# USE AND EVALUATION OF THE ENVI-MET MODEL FOR ENVIRONMENTAL DESIGN AND PLANNING: AN EXPERIMENT ON LINEAR PARKS


**Ozkeresteci, I.[1], Crewe, K.[2], Brazel, A.J.[3] and Bruse, M.[4]**

[1]Environmental Design and Planning Program, College of Architecture and Environmental Design, Arizona State University, Tempe, AZ, USA.
[2]School of Planning and Landscape Architecture, College of Architecture and Environmental Design, Arizona State University, Tempe, AZ, USA.
[3]Southwest Center for Environmental Research and Policy, Arizona State University, Tempe, AZ, USA.
[4]Department of Geography, University of Bochum, Germany.



## ABSTRACT

Rapidly developing cities with large populations face a number of critical problems today. A range of government agencies and citizen groups are typically involved in decisions for an entire metropolitan area. At the same time the social and environmental consequences of rapid urban growth are potentially widespread and harmful, requiring judicious and informed planning. In addressing urban issues of this kind, many metropolitan area planners have turned to the high technologies of GIS, Geo-visualization, remote sensing and model simulations in 3D and 4D formats, since these have the potential not only to investigate alternatives for factors like economic growth, landscape change and population density, but also to display information to audiences at the local planning scale. Typically in such situations, universities and other technological centers have played a key role in assisting city governments. In this context, this paper discusses the detailed constructs of a simulation modeling procedure to assist the Phoenix metropolitan area planners in advancing their open space and park planning strategies. Using the advanced 3D-4D numerical models called ENVI-met and LEONARDO, which have the capacity to project small to large-scale climatic impacts, the model can evaluate future parkways in areas of optimal outdoor comfort, optimal citizen use and minimal environmental damage. As a non-hydrostatic model that simulates surface-plant-air interactions inside urban environments on a three-dimensional rectangular grid with variable spacing in x-, y- and z-directions, the model functions over a range of spatial scales. The benefits of such a climate model are considerable in extreme desert climates. Local weather station records indicate a potential lowering of outdoor temperatures by as much as 50C at critical times of early evening and early morning--which could be highly important in a linear park system for the entire metropolitan region. By promoting cooling at this level considerable savings of energy can be realized in this hot, dry region (some estimate this degree of cooling could promote 25% energy savings). In addition, the model can shed light on some critical trade-offs between vegetation for cooling, costs of water, and heat retention as they affect the area's entire climate regime. This paper also discusses ways to communicate model outputs through visualization adaptable for the planning community. This is done most effectively through a 3D representation initiated by a component of the existing ENVI-met and LEONARDO models. Given the complex planning problems facing cities in extreme climates, partnerships between universities and city governments are increasingly important to look into the future on a more regional scale, yet assessing the local scale that constitutes the planning domains of towns and cities of the region.


## 1. INTRODUCTION

For sustainable urban futures, actors in the city-making process need to make informed decisions about land-use choices and development patterns. These decisions must be based on accurate and detailed spatial information. For this reason, efficient urban information systems are essential for a comprehensive understanding of sustainable urban environments. Geographic information science has become an integral part of urban information systems, providing many tools and techniques necessary for planning and evaluating environmental contexts, such as environmental models, spatial databases and visualization techniques. Given this need for information tools among planners, urban designers and architects, however, it is important for geographic information systems (GIS) to adapt to current real-life planning issues.

The solutions of pragmatic problems in the urban environment are dependent not only on sensitive and advanced information systems themselves, but by the adoption of these systems by stakeholders in the environmental design, planning and intervention processes. This paper focuses on the second aspect; the adaptive use of a climatic modeling software innovation named ENVI-met (and LEONARDO) developed by Michael Bruse, of the University of Bochum, Germany (1, 2).

These two interactive programs are used to model climatic models of general structural changes or structural modifications that include elements of the natural and built environment such as vegetation, buildings, roads, soil and also climatic behavior simulation of people (3). This paper focuses on the adaptive use of this environmental modeling tool to plan and design energy efficient and healthy environments for improved bio-climatic performance.

