Incorporating expert geographic information systems into urban land use and transportation planning models(*)

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Abstract. A key urban planning question concerns the impact that evolving land use and population levels have on the provision of infrastructure based services, particularly transportation. This paper outlines a method by which expert systems (ES) can be used in conjunction with geographic information systems (GIS) to analyze this question rigorously and practically. Together with adjunct production models, GIS is used to model the production of infrastructure based services in an explicit spatial context defined by land use and population characteristics. As these characteristics change, so too does the aggregate level of service delivered by the existing infrastructure system. ES is used to help determine the most cost-effective means of restoring service levels.

We contend that such a method is feasible given the increasingly sophisticated computational and data environments of North American urban areas. To support this argument we consider in some detail a specific laboratory setting, that of the Southern California Association of Governments (SCAG). We outline how an expert geographical information system (EGIS) could be deployed within the SCAG environment, and then assess the general feasibility of the EGIS modeling approach.

Key words: expert systems, geographic information systems, infrastructure based services, urban land use, local government planning models.

1. Introduction

A principal responsibility of urban governments is to efficiently provide infrastructure based services to residents. The level of service derived from infrastructure depends as much on prevailing land use and demographic characteristics as it does on the attributes of the infrastructure itself. For this reason, urban planning for the provision of infrastructure based services is made more difficult in large urban areas that are subject to rapid change in size or character. Recognition of this basic fact is the underlying motivation for this paper.

Unfortunately, most models of the interaction between infrastructure systems and the evolution of urban land uses and activities are quite limited. These limitations stem from a failure to address nonlinearities in production technologies, and a failure to capture the spatial relationships inherent in many service delivery systems. It is essential that such effects be accounted for if local governments are to undertake meaningful analyses of the infrastructure-based service impacts imposed by urban land use changes. This is particularly pertinent for urban areas that are undergoing a spatial restructuring of activities and land uses, because in these instances the incompatibility between new uses and inherited infrastructure systems is most likely to become expensive.

The purpose of this paper is to evaluate the general feasibility of incorporating expert geographic information systems (EGIS) into local government infrastructure planning models. To help guard against unrealistic prognostication on our part, the subsequent analysis is rooted in a particular local government modeling environment, that of the Southern California Association of Governments (SCAG). The next section describes the salient features of SCAG’s current transportation modeling environment. Following this is an examination of how expert geographic information systems (EGIS) can be used to evaluate the impacts of urban change on the Southern California transportation system. The penultimate section outlines how EGIS could be incorporated directly into SCAG’s modeling environment. The concluding section assesses the general feasibility of this approach.

2. Land use transportation modeling at SCAG

As a Council of Governments, the Southern California Association of Governments is a regional planning organization responsible for developing forecasts of population and land use changes for the five counties of the Los Angeles metropolitan area(*). At present, SCAG’s modeling efforts are supported by a conventional urban transportation modeling system, as well as a small area forecast model and a resident geographic information system. Viewed in aggregate these model components provide SCAG’s staff with the capability to produce baseline population and land use forecasts that reflect the current state of the art in iterative land use and transportation forecasting applications.

SCAG makes its transportation modeling projections by combining a sequential application of its urban transportation planning (UTP) procedures with an informal set of expert assumptions concerning future land use and growth controls in the Los Angeles basin. The spatial configuration of land uses and activities that initiate the UTP system can be empirical, or can be the outputs of a small area forecasting model derived from DRAM-EMPAL (Putman, 1977). This small area forecasting model assigns aggregate growth estimates for the region on a top-down basis.

For any given land use configuration, a fully iterated UTP system generates an internally consistent set of predictions for trip generation, trip distribution,
mode split, network assignment and level of service. These outputs from the UTP system could serve as inputs to SCAG's small area forecast model. The small area forecasts that result could then be used as inputs to the UTP system's trip generation component. Ideally the outputs of this system would iteratively converge to a general equilibrium forecast in which the UTP and DRAM—EMPAL forecasts are mutually consistent. This idealized state-of-the-art approach is summarized in fig. 1.

Figure 1 An iterative approach to general equilibrium forecasts: land use and transportation
SCAG’s conventional UTP procedures are enhanced by the Association’s GIS capability. The GIS is currently used in this context as a means of storing and retrieving spatially oriented data pertaining to land use activities and the transportation network. However, neither the UTP models nor the small area forecast model nor the GIS software is sufficient to adequately model all anticipated interactions between the transportation and land use activity systems.

