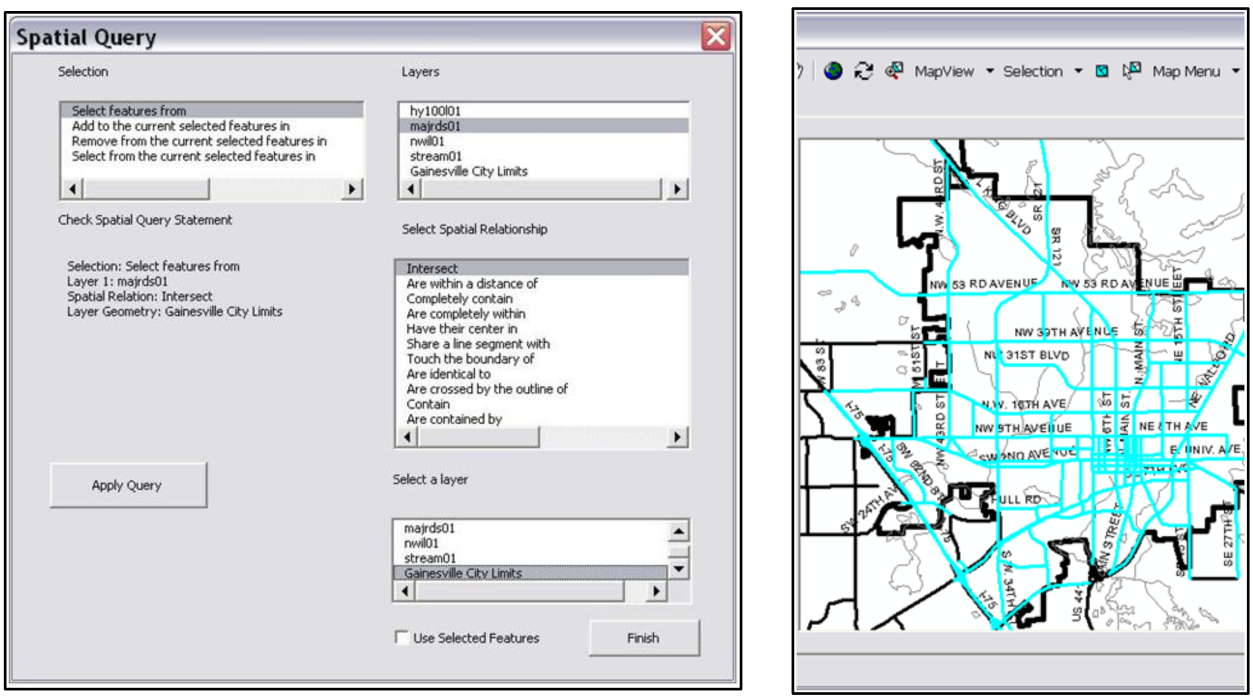


Figure 4-18. Spatial query dialog box and output

It is also necessary for most spatial queries to work, that the datasets involved have the same projection. The ArcMap software can handle datasets having different projections in the spatial query, by re-projecting each shape during execution to match the projection of the input dataset, but the ArcEngine objects seem to fail when executing in a similar manner. Therefore it is necessary to have the datasets with matching projections for the execution of spatial queries. This should not be much of a problem, since most dataset repositories, like the FGDL library in case of the Florida state, maintain consistent datasets, usually in one standard projection. Also, projection information about a layer can be checked via Show Projection Information command present in the layer right-click menu.

Buffers

The prototype supports creation of graphic buffers as well as feature buffer shape file that is creation of a new shape file containing buffered shapes of the selected features.

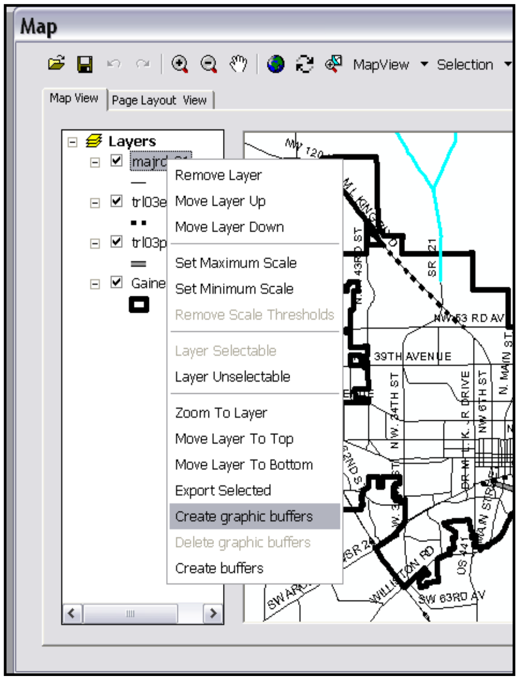


Figure 4-19. Graphic buffer command

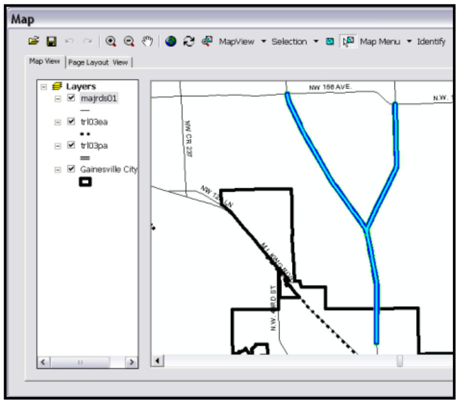


Figure 4-20. Graphic buffer output

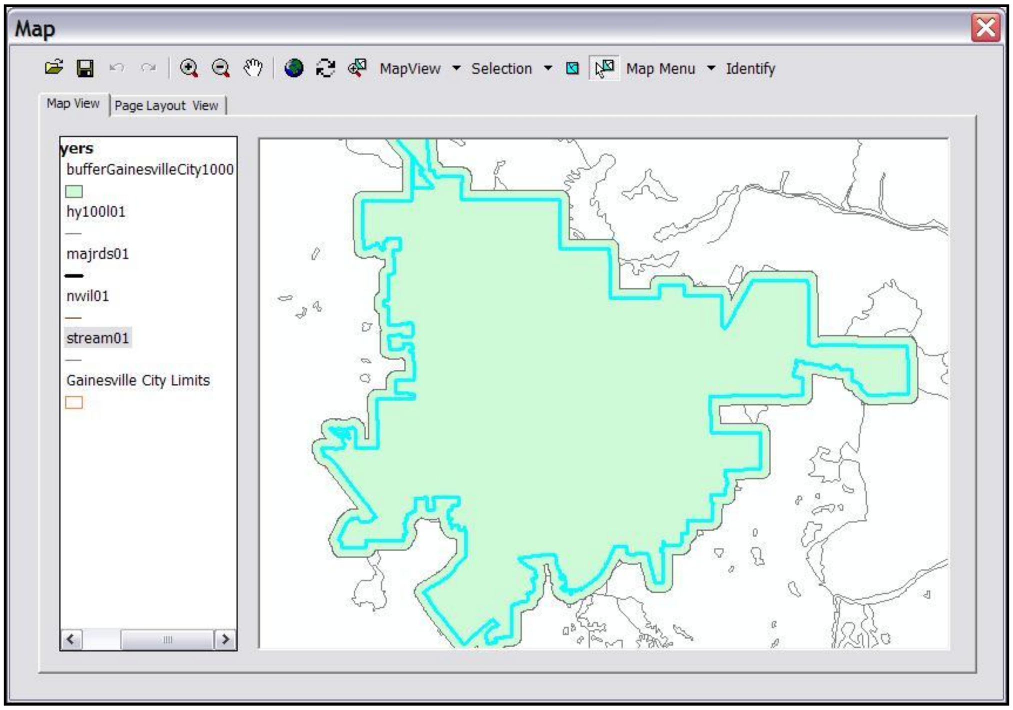


Figure 4-21. Feature buffer output

Integration between text and maps

One of the objectives of the map-enabled planning document was to facilitate better integration between text and spatial data. In the literature review some examples were presented that attempted linking text with maps. In one such example, the ePlanning application generates a URL for a user made map from their web GIS interface; users can then embed that URL into their web documents, thus enabling access to the maps from within the document. In another example with Dito tool and CommonGIS tool, a link is developed between annotation on the map features and the discussion sessions. Following from these, it is clear that web GIS offers linking capabilities between the map and text; either direct links can be created with maps, or they can be created with selected features from the maps.

Similarly this prototype application aimed for a tighter integration between text and maps and considered portions of the text and maps for linkage. There are different units that can be linked; in case of text, a word or a paragraph can be chosen for linking. In case of a map a single feature, or multiple features, a single layer or a single map can be chosen for linking. These possibilities were considered in the application, and eventually tools were developed to allow linking between text and maps. In the prototype, a word or a paragraph can be linked with a feature or features (from the same layer) on the map, or a word or a paragraph can be linked with a particular layer or a particular map associated with one of the map pictures in the document.

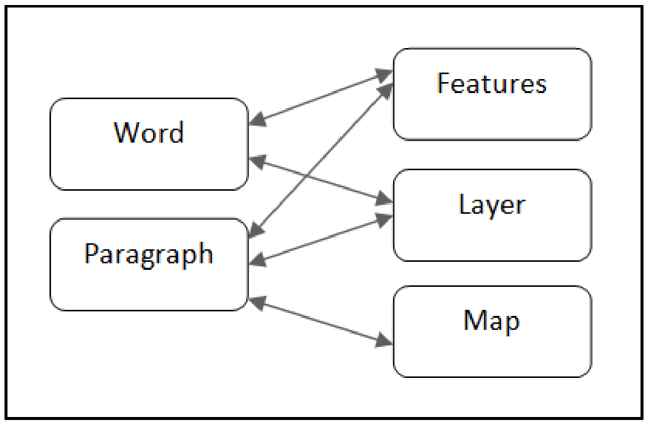


Figure 4-22. Linking opportunities between text and map data

The Show All Map Links command from the Map Related menu item brings up a dialog box titled Display Links. The display links dialog box gives information about existing links in the document with a small picture of the features associated, and the text associated. There may be 3 types of links namely layer links, feature links or map links. There can also be multiple links for a word, or a feature. For instance a word in the document may be linked with a layer or a combination of two three words in the document may be linked to a feature in the map. If a linked word is selected in the document, then a user can open the right-click menu, and execute command Show Links for the Selection, and that will also bring up the same dialog box as shown in the Show All Map Links command, except that it will only contain the links related to the word selection in the document. It is also possible to see all the linked text in the document, with the command Highlight Text with Map Links from the Map Related menu present on the word application menu bar. The Remove Highlights from Text with Map Links command upon execution removes the highlights from the linked text in the document. This functionality makes it easy to view all the linked text in the document.