Environmental modeling has been a major component of the scientific approach in understanding and solving problems in complex environmental settings. The essence of modeling lies in the systems thinking approaches to understand environmental behavior. While environmental modeling exists as a scientific discipline alone, it is nevertheless part of an interactive subsystem of planning and decision support systems. The technological and methodological developments of the field have given the possibilities of using such models in the daily practice of city-making processes. A major critique to use of modeling in environmental design disciplines originates from not using these possible tools and techniques in an extensive way for the practical and pragmatic implementation within a real world environmental and community planning and design systems. In addition to this, scientific inquiries of the socio-cultural shaping of environmental modeling methods and tools are not explored extensively (4). "An urban information system, or more exactly an information system, must be the ideal tool allowing some kind of decision or negotiation support between its actors” (5). We believe that all socio-political approaches to land use and development practices, whether in cooperation or in conflict, are generated at least in part by value and belief systems, and that these should be reflected in the environmental modeling process.

This descriptive inquiry will be based on experimental use of the ENVI-met model for a study of well-known topic of urban design and planning; linear parks in metropolitan cities in Arizona, such as Phoenix and Scottsdale. The choice of the Phoenix Metropolitan area is purposeful, due to its unique climatic characteristics as part of the semi-arid Sonoran Desert, and a range of social dynamics evolving from the area's phenomenal population and urban growth since the l980s, and the serious implications of this growth for issues of environmental quality, quality of life, and urban management (7).

This study addresses a number of issues. The first section will discuss the practical issues associated with the model: What are possible ways of utilizing the ENVI-met model as a planning and environmental design tool? The second section will relate the model experiment to a community development system in the theoretical sense: How can this model be integrated as part of an information system within professional and regulatory settings? Lastly, we develop earlier discussions to provide insight as to the use of this tool in the service of sustainable development within the interdisciplinary nature of environmental design disciplines and geographic information science.

## 2. ENVI-met AND LEONARDO: BASIC ASPECTS OF THE ENVIROMENTAL MODEL

ENVI-met is a three-dimensional non-hydrostatic microclimate model and is able to calculate and simulate climate in urban areas with a typical grid resolution of 0.5 to 10 meters in space and 10 seconds in time. It calculates the dynamics of microclimate during a diurnal cycle [24 to 48 hours] using fundamental laws of fluid dynamics and thermo dynamics. Main prognostic variables of the program are wind speed and direction, air temperature and humidity, turbulence, radiative fluxes, bioclimatology and gas and particle dispersion. The basic data structure of ENVI-met is represented in Figure 1 (8).