In particular, expert assumptions regarding the pattern of future land use controls and infrastructure investments underlying these projections are at present introduced on an informal or ad hoc basis. Consequently, the market-based interactions between the evolving urban activity system and the level of service provided by the transportation network are accounted for in SCAG’s Draft Baseline Projection for the year 2010, but in an indirect, unsystematic way. An EGIS is best suited to assist with this aspect of the overall modeling framework.

3. Modeling the impact of growth on transportation infrastructure using an expert geographic information system

3.1. Defining impacts

The impact of growth on infrastructure based transportation services has two principal aspects. One is the change in service levels brought about by imposing changing land uses on a fixed infrastructure system. For example, as residential densities and the distribution of employment centers change, congestion levels will typically rise or fall by varying amounts over different network links. An aggregate index of the level of service derived from the transportation system might include median trip duration or measures of congestion throughout the system.

The second aspect of the impacts of growth on transportation based services pertain to mitigation costs. These are the costs of additional public investments required to offset what would otherwise be an unacceptable decline in transportation level of service. Most notably this would include the costs of system expansion, i.e., the construction of new transportation arteries or an increase in the capacities of existing links. If land uses are intensifying both increased investment and congestion costs will be experienced, as congestion is traded off against additional infrastructure improvements.

3.2. Using GIS to model the production of infrastructure-based services

The manner in which these impacts are manifested is both geographic and complex. For this reason GIS can be a useful tool for modeling these phenomena. A GIS is a unique database management system (Han and Kim, 1989) that facilitates the storage and retrieval of information on the spatial
attributes of objects, and on the spatial relationships between objects. The ability of a GIS to efficiently infer these spatial relationships (such as “near” or “downhill from”) is determined by the manner in which the spatial attributes of objects are represented in the database (Dueker, 1987). This inference capability distinguishes GIS from more conventional computer-aided mapping (CAM) programs (Croswell, 1986). CAM systems merely overplot separate layers of data types and are unable to relate data across layers.

GIS is a useful tool for modeling the spatial aspects of production processes for infrastructure based urban services. Together with adjunct engineering, economic, or behavioral models it can provide a very direct representation of traffic flows along transportation corridors, water flows though a network of pipes, messages across telephone trunks, or potentials along power lines. And, it can relate these representations to surrounding land uses and other neighborhood characteristics. Level of service indexes such as congestion, median trip time, water pressure, network access, or potential may be directly inferred from the state of the system at any time. Moreover, changes in these service levels brought about by shifts in the land use activity system may be inferred by incorporating appropriate engineering, economic or behavioral assumptions. In short, it is this capacity for complex spatial analysis that identifies a GIS production model as the spatial analogue to more standard economic models of production in an aspatial context (Heikkila, 1990).

A GIS production model comprises not only the GIS but also the adjunct models that facilitate the simulation of production flows or outputs within the specific land use and infrastructure context defined by the GIS. Interactions between the GIS and its adjunct production models are summarized in fig. 2. In this diagram the endogenous level of service s derived from an infrastructure system is based on the (exogenous) level of past investment $ in infrastructure and on the spectrum of (exogenous) land use activities x throughout the urban system. An underscored variable indicates that its value captures an existing or exogenous state. This relationship may be summarized symbolically by the production relation:

\[ s = f(x, \$) \] (1)

Similarly, the adjunct production models may produce endogenous estimates of repercussive activity shifts resulting from changing service levels. For example, as congestion increases along certain transportation links, land use activities may relocate to less congested areas. This response may be summarized symbolically as

\[ x = g(s, \$) \] (2)

Given fixed infrastructure investments, a general equilibrium forecast would yield mutually consistent estimates of land use activities and transportation service levels. This general equilibrium condition may be expressed symbolically in two ways:
\[ \Delta X \]

\[ \Delta X + \Delta X, \Delta S \]

**Geographic Information System**

Spatially organized measures/estimates of \( X \) and \( \$ \)

