The Utility Value of Land Use: Theoretical Foundations and Application to Shanghai[1]

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Abstract: Contemporary urban areas are complex economic and transportation systems having a structured land use pattern. The utility value of land use is a measurement unit of the value of a specific land use zone in relation to the whole economic system. It is the effective economic output value of land use and it is defined according to concepts of accessibility level, economic level and spatial interactions. With the utility value, it is possible to assign more efficiently transportation resources to land use zones and help solve transportation / land use optimization problems. A Geographic Information System is used to assign the utility value of land use in Shanghai. Results underline that transportation / land use optimization in Shanghai is far from being efficient.

Key Words: Transportation, Land Use, Optimization, Geographic Information Systems (GIS), Utility Value, Shanghai.

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Introduction

There is a growing concern in urban planning to evaluate the impacts of decision making over the transportation / land use system (Jeffers, 1988). However, no decision should be taken without an evaluation of possible alternatives because of the complex transportation / land use processes involved and more specifically the scarcity of available resources. The evaluation of alternatives is the decision thinking process and relies on tools such as modelling and spatial analysis. Decision making involves actions prescribed by decision thinking that requires numerous types of relevant information. Goals are endogenous to decision making while information is exogenous. Information must be compiled, standardized and synthesized to effectively represent the reality. The more we are informed about a situation, better the chances are that our decisions will be appropriate. This underlines the difference between data and information where information is what is relevant to the problem.

Over the last two decades, new tools of geographic data management, spatial analysis and modelling commonly denoted as geographic information systems (GIS) have appeared. Those systems offer powerful means to manage and analyze the available information, and through

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modelling and analysis, produce new spatial information. The efficiency of those systems rests on their ability to store and manipulate large quantities of spatially referenced data so it can become spatial information. Therefore, GIS are a promising way to answer the requirements of the decision thinking and decision making processes. We must consider as much options as possible in order to find the one most suitable to a set of goals and within available resources. Actually, transportation, land use and their relationships are the primary fields of information and concern in urban planning (see Berechmann and Small, 1988; Webster, Bly and Paulley, 1988). However, while aspects covering the transportation and economic systems in cities are well understood, there is a need to evaluate the interactions between transportation and land use. To do so, we propose a utility value of land use, which is a measurement unit of the economical output of a specific land use zone in relation to the whole urban system. With this value transportation resources could be assigned more efficiently to land use zones and thus help solve transportation / land use optimization problems.

Transportation / land use planning has, and continues to raise the following questions: 1) How to express transportation costs? In energy spend, in distance, for the environment, or in time? For instance, the choice of minimizing energy spent in transportation is quite incompatible with minimizing the travel time. The optimal would be minimizing all those factors simultaneously, but this would be a compromise between several choices. 2) How to optimize the relationships between transportation networks? Intermodality offers that possibility by giving transportation alternatives and a higher fluidity to movements. 3) What is the maximum spatial accumulation a zone can have? This underlines notions like economies of scale, diminishing returns, and maximal land use density. There is a limit to the spatial accumulation of movements, transportation infrastructures and economic activities that can be set by planning or be observed in reality. When this limit is reached, a land use zone loses part of its comparative advantages. 4) In which way transportation and land use have feedbacks on each other? Do transportation changes precede land use changes, or is it the opposite? Transportation infrastructures and land use are long term processes of spatial accumulation while interactions (movements) are far more flexible and adaptable. 5) How externalities affect the relationships between transportation and land use? There is a growing concern on the effects of factors like administrative divisions, congestion, air pollution and noise on transportation and spatial accumulation. 6) What is the required transportation supply for a land use zone, and by what mode? Each land use zone requires a capacity to convey movements to support the transportation demand of its economic activities.

Those questions represent current research concerns in optimizing transportation and land use. In this article, we will contribute to the discussion with the use of a geographic information system to assess the utility level of land use. The objective is to develop the notion of utility value of land use and to contribute to the development of Geographic Information Modelling (GIM) methodologies in transportation / land use planning. The hypothesis is that an efficient urban system has the geographic distribution of its utility level in relation with the geographic distribution of land use types. This represents an efficient state of transportation / land use optimization and spatial accumulation. In order to answer this hypothesis, we first present a brief overview of geographic information systems and their relevance in transportation / land use planning. Secondly, we develop the notion of utility value of land use. Thirdly, we propose an update to the concept of transportation / land use optimization. Lastly, an assessment of the utility value to the land use of Shanghai is undertaken.

Geographic Information Systems in Transportation / Land Use Planning

A geographic information system is a database system that deals with geographic data. Most geographic information systems include four components (Bracken and Webster, 1990): 1) An information input system that collects and processes spatial information such as maps, remote sensing images and digital input. 2) An information storage and retrieval system that organizes spatial information in a structured topological form that can be retrieved on queries for manipulation, analysis and display. This system must have the capacity to be updated and maintained. 3) An information manipulation and analysis system that performs tasks such as changing the form of the information through aggregation rules and modelling. 4) A display system that is able of displaying selected portions of the spatial database as reports or cartographic results. The third component of a GIS (data manipulation and modelling) is the main focus of this article.