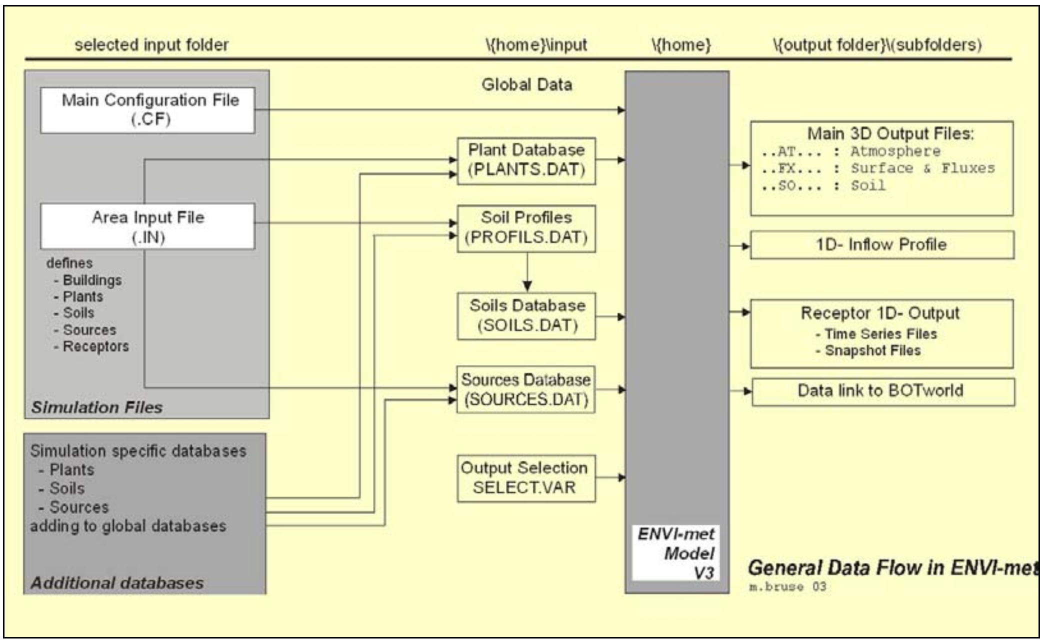



Figure 1. Basic data structure of ENVI-met.

In addition to this structural configuration, some basic design characteristics of ENVI-met as a simulation program includes;

- Simulate the complete coupled climate system including fluid mechanics, thermodynamics, pollutant dispersion;
- Provided a high resolution model resolving single buildings;
- Adequate simulation of surface-vegetation-atmosphere processes such as photosynthesis rate;
- Use of state of the art computational techniques;
- Easy to use interface and input/output data handling (9).

The modeling program has four user interfaces. First one is editing the input of prepared digital maps of layout of the domain. Therefore one has to generate baseline data from other geographic information systems and/or has to generate the data herself/himself in ENVI-met's own cartographic format. This stage can be quite complex depending on the environmental domain that is chosen to work. The high-resolution aspects of the program enables the user to go into finer details in smaller scales (0.5) or and to be more coarse (and less detailed) in lower scales (e.g.10 meters in a neighborhood study of 1 km by 1km). The program consist of modules of working areas such as 130 by 130 maximum, so theoretically one can go to an are study of approximately 1300 m by 1300m.

The second interface is the configuration editor, where databases for soil types, humidity, temperature, temporal input, etc. are entered. The third one is the modeling area, where additional parameters are present and the modeling process takes place. The output data can be interpreted and visualized in LEONARDO. It is also possible to edit the data to other programs since the program structure is public.

## 3. METHODOLOGY

The basic aim of this study is to evaluate the practical applications of the model and to generate an innovation framework for its use. In this context, this paper discusses the detailed constructs of a simulation modeling procedure to assist Phoenix metropolitan area planners in advancing their open space and park planning strategies. This paper will demonstrate an application of the program in a desert urban environment and will demonstrate the systematic design of an environmental planning tool that can be useful for professionals such as architects, landscape architects, and planners. It is also a framework for applying the tool to policy domains. The methodology will follow the model's own procedures, from establishing an information base to evolving criteria for the design of micro-scale (and macro-scale) environments.

Each environmental modeling system serves a purpose and has certain characteristics. Beck et al. (9) offers three objectives for constructing and evaluating environmental models that are useful in understanding the micro-scale climatic behavior of building structures and landscape elements in an environment for this study.

These three objectives are (also see Figure 8):

- Prediction of future behavior under various courses of action, *i.e. in the service of informing a decision* (for example project development/evaluation, impact analysis building design regulation, planning regulations),
- Identification of those constituent mechanisms of behavior that are crucial to the generation of a given pattern of future behavior but insufficiently secure in their theoretical and empirical basis, i.e., *in designing the collection of further observations* (future planning, development/redevelopment decisions),
- Reconciliation of the observations of the past behavior with the set of concepts embodied in the model, i.e. in the modification of theory and in explaining why a particular input disturbance of the system gave rise to a particular output response (the impact of different structural modifications in the environment – see Crewe (10)).

The study group followed these three objectives in constructing the research design for this inquiry.

Those objectives are reflected on the steps of this research process in the following order.