**Adjunct Production Models:**
- Engineering: \( S = f (X, \$) \)
- Economic: \( X = g (S, \$) \)
- Behavioral

**Equilibrium Conditions:**
- \( S = f (g (S, \$), \$) \)
- \( X = g (f (X, \$), \$) \)

\[ X = \text{existing land use/demographic context} \]

\[ X = g (S, \$) = \text{endogenous land use and population consistent with S and } \$ \]

\[ \Delta X = \text{exogenous change in land use/demographic context} \]

\[ \Delta X = \text{endogenous activity shift} \]

\[ \$ = \text{existing infrastructure level of service} \]

\[ S = f (X, \$) = \text{endogenous level of service consistent with } X \text{ and } \$ \]

\[ \Delta S = \text{endogenous change in infrastructure level of service} \]

\[ \$ = \text{existing infrastructure system} \]

*Figure 2* A geographic information system linked to adjunct production models: a GIS production model

\[ s = f [g (s, \$, \$)] \tag{3a} \]

\[ x = g [f (x, \$, \$)] \tag{3b} \]

Ideally, this is the type of forecast that would be generated by the SCAG modeling environment depicted in fig. 1. The UTP models estimate levels of service for a given land use and infrastructure configuration, and the small area forecast model addresses how the spatial allocation of land use activities responds to changes in transportation costs. However the forecasts currently generated by SCAG are not yet fully iterated and so cannot be viewed as
general equilibrium predictions in the sense of equations (3).

Because the infrastructure system is exogenously determined, the GIS production model described above is not sufficient for calculating estimates of efficient mitigation costs. Specific knowledge and expertise are required to determine which mitigation options are appropriate in any given context. The GIS production model in fig. 2 does include adjunct models that simulate traffic flows for a given transportation network, but these model components are only used to determine the service impacts and repercussive activity shifts resulting from exogenous land use changes. They do not indicate what the most appropriate mitigation strategy might be. It is our contention that an expert system is the appropriate vehicle for incorporating such judgemental capabilities in a predictive modeling context.

3.3. General equilibrium forecasts: using ES to estimate infrastructure improvements endogenously

Conveniently, the cost of infrastructure investment can also be explored in this same general framework. Ideally we want to determine the least cost of reconfiguring the infrastructure system so that specified service levels can be maintained despite projected changes in land use activities and transportation flows. That is, the infrastructure configuration must itself be determined endogenously. Expressed symbolically, we want

\[ \$ = h \ (x, s) \]

And the full set of equilibrium conditions becomes

\[ s = f \ [g \ (s, \$), h \ (x, s)] \]  \hspace{1cm} (5a)

\[ x = g \ [f \ (x, \$), h \ (x, s)] \]  \hspace{1cm} (5b)

\[ \$ = h \ [g \ (s, \$), f \ (x, \$)] \]  \hspace{1cm} (5c)

In complex infrastructure systems, there are likely to be innumerable infrastructure improvements that could restore service levels. Consider for example all possible improvements that might be made to the transportation network in a metropolitan area. Formal and informal reasoning processes based on expert knowledge and judgement may be needed to determine reasonable bounds for the technically feasible set of alternatives. To specify a complete model of impacts for spatially based services, it is necessary to emulate this expert knowledge and judgement. What this requires is an efficient (heuristic) algorithm for reducing the complete set of possibilities to a few candidate choices. The optimal choice may not be contained in the candidate set. All that is known is that the optimal solution has not necessarily been excluded from this set, and that all candidate choices are likely to be good alternatives.

This is precisely the type of task that an expert system is designed to undertake (Goodall, 1985). An expert system is software designed to replicate human experts’ reasoning processes within the context of specific problem-
solving domains. The essence of an ES is that it systematically incorporates the (useful) judgment, experience, rules-of-thumb, and intuition of human experts into problem solving. According to Waterman (1986), “an algorithmic method of conventional programming is designed to produce an optimal solution whereas the heuristic method of expert systems produces an acceptable solution most of the time”. Thus the problems suitable for expert system development must accept heuristic solutions. Urban infrastructure decisions clearly fall into this category. In the context of infrastructure, identifying the optimal member of a feasible decision set is not usually a tractable exercise. Success is constrained by limited information concerning both alternative courses of action and their outcomes (Moore, 1986).

An analogy to chess-playing is helpful. For any given state defined by a configuration of playing pieces, there may be innumerable feasible moves. Yet chess masters quickly disregard all but a handful of these and explore only a few options rather intensively. What permits them to do so is a well-structured knowledge base regarding types of positions, the rules of the game, and related implementation strategies directed towards a specific objective. This (heuristic) approach is equally useful in the context of urban infrastructure and land use planning problems.