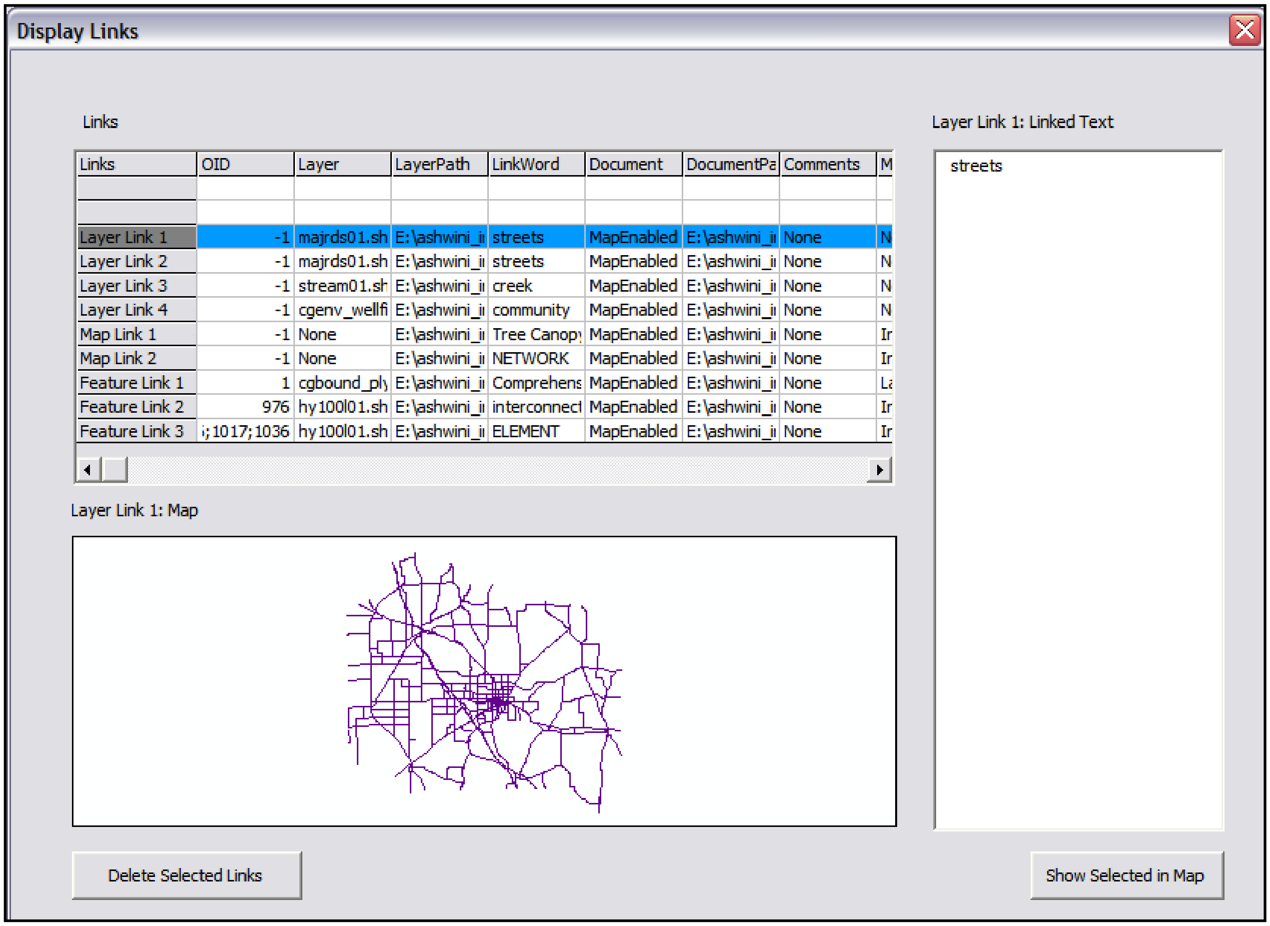


Figure 4-23. Display links dialog box

The display links dialog box gives information about existing links in the document with a small picture of the features associated, and the text associated. There can be three types of links, a layer link, a feature link or a map link. We can also link layers with a word or paragraph selection in the document.

The Link Text to Layer right-click menu item associated with word selection brings up a list of layers available for linking, from which users can select one, and proceed with linking. Similarly a list of maps is displayed when the user wishes to link selection with maps.

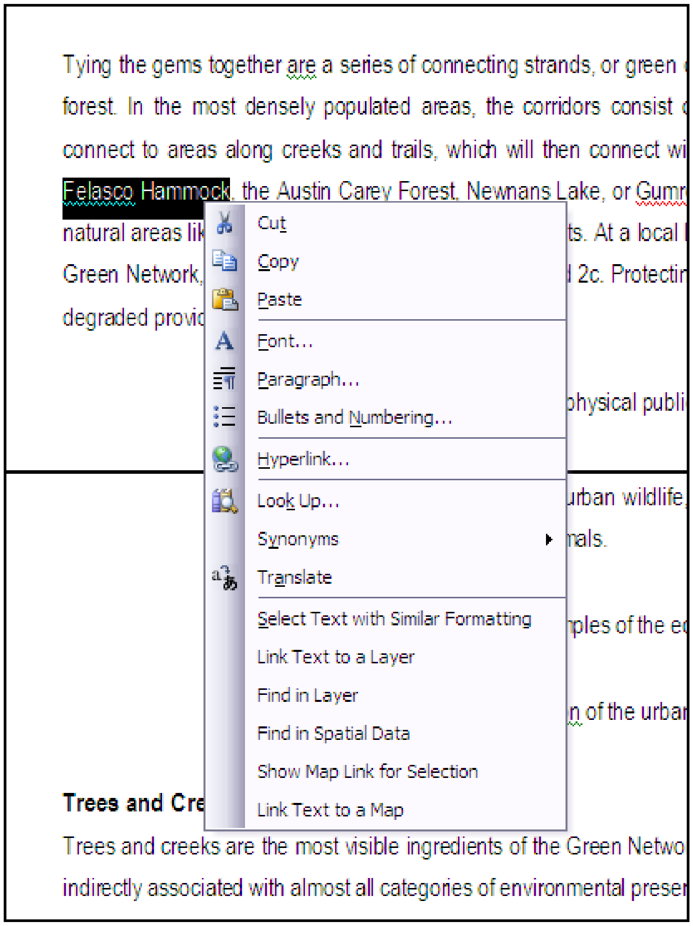


Figure 4-24. Right-click menu associated with text selection

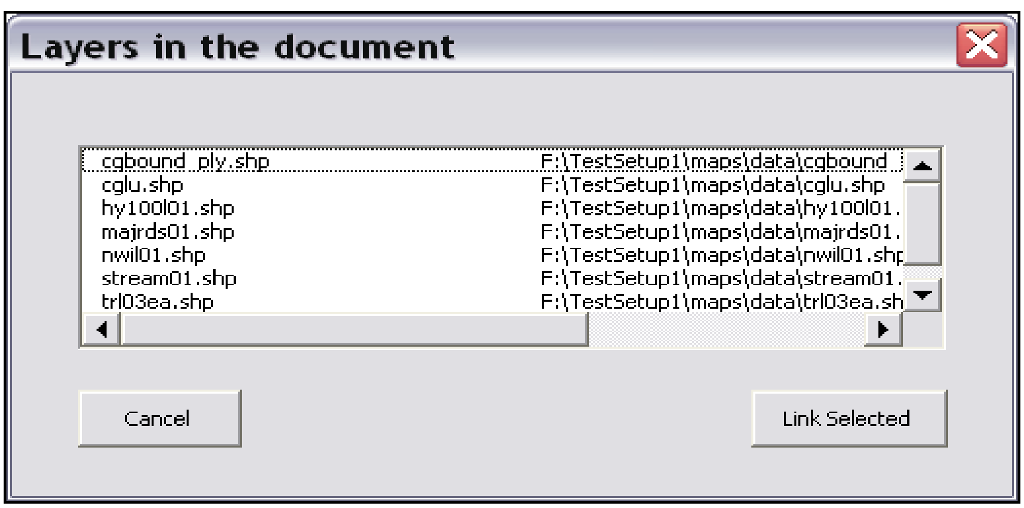


Figure 4-25. Layers in the document dialog box

Search for text in maps

Besides linking features, efforts were made to build search tools for searching text in the associated map data with the planning document. A search for the selected text in maps can be conducted with Find in Spatial Data command, associated with the right-click menu of the word selection. It lists all the feature details along with the layer names, and object ids, the name of the field in which the searched text was found, and the actual text value in that field that contains the selected word in their table.

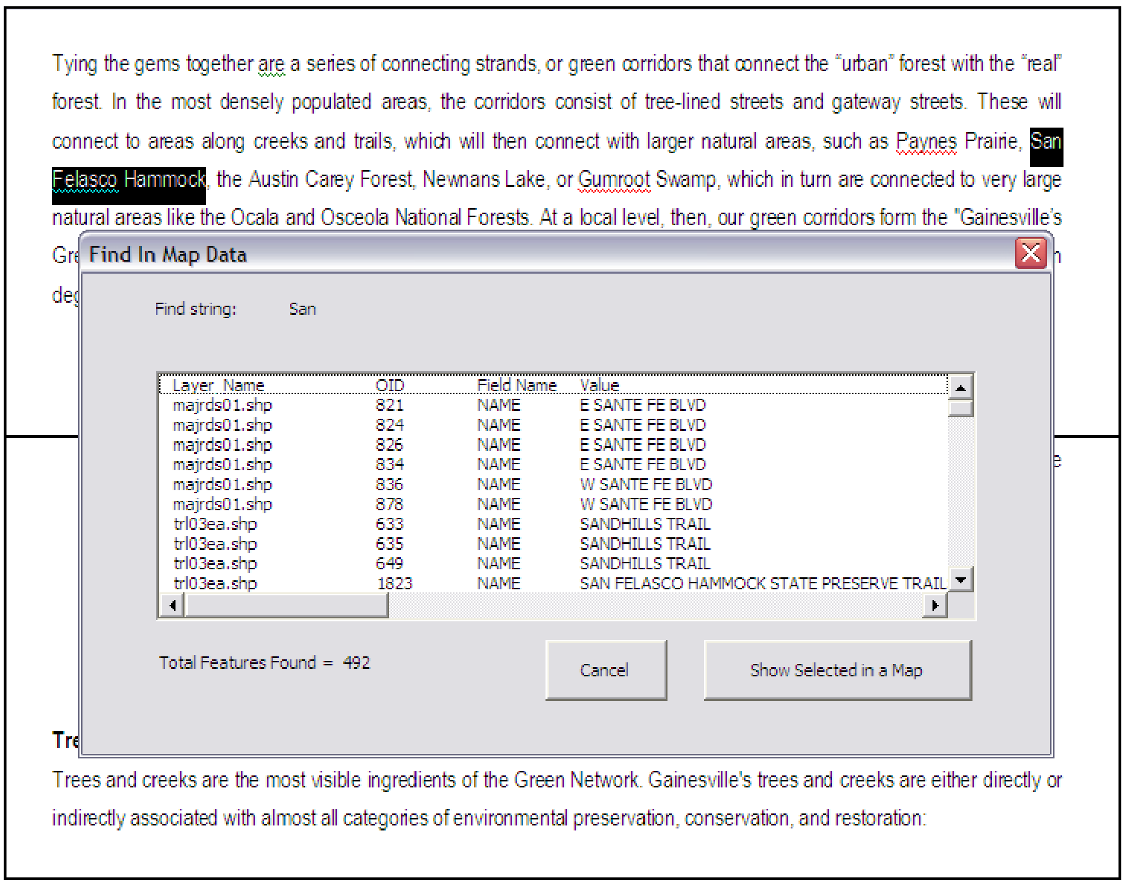


Figure 4-26. Text selection in the document and results of the find command execution

The feature selected can be then displayed in the map dialog, with the Show Selected in a Map command execution, if the user wishes to do so. Another variant of the same command is the Find in Layer command. Sometimes too many results are returned from the Find in Spatial

Data command, and the user still may not know if the searched word is present in the layer of their interest. Therefore the Find in Layer command is implemented; this command first displays a list of layers in the document, from which a user can select one layer and then the find operation looks for selection of the word, in the attribute data of just that layer.