- Experimenting a sample area with the model, i.e. finding a proper site with the planning theme (linear park) already existing and having the necessary elements to be used in the model (landscaping, building, environment, climatic data, etc…)
- Comparing it with real measurement taken on the site (validity check).
- Experimenting with the different configuration of landscape and built environment in different scale.
- Infer about the utility of the model as a planning and design tool.
- Hypothesize on the use of the model on different planning environments.
- Introducing the model to planning environments in academic, professional and governmental domains and observe its innovation qualities.
- Inferring about the outcomes and the process and relate it to planning and design context with actor involved.
- Make further observations and tests.

At present our study is at stage 5, studying how ENVI-met can be utilized functionally in different institutions. The validity check (stage 2) is also in progress.

## 4. EXPERIMENTATION WITH ENVI-MET

In order to test and evaluate the model in terms of the above criteria, an existing linear park was adopted as a basic study area in the context of Phoenix (metropolitan), Arizona. The idea of linear parks is crucial from a city design perspective, for both socio-cultural and bio-climatic reasons (11,12). This provides a proper context for the experiment. In addition to this needs perspective, the model's characteristics are another factor in the choice of the problem.

Photo 1.

Photo 2.

Photo 3

Scottsdale's Indian Bend Wash is a greenbelt area running from north to south more of about 10 km in various widths. Embedded in a flood-control area, it also provides the green space for sports and other recreation activities like golf, bicycling and hiking, together with miscellaneous parks and picnic areas. This linear park is surrounded by miscellaneous residential and commercial developments along its edges. The sample study is conducted in a single city block within this linear park; the study area includes a number of axis distinct residential dwelling types, from single story homes to two-three story multi-family residences (see Photos 1, 2, 3 and Figure 2).

The digital map data for the area was obtained for the City of Scottsdale Information Systems and but additional surveying took place to correct changes and adapt local plants and soil details for the modeling environment. ENVI-met uses its own graphic interface to plot the layout of the area, and also its own configuration editor for the climatic data plus the plants, soils, and sources databases. Therefore all cartographic information had to be gathered first on a digital map and then redrawn in ENVI-met`s own graphic editor for the modeling language. These databases (soils, plants, buildings, surface materials) are used as generic types for in the first stage, so a comparative matching to the nearest resemblances are chosen as for soil, plant and building characteristics. These data can also be localized and additional plants; soils and sources information can be added to the model. The outputs are basic 3D information on atmosphere, surface and fluxes and soils. Whilst the first phase of the model was to accurately model the context, second phase included changing certain variables related to the linear park composition such as width, wind direction, plantation, surface character, etc… Figure 3 shows how this process is implemented in this modeling study. This editing process is crucial in the practical level, and must be undertaken by any user of the ENVI-met model.

Figure 2. Digital Map.

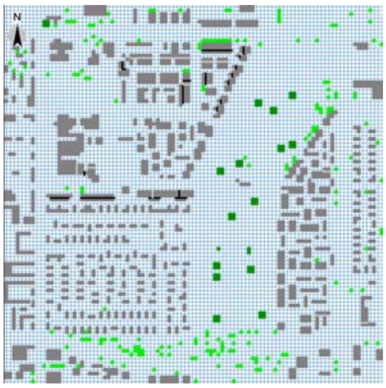


Figure 3. ENVI-met Interpretation.

Figure 4. Output.

## 5. PRELIMINARY FINDINGS AND REFLECTIONS

The experimentation has so far consisted of two brief studies of the area. The first one is the modeling of an area with its present qualities to see the basic output characters of the model. This is shown in Figures 2, 3 and 4.This stage is used to explore calculation and visualization potentials of the model plus also helped the researcher to hypothesize on the certain factors, of the model itself and of certain characteristic of the linear park theme. The inferences from the second phase are discussed in detail in Crewe's article (13). There are some basic reflections from these experiments.

