Presenting a Potential Bus Rapid Transit Line with GIS, Analytical Models and 3D Visualization

Xinhao WANG & Hexiang HUANG & Jun SHI

Xinhao Wang, PhD, Associate Professor School of Planning, University of Cincinnati, Cincinnati, OH 45221-0016, xinhao.wang@uc.edu
Hexiang Huang School of Planning, University of Cincinnati, Cincinnati, OH 45221-0016
Jun Shi, PhD; Intelligent CAM Systems Laboratory, University of Cincinnati, Cincinnati, OH 45221- 0072

ABSTRACT

Cincinnati is a typical American city where private automobiles are the primary means of transportation. It is not hard to envision the future of serious traffic tie-ups. Adequate mobility is a key factor for improving the residents' life quality and consequently the prospects for economic development. The two options are 1) adding more highways and 2) improving mass transit. Within this context, this paper presents a study that uses information technologies to help explore if a mass transit can be a valid alternative for Cincinnati. In particular, the research team explores the effect of a potential Bus Rapid Transit (BRT). Although BRT has been implemented in many cities around the world, it has not been proposed in this region. To help people understand the impact of a BRT the research team uses a combination of Geographic Information Systems (GIS), simulation models (SM) and 3-dimensional visualization (VIS) to present the current and future scenarios related to a potential BRT along a previously proposed bus line in terms of traffic flow and air pollution related to automobile emissions. The value of such a system as an information communication tool in planning processes is discussed from its spatial, temporal and visual realistic aspects.

1. INTRODUCTION

As the concept of sustainable development and the need for public involvement in planning of diverse groups become more widely accepted among politicians, policy-makers and the general public, it is critical to incorporate impact assessment and analysis into the planning and decision-making process. During such a process, all stakeholders in a region, including public/private organizations and residents should work together to analyze, compare, contrast and prioritize different development alternatives for a sustainable future (Smith, Blake, & Davies, 2000; Wang, 2001). Planners, in particular, have the responsibility of accurately and realistically presenting future consequences of proposed actions to all stakeholders. The ability of selecting and presenting information to support decision-making is an integral part of such a process (Halls, 2001). Applying information technology will enable planners to collect and analyze data to effectively design, simulate and present future scenarios using computers before the building phase. Such presentations are important to enable people to envision the future consequences of a proposed development in order to build a consensus among stakeholders and to formulate appropriate proactive measures. This paper presents an effort toward the integrated use of three specific components of information technology – Geographic Information Systems, simulation models and computer visualization to support this planning process. The goal is to enable policy makers, planners and citizens to better understand the impact of a potential Bus Rapid Transit. Visualization features of such a system can present scenes of the present and future. The work reported here demonstrates the advantage of the integration and challenges faced in such integration through a prototype application.

GIS applications have been used to quickly and reliably process spatially referenced data as a decision support tool (Badard & Richard, 2001; Dangermond, 1989; Lee, 1990; Worrall, 1990). Many research projects have explored the potential of using GIS to store spatial data, to perform interactive spatial analysis, to sketch a city and to display data and modeling results through maps and tables (Singh, 1999; Shamsi, 1996; Grossmann & Eberhardt, 1993; Wang,1997; Batty et al., 1999; Gahegan & Lee, 2000; Bailey & Gatrell, 1995).

Various simulation models have been used in planning practices. For example, surface and subsurface water models are used to address resource and environmental issues (Darbar et al., 1995; Cowen et.al., 1995; Merchant, 1994; Smith & Vidmar, 1994; Warwick & Haness, 1994; Tim & Jolly, 1994). Another set of models commonly used in planning simulates the interactions between land use and transport to connect economic activities in space with accessibility and; demands and supply for flows (Barra, 2001). In general, simulation models provide the information necessary for analysis and evaluation between planning alternatives (Putman & Chan, 2001).