Add comments table, set reviewer information

These commands allow users of the document to change the reviewer information, so that comments added by different persons can be tracked from the reviewer information entered. The Add Comment Table command places a table showing all the comments and commentator's names at the end of the document. After inserting this table, it is just like any other table in the word document, and therefore it can be moved anywhere, or edited further.

Discussion

The prototype of a map-enabled planning document was developed with the aim to provide the following commands with at least some functionality on the minimum end and full functionality of the maximum end of the range of desired functionality. The following list identifies functionality that could be successfully implemented in the prototype.

Mapping functionality

- **Add data**: Addition of local shape file data possible.
- **Save maps**: Implemented as desired.
- **Basic map display functionality**: Implemented as desired.
- **Layer arrangement**: Implemented as desired including layer order change and symbology.
- **Query, selection, and buffer**: Implemented as desired including spatial queries, graphic buffers, and feature buffers.
- **Saving query results**: Implemented as desired, query results can be saved in a tabular format or exported in a shape file format.

- **Modification of datasets**: Clip, merge functions are not implemented, however entire dataset or selected features can be exported to form a new shape file.

- **Providing list of referenced datasets, and map files**: Implemented as desired through the dialog box associated with the update paths command.

Non mapping functionality

- **Comments on the map and the text portions of the document**: Implemented as desired.

- **Ability to distribute the dynamic planning document with maps and map data**: Implemented as desired.

- **Integration between text and map data**: Implemented as desired.

It was possible to implement most of the commands in the prototype except for support of partial functionality in the symbology. Also it was not possible to implement spatial queries with all the spatial relationships that are made available in the ArcGIS suite of applications, however with the exception of two three spatial relationships rest of the spatial queries were implemented. The application was also successful in exporting selected features in the shape file format for both the queries, and in exporting selected records in tabular format for attribute queries. Commenting tools were also integrated in the application. Comments can be added to the linked features at the time of developing links, and a complete list of comments can be inserted for reference at the end of the document. Linking functions were implemented as desired. The find function was something that was not thought of initially, but during the implementation process, its usefulness was realized and it was implemented.

Prototype limitations

In this section some of the limitations of the prototype are identified. Most of the limitations of the prototype are not limitations imposed by ArcEngine, but they exist because the purpose behind making of a prototype was to prove the concept, and therefore only partial functionality was implemented since adding complete functionality was found time consuming considering that all commands had to be programmed.

Maps included in the prototype currently take into consideration only feature layers with shape file format. Shape file format is a common file format for vector data available in the public domain. Providing support for multiple data formats was not a restriction of ArcEngine, but it required considerable effort on the programming side, because each data format had to be handled separately for symbology, for queries (not all data formats have attribute tables associated with them) and for linking features with text.

Maps in the prototype are saved in mxd file format, when they are inserted in the word document. When a new map is created in the prototype, the user is asked to enter a unique name for it. This unique name connects a picture inserted in the document with the mxd file saved as a map. Therefore, it is necessary that each map inserted in the document be associated with a unique mxd document. If a user requires same arrangement of layers in another map, then the user can just save the relevant mxd document with another name, and use that to associate required layer arrangement with another map. It is essential for the correct working of the prototype that different maps in the document refer to different mxd files.

It is assumed that a map document in mxd format will have only one data frame. Having an mxd file with more than one data frames can disturb the information stored in the word document with reference to each map. At present, the prototype is not designed to handle more than one data frames in the mxd file, and there are no checks present to verify whether the mxd file selected has more than one map or not. Therefore, the user needs to be aware of this requirement.

Currently, deletion of map related graphic elements (legend, scale, north arrow) in the page layout does not work with the execution of the delete button on the keyboard, due to a bug in the ArcEngine software, therefore it is recommended that the user should avoid deleting these elements and just move them outside of the page boundary and work with new elements as per necessity.

An occurrence of redundant links between text and features or text and layers is another issue. The prototype stores link information whenever it is created. However if users at another time remove the associated map data, or text data from the document, then there is no event in the Microsoft Word software that can check for presence of a link related to the deleted data, and then delete the relevant links. Feature links can be checked programmatically for their presence, but a layer may contain more than one thousand records and periodically checking for the presence of linked features in the dataset can create a vast overhead on the system resources. Therefore, if some links do not show up in the display links table, it is recommended that users check for the layer names of those links, and make note of linked words with those links, and verify that the linked words and layers exist in the document. In case of missing linked words or layers, those links can be deleted. The display links form has a Delete Redundant Links button and this button checks for presence of links associated with maps that are nonexistent in the document, deletes such links. Thus the issue of redundant links associated with deleted maps has been taken care of, although the user needs to manually handle issue of redundant links pointing to missing layers or missing words in the document.

The page layout view of the map does not offer tools to draw neat lines; it was assumed that most often maps will be prepared outside the prototype document with dedicated GIS software, but they will be inserted in the prototype for the purpose of review, or distribution.

Therefore, emphasis was not placed on beautification of maps and functionality of drawing neat lines was not provided.

While working with the prototype it was realized that it may be possible to make use of the network based data layers in the map documents associated with the ArcEngine 9.2 version. However, this functionality was not implemented as the version upgrade from ESRI occurred while the prototype was already being developed. If implemented, in future this command will enable the prototype to refer to the map layers that may be online, and this could simplify the task of distribution of large data layers. On the whole, it was possible to implement most of the desired functionality, and limitations listed here are procedural limitations such as using map file with only one data frame, but they do not affect the desired functionality of the prototype.

CHAPTER 6
FINDINGS OF THE STUDY AND DISCUSSION

The prototype of a map-enabled planning document was submitted for review and comments to the GIS manager of the East Central Florida Regional Planning Council. The region served by the East Central Florida Regional Planning Council (ECFRPC) includes 6 counties, namely, Brevard, Lake, Orange, Osceola, Seminole and the Volusia County. Being a regional planning council, this agency has an involvement in various planning activities such as comprehensive plan reviews, coordination of multi-agency reviews of the developments of regional impact, overall regional planning, and in providing assistance to the local governments. The Alachua County reviewers were also shown the prototype of a map-enabled planning document, its usage was demonstrated to them, and their comments were sought through a discussion. Their comments are discussed later in the discussion of comments section.

Comments

The reviewing agency (ECFRPC) found the application user friendly, since GIS functionality was available in Microsoft Word, popular word processing software. The menu options and overall functionality was found sufficient for the needs of dynamic mapping manipulation from a basic GIS end user's standpoint. The agency liked the linking between text and layer functionality, and mentioned that it would prove useful for the comprehensive plan review, because users of the map-enabled planning document would be able to easily navigate to maps of related links in the document.

The ability to delete maps was raised as a concern in the comments, as it was felt that in the planning environment, making comments, conducting spatial analysis and interacting with maps was required. The reviewing agency commented that the Delete Map functionality should not have been made available at all times. This functionality is necessary for the author of the map-enabled document, because he/she needs to have the ability to add or delete maps as required. The agency recommended that the author of the document should have the ability to enable or disable the Delete Map button, or alternatively a user access control level may be integrated in the application, so that a particular user level may have reduced access to commands available for use. Besides these comments there were no specific comments on particular commands. The installation process was found to be fairly easy, and the documentation that came with the application was also regarded as sufficient. The agency recommended use of a quick command reference sheet for easy command reference, and a separate readme file for installation purposes. At the time of the review, the installation notes were included in the prototype documentation. The application was found reliable, since it did not cause any crashes or failures when it was used by the reviewing agencies.

The reviewing agency suggested that the ArcEngine application may be particularly beneficial for those users who weren't going to be GIS power users, but still needed to learn GIS, and that all such users would find the ArcEngine based map-enabled document application easy to learn, it being embedded in the Microsoft Word software. Further, the agency would save on the training costs and the time involved in training these users. They also commented that this application may also be useful for users outside the field of planning, who deal with documents and maps. The agency pointed out that the ArcEngine application cost as much as the ArcView (ESRI solution) application, a standalone desktop GIS technology. However, even in case of a similar pricing with regards to ArcEngine and ArcView, if the agency felt inclined to purchase the ArcView license rather than the ArcEngine license, they would still be able to use the map-enabled document prototype for viewing and working with maps inside the Microsoft Word application, as the application has the ability to make use of ArcView, ArcInfo, or ArcEditor licenses, all of which belong to the ArcGIS application suite. Their comments are kept in the appendix F for additional reference.

Discussion on Comments

The map-enabled planning document's functionality was found sufficient by the agency, and its suggestions about disabling the delete map command arose from the concern that the user may inadvertently delete a map embedded in the document. If the current user of the document is not the author of the document, then there is a possibility that the command can be programmatically disabled. Integration of user level access controls for command enabling was found to be difficult. The agency's suggestions of a quick command reference sheet and a readme file detailing installation guidelines were incorporated in the prototype documentation.

The agency's observations regarding costs of the ArcEngine application did not match with costs obtained by us. According to our information of ESRI prices in 2008, the Standard ArcEngine Runtime License (which is necessary to run this application) costs $408 per single use license, the ArcView Single Use License costs $1224, and the ArcView Concurrent Use License costs $2857. However since the prototype can make use of any license belonging to the products in the ArcGIS family, cost of ArcView versus cost of ArcEngine is not an issue, as the user could purchase ArcView if it was found economical to have rather than the ArcEngine application, and still run this application.

Informal comments were also sought from the Alachua County's reviewers. They found the functionality included in the prototype sufficient for the purpose of the review. They felt the utility of the web GIS application was different, since the datasets did not have to be distributed, and that the data accessed were always updated. They liked the find functionality and the linking functionality. They suggested that additional functionality of displaying of text links on the map view dialog box would be useful in certain circumstances. They commented that the web GIS technology was not much useful for displaying maps in the public participation meetings, because it did not store map session details, meaning if a map was made by keeping some layers visible and the rest of the layers invisible, then that setting could not be saved once the internet browser was closed. Therefore in meetings the maps to be referenced would have to be set up again in a web GIS application. However, in the map-enabled planning document, maps can be saved, and therefore they can be brought up during discussion sessions for reference, or demonstration purposes. They mentioned that the map-enabled planning document would be useful in public meetings, staff reports, and commissions. They also felt that the application would be useful for agencies that are new to the GIS because the GIS functionality was easy to use with the map-enabled planning document.

The committee members involved with this study also had some comments such as adding Minimize, Maximize buttons on the map dialog box, which is used to display maps in the prototype document. Lack of minimize and maximize buttons was because of the limitation of the Visual Basic for Applications (VBA) language used for customizing Microsoft Word, and therefore this functionality could not be implemented. There are some round about ways to simulate minimize and maximize buttons on such forms (termed userforms in VBA), however, there’s no assurance that these buttons would work with this application. The purpose behind this suggestion was that the users would be able to control the size of the map dialog box, using these buttons and if there was extra screen space, the map view could be enlarged. The committee members also noted that the menus in the ArcMap application were normally placed on the menu bar, whereas in the prototype they were placed on the map dialog box, and commented that this would not be intuitive for the ArcMap users. The reason for this kind of placement was that, map specific commands such as Select Features or Zoom In only worked when a map was visible, and when the map dialog was not open, these commands did not have any relevance. Therefore, they were not placed on the Microsoft Word menu bar, and were positioned on the map dialog box only. On the whole comments obtained on the prototype were positive, and some suggestions were provided to enhance the prototype's usefulness.