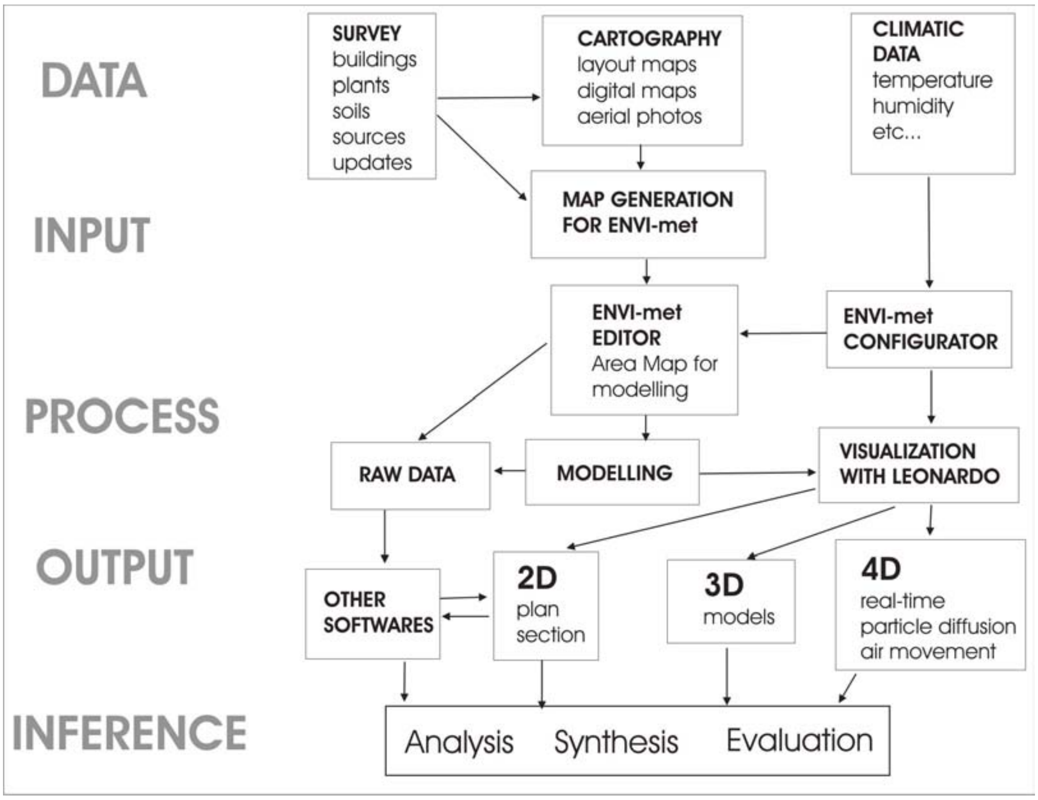
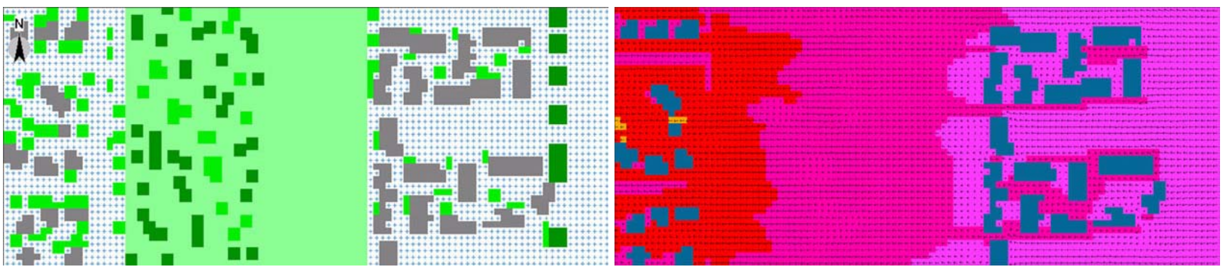



Figure 5. Process of working with the model in the research

These are as follows.