3.4. Components of an expert system

As fig. 3 illustrates, there are three primary components in an expert system; a user interface, a knowledge base, and an inference engine. The user interface facilitates user interaction with the system. It performs queries to obtain additional facts and possibly rules that can be added into the knowledge base. Likewise, it transmits advice and explanations to the user.

The knowledge base comprises facts and rules that pertain to the problem at hand. For example, a specialized knowledge base corresponding to an urban transportation network would contain facts regarding speed limits, adjacent land uses and land values, material and construction costs, grid layout, and link capacities. In addition it might contain rules pertaining to grid design, physical relationships, engineering performance and policy interdicts. Other rules may pertain to tradeoffs between the cost of infrastructure improvements and increased congestion levels. The proposed system would draw on this knowledge base during its search for alternatives. Thus the knowledge base is essentially a database that contains the same facts and rules that an expert would use in determining how to restore service levels in the most feasible way. Occasionally rules will conflict with each other and so a knowledge base also contains meta-rules for resolving those conflicts (Parsaye and Chignell, 1988).

The other primary component of an expert system is the inference engine or control mechanism. The specific goals and subgoals of the consultation are determined by the inference engine during the reasoning process based on the current state of solution. This can be constructed by using a high level programming language based on Boolean algebraic logical structures. Because
expert systems combine this reasoning capability with a well structured body of facts and rules, they have become the most successful commercial application of artificial intelligence. A unique attribute of expert systems is that the control mechanism and the knowledge base are functionally distinct. This has encouraged the development of disembodied inference engines such as GURU (Micro Database Systems, Inc.), known as expert system shells. These shells also provide a mechanism for introducing new facts and rules into the knowledge base.

3.5. *EGIS: coupling ES and GIS*

Fig. 4 depicts the conceptual framework for an integrated expert geographic
Figure 4 Components of an Expert Geographic Information System (EGIS)

- $ = existing land use/demographic context
- $X = g(S, $) = endogenous land use and population consistent with $S$ and $$
- $\Delta X = exogenous change in land use/demographic context$
- $\Delta X = endogenous activity shift$
- $S = existing infrastructure level of service$
- $S = f (X, $) = endogenous level of service consistent with $X$ and $$
- $\Delta S = endogenous change in infrastructure level of service$
- $\$ = existing infrastructure system$
- $\Delta \$ = candidate infrastructure investment identified by the expert system$
- $\Delta $ = minimum $\$'

Knowledge Base:
- Petri-Rules: Recognizing infeasibilities.
- Objectives: Trade-offs between $X$ and $$$$
- Facts: State definitions for $X$, $S$ and $$; budget constraints.

Data-Structure Interface

Inference Engine

Geographic Information System
- Spatially organized measures/estimates of $X$ and $$$$

Adjunct Production Models:
- Engineering
- Economic
- Behavioral

Equilibrium Conditions:
- $S = f (g (S, $), $$
- $X = g (f (X, $), $$

User Interface
- queries and additional data
- advice and explanations

Expert System
information system (EGIS). Here the ES judges which infrastructure improvements are appropriate within a particular context defined by the GIS production model. Put another way, ES can be used in conjunction with the GIS production model to organize a cost-of-mitigation model (Heikkila, 1990). This modeling approach permits infrastructure improvements to be determined endogenously.

Consider the introduction of an exogenous change in demographic and land use conditions x. As before, the GIS production model (now resident within the EGIS) produces a spatially discriminated vector of endogenous changes in transportation service levels s and in land use activities x that would result from these land use activity changes in the absence of infrastructure improvements. The inference engine of the expert system then searches the knowledge base for facts and rules to identify a candidate change in infrastructure investments ($^*$) for maintaining the target level of service provided by the system. The target level of service is also determined endogenously with the application of rules governing the tradeoff between investment costs and service losses. The candidate investments ($^*$) are spatially defined, as are their associated service impacts. The adjunct production models then evaluate these proposed infrastructure changes within the context of the GIS. On the basis of this evaluation a revised vector of endogenous changes in land use activities (x) and service levels (s) is returned to the inference engine for evaluation by the heuristic decision rules that reside in the knowledge base. These decision rules evaluate the tradeoff between resource availability and desired service levels, and may be re-invoked to produce an alternative set of investments. These new investments would be identified in light of the fact that the previous alternative was unsatisfactory. Even if the target service levels were being met, additional searches may occur within well defined limits. In any event, the knowledge base would be updated with information on the performance of the inference rules employed, including whether or not a good feasible solution was found.