The importance of computer visualization for planning practice lies in its potential for improving the quality of decision-making. The physical nature of planning practice demands that three-dimensional images should be used to evaluate the effects of planning that takes place in space. Recent efforts demonstrate that 3D models can be used to visualize and quantify abstract policy and planning simulations (Kwartler & Bernard, 2001; Batty et al., 1999, Ranzinger & Gleixner, 1997). A visual representation should help to avoid misunderstandings of the consequence of development (Hall, 1993). In other words, the future can be presented graphically and evaluated as the base for discussing different planning alternatives. Martin and Higgs (1997) suggest two areas of visualization applications in planning: representations of physical environment and the abstract statistical relationships. In both cases, the use of 3-dimensional (3D) models provides certain degree of realism that can help viewers link data to a particular physical setting.

Although planners use GIS, simulation models and 3D visualization in various projects, the development of each has been primarily independent and integrative uses are still at an early stage. Langendorf (2001) argues that it is necessary to analyze the world from multiple viewpoints in order to understand any subject of consequence. In the following sections, current approaches to integrate GIS, simulation models and visualization are first reviewed, then a prototype of such integration, using traffic impact analysis as an example is presented. Lastly, the needs, benefits and challenges for such an integrated system are discussed.

2. STUDY AREA

After a decade long effort for a light rail system in Greater Cincinnati, a proposal to raise a half-cent sales tax to help pay for a $2.7 billion transportation plan was put on the Hamilton County ballot, known as Issue 7. It would be used for a network of five light rail lines, expansion of its bus system, construction of 30 transit hubs, addition of 13 neighborhood shuttles running from those hubs, streetcar lines along the downtown riverfront, direct bus routes to the University of Cincinnati and the medical complexes around it. Issue 7 encountered sharp, well-organized opposition, which resulted in a defeat by a ratio of more than 2-to-1. The centerpiece of the cause of most of the controversy was a 60-mile, $2.6 billion light-rail system. Transit officials expected the sales-tax hike to raise about $60 million and pay for about 25 percent of the plan. The plan then called for the federal government to cover half the cost and the state to cover 25 percent. One of the major concerns was about the lack of a binding commitment to roll back the sales tax if the light rail portion doesn't win adequate state or federal funding.

Many believed that the only thing keeping light rail from coming to the area was the lack of a local funding source. The last proposal to the federal government for a light-rail line along Interstate 71 received a passing grade on all aspects of the plan except local funding from the Federal Transit Administration. That forced the agency to give a "not recommended" rating overall.

Rejecting Issue 7 does not solve the need for a better public transit in Cincinnati. It is not hard to envision the future of serious traffic tie-ups - the fact that a rainy day can double the commuting time ought to give people an idea of what lies ahead. Adequate mobility is still a key factor for improving the quality of life of residents and consequently the prospects for economic development.

One alternative is to add more highway lanes and more highways. Expanding the highways is expensive and will pave over a lot of real estate that homeowners, business owners, etc., would be loathe to give up. Furthermore, experience in other cities has shown that it may not work. Atlanta tried to build its way out of traffic jams with highways. It didn't work.

The other alternative is to reconsider the mass transit option. People predict that the defeat of Issue 7 will put mass transit planning on ice for several years in Cincinnati. Cincinnati will remain one of the largest cities in the world without a single mile of any form of rail transit. This study will help to explore if a mass transit without light rail can even be a better alternative for Cincinnati.

3. THE MODELING AND VISUALIZATION STUDY

An effective planning support system can significantly enhance the collaboration among stakeholders and facilitate agreement on the most appropriate alternatives. To achieve these goals, such a system ought to be used by stakeholders with diverse backgrounds, interests, and knowledge to analyze and evaluate, both effectively and accurately, development alternatives. The integration of GIS, simulation modeling, and visualization is expected to greatly enhance the analytical capabilities of GIS-based spatial decision-making through a three dimensional format. The net effect will be to improve both the decision-making process and communication among planners, decision-makers and the various groups comprising the public; as well as to encourage citizen participation through graphical presentations that are familiar and easy to understand.

Mitigating congestion and estimating pollution emission are always primary issues faced by transportation planners. Understanding traffic conditions and pollution levels from different scenarios is indispensable in the traffic planning and decision making process. The significance of an integrated traffic impact analysis system is related to using best available technologies to analyze spatial data and predict and present future scenarios and changes. Planning alternatives are to be evaluated and presented using various methods, including numerical data tables, two- and three-dimensional maps and images, and three-dimensional animations.