- Model shows a fine detail in the analysis of the atmospheric data form the user's point of view.
- It provides area-based information about critical areas in the study domain like very hot sports, problematic areas and area of bio-climatic path,
- It plots in 3D and 4D the path and the direction of the wind movement and particle diffusion around the landscape elements therefore critical areas of polluted spots in the study domain.
- The above inferences are critical design and planning data either from an urban designer's point of view preparing a development project in the area or from the point of a planner's working in the city reviewing and communicating the development in different stages. The last section of the paper will be discussing this process. How can the model be adopted in an institutional setting?
- The ENVI-met model can be a basic bio-climatic tool from the microanalysis of design and planning studies, such as site development, environment assessment, etc. (Figure 6 and 7).
- While certain micro-scale experiments are possible and useful for applications, hypothetical assumptions can be generated to study larger scales of the environment. This framework can organize the processes needed to reach to a grand design in this case the linear park system, incorporating building structures, vegetation differences and the configurations. Therefore integration of this model to macro-scale evaluation of urban environments in geographic information systems is also possible.
- It is also possible to compare the model with other models of the same geographic domain and purpose.




Figures 6 and 7. Mixed-landscape scenario drawn in ENVI-met and its output (temperature and wind).

The participants to this study were an architect/planner, a landscape designer, and two geographers, one a climate expert and the other the designer of the model. In order to infer about this paper, it was made sure that the cartographic and surveying methods were recorded and discussed (Figure 5). Brainstorming sessions were held in order to reflect these experiences to the professional and organizational context (Figure 8). The last section will discuss these experiences.