4. Incorporating EGIS into SCAG’s modeling environment

As noted in section 2, the current SCAG modeling environment does not include EGIS. Under present conditions forecasting the general equilibrium location and transportation behaviors of households and firms would require extensive iteration between component models. Unfortunately, iteration implies expense, and even with a general equilibrium modeling capability, SCAG will not be in a position to undertake an exhaustive enumeration of the infrastructure alternatives it is routinely charged with evaluating. The alternative to an exhaustive enumeration is a systematically applied heuristic search, but at present expert judgement is applied to the forecast models in a rather informal or ad hoc fashion. Fig. 5 illustrates how an EGIS can be used to formalize and improve this search within the SCAG modeling environment.
Figure 5 Using an expert geographic information system to formalize the search for infrastructure improvements

Consider for example the analysis of an anticipated population increase. The expert system feeds the projected population increase to the GIS which, in conjunction with existing UTP models, determines that the existing transportation grid cannot provide the specified level of service. Drawing on a knowledge base established for this purpose, the expert system executes an efficient exploration and evaluation of alternative transportation network investments. The outcome of this process is an estimate of the minimum expenditure required to maintain target transportation flows in light of the projected population increase. As in fig. 4, the target service level is itself determined via rules governing the tradeoff between investment costs and congestion. The output is an assessment of the mitigation and congestion costs associated with this population growth, based on a systematic application of
the UTP and small area forecast models currently used by SCAG. These impact estimates are based on a general equilibrium conception of how land use activities, transportation service levels and infrastructure configurations will respond to exogenous shifts in demographic or land use variables. The EGIS model captures the complete set of general equilibrium conditions specified in equations (5).

5. General feasibility of EGIS for local government planning agencies

The preceding sections describe a framework for applying a generic method (EGIS) in a particular modeling environment (SCAG). This hypothetical EGIS has four attributes that must be described in detail before this approach can be adapted by local government planning agencies for infrastructure management purposes. These four areas pertain to (i) the land use and infrastructure models the EGIS uses to refine alternatives, (ii) the GIS data structure, (iii) the characteristics of the expert system knowledge base, and (iv) the input-output specifications of the system.

In several respects SCAG’s modeling environment is more advanced than that of most local government planning agencies. Its GIS is well supported and is integrated into the agency’s ongoing planning and forecasting efforts. Moreover the general equilibrium forecasting methods SCAG is striving for are exemplary. In sum, SCAG’s current modeling environment combines with the Association’s research agenda to address area (i) uniquely well. Notwithstanding these considerations, there is little reason to think that this modeling approach is beyond the ken of medium sized planning agencies focusing on appropriate problems.

Areas (ii) and (iii) are closely related because of the necessary complementarity between the GIS and the ES subsumed within the EGIS modeling approach. It is probable that any existing GIS database would require some modifications ancillary to the requirements of an expert system component. The expert system knowledge base presents a very significant challenge in any planning application. What is required are the same kinds of data that are used by public officials, municipal engineers, and senior planning staff to evaluate alternative plans for expanding infrastructure capacity. This includes information on existing land uses, construction costs, existing supply and demand relationships, and policy based interdicts bearing on expansion alternatives. Also, a set of decision rules for determining how these considerations should be applied in the search for a good feasible alternative must be obtained from the knowledge sources identified above, and then encoded into the expert system.

These rules must ultimately be elicited from human experts, and the elicitation procedures involved must be basic yet consistent with the literature supporting existing decision analysis procedures for expert systems. Likely sources of experts include academics with specialized expertise in transportation
systems modeling together with local government engineers and administrators. The rules defined for any specific problem context will partially dictate the content of the system’s interface, though the form of this interface would be largely determined by the choice of expert system shell. In and of itself, a formal encoding of the assumptions and heuristic procedures already in use within the relevant planning agencies will promote improved decision making within the agency involved. Communication between system components (iv) is a crucially important aspect of the EGIS design. Part of the expert system knowledge base must be self-contained, notably the logical rules used for evaluating alternative decisions. The expert system will be responsible for guiding the GIS and supporting land use and engineering models in a coordinated manner, and the expert system must communicate with these other system components as it undertakes its deliberations. The expert system is also responsible for guiding interactions between the user and the system as a whole. Thus, its input-output specifications must be developed with careful intent.