Two analytical transportation models were used in this study to predict the traffic conditions and hourly Carbon Monoxide (CO) concentration levels. Both models are applied to street segments called free flow links. A free flow link used in travel demand modeling is defined as a straight segment of roadway having a constant width, height, traffic volume, travel speed and vehicle emission factor. The coordinates of the two end nodes, (X1, Y1) and (X2, Y2) determine the location of a free flow link. Data used in this study, provided by the Ohio Kentucky Indiana Council of Governments (OKI), included street link-based traffic count data for 2002 in the Greater Cincinnati Metropolitan Area.

One of the most widely used models to predict link-based travel speed, the standard BPR curve model (Dowling, 1997), was coded with Visual Basic Application as part of the ArcMap application. From the model output, the time taken for a car to pass a street link is calculated from the link length and travel speed. Multiplying the time and volume will get the number of cars per link.

The concentrations of Carbon Monoxide along streets are calculated with CAL3QHC model (Version 2.0), developed by the U.S. Environmental Protection Agency (USEPA, 1995). The inputs for CAL3QHC include roadway geometries, receptor locations, meteorological conditions and vehicular emission rates, among which meteorological variables are assumed to be spatially constant over the entire study area. Vehicles are assumed to be traveling without delay along free flow links. The link speed represents the speed of a vehicle traveling along the link. The CO concentrations are measured at receptors specified in X, Y and Z coordinates. A vehicle Emission Factor table was obtained from OKI that contains emission factors for nine vehicle types and a Composite Emission Factor (CEF) for all vehicle types at different travel speeds.

GIS was used to manage a digital database and to connect to visualization and simulation models. Several GIS operations were performed with ArcGIS 8.3, product of the Environmental Systems Research Institute (ESRI, Redlands, CA). In order to represent the geometry of streets more accurately than the straight-line roadway links used in the simulation model, street data were acquired from CAGIS, a local organization maintaining high quality data. Receptor locations were created as a point coverage.

The source codes of the CAL3QHC program downloaded from the USEPA website was in Fortran language. The codes were translated into Visual Basic for Applications (VBA), in the format of a Class Module, which can be used in ArcMap directly. Several improvements were made to the original model.

- The Fortran model can only calculate a fixed maximum number of 120 links and 60 receptors. To remove this limitation, we introduce the dynamical memory allocation in the program. With this approach, we are able to model a much larger number of street links and receptors. The model analyzes 100 receptors at a time, during which the program collects all information for the 100 receptors and generates an XML file of "in.xml", which provides all data needed by the model. Then the Class Module will read this XML file and export another XML file of "out.xml", as well as a text file of "out.txt". "out.xml" provides the same information as the output text file in the old version of model. "out.txt" gives a comma-separated table of receptor ID, coordinates, and CO values. At the end of each run, the "out.xml" and "out.txt" will be appended in specific XML and text files respectively.

- To operate the original model, a user must prepare an input file, which is a text file using the punch card style of data lines. To make the data preparation more efficient and user friendly, we develop a toolbar of the air quality model in ArcMap for user input control. After clicking a button, a user sees a User Data Entry Form whic is the main interface of the program (Figure 1). From the form, a user can set the input parameters. The original model only can run one set of receptor height, the modified model has the option of running many different heights, as specified the lowest and highest height and the elevation increment. For the wind direction, a user may choose to calculate for one wind direction or calculate the 360 degrees with a specified direction increment. In addition, a user may specify the unit for distance, the pollutant type. All output files are saved under the folder named by the user.