Map-Enabled Planning Document: Usefulness in Reviews

Comprehensive plan review is mandatory in the State of Florida, and all the cities, counties and regional agencies in Florida have to prepare a comprehensive plan once every seven years. The task of comprehensive plan review is substantial and repetitive, and it involves multiple agencies in the process, and uses various datasets in the analysis. The comprehensive plan documents contain goals and objectives for a variety of planning elements, and all the decisions pertaining to goals and objectives are backed by a thorough comprehensive analysis, presented in the data and analysis section of the comprehensive plan documents. It was felt that if the map-enabled planning documents were used in the comprehensive plan review process, then presence of included maps may aid the task of comprehensive plan review.

The map-enabled planning document can be viewed as a new tool that provides planners with additional mapping capabilities within the planning document and it offers direct access to the actual maps referenced within the document. It is a tool, and therefore it is only as good as the use it is put to, hence it does not have the ability to transform the review process. It may however save some time for reviewers if they can take care of some map-related analysis using the map-enabled planning document.

The mapping functionality of the map-enabled planning document prototype is derived from the functionality of the web GIS application GeoGM Mapper, currently used by the Alachua County reviewers for the purpose of the review. All the functions supported by the web GIS application are incorporated in the prototype of the map-enabled planning document and some of the functions such as queries and manipulation of selection sets are enhanced by adding advanced GIS functionality to the prototype. Besides, additional functionality related to linking text and map data, and searching text data in the map data is also incorporated in the prototype.

With the map-enabled planning document prototype, reviewers can perform proximity analysis, add their own data to the maps, create new maps, save maps, explore spatial relationships between different datasets, search map data from the planning document, query the map data by attributes and by spatial relationships, extract the results of queries or selections in the tabular format or in a new shape file format for further work, create meaningful links between features, layers or maps of importance and relevant text in the planning document, and associate comments with the feature links. This range of functionality available with the prototype was found sufficient for the basic needs of comprehensive plan review by both the reviewing agencies.

The review of comprehensive plan documents results in submission of comments by the reviewing agency to the DCA, other reviewing agencies, or to the plan preparing agency. The DCA, based on all the comments obtained from different reviewing agencies, and its own review, prepares an ORC document, and submits it to the plan preparing agency for further action. During examination of the review related documents it was found that the ORC documents in their objections section addressed issues of data insufficiency, issues of analysis insufficiency, or lack of analysis, issues of conflicts with the state goals or regional goals or growth management policies and issues of failure in meeting with the concurrency requirements. Some of these issues mentioned above may involve spatial analysis during the review, others may require numerical analysis during the review or both numerical and spatial analysis, and some of the issues such as presence of conflicting policies may be directly apparent to the reviewers without performing any kind of spatial analysis.

Reviewers could use the map-enabled planning document in a number of ways, to conduct the review. The maps included in the planning documents could be used by the reviewers in cases of conflicts with the state goals or regional goals to indicate conflicting issues if possible, or to highlight incompatible land uses, or to point out areas of insufficient infrastructure. Reviewers could use the attribute queries, spatial queries, search functionality and the buffer functionality in the map-enabled planning document to extract information about an area of interest in the included maps in order to verify the analysis presented in the proposal and to point out any inaccuracies if present. Having readymade maps at their disposal may be useful to the reviewers in two ways, firstly they may not need to recreate maps to verify some spatial information, and secondly they could use the maps available in the document to convey spatial reasoning behind their approval or disapproval of the issues involved. Moreover, they could create new maps using their own datasets, and insert these maps in the plan proposal documents, to show additional spatial analysis or to justify their comments, and then send these documents to other reviewing agencies or the plan preparing agency.

The reviewers could use linking functionality available in the document to associate their comments with references to maps, and features wherever necessary. If the reviewer’s comments were illustrated with associated maps and map data in case of issues of spatial dimension, then such comments might be able to convey the issues involved with additional clarity to the agencies involved.

As a result of having mapping functionality and live maps in a planning document, reviewers can better understand the plan preparing agency's plans, and spatial reasoning behind plan proposals by accessing interactive maps contained within planning documents. Also reviewers can better describe spatial reasoning in their review by incorporating new maps or through modification of existing maps in the planning documents. Reviewers could make use of various mapping functions such as queries, linking, or buffers to highlight issues of interest in the maps and link those with their comments. Therefore, on the whole, comprehensive plan review process benefits from increased transparency as far as spatial reasoning is concerned. Moreover, the review process may benefit from time savings and increased efficiency due to presence of readymade maps and suitable mapping tools within the planning documents. Besides, review documents can benefit from inclusion of review specific maps and associated data and analysis within the documents, presence of relevant maps inside the planning document may prove to be a valuable resource especially for purposes of future reference, and in case of disputes.

The purpose of this research was to create a map-enabled planning document with mapping capabilities and tools for better integration between map and textual data in order to aid the process of comprehensive plan review. This primary goal of the research was met through the development of map-enabled planning document prototype in terms of adding actual maps to the document, and providing of required mapping functionality in the planning document. As explained earlier, while the map-enabled planning document contains maps and mapping tools in it, the extent of usefulness of such a document for the purpose of the comprehensive plan review is dependent on the way in which it is used in different circumstances.

Relevance of the Map-Enabled Planning Document in Planning

In recent times, especially since the development of desktop computers and faster processors, widespread computer use has revolutionized practically every field. Developments in the computer science field have been occurring at a dynamic pace, and opportunities for applying technology for different purposes are numerous. In the field of urban planning, planners regularly employ GIS technologies to conduct an in-depth analysis with a large amount of thematic data. With the advent of newer internet technologies, the planning agencies serve maps through web GIS for a variety of uses; to broadcast real time wild fire data, to demonstrate city planning proposals, to show location of buses real time in the city and so on. Now, planners use advanced planning support systems to simulate various planning scenarios and model growth in the field of transportation and urban development. Tools like model builder present in the ArcGIS software can be used to build highly sophisticated analytical models. Thus the tools available to planners for conducting planning work have changed immensely in the last few years.

Amongst all these technologies, static map images are still being used as a part of the planning documents. Static map images are just like paper maps used in the past, in the sense that they do not allow any interaction with the map data, or allow users to change display parameters (scale, layer order) of the map. They differ from the paper maps in being a digital image instead of a paper document. However, most of the maps are now created using computers, all the planning related map data is available in the digital format, and the tools used for spatial analysis are also digital in nature. But the power of digital maps is not being harnessed in the planning documents, though the present technology has the potential to make this possible. This can be facilitated in more ways than one, with different types of mapping technologies such as the web GIS technology, embedded GIS technology, or the open source GIS technologies as seen in this study from the examples illustrated or the prototype developed.

Planners can benefit significantly from having map-enabled documents, since much of the planning activity requires discussion and communication of planning ideas with multiple agencies, interest groups, citizens and politicians. Planning activity is also never undertaken in isolation. A planning activity in one area impacts the adjacent areas, and can spill over growth in other areas, therefore planners have to ensure that their plans are in alignment with the state policies, regional planning goals, and other local agencies' plans. Planning is spatial in nature; so many planning elements have a location component that determines planning decisions. Maps are one of the important instruments with which planners can convey spatial aspects of the planning processes to other parties, which could be other planning agencies, or citizens trying to understand the where and why of some planning scheme. If these maps are digital and are interactive maps instead of paper maps or static maps, then it just enables the planners with more explanation power. They could at any moment, zoom onto the map, show interaction between different datasets, or demonstrate spatial relationships between datasets to the collaborators or citizens and try to explain their point with a lot more detail. They could also describe the datasets used in the maps in a better way by filtering datasets with attribute queries, or spatial queries. With the facility of having interactive maps, additional data or maps from the other sources could be added to the maps included in the planning documents and the interaction between different datasets can be examined and discussed upon. Thus, interactive maps in planning documents, may contribute to the discussion and also to the analytical process. In general having interactive maps in the planning documents may extend the planner's ability to convey spatial reasoning behind the concepts explained in the planning documents.

The map-enabled planning document is developed in the context of the comprehensive plan review, which helped in identifying the functionality of the map-enabled document and assigned a purpose to the map-enabled planning document. In the comprehensive plan review process, the mapping functionality and associated tools of this document are expected to be used by various reviewing agencies. However, this kind of a document can also prove to be useful in other planning situations such as public participation meetings, or inter agency or inter department meetings where collaborative discussions over planning ideas or schemes may take place. In collaborative meeting where all the parties involved have a good understanding of GIS techniques, the map-enabled planning document may help generate a lively discussion with manipulation of maps on the fly, and support exploration of the maps with queries and other additional data if necessary.

It may also be used in web based collaborative meetings, as such a document may be passed around to the participants and they can view the maps, or work with the maps, to conduct any related analysis, or just see the linked features of interest and get familiarized with the document contents. While the document makes use of the ArcEngine technology, it can still work in the absence of ArcEngine, with Microsoft Word, provided one of the three standalone GIS applications (ArcView, ArcInfo, ArcEditor licenses) is present on the user's computer.

Public involvement is an important aspect of the planning process, and its importance has been stressed upon by many theorists, Healey (1992) comments upon the communicative turn in planning theory in her articles. In various public participation sessions, that take place during the comprehensive plan review process, the plan amendment process and other planning related discussions between planners and the community, planners may be able to describe their plans with interactive maps, and demonstrate interaction between various data layers through spatial and attribute queries, and also highlight features of importance through linking mechanism and the search facility present in the document. In such a discussion, the spatial reasoning behind decision making may be explained with a little more detail and some of the spatial analysis processes may be exposed to the people in general.

Since map-enabled planning document makes use of familiar word processing software, and the presence of GIS tools inside familiar software may put people at ease, and engage them in browsing the maps included in the planning documents. Such a document may be kept on a computer at a public place like the office of the planning department in the local government, or in a public library or in schools, and people could then browse map-enabled planning documents related to a new proposal of the comprehensive plan or a planning scheme such as the revitalization of the downtown. While GIS has been claimed at times to be an elitist technology, because only a few persons may possess the knowledge of using it, the provision of mapping tools in familiar software like Microsoft Word may help change that a little bit.

The RTCP employs a rational decision making process based on comprehensive analysis of the information and alternatives. This theory stresses upon the comprehensiveness of the analysis, and the criticisms on the theory question if truely comprehensive analysis can be ever achieved, considering the limited availability of resources such as time, budget and information (Lindblom, 1959). While reaching a state of 100 percent comprehensiveness in the analysis is always impossible, planners continue to strive for achieving a higher degree of comprehensiveness in their analysis.

However, over time, planner's or planning agency's ability to conduct comprehensive analysis has certainly increased, if one imagines the days of paper maps and manual calculations, as against present times, when maps can be created with sophisticated symbology and displayed in a very less time, and also large amounts of data can be quickly processed using computers. Technology has played a great role in improving (planner's or planning agency's) our ability to achieve a higher degree of comprehensiveness over time, and in freeing up valuable time for carrying out more important tasks and conduct a thorough analysis. In that context, the map-enabled planning document may also be viewed as a technologically advanced tool compared to the planning documents with static maps, and it may help save planners some time if used effectively, and it may allow planners to communicate planning concepts with more explanation power. Time is always a valuable resource, and even with advanced technologies and newer tools, planners continue to struggle to achieve complete comprehensiveness in their analysis, because the definition of comprehensiveness also expands with time to encompass capabilities of newer technologies, and places high demands for a thorough analysis.