On the basis of these considerations the potential for incorporating EGIS into local government transportation planning efforts may be stated as follows: probably feasible, but by no means trivial. A planning agency that might be considering such an undertaking would need to carefully evaluate its own circumstances to determine whether the expected benefits from more efficient infrastructure management outweigh the costs of incorporating EGIS. We conclude that EGIS modeling of the impacts on infrastructure brought about by urban change is likely to be most suitable for planning agencies (i) that are responsible for making critical decisions regarding infrastructure improvements; (ii) whose planning jurisdictions are experiencing rapid growth or change, and where those changes are leading to obvious strain on existing infrastructure capacity; (iii) whose current modeling environments are reasonably sophisticated and supported by a well-trained staff; and (iv) who have the administrative and/or political will to undertake to encode their implicit or ad hoc judgements into a more formalized structure.

In a period characterized by local infrastructure shortfalls of every type, the social payoffs of effective infrastructure management are enormous. SCAG recently estimated that transportation mitigation measures for anticipated growth in Southern California over the next two decades would require expenditures of $42 billion. In this context, even small proportional savings could be substantial in financial terms.

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References


**Riassunto.** Una questione centrale nella pianificazione urbana concerne l'impatto che cambiamenti negli usi del suolo e nei livelli di popolazione hanno sulla fornitura di servizi offerti da un certo sistema infrastrutturale, in particolare sulla fornitura di servizi di trasporto. Questo articolo delinea un metodo attraverso il quale una sistema esperto (SE) può essere utilizzato in connessione con un sistema informativo geografico (SIG) allo scopo di affrontare rigorosamente e concretamente la questione sopra posta.

SIG è utilizzato, in connessione con modelli di produzione, per modellizzare la fornitura di servizi in un contesto spaziale espressamente definito in termini di caratteristiche degli usi del suolo e della popolazione. Al variare di tali caratteristiche, muta il livello aggregato di servizio fornito dal sistema infrastrutturale esistente. SE è utilizzato quale strumento di aiuto per determinare i modi maggiormente efficaci dal punto di vista dei costi per riadeguare i livelli di servizio. Si ritiene che il metodo in oggetto sia applicabile in contesti per i quali si disponga di adeguate informazioni ambientali e di adeguati sistemi di calcolo, come è quello delle aree urbane del Nord America. Per giustificare tale affermazione si considera quale contesto di sperimentazione il Southern California Association of Governments (SCAG). Al riguardo si descrive come un sistema informativo geografico esperto (SIGE) può essere organizzato, fornendone inoltre una valutazione di fattibilità generale dal punto di vista dell'approccio modellistico.

**Résumé.** Un problème central dans la planification urbaine concerne l'impact que les changements dans les utilisations du sol et dans les niveaux de population produisent sur la fourniture des services offerts par un certain système infrastructuel, et notamment sur la fourniture des services de transports. Cet article esquisse une méthode à travers laquelle un système expert (SE) peut être utilisé conjointement avec un système informatif géographique (SIG) dans le but d'affronter rigoureusement et concrètement le sujet en question.

Le SIG est utilisé, avec des modèles de production, pour modéliser la fourniture de services dans un contexte spatial explicitement défini où concerne les caractéristiques des utilisations du sol et de la population. Lorsque ces caractéristiques changent, le niveau rattaché du service fourni par le système infrastructurale existant varie aussi.

Le SE est utilisé comme outil complémentaire pour déterminer les modalités les plus efficaces du point de vue des coûts, en vue de réadapter les niveaux de service.

Les auteurs estiment que la méthode en objet s'applique dans des contextes disposant d'informations adéquates sur l'environnement et de systèmes de calcul appropriés, comme dans le cas des agglomérations métropolitaines de l'Amérique du Nord.

Pour justifier cette affirmation, la Southern California Association of Governments (SCAG) est considérée comme contexte d'expérimentation. A cet égard, l'article décrit comment peut être organisé un système informatif géographique expert (SIGE) et fournit également une évaluation de faisabilité général du point de vue de l'approche modéliste.