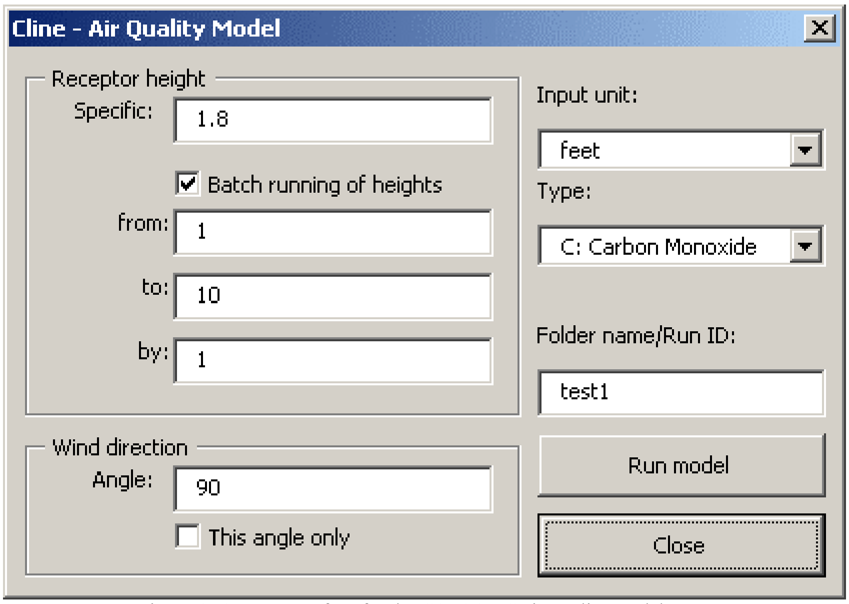

Figure 1: A User Interface for the CAL3QHC air quality model

Normally, the automobile generated carbon monoxide (CO) concentrations would be displayed as a color thematic map, such as color coded mesh points or concentration isolines. Using the simulated receptor CO concentration as the z value, we created a 3D surface with the GIS 3D surface construction function for each modeling output. Figure 2 displays such a concentration surface created from a CO concentration model output. The z value of the surface is replaced with Carbon Monoxide concentrations. Street segments that are experiencing high level of CO concentration can be identified and highlighted, which allows the system's users toquickly prioritize their problem-solving effort in searching for alternatives to minimize air quality degradation.

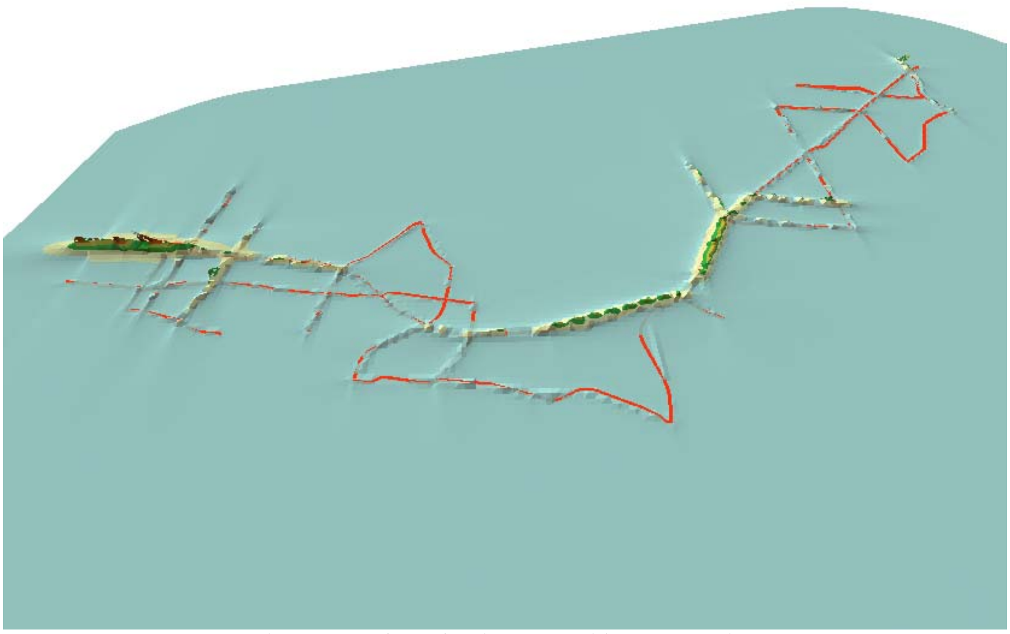
Figure 2: Surface of carbon monoxide concentration

Following Shiffer's (1999) idea of using digital video clips taken at various Level of Service (LOS) conditions to represent traffic at a given LOS, we created a series of animations based link-based automobile density and travel speed produced by the simulation model. Figure 3 shows an example of the animations for the entire BRT line, which is about 8 kilometers. We used the aerial photos as the background, the potential BRT line was highlighted as the red line. The yellow line indicates the half of a mile distance from the bus line. The buses are shown as gloring points. The brighter points represent the rapid buses traveling at both directions. The buses travel at predetermined speeds to represent different scenarios. We have identified 12 bus stops along the BRT line. The buses stop for 1 minute at each bus stop.