Prototype Development: Implementation, Challenges, Future Work

In this study, embedded GIS technology (ArcEngine, ESRI’s embedded GIS technology solution) was chosen for implementing mapping functionality within the planning documents. Other main choice of GIS technology for implementing the prototype was the web GIS technology. ArcEngine was chosen over web GIS technology for two reasons, one being that it allowed for development of any GIS functionality in the application as per the requirements, as opposed to fixed and limited GIS functionality offered by proprietary web GIS technologies, and the second reason for choosing ArcEngine was that ArcEngine worked well with popular word processing software, Microsoft Word, since it used VBA, the same customization language used in the Microsoft Word. Open source GIS technologies could also have been used for the development of the prototype, however that technology was eliminated due to possible difficulties in its implementation, deployment and customization to achieve map and text data integration.

One of the arguments for eliminating the web GIS technologies for prototype development was that while it could easily support linking capabilities between text and map data through hyper linking characteristics of the internet media, it may be able to serve only the minimum range of GIS functionality desired in the map-enabled document. In light of that argument, some of the features that were successfully implemented in the prototype developed with the embedded GIS technology, but implementation of which might not have been possible with the web GIS technologies are pointed out below.

1. The prototype allows saving of map in the mxd format, such maps may also be used with other standalone applications in the ArcGIS suite. This is not possible with web GIS technologies, because maps are saved in an image format.

2. The prototype allows addition of local data (shape files) to a map in the document; this functionality may be important and useful for reviewers. Also this application allows for extraction of selected features, or buffered features as new shape files. The latest versions of web GIS application with a data delivery extension may support download of datasets by current extent or by full extent. However, they may not support addition of local data to the maps. They do support use of other standard map services in some cases.

3. The prototype supports spatial queries that are normally not available in any web GIS implementations. The prototype supports attribute queries with SQL operators such as like, percent, or, and so on. Web GIS has traditionally supported attribute queries, but they may not always support use of SQL operators such as percent.

4. The prototype allows modifications to the selections on the map, such as addition to an existing selection or removal of features from a selection, which are not possible with the web GIS implementation. Modifications to the selection sets offer more flexibility in conducting spatial analysis.

5. The prototype offers tools for altering layer symbols, these are normally not seen in the web GIS, also because web GIS maps conventionally use a predetermined set of data layers in their display (if a large data set is served on web GIS, at least the base layers are identified) and therefore they have already set up the best possible symbology and layer order to display their data in the best possible manner.

6. The prototype supports extraction of layer attribute tables for the selection or for all the records in the csv format. Latest versions of web GIS (ArcIMS 9.3. or ArcGIS server) support extraction of layer attribute tables.

7. The Find (selected text) in Spatial Data command, searches for the selected text’s occurrence in the layer attribute tables. This feature is unique to the prototype and is not seen elsewhere in the web GIS implementations, although Google of course has an excellent search engine for finding addresses that works in the Google maps. However, the functionality of Google Maps is not exactly the same as general web GIS functionality in the sense that they support limited data layers in Google maps, and allow for address matching only.

8. The map-enabled document prototype also makes use of commenting tools present in the Microsoft Word, to allow reviewers to comment on the text data, or on the linked text.

Linking features are unique to the prototype although they can be implemented in the web GIS systems, as demonstrated in the BLM example covered in the literature review. However this capability is not common in web GIS, probably there is no need for it in the most web GIS applications. Thus there was a successful implementation of the desired mapping functionality in the prototype with the use of embedded GIS technology, all of which might not have been possible with the use of web GIS technologies.

Difficulties of Implementation and Challenges

The technologies used in the prototype supported use of VBA, and made interfacing between software somewhat seamless due to use of one language that could access pre programmed core objects of both the software. Even then, the linking capabilities were difficult to integrate, especially because this was a new functionality, so there were no examples to follow, and implementing ability to store link data after the document was closed, was found extremely difficult. After choosing a number of ways of doing it and discarding those, an option of saving link information in the document variables was selected. Alternatively, an external text file could have been used, or the information could have been stored in the word document itself as an appendix.

Although the Microsoft Word software is rich in terms of large number of preprogrammed core objects such as a selection object or a range object, it does not provide much in terms of event handling. There is no way of knowing if the user has changed something in the Microsoft Word such as a bookmark, and deleted it. This was not anticipated before, as the ArcGIS suite of applications support event handling for many of its events, such as map loaded or map changed. Such issues had to be worked around with. The support documentation for ArcEngine is not detailed beyond the description of basic development. However the user forums were found extremely helpful in solving a variety of problems.

In the application, implementation of regular GIS functionality consumed lot of time, because even basic functionality like change layer order was not provided in the ArcEngine in a ready to use format like availability of selection tools, so it had to be programmed. The time cost of development required that we keep scope of the application limited, and therefore the application supports only shape file data, and supports use of one data frame in the mxd document.

Performance and Scale of Data

Since the map related objects are the same as those used in the ESRI's standalone software such as ArcView or ArcInfo, performance of regular operations such as zoom, pan, or loading map data, refreshing map display at different scales of data is similar to that of the stand alone software. This means that the larger datasets may take somewhat more time to load, but they will consume probably the same time as that is taken in the standalone software provided by ESRI.

Queries however are implemented programmatically and therefore the ArcView and other software using generic ESRI code may perform better in that area due to use of internal indexing and other refined coding techniques. However, there should not be that much of a difference in time required in executing attribute queries, since they work with SQL operators. But populating tables in the dialog boxes may take some time. Spatial queries may be somewhat slower compared to the standalone GIS applications, because they also do not benefit from the indexing techniques or other data processing techniques, and the code used to execute queries may not be optimized.

Although smaller datasets were used during the development phase, the record count was in thousands for some data sets, and no significant delays in processing were noticed. On the whole, scale of the data may impact the time taken to perform queries in the prototype, otherwise for rest of the operations time consumed should be more or less the same as that consumed by the stand alone ESRI software.

Future Work

Support for raster data may be added in the map-enabled document, considering the fact that large amount of diverse imagery data is available and is used in the maps. Also if new development has to be done in the prototype, then using modern software such as Visual Studio 2005, with development tools for Office 2007 may be better. These tools offer better GUI, time saving programming techniques, and also the Word 2007 software offers more event handling. Since the ArcEngine 9.3 version has not yet been released, the advances therein cannot be commented upon yet.

The map-enabled planning document could be improved with suggestions obtained in comments by the reviewing agencies. It could be modified to support the Delete Map command, resize capabilities could be added to the map dialog box, and text links could be brought up upon selection of the linked features on the map. Future work in terms of extending the utility of the map-enabled planning document, would be to allow support for using web based data sources in the maps loaded in the map-enabled document. The mxd format map files allow such functionality in the ArcView, and other standalone GIS software using version 9.3. This functionality does not work right now in the prototype because, it is not designed to store data paths with web URLs, but it can be implemented. The web based data sources may eliminate the need to move common datasets from one user to another user, and maintain data integrity in the maps.

If more comprehensive plan reviewers / reviewing agencies could be persuaded to use this prototype to review a few review cases, then from their responses it may be possible to deduce if the prototype can generate significant time savings in the review process, and it may be possible to quantify the benefits. However, review cases vary and they may be different in scale and scope, so all the cases may not benefit equally by the presence of the application for the review. Besides, the reviewing agencies / reviewers may require some time to be familiar with the prototype functionality and use it effectively, and thus there may be some learning curve before effective use of the new functionality of the map-enabled planning document can be expected. On the whole such testing was found difficult at present, due to unavailability of willing agencies to try out the application, install it on their machines, and also the reviewers having less time was an issue.

This type of an application could be tried out in a public participation setting to see if it enhances communication of the planning ideas to the public. It could also be used to demonstrate planning schemes to the public in general, by loading it on public computers at libraries or schools as explained before.

Conclusion

The central research question of my study was whether a map-enabled planning document with interactive maps and mapping functionality could be created and whether such a document would be useful in the review process. I was successful in developing a prototype of a map-enabled planning document containing interactive maps, and mapping tools using embedded GIS technology. Moreover, a complete range of desired functionality derived from the perspective of comprehensive plan review process was successfully implemented in the prototype. One of the important goals of this study was to bring about tighter integration between text and maps, and that was achieved by creating links between text and maps, map features and map layers. Commenting functionality was also incorporated in the linking mechanism. Moreover a search functionality that allowed for searching selected text in the map data included in the document was implemented. The prototype was found useful for comprehensive plan review by the reviewing agencies that tested it. The overall functionality of the prototype was deemed sufficient for the purposes of comprehensive plan review. The prototype demonstrated that interactive maps within planning documents could be accessed easily, and worked upon to create new maps, or to analyze various datasets included in maps. The prototype further demonstrated that the presence of interactive maps in the planning document and ability to link map data with text data can significantly extend descriptive power of planning documents and also incorporate transparency in the review process, by bringing out relevant spatial analysis clearly through interactive maps. Prototype's ability to store associated maps, and map data with planning documents, was also found useful to maintain records of review process for later reference. While this study focused on development of a map-enabled planning document for the purposes of comprehensive plan review, a map-enabled planning document could also be used in other situations such as collaborative meetings, public participation sessions; this has been discussed previously in detail and therefore is not being mentioned here.