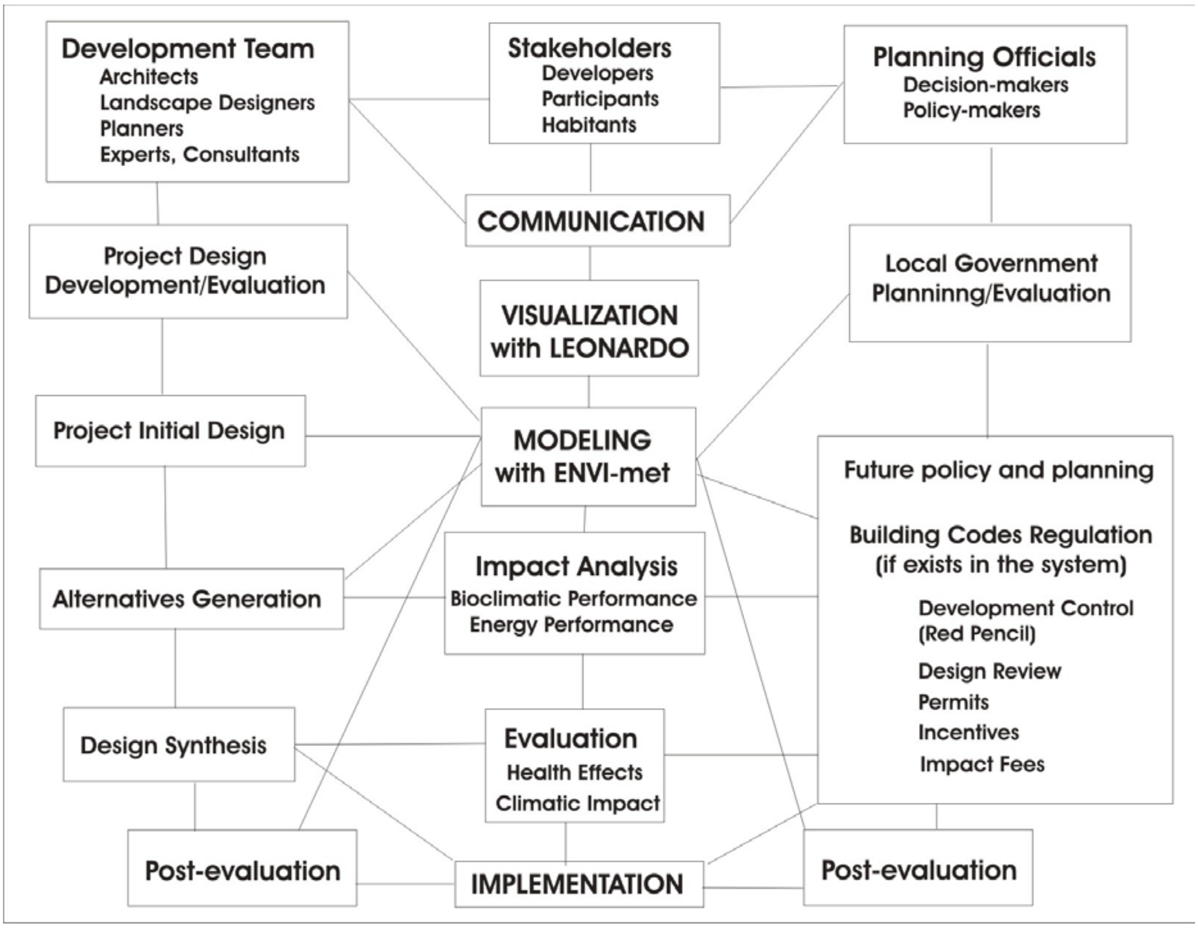



Figure 8. ENVI-Met in a design and planning environment.

## 6. CONCLUSION: PLAUSIBLE USES OF ENVIRONMENTAL MODELING IN DESIGN AND PLANNING ENVIRONMENTS

A purpose lies in under every systems construction.

This model as a subsystem of an urban information system can be utilized in three important pragmatic domains in schemes for sustainable development.

- Saving energy by optimized heat distribution, usage of low-energy architecture and natural energy sources.
- Reducing health risks by ventilation and decreasing the near surface pollutants
- Improving life quality by creating comfortable bioclimatic conditions.

However, the successful use and adoption of this environmental model is as critical as its practical functioning. Therefore, it is always important for model users to evaluate the disciplinary cultures and environmental contexts within which the model will be operating; successful evaluation can significantly improve the model's usefulness. Ideally, the model will be available to all stakeholders at the same time, as a shared information subsystem of a larger urban information system network.

As a conclusion, interaction of the model in real life will be discussed in major environmental design disciplines. Figure 8 shows the outline of the model’s user environment and establishment of this system from the application point of view. The term plausibility in planning is used to denote arrange of activities that area between possible and feasible actions (14). Therefore plausible frameworks can help to construct project/program/policy guidelines for implementation. An environmental model like ENVI-met can be successfully used insofar as it can become an integrated part of the information system of the city. “The wish for knowledge of the outcome of one or more ‘experiment’ (or program of field research) - before the policy decision is made - should have become so important to

scientific enquiry... it is equally important that the 'correct' kernel of ignorance and ambiguity can be identified - from the bewildering web of incompletely understood interactions that may bring about undesired future behavior - for further monitoring and experiment"(15).
From an environmental design point of view it is the architect or planners; responsibility to ensure the participation of all possible stakeholders in an urban design, redevelopment or building project in the micro-scale level. At this level, the model can both create insights and evaluative data for better design decision, from the general layout to a detailed choice of a plant or soil type. As mentioned before, the tool is powerful in determining areas of critical impact from bio-climatic and pollutant dispersion criteria, which can enable necessary structural modifications in the design phase. The study of each structural modification can be a powerful design criteria tool for the environmental designer.

In the city planning process the tool can be both informative and evaluative. It can communicate a development project; it can be directly used in the planning and design review of the development projects. The notion of *planner's red-pencil* can be virtually applied to the model's capabilities (16). It can also become a part of the policy making tool: part of a pedestrian and bike path program and planning, or a grand design like a linear park system in the macro scale level. Even though the model can be used mostly in the micro-scale, a careful sampling procedure and research design can help to utilize the program in the city and regional level. Such a study exists already in Europe; Benefits of Urban Space (BUGS) project funded by European Union utilizes the model to as a decision support system for urban futures utilizing the interaction of the landscape and the built environment (17).