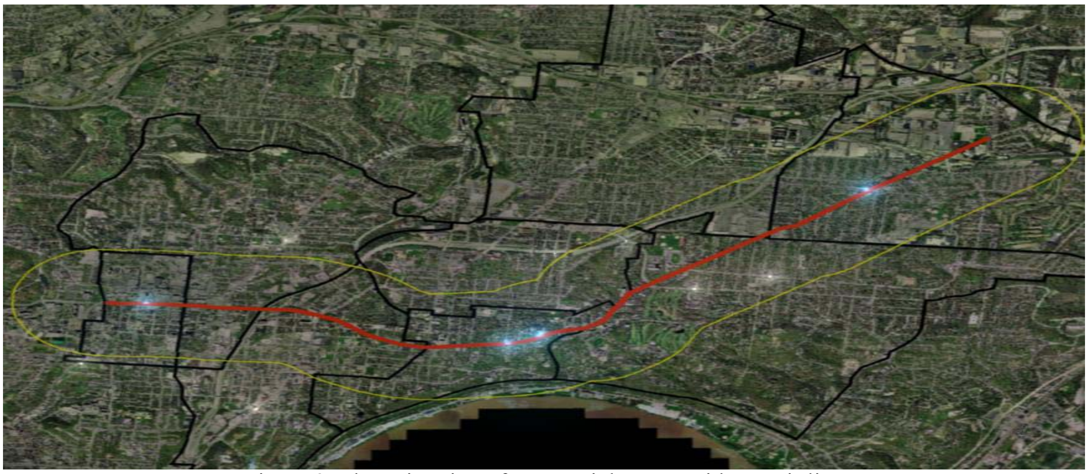

Figure 3: The animation of a potential Bus Rapid Transit line

Figure 4 is an example of the animation of as a bird view of a few blocks. From such animation, the rapid buses and other automobiles are animated to demonstrate the traffic conditions. A viewer can use animations at this scale to examine a segment of the bus line in order to understant the traffic conditions at different scenarios.

The third type of animation takes a viewer to the block or intersection level. At this level, detailed models of the background, such as buildings, streets and trees are created as 3D models. The automobiles are also shown with details (Figure 5). Viewers are more likely to tie the scene with their real life traffic experience.

These animations represent an effort to widen audiences and support space-time analysis (MacEachren et al., 1994; Openshaw et al., 1994). The significance of these animations is that one can easily see how does a BRT line interact with other transit lines and private automobiles and contrust and compare traffic conditions at different scenerios.