APPENDIX A
DCA PLAN REVIEW PROCESS CHART

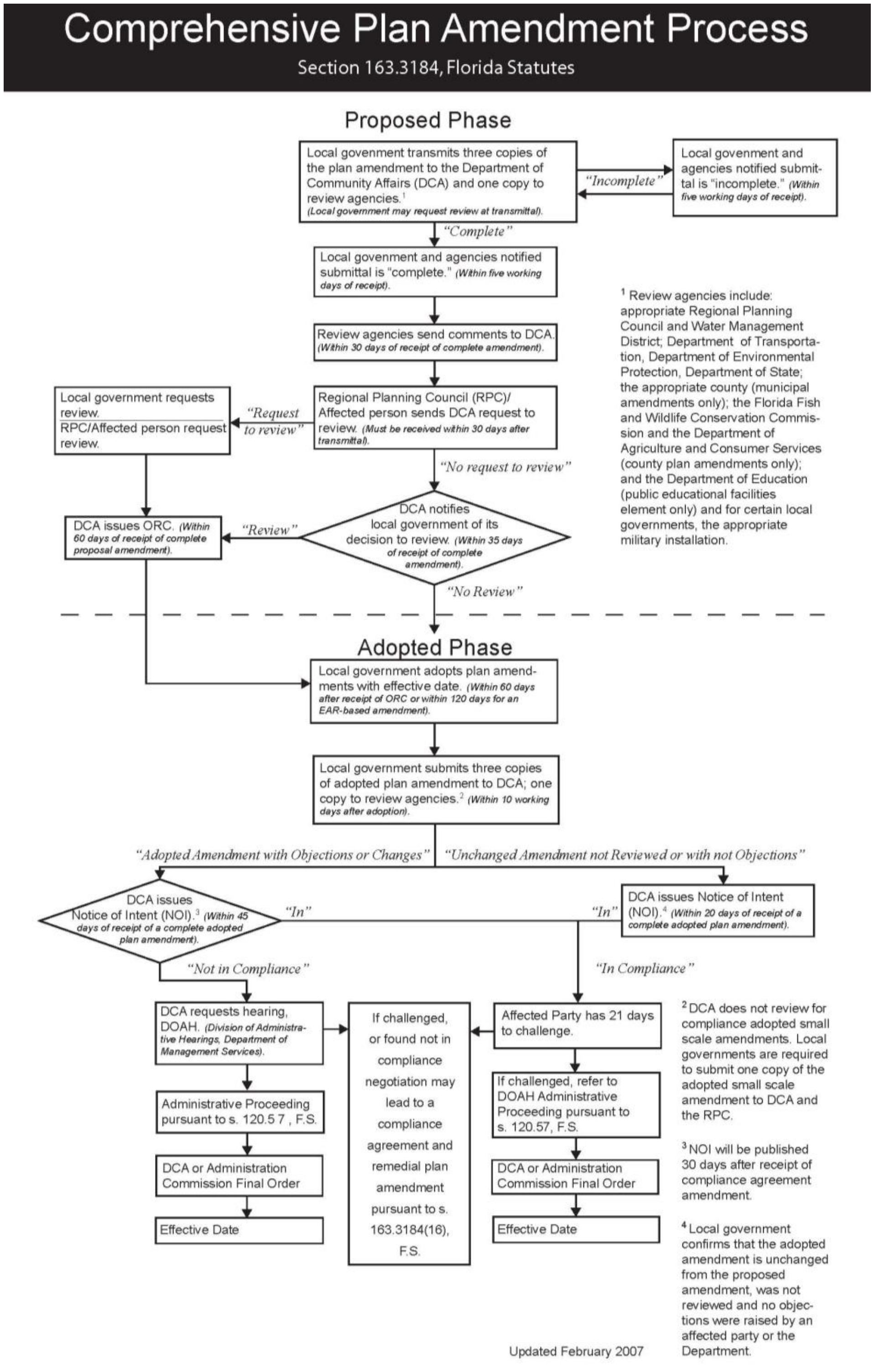


Figure A-1. Comprehensive plan amendment process (Source: Department of Community Affairs, Tallahassee, FL.)

APPENDIX B
EXCERPT FROM ORC DOCUMENT

1. Objection: The above amendments have the potential to add an additional 3,907 residential units and over 2,000,000 square feet of commercial uses to the City's Future Land Use Map. The City has not demonstrated the need for the additional residential or commercial uses related to the amendments.

[Sections 163.3177(2), (6)(a), (8), F.S.; Rules 9J-5.005(2) and (5)(a), 9J-5.006(2)(c), F.AC]

Recommendation: Revise the amendment to include a land use needs analysis demonstrating there is a need for the amount of development allowed by the amendments in order to accommodate the Comprehensive Plan's projected population growth within the planning timeframe of the FLUM. The analysis should be based on the maximum development potential allowed by the future land use designations. Revise the amendment as necessary to be consistent with and supported by the data and analysis

2. Objection: The data and analysis provided with the proposed amendments identifies a deficiency with the City's ability to serve the amendment sites with both central water and sanitary sewer. However, the City has not included information on the central water or sanitary sewer facility improvements (scope, timing, and cost of improvements) to maintain the adopted level of service standards for the facility; nor has the City included evidence of the coordination of any needed facility improvements with the Infrastructure and Capital Improvements Elements, including implementation through the Five-Year Schedule of Capital Improvements.

[Sections 163.3177(2), (3), (6)(a) and (c), (8), F.S. and Rules 9J-5.005(2); 9J-5.006(3)(b)1, (3)(c)3; 9J-5.011(1)(a through f), (2)(b)2, (2)(c)1; 9J-5.016(1)(a), (2)(b, c, and f), (3)(b)1, 3, and 5, (3)(c)1.d, 1.e, 1.f, and 1.g, (4)(a), F.A.C.]

Recommendation: The City must ensure that there is adequate water and wastewater capacity to serve the amendment sites at full build out potential. The City may choose to reduce the amendments in size and density to that which can be served by the existing City facilities. Alternatively, the City may wish to revise the amendments to include the required analysis necessary to support the increase in density and demonstrate coordination of land use with the planning and provision of public facilities. The analysis should look over the 5-year planning time frame and the overall planning horizon, and be based on the maximum development potential allowed by the proposed amendment. The analysis should include information on necessary sanitary sewer facility improvements (scope, timing, and cost of improvements) to maintain the adopted level of service standards for the facility. Any facility improvements required by the proposed amendments within the five-year timeframe should reflect coordination of the Community Facilities and Natural Groundwater Aquifer Recharge Element and Capital Improvements Elements, including implementation through the Five-Year Schedule of Capital Improvements. Improvements needed beyond the five years but within the planning horizon need not include capital improvements but should include policies or revisions to service areas to reflect strategies for needed plant expansions, upgrades or new facilities. Revise the amendments as necessary to be consistent with and supported by the analysis.

3. Objection: The proposed amendments are located in an area of high aquifer recharge and classified as 'extremely vulnerable' on the FAVA index. Proposed amendments to the Community Facilities and Natural Groundwater Aquifer Recharge Element would allow the sites to develop without connecting to central sewer service; therefore, allowing conventional septic tanks to serve the amendment sites. The Florida Department of Environmental Protection has indicated within areas classified as 'extremely vulnerable' the provision of central services, particularly sanitary sewer, is essential for densities at or above 1 unit per acre.

Figure B-1. Excerpt from objections, recommendations, comments document (Source: Division of Community Planning, Tallahassee, FL. Retrieved Dec 14, 2008, from http://www.dca.state.fl.us/fdcp/dcp/Procedures/noiorcpage.cfm)

APPENDIX C
EXCERPT FROM FLORIDA STATE PLAN

(9) *Natural Systems and Recreational Lands*.

(a) *Goal.* Florida shall protect and acquire unique natural habitats and ecological systems, such as wetlands, tropical hardwood hammocks, palm hammocks, and virgin longleaf pine forests, and restore degraded natural systems to a functional condition.

(b) *Policies.*

1. Conserve forests, wetlands, fish, marine life, and wildlife to maintain their environmental, economic, aesthetic, and recreational values.

2. Acquire, retain, manage, and inventory public lands to provide recreation, conservation, and related public benefits.

3. Prohibit the destruction of endangered species and protect their habitats.

4. Establish an integrated regulatory program to assure the survival of endangered and threatened species within the state.

5. Promote the use of agricultural practices which are compatible with the protection of wildlife and natural systems.

6. Encourage multiple use of forest resources, where appropriate, to provide for timber production, recreation, wildlife habitat, watershed protection, erosion control, and maintenance of water quality.

7. Protect and restore the ecological functions of wetlands systems to ensure their long-term environmental, economic, and recreational value.

8. Promote restoration of the Everglades system and of the hydrological and ecological functions of degraded or substantially disrupted surface waters.

9. Develop and implement a comprehensive planning, management, and acquisition program to ensure the integrity of Florida's river systems.

10. Emphasize the acquisition and maintenance of ecologically intact systems in all land and water planning, management, and regulation.

11. Expand state and local efforts to provide recreational opportunities to urban areas, including the development of activity-based parks.

12. Protect and expand park systems throughout the state.

13. Encourage the use of public and private financial and other resources for the development of recreational opportunities at the state and local levels.
(Source:
http://www.flsenate.gov/statutes/index.cfm?App_mode=Displat_Statute&URL=Ch0187/ch0187.htm)

APPENDIX D
COMMAND REFERENCE PROTOTYPE DOCUMENT

This document was part of the usage documentation submitted to a reviewing agency. It contains brief description of each command and presents a screen cast link pointing to the video of each command demonstrating its usage.

Map Menu in the Microsoft Word Menu Bar

In this prototype, all the GIS functionality is accessible via an additional item in the main menu bar in the Microsoft Word software; the additional menu item is titled Map Related.

New Map, Open Map and Delete Map

New Map command lets users add a new map, via a dialog box. New map is inserted at the current cursor position in the document. New map addition requires specification of a unique alphanumeric name for the map. It is possible to open a new map, that has no data, or select a map document (*.mxd) for opening of a map, or user can specify shape file data for loading in a new map. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/InsertNewMap.htm

Open Map command lets users open a map, from a list of maps inserted in the document. Screen-cast link: http://ashwinimail.web.officelive.com/Documents/OpenMap1.htm

Delete Map command lets users delete a map from a list of maps inserted in the document. It uses the same interface as that of the open map command, except users click on the delete map command button instead of the open map command button.

Show All Map Links

This command shows all the links between text in the current word document and features or shape files or maps included in the document. User can select a link on the Display Links dialog box to see related features on the map. There may be three types of links in the document as explained below.

1. A text selection can be linked to a single feature or multiple features present in a shape file, referenced by one of the maps within the document (Feature Link).
2. A text selection can be linked to a single shape file (layer), referenced by one of the maps within the document (Layer Link).
3. A text selection can be linked to a single map from one of the maps referenced within the document (Map Link). Screen-cast link: http://ashwinimail.web.officelive.com/Documents/showMapLinks.htm

Highlight Text with Map Links

This command highlights all the text in the document that is linked with features, shape files or map documents referenced within the document. This makes it easier for the user, to identify what words are linked in the document. User can also choose to select a linked word, and see the related link by choosing Show Map Link for Selection from the right click context menu. There are two types of highlights; the first type of highlight involves text highlighted with grey background. The second type of highlight involves text colored in blue. Blue colored text

indicates association of a link with every occurrence of the selected word in the document. The highlighted text (with grey background) indicates association of a link with text only at that location in the document, even if the same text is repeated elsewhere, it will not be associated with the link. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/Links_highlight_add_remove.htm

Remove Highlights from Text with Map Links

This command removes highlight effect created by the command Highlight Text with Map Links explained previously. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/Links_highlight_add_remove.htm

Comments

This command offers two sub commands, the first one lets user change Reviewer Information. This command lets users select username and other details for the purpose of identification of the reviewer. The second command lets users insert a comment table inclusive of all the comments made in the current document. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/CommentsAddReviewerInsertCommentShowTable.htm

Update Paths for Distribution

This command allows users to organize data for distribution and also correctly associates all the links, and the data files with the document, upon distribution. Any errors that may occur in the copying process due to unavailability of the referenced files are displayed to the user, so that the user may correct those manually and invoke the Update Paths for Distribution command again. This command's functionality is described below. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/updatePaths.htm

Case 1

When user adds a map to the document, the files associated with the map may be located anywhere on the user's computer. Upon invoking the Update Paths for Distribution command, new folders are created at the path of the word document, and the data files associated with the maps, images, and shape files are copied in the newly created folders. The conceptual folder arrangement resulting after updating paths is shown below.

..\DocumentPath\planning document.doc
..\DocumentPath\Maps\
..\DocumentPath\Maps\Data
..\DocumentPath\Maps\Images

The maps folder stores .mxd files, the data folder stores .shp files and the images folder stores .jpg files used in the maps associated with the document.