The benefits of such a climate model are considerable in extreme desert climates. Local weather station records indicate a potential lowering of outdoor temperatures by as much as 50C at critical times of early evening and early morning--which could be highly important in a linear park system for the entire metropolitan region. By promoting cooling at this level considerable savings of energy can be realized in this hot, dry region (some estimate this degree of cooling could promote 25% energy savings). In addition, the model can shed light on some critical trade-offs between vegetation for cooling and costs of water, and heat retention as they affect the area's entire climate regime.

In order for new possibilities and solutions to become practically feasible, the human dimension needs to be integrated. No matter how powerful the model is, the model, as a geo-information tool has to go through the socio-cultural filtering of city-policy making. It is through the adaptive use of such innovative tools like ENVI-met, there is a possibility of progress for urban information systems to serve for sustainable environments.

## 7. REFERENCES


[1] M. Bruse, ENVI-met website: www.envimet.com (2003).
[2] M. Bruse, The Influence of Local Environmental Design on Microclimate, PhD Thesis, University of Bochum (1999).
[3] Bruse (2003).
[4] M.B. Beck et al., Construction and Evaluation of Models in Environmental Systems in *Modeling and Change in Environmental Systems*, pub John Wiley & Sons Ltd., (ed. A.J. Jakeman et al.) (1993).
[5] R. Laurini, Information Systems for Urban Planning, pub Taylor & Francis, London, p.1 (2001).
[6] Bruse (2003).
[7] B. Katz & R.E. Lang Redefining Urban & Suburban America: Evidence From Census 2000, pub Brookings Institution Press-Washington, D.C. (2003).
[8] Bruse (2003).
[9] Bruse (2003).
[10] K. Crewe, The Potential Of Climate Modeling In Greenway Planning For Phoenix, Arizona, paper for 21st Int. Cartographic Conf. (2003).
[11] T. Beatley and K. Manning, The Ecology of Place, pub; Island Press, Washington, D.C. (1997).
[12] F. Steiner, The Living Landscape: An ecological approach to landscape planning, pub; McGraw Hill, New York (2000).
[13] Crewe (2003).
[14] C. Steinitz et al., Alternative Futures for Changing Landscapes, Island Press, Washington, (2002).
[15] Beck et al., p. 10 (1993).
[16] A. Solnit et al., The job of the practicing planner, APA Planners Press, Washington, D.C. (1988).
[17] K. De Ridder, BUGS: Benefits of Urban Green Space: First Research Brief, Vito-TAP, (2003).

# USE AND EVALUATION OF THE ENVI-MET MODEL FOR ENVIRONMENTAL DESIGN AND PLANNING: AN EXPERIMENT ON LINEAR PARKS

**Ozkeresteci, I.[1], Crewe, K.[2], Brazel, A.J.[3] and Bruse, M.[4]**

[1]Environmental Design and Planning Program, College of Architecture and Environmental Design,
Arizona State University, Tempe, AZ, USA.
[2]School of Planning and Landscape Architecture, College of Architecture and Environmental Design,
Arizona State University, Tempe, AZ, USA.
[3]Southwest Center for Environmental Research and Policy, Arizona State University, Tempe, AZ, USA.
[4]Department of Geography, University of Bochum, Germany.

**Biography**

Izzet Ozkeresteci is currently doctoral candidate in the Ph.D. Program in Environmental Design and Planning College of Architecture and Environmental Design, Arizona State University, Tempe, AZ. His dissertation topic is *Planning, Urban and Architectural Design Innovation in Post-Disaster Recovery and Reconstruction in California - USA with Emphasis on Earthquake Cases.* He has an architectural degree from Middle East Technical University, Ankara, Turkey and M.A. degree from the same university with the topic: *Evaluation of the Built Environmental From the Ecological Perspective and Ecological Guidelines for Architectural Design*.

He has taught both in planning and architectural departments in Turkey and in the U.S. He has recently taught Environmental Planning, Environmental Impact Statement and Planning Methods Using Computers in the Arizona State University.

He is currently interested in inquiries on innovative tools and techniques for urban development and regulation that relates to environmental dimensions and sustainable development.