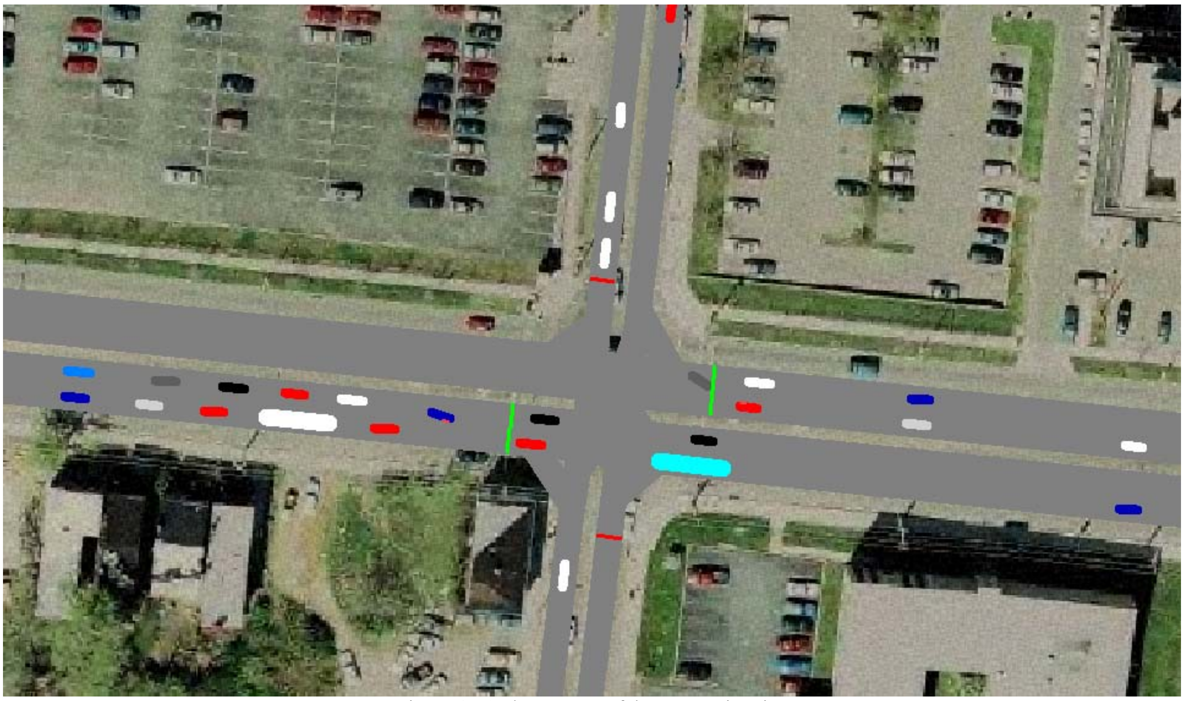

Figure 4: A closer scene of the BRT animation

4. DISCUSSION

Actions that modify the built environment often lead to significant and irreversible impacts, therefore it is crucial for people to understand the anticipated consequences of proposed changes before a decision can be made. The most important purpose of integrating GIS, simulation models and visualization is to support such decision-making processes.

This study presents an effort to integrate GIS, simulation modeling, and visualization in order to help the planning and decision-making process. Simulaiton models – the BPR traffic model and the CAL3QHC model are implemented as part of the GIS platform through a customized user interface. The visualization functions provided with GIS software were also used to construct CO concentration surfaces,. We also used GIS functions to create the points representing receptors with specified distance intervals and to establish node-line topology for roadway links. We created 3D models of highway segments and buildings with Maya, a software application widely used in the visualization industry (Alias Wavefront, Toronto, Canada) and Vissim, a traffic annimation software (Innovative Transportation Concepts, Corvallis, OR, USA), based on GIS data and field observations. To reflect traffic flows, animations were created manually based on the BPR model output, using the MEL scripting language in Maya.

Figure 5: A street level anamination

Although technologies have provided a solid foundation for such integration, none of the off-the-shelf commercial software alone has sufficient functions across all three areas. Moreover, they are often prohibitively expensive and require a significant investment in time to master. This is not currently as easily achievable as we might anticipate. The types of smoother integration and closer coupling that would improve accessibility and uptake still requires more effort from researchers and software vendors, in all three fields.

The most challenging effort is to integrate simulation models and visualization within a GIS platform. There is still no commercial software available for such integration. Some are capable of converting a GIS data file into a format that can be visualized. Geometry is the only thing can be retained during the process. As a result, analysis and presentation are operated separately. This is the case presented in this paper. In the analysis component, GIS, simulation modeling, and visualization are collectively used to prepare outcomes of planning scenarios. The presentation component combines GIS and visualization features to link maps, modeling results, and 3D images and animations. This two-phase design provides a practical tool to planners since current technology is not ready for preparing real time simulation and animation. To use this system as a planning decision support tool, an analyst would prepare maps, images, and animations for different planning scenarios. Any stakeholders can operate the presentation system to assist their decision-making.

Built upon Martin and Higgs' (1997) classification of visualizing physical characteristics and abstract statistics, researchers have tried to bring these two together. The study presented here provides one of such examples. This study has been primarily designed to illustrate the potential and importance of the integrated system that saves the simulation model output into a GIS database and displays the results with visualization tools. The outcome from such study can be an interactive tool for planners and decision makers to review the modeling outputs and GIS data with maps and 3D scenes.