Example 1

The document worddocument.doc at path c:\temp on computer a contains a map of USA, residing at path c:\ArcGIS\data\USA.mxd and it refers to the shape files States and USHighways located at path c:\data\States.shp and c:\data\USHighways.shp respectively. To update the map related data in the word document, execute the Update Paths for Distribution command from the word document. This will arrange data as shown below.

c:\temp\ worddocument.doc – The document location is not altered by this command.
c:\temp\ maps\USA.mxd
c:\temp\maps\data\USHighways.shp
c:\temp\maps\data\States.shp
c:\temp\maps\images\USAMapImage.jpg

Case 2

If user wants to move the document from the current path to another location, either on the same computer or another computer or a portable device, then user needs to execute the Update Paths for Distribution command on the current computer to organize data. Then user can manually copy the organized data and the Microsoft Word document, on a portable device / or to another location. Upon successful copying of the data files, it is necessary to link the data files, with the Microsoft Word document, and therefore, it is necessary to execute the Update Paths for Distribution command again by opening the copied document at the new location. This method is particularly necessary if user wishes to transfer the data from one computer to another computer via a compact disc or a DVD media.

Example 2

To copy a map-enabled document worddocument.doc from current computer A at path c:\temp to CD media that is d:\document and then to another computer B at e:\mapDocument, follows the steps shown below.

1. Execute the Update Paths for Distribution command from the map-enabled document on the computer A.
2. At computer A, burn a CD with word document at path c:\temp\worddocument.doc, and all the data at path c:\temp\maps*.*
3. At computer B, copy data from CD media at the desired location e:\mapDocument.
4. On computer B, open the map-enabled document at path e:\mapDocument\ worddocument.doc and execute the Update Paths for Distribution command from the document to associate map related data to the word document.

Case 3

If user wants to move the document from the current path to another location on the same computer, or on a USB drive or flash card media (not CD or DVD media) attached to the same computer, then the user can just choose to copy the word document at the new location, and execute the Update Paths for Distribution command by opening the copied document at the new location. The update paths command will look for data files at the old location and copy those to the new location.

Example 3

To copy a map-enabled document worddocument.doc from current computer A at path c:\temp to a USB drive or a flash drive media such as a SD Card or a Compact Flash card to g:\document then, follow the steps shown below.

1. Execute the Update Paths for Distribution command from the map-enabled document on the computer A.
2. From the computer A, copy the word document at path g:\document\worddocument.doc on the USB drive or flash drive, or external hard drive.
3. From the computer A, open the copied map-enabled document on portable media used in the step 2, at path g:\document\worddocument.doc and execute the Update Paths for Distribution command from the document to associate map related data to the word document. The command will look for map files present on computer A at old paths, and create appropriate paths on portable media, and link the files. New paths created on the portable media will be as follows.

   G:\ document\worddocument.doc
   G:\ document\Maps*.mxd
   G:\ document\Maps\Data*.shp
   G:\ document\Maps\Images*.jpg

Context Sensitive Menu for Text Selection

The text shortcut menu pops up when we right click while the cursor is on some text in the Microsoft Word document. Five additional commands have been added to this menu, that relate to finding text in map data, and creating and displaying links between text and map data. These commands are briefly described below.

Link Text to a Layer

This command works on a text selection in the document and brings up a dialog box containing a list of all the layers referenced by maps in the document. User then can select a layer, and link it with the selected text.

Link Text to a Map

This command works on a text selection in the document and brings up a dialog box containing a list of all the maps referenced in the document. User then can select a map, and link it with the selected text. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/Text%20to%20Layer%20and%20text%20to%20map%20link.htm

Find in Layer

This command works on a text selection in the document and brings up a dialog box containing a list of all the layers referenced by maps in the document. User can select a layer, and then the find command executes, it looks for the selected text in the string fields of the layer table. Results of the find operation are listed in a listbox, from which user may navigate to the map containing that particular feature. The find criteria used in the search is not case sensitive and besides exact matches, it also outputs results that may have the selected text occurrence in the middle of a description. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/FindInLayer.htm

Find in Spatial Data

This is command is exactly the same as above command, except this command searches for the text selection in all the layers referenced by all the maps in the document. So the search is wide, however if the user has an idea of where the selection may occur then the user can invoke above command and only perform search in a single layer. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/FindInSpatialData.htm

Show Map Link for Selection

This command works on a text selection in the document and looks for presence of any links with spatial data, containing selected text. It brings up the links dialog box, and displays links if present for the selection. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/ShowMapLinkForSelection.htm

Context Sensitive Menu for Image Selection

The image shortcut menu has just one additional map related command associated with it, and that is open map. This command brings up the open map dialog box, and user can choose to open a map from that dialog box. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/UpdateMap.htm (The update map command's screen cast uses the right click context menu for opening a map, hence that link is provided here.)

Map View: Menus and Commands

All the map display, query and manipulation functionality is available through a form that hosts a map control and a page layout control object. This form is henceforward referred as a map dialog box. It supports a map view (display geography) and a page view (displays map and related elements on a page layout).

The tools and commands displayed in the map view's toolbar from left to right are; Open Map, SaveAs Map, Undo, Redo, Zoom In, Zoom Out, Pan, Zoom to Full Extent, Refresh, Zoom to Selected Features, MapView menu (contains more zoom tools), Selection menu (contains selection related tools such as select features, clear selection), Select All, Select Features, Identify, and Map Menu (contains customized tools for map view). Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/OpenMap1.htm

The tools and commands displayed in the page layout view's toolbar from left to right are; Open Map, SaveAs Map, Undo, Redo, Page layout related tools such as Zoom In, Zoom Out, Zoom to Full Page, Zoom to Page Width, Fixed Zoom In, Fixed Zoom Out, Go Back to Extent, Go Forward To Extent, and Map related tools such as Zoom In, Zoom Out, Pan, Identify, MapView menu (contains more zoom tools), Selection menu (contains selection related tools such as select features, clear selection), Select All, Select Features, and Map Graphics menu (contains customized tools for layout view).

It is expected that most of the map related operations will be performed in the map view, and only page layout related functions will be executed in the page layout view. Therefore, the map view has more functions, and additional layer, and map based context menus. These map view related menus and commands are described below.

Symbology

This command works with feature layers in the map. In the symbology dialog box, user can work with symbology of one layer at a time. User can alter the symbology of a layer using values in selected field of the layer attribute table. The available choices present in the symbology dialog box include simple rendering, unique value rendering (based on a field), proportional rendering (based on comparison of values from 2 fields, for example population in 1990 and population in 1999), dot density rendering (based on a field), and bar chart rendering (based on values from 2/3 fields). Layer rendering tools present in the ArcMap are quite comprehensive, and it is not possible to include such a range of choices, the rendering choices made available in the symbology dialog box are there to demonstrate that it is possible to program such tools. This dialog box also allows users to associate labeling on a layer based on values in a field from the layer attribute table.

Screen-cast link1:
http://ashwinimail.web.officelive.com/Documents/symbology_simple.htm

Screen-cast link2:
http://ashwinimail.web.officelive.com/Documents/Symbology_uniqueValue.htm

Screen-cast link3:
http://ashwinimail.web.officelive.com/Documents/Symbology_Proportional.htm

Screen-cast link4:
http://ashwinimail.web.officelive.com/Documents/Symbology_dotDensity_2.htm

Screen-cast link5:
http://ashwinimail.web.officelive.com/Documents/Symbology_Barchart.htm

Screen-cast link6:
http://ashwinimail.web.officelive.com/Documents/SymbologyUniqueLabelsUpdateMap.htm

Attribute Query and Spatial Query

Attribute query command works with feature layers in the map. In the attribute query dialog box, user can view the layer attribute table, user can query layer data based on values in the selected field, and user can also view the query results in a tabular form. Further, it is possible to export the query results in the form of a csv file (comma delimited value file), and user may also insert the query results in the word document. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/AttributeQuery.htm

Spatial query command works with feature layers in the map. In the spatial query dialog box, user can select the querying layer, and the layer from which selection is sought based on the query criteria. User can also choose from various spatial criteria available. Some spatial relationship criteria such as within, and contained by are not implemented. Also most spatial queries require that the layers involved in spatial relations are in same projection. If the layers do not have same projection, the spatial filter tries to re-project features from one layer on the fly during queries, and this may result in some spatial queries not producing any result. Therefore, during spatial queries a message box informs the user if the projections of both the layers match or do not match.

Screen-cast link1:
http://ashwinimail.web.officelive.com/Documents/spatialQuery_intersection_hy_majrd.htm

Screen-cast link2:
http://ashwinimail.web.officelive.com/Documents/spatialQuery_majrd_crossed_gnv.htm

Screen-cast link3:
http://ashwinimail.web.officelive.com/Documents/spatialQuery_gnv_contains_majrdl.htm

Screen-cast link4:
http://ashwinimail.web.officelive.com/Documents/spatialQuery_AddtoSeln_subtractFrmSeln_etc.htm

Access Tables

This command works with feature layers in the map. User can export all rows or some rows, from the table in a csv file (comma delimited value file) or user can insert rows in the document. User has a choice of selecting a few fields of importance for the export or insert rows operation. The statistics for a numerical field can also be checked in the dialog box. Screen-cast link: http://ashwinimail.web.officelive.com/Documents/AccessTables.htm

Link Selection

This command works with selection of one or more features in the one layer of the map open in a map view. If feature selection is present then user can continue with the link selection command. This command prompts user to also select text in the word document, and then using the information of selected text and object ids of selected features in the map, a text to feature link is formed.

Screen-cast link1:
http://ashwinimail.web.officelive.com/Documents/CreateFeatureLinkWithText.htm

Screen-cast link2:
http://ashwinimail.web.officelive.com/Documents/CreateFeatureLinkForEveryOccurenceOfSelectedText.htm

Insert Map Image and Update Map

Insert Map Image command is enabled when a new map is opened. When user is satisfied with the map display and is ready to insert the map image in the document, this command is executed. This command saves the map or prompts the user to save the map if no mxd document is specified in the new map dialog box, and then inserts a map image (based on user selected dots per inch resolution) in the word document at the cursor location. If users do not execute this command after opening a new map, then the map information will not be stored in the document, and its image will not be inserted in the document. Screen-cast link: http://ashwinimail.web.officelive.com/Documents/InsertNewMap.htm

Update Map command does the same job as the Insert Map Image command; however this command is used for updating a map. At that time, the Insert Map Image command is disabled. This command also saves the map, updates layer information for the map, creates a new map image, and replaces original map image in the word document with the new map image. If users do not execute this command after opening an existing map, then the map information will not be stored in the document, and its image will not be inserted in the document. Screen-cast link: http://ashwinimail.web.officelive.com/Documents/SymbologyUniqueLabelsUpdateMap.htm

Add Shape File

This command allows user to add a shape file to the map. Only shape file data layers can be currently added to a map. This command is only available in the map view, since it is expected that any major map manipulations will be completed in the map view. Screen-cast link: http://ashwinimail.web.officelive.com/Documents/AddShaeFile.htm

Right-Click Menu for Data Frame Selection

This menu contains commands that apply to all the layers present in the map. Commands Turn All Layers On and Turn All Layers Off alter visibility of all the layers at once. Similarly selection related commands alter selectability of all the layers at once. Selection command present the selection related options. This menu is not accessible in the page layout view.