5. CONCLUDING REMARKS

A review of the literature reveals that while there is a long history of using GIS, simulation models and visualization in various planning related research and practice projects, integrated applications are a more recent phenomenon. In addition, such integration is often between any two of the three, such as GIS-simulation modeling, GIS-visualization, or simulation modeling-visualization integration. Recently, with the advance of computer technologies, especially the dramatic improvement of computer hardware and software, GIS, simulation models and visualization have become more accessible to planners. However, a true three-way integration is still elusive.

An integration of all three technologies will provide solid support for planning and decision-making. When simulation modeling results are displayed by a combination of maps, images and animations, with geographical data in addition to tables, more people may be able to understand the consequences of plan and design alternatives. In addition, 3D visualization may enable the detection of potential errors of simulation results which are hard to achieve with tables and 2D maps.

The objective of study presented here is part of a long-term goal that applies information technology in planning. Such an objective is achieved by developing a system that is able to utilize the current data collected by planning agencies and various government agencies to evaluate highway projects with computers before the building phase. In a city with a controversial light rail alternative, the model simulations and 2- or 3-D presentations and animations of traffic conditions, with or without a BRT, can provide a contrasting view that residents and policy makers need to see before they can take a stand on the issue. With such a system, people will be able to actually evaluate traffic conditions and related CO concentrations from the simulations. It will give planners and citizens a better understanding of how a major construction project will impact their community. This will, hopefully, foster a sense of collaboration between stakeholders.

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REFERENCES

BADARD, T. & RICHARD, D.: Using XML for the exchange of updating information between geographical information systems. *Computers, Environment and Urban Systems*, 25(1), 17-31. 2001.

BAILEY, T. C. & GATRELL, A.C.: *Interactive Spatial Data Analysis*. New York: John Wiley & Sons Ltd. 1995.

BARRA, T. DE LA.: Integrated land use and transport modeling: The Tranus experience. In R. K. Brail & R. E. Klosterman (eds), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools* (pp.129-156). Redlands, CA: ESRI, Inc. 2001.

BATTY, M., DODGE, M., JIANG, B. & SMITH, A.: Geographical information systems and urban design. In J. Stillwell, S. Geertman & S. Openshaw (eds), *Geographical Information and Planning* (pp. 43-65). Berlin: Springer-Verlag. 1999.

COWEN, D. J., JENSEN, J. R., BRESNAHAN, P. J., EHLER, G. B., GRAVES, D., HUANG, X., WIESNER, C. & MACKEY, H. E.: The design and implementation of an integrated geographic information system for environmental applications, *Photogrammetric Engineering and Remote Sensing,* 61(11), 1393–1404. 1995.

DANGERMOND, J.: Trends in GIS and comments. *Computers, Environment and Urban Systems,* 12(3), 137-159. 1989.

DARBAR, P. M., BLOOD, E. R. & CHOI, K-S.: Modeling of urban nonpoint source pollution using a GIS in Charleston Harbor, South Carolina. *GIS/LIS '95 Annual Conference and Exposition Proceedings*, pp.235-246. Nashville, TN. November 14-16. 1995.

DOWLING, R.: *Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications*. Washington DC: National Academy Press. 1997.

GAHEGAN, M., & LEE, I.: Data structures and algorithms to support interactive spatial analysis using dynamic Voronoi diagrams. *Computers, Environment and Urban Systems* 24(6), 509-537. 2000.

GROSSMANN, W. D. & EBERHARDT, S.: Geographical information systems and dynamic modelling. In M. M. Fischer & P. Nijkamp (eds.) *Geographic Information Systems, Spatial Modelling, and Policy Evaluation*. Berlin: Springer-Verlag. 1993.

HALL, A. C.: The use of computer visualization in planning control: An investigation of its utility in selected examples. *Town Planning Review*, 64(2), 193-211. 1993.

HALLS, P.J.: Geographic information science: innovation driven by application. *Computers, Environment and Urban Systems*, 25(1), 1-4. 2001.

KWARTLER, M. & BERNARD, R. N.: Community Viz: An integrated planning support system. In R. K. Brail & R. E. Klosterman (eds), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools* (pp. 285-308). Redlands, CA: ESRI, Inc. 2001.