Right-Click Menu for Layer Selection

Most of the commands in layer right click menu deal with layer related actions. Commands Move Layer Up, Move Layer Down, Move Layer To Top, Move Layer To Bottom alter layer's position in the table of contents. Command Zoom to Layer alters map extent to the extent occupied by all the features in the selected layer. Commands Layer Selectable and Layer Unselectable, alter layer's selection properties. Other commands related to scale such as Set Maximum Scale, Set Minimum Scale affect layer's visibility at different scales of the map. The command Remove Scale Thresholds is used to remove maximum and minimum scale settings for the layer.

Some commands work on the selection of features in that layer. The Export Selected command allows user to export selected features from that layer into another shapefile. The Create Graphic Buffers command creates graphic buffers at a specified buffer distance around the features from that layer in the map. The Delete Graphic Buffers deletes graphic buffers if present in that layer. The Create Buffers command creates feature buffers around the selected features from that layer, and exports the new buffer features into another shapefile.

Screen-cast link1:
http://ashwinimail.web.officelive.com/Documents/SelectedLayerRightClickMenu.htm

Screen-cast link2:
http://ashwinimail.web.officelive.com/Documents/GraphicAndFeatureBuffers.htm

Page Layout View: Menus and Commands

The page layout view has standard page layout navigation, map navigation, and selection commands on its toolbar. This view contains no right click menus because, it is assumed that most of the map query and data analysis will take place in the map view. The page layout view, has a customized menu, titled as the Map Graphics menu on its toolbar. That is described below.

Add and Delete Graphic Elements

Add Legend, Scale and North arrow command inserts the legend, scale and North arrow on the map. The type of scale inserted in the map and the type of North arrow inserted in the map are predefined. The legend format is also a predefined format. Use of different styles, and formatting options is available in the ArcEngine, however to program each option is time consuming, hence only default capabilities are provided. Add Text Element command allows user to insert a text element with user specified text and font size. Delete Selected Graphic Element command allows users to delete selected graphic elements in the page layout. Screen-cast link:
http://ashwinimail.web.officelive.com/Documents/PageLayoutAddElementsUpdateMap.htm

Other Common Commands

Symbology, Insert Map Image and Update Map commands are also present in the map view, and their functionality is previously described under the commands listed in the map view.. They have same functionality in both the views.

APPENDIX E
QUICK SCREEN CAST LINKS FOR SELECTED COMMANDS

Table E-1. Screen cast links for selected commands

Command name	Screen cast link
New Map	http://ashwinimail.web.officelive.com/Documents/InsertNewMap.htm
Open Map	http://ashwinimail.web.officelive.com/Documents/OpenMap1.htm
Update Paths for Distribution	http://ashwinimail.web.officelive.com/Documents/updatePaths.htm
Show All Map Links	http://ashwinimail.web.officelive.com/Documents/showMapLinks.htm
Highlight Text with Map Links	http://ashwinimail.web.officelive.com/Documents/Links_highlight_add_remove.htm
Remove Highlights from Text	http://ashwinimail.web.officelive.com/Documents/Links_highlight_add_remove.htm
Comments	http://ashwinimail.web.officelive.com/Documents/CommentsAddReviewerInsertCommentShowTable.htm
Link Text to a Layer	http://ashwinimail.web.officelive.com/Documents/Text%20to%20Layer%20and%20text%20to%20map%20link.htm
Link Text to a Map	http://ashwinimail.web.officelive.com/Documents/Text%20to%20Layer%20and%20text%20to%20map%20link.htm
Find in Layer	http://ashwinimail.web.officelive.com/Documents/FindInLayer.htm
Find in Spatial Data	http://ashwinimail.web.officelive.com/Documents/FindInSpatialData.htm
Show Map Link for Selection	http://ashwinimail.web.officelive.com/Documents/ShowMapLinkForSelection.htm
Symbology	http://ashwinimail.web.officelive.com/Documents/symbology_simple.htm
	http://ashwinimail.web.officelive.com/Documents/Symbology_uniqueValue.htm
	http://ashwinimail.web.officelive.com/Documents/Symbology_Proportional.htm
	http://ashwinimail.web.officelive.com/Documents/Symbology_dotDensity_2.htm
	http://ashwinimail.web.officelive.com/Documents/Symbology_Barchart.htm
	http://ashwinimail.web.officelive.com/Documents/SymbologyUniqueLabelsUpdateMap.htm
Attribute Query	http://ashwinimail.web.officelive.com/Documents/AttributeQuery.htm
Spatial Query	http://ashwinimail.web.officelive.com/Documents/spatialQuery_intersection_hy_majrd.htm
	http://ashwinimail.web.officelive.com/Documents/spatialQuery_majrd_crossed_gnv.htm
	http://ashwinimail.web.officelive.com/Documents/spatialQuery_gnv_contains_majrdl.htm
	http://ashwinimail.web.officelive.com/Documents/spatialQuery_AddtoSeln_subtractFrmSeln_etc.htm
Access Tables	http://ashwinimail.web.officelive.com/Documents/AccessTables.htm

Table E-1. Continued

Command name	Screen cast link
Link Selection	http://ashwinimail.web.officelive.com/Documents/CreateFeatureLinkWithText.htm
	http://ashwinimail.web.officelive.com/Documents/CreateFeatureLinkForEveryOccurenceOfSelectedText.htm
Insert Map Image	http://ashwinimail.web.officelive.com/Documents/InsertNewMap.htm
Update Map	http://ashwinimail.web.officelive.com/Documents/SymbologyUniqueLabelsUpdateMap.htm
Add Shape File	http://ashwinimail.web.officelive.com/Documents/AddShaeFile.htm
Layer Right-Click Menu	http://ashwinimail.web.officelive.com/Documents/SelectedLayerRightClickMenu.htm
Create Graphic Buffers	http://ashwinimail.web.officelive.com/Documents/GraphicAndFeatureBuffers.htm
Create Buffers	http://ashwinimail.web.officelive.com/Documents/GraphicAndFeatureBuffers.htm
Add Legend, Scale, North	http://ashwinimail.web.officelive.com/Documents/PageLayoutAddElementsUpdateMap.htm
Add Text Element	http://ashwinimail.web.officelive.com/Documents/PageLayoutAddElementsUpdateMap.htm

APPENDIX F
COMMENTS SENT BY THE REVIEWING AGENCY

The application developed by Ashwini is a great way to bring the basic GIS analysis to end users that do not have GIS knowledge and / or skills but still can take advantage of the visualization and basic analysis offered by GIS. Not only planners, but any professional that accesses documents with maps could take advantage of this dynamic mapping application.

By enabling basic GIS functionality on a Microsoft Word document the "map enable document" (MED) tool becomes easily accessible and virtually eliminates the need of training for its use, as it keeps the Word interface standard. MED requires certain software to be installed. Ashwini developed user friendly and automated software recognition applications that do not take much time to be run or require high level IT skills from the end user to check for installed minimum software requirements.

The MED installation is smooth and easy for an experienced GIS or IT professional to install. If there is an intention to distribute MED to other users with various levels of IT expertise, my suggestion would be to write a quick fact sheet walking the users through the various steps and menus that are needed to enable/disable libraries and such. This would make the application to become more stand alone and easier to be distributed.

As part of the MED installation process on my computer, the application initially tested if ArcEngine was installed. Since I have a floating ESRI ArcInfo version installed, ArcEngine is already embedded. Initially MED tested only for ArcEngine availability. On the fly, Ashwini made quick adjustments to the application check for not only ArcEngine, but also verifying if any other versions of ESRI products that come with this packet embedded were available. I observed that manipulating the application code was quick, effective and very easy. The code Ashwini developed is clean and organized. It demonstrated to me how much time and effort she put into the development of this application. On a no organized code environment, such simple application tweak would necessarily take much longer. I congratulate her for such organization and effort. Analyzing the application by itself, the menu options available to the end user seem to suffice the basic needs of dynamic mapping manipulation to a basic GIS end user level.

The option "Delete map" being available all the time concerns me. Enabling the user to delete a map that was originally placed on a Word document should be something controlled via user access level. I recognize that developing a controlled access level interface for this application would make the installation and initial configuration process of MED much more complex and less user friendly, requiring a higher level of IT skills. An alternative suggestion to address this concern would be giving the Word document creator the ability to enable or disable the "delete map" option during the "save" process of the original document. On a planning environment "deleting a map" is not critical. Making comments, enabling spatial analysis and interacting with a map are the most critical part of daily activities.

The "link text to a layer" is another functionality that will make the overall review of comprehensive plan very easy and dynamic. Without much effort the end user can navigate to maps displaying such themes. The application is very intuitive and user friendly.

By enabling basic mapping manipulation functions such as symbology, query, navigation (pan, zoom, table of contents) MED brings powerful GIS tools to a known and user friendly MS Word environment. It becomes just easy to the end user manipulate basic GIS in a well known interface such MS World rather than learning a new software such ArcView.

The documentation that goes with the application seems to be enough to give the user a quick overview of what the tool can deliver. A quick reference sheet containing the application functionality listed on a summarized format would be very helpful as well.

To summarize, the concept of Map Enable Document tool (MED) is brilliant. The application is easy to use, it is user friendly and powerful to any environment that utilizes maps. That includes but do not limit its use to a planning environment.

The MED application is user friendly, intuitive and on my opinion will enable users to interact much easily with GIS. By eliminating the need to know how to manipulate a GIS application environment, the end user is being empowered to perform basic GIS functions and analysis. I don't see a need for training to utilize this application. A "help on line" as one of the options in the menu bar would suffice this purpose.

The installation process is easy for a medium level user that feels comfortable manipulating a Windows environment. A "readme" installation guide would be highly recommended to make the application portable and more stand alone.

Cost wise, MED needs ArcEngine, which costs the same as a single use, stand alone ArcView application. MED becomes more cost efficient for organizations that do not intend to invest time and money in GIS training and / or do not identify the need of having staff developing GIS to the edge. Training takes time and costs money. Becoming a GIS user takes more than just creating and interacting maps. Not all users feel comfortable with an ArcView environment. For those cases, I would strongly recommend the use of MED. Organizations and departments could take advantage of GIS in an easy and user friendly way by utilizing MED.

In my opinion Ashwini had a brilliant idea to make GIS accessible through one of the most popular application in the world: MS Word. The tool is robust, reliable (I could not crash it!!) and it is extremely user friendly. **She did a very good job.** I hope she takes the Map Enabled Document tool to the next level and makes it widely available to a corporate environment.

Claudia Paskauskas, MCSD, GISP
GIS Manager
East Central Florida Regional Planning Council
631 N. Wymore Rd, St.100
Maitland FL 32751
www.ecfrpc.org
claudia@ecfrpc.org

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BIOGRAPHICAL SKETCH

Ashwini Wakchaure was brought up in Thane, India. She studied at the L. S. Raheja School of Architecture, in Mumbai, and earned her bachelor's degree in architecture in India. Later she pursued a master's degree in urban planning at the Center for Environmental Planning and Technology, in Ahmedabad, India. After working at Stup Consulting Services, Mumbai, India, as an Architect and later at Mumbai Metropolitan Region Development Authority, Mumbai, India, as a Deputy Planner, she came to the United States to pursue an M.S. degree in Urban and Regional Planning at Virginia Tech University. She then worked as a GIS programmer at URS Corporation, Tampa, Florida, and afterwards joined the University of Florida for her doctoral studies in urban planning. Upon completion of her doctoral studies she plans to teach at a suitable university.