LANGENDORF, R.: Computer-aided visualization: Possibilities for urban design, planning, and management. In R. K. Brail & R. E. Klosterman (eds), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools* (pp. 309-359). Redlands, CA: ESRI, Inc. 2001.

LEE, Y C.: Geographic information systems for urban applications: problems and solutions. *Environment and Planning B: Planning and Design*, 17(4), 463-473. 1990.

MACEACHREN, A., BISHOP, I., DYKES, J., DORLING, D., & GATRELL, A.: Introduction to advances in visualizing spatial data. In H. M.Hearnshaw & D. J. Unwin (eds.) *Visualization in Geographical Information Systems* (pp. 51-59), Chichester, UK: John Wiley & Sons Ltd. 1994.

MARTIN, D. & HIGGS, G.: The visualization of socio-economic GIS data using virtual reality tools. *Transactions in GIS,* 1(4), 255-266. 1997.

MERCHANT, J. W.: GIS-based groundwater pollution hazard assessment: a critical review of the DRASTIC model. *Photogrammetric Engineering and Remote Sensing,* 60(9), 1117-1127. 1994.

OPENSHAW, S., WAUGH, D. & CROSS, A.: Some ideas about the use of map animation as a special analysis tool. In H. M. Hearnshaw & D. J. Unwin (eds.) *Visualization in Geographical Information Systems*, Chichester, UK: John Wiley & Sons Ltd. 131-138. 1994.

PUTMAN, S. H. & CHAN S-L.: The Metropilus planning support system: Urban models and GIS. In R. K. Brail & R. E. Klosterman (eds), *Planning Support Systems: Integrating Geographic Information Systems, Models, and Visualization Tools* (pp. 99-128). Redlands, CA: ESRI, Inc. 2001.

RANZINGER, M. & GLEIXNER, G.: GIS datasets for 3D urban planning. *Computers, Environment and Urban System*, 21(2), 159-173. 1997.

SHAMSI, U. M.: Storm-water management implementation through modeling and GIS. *Journal of Water Resources Planning and Management,* 122(2), 114-127. 1996.

SHIFFER, M. J.: Augmenting transportation-related environmental review activities using distributed multimedia. In A. Camara & J. Raper (eds.), *Spatial multimedia and virtual reality*. London: Taylor and Francis. 1999.

SINGH, R. R. Sketching the city: A GIS-based approach. *Environment and Planning B: Planning and Design,* 26, 455-468. 1999.

SMITH, J., BLAKE, J. & DAVIES, A.: Putting sustainability in place: sustainable communities projects in Huntingdonshire, *Journal of Environmental Policy and Planning,* 2(3), 211-223. 2000.

SMITH, M. B. & VIDMAR, A.: Data set derivation for GIS-based urban hydrological Modeling. *Photogrammetric Engineering and Remote Sensing,* 60(1), 67–76. 1994.

TIM, U. S. & JOLLY, R.: Evaluating agricultural nonpoint-source pollution using integrated geographic information systems and hydrologic/water quality model. *Journal of Environmental Quality,* 23, 25-35. 1994.

USEPA: *User's Guide To CAL3QHC Version 2.0: Modeling Methodology For Predicting Pollutant Concentrations Near Roadway Intersections (Revised)*. EPA454R92006R. Research Triangle Park, NC : U.S. Environmental Protection Agency Office of Air Quality Planning and Standards. Available at http://www.epa.gov/ttn/scram/userg/regmod/cal3qhcd.zip. 1995.

WANG, X.: Conceptual design of a system for selecting appropriate groundwater models in groundwater protection programs. *Environmental Management,* 21(4), 607-616. 1997.

WANG, X.: Integrating water quality management and land use planning in a watershed context. *Journal of Environmental Management.* 61(1), 25-36. 2001.

WARWICK, J. J. & HANESS, S. J.: Efficacy of ARC/INFO GIS application to hydrologic modeling. *Journal of Water Resources Planning and Management,* 120(3), 366–381. 1994.

WORRALL, L.: (ed). Geographic Information Systems: Developments and Applications. London: Belhaven Press. 1990.