Table 1: Types of Geographic Information Modelling (GIM)

GIM Type	Example of tasks
1) Static, deterministic modelling	Reclassification, interpolation, arithmetic and logical manipulation
2) Simulation modelling	Transportation model, land use (economic) model, spatial interaction model
3) Modelling interactions between systems	Transportation/Land Use model
4) Modelling in a decision analysis environment	Expert system

According to Dangermond (1987), Geographic Information Modelling (GIM) is a methodology that has four levels of ascending complexity (see table 1): 1) Static, deterministic modelling. This level involves simple modelling like reclassification, interpolation, arithmetic and logical manipulation of geographical data. 2) Simulation modelling. These models try to simulate the behaviour of a system by quantifying the relations between a set of variables that are believed to represent the state of that system. Land use models are good examples of that type of attempt. 3) Modelling the interactions between systems. It is an attempt to join separate models that deal with specific systems to simulate a meta-system. Transportation / land use models try to simulate such a meta-system. 4) Modelling in a decision analysis environment. This requires the design of an environment in which models are used for decision thinking and decision making. It includes not only the application of the models over a meta-system but the analysis of results. Expert Systems (ES) are a potential set of tools and methodologies to assist the planner in complex decision thinking and making situations like transportation (Rodrigue and Comtois, 1991; Taylor, 1990; Faghri and Demetsky, 1988). For GIM, artificial intelligence methodologies have received a lot of attention (Smith and Yiang, 1991; Peuquet, 1987; Robinson and Frank, 1987).

The literature on transportation / land use planning is quite numerous, and it is not the intention here to make a review of that literature. Notions of transportation and land use planning in a variety of situations can be found for instance in Black (1981), Blunden and Black (1984), Fabos (1985), Pryor (1987) and Dimitriou and Banjo (1990). Our statement is that geographic information systems offer a powerful tool for transportation / land use planning. The main factor favouring GIS is their ability to handle large amounts of geographical information. Other factors are geographic information modelling and cartographic display capabilities. However, the GIS technology applied to transportation / land use planning is nearly nonexistent, principally for two reasons: 1) It requires geographic information modelling methodologies that are not yet been developed (Dangermond, 1987). Existing GIS packages are still embryonic modelling tools, especially for transportation networks, but important breakthroughs have been attained over the last decade (see Grothe and Scholten, 1990; van Est and Sliepen, 1990); 2) The relationships between transportation and land use are only partly understood. There still is no reliable theory that simulates effectively transportation / land use systems, especially in developing countries. The overall problem is a lack of theories, concepts and methodologies more than a lack of hardwares and to some extent softwares.

Using the information implemented in a GIS to the purpose of transportation / land use planning can be conceived at three general levels of planning: strategic, tactical and operational. We present here a brief overview of the implications of GIS in planning.

Strategic Planning

Strategic planning involves long term decision thinking and decision making over transportation land use. It is the recognition of a situation and the elaboration of policies to modify that situation. Policies can vary rapidly, so the necessity of an adaptable planning environment is even more required. This is why strategic planning often requires more qualitative than quantitative information. Using a GIS at this level of planning presents few difficulties because of its capability to deal with qualitative and quantitative information on a wide range of scenarios. Information gathering is not very difficult, particularly because of the geographical scale and because the data is often required for only one period in time.

Strategic planning is often a "before" and "after" planning process starting from an initial situation through a new state corresponding to a given scenario. In that context, planners have two alternatives: 1) With a desired planned state of the urban system, trying to assess the strategies to attain that state. This is an inductive approach. 2) With fixed planning strategies, trying to find the resulting state of the system. This is a deductive approach.

Using a GIS in strategic transportation / land use planning offers a perspective that helps planners to deal with problems like: 1) The geographic definition and context of the planning area. It is the inventory of the geographical characteristics of a territory like hydrography, topography, transportation infrastructures, land use zones and administrative divisions. They can be implemented in a GIS for reference and constraints on the transportation / land use planning process. 2) The location of new transportation infrastructures. A GIS offers tools to design transportation networks by monitoring their impacts over a territory. 3) The assignation of land use zones. A GIS can help design the general land use pattern with criteria like the distance from transportation facilities, employment sources, the density of the land use types and the availability of land. 4) The evaluation of transportation demand and supply. The objective is to calculate accessibility levels and identify zones that require higher levels of accessibility.

Tactical Planning

Tactical planning involves processes occurring over an average period, which is from 1 to 2 years. It covers decisions affecting specific types of land use and transportation infrastructures. The required information is often more detailed and needed for two or more periods in time. Most available transportation / land use models work at that scale of urban planning (Berechman and Small, 1988; Webster, Bly and Paulley, 1988). The existing GIS tools are adaptable with data over time and using a GIS for this level of planning is highly recommendable. However, time series can create a large number of maps for the same attribute that can be quite difficult to handle.

A planner using a GIS for tactical planning can for instance: 1) Evaluate the spatial interactions of passengers and freight to plan the transportation network according to the spatial distribution of economic activities. This is optimizing transportation supply with transportation demand, which is a part of the transportation / land use optimization process. 2) Assign the demand on the transportation newtork. This could help find the most convenient intermodal points for passengers and freight. 3) Evaluate the impacts of transportation infrastructures and demand on land use zones.

Operational Planning

Operational planning involves decisions over the day to day use of the transportation / land use system and its logistics. In our context, it is more a transportation system planning than a land use planning because land use changes are often occurring over a long period. Therefore, the operational level has few relevance in land use planning. This level uses a great amount of information over several time periods like the hourly traffic flow through a road segment. GIS are not currently designed to deal with operational planning but they still can be used as a source of information. Spatially referenced urban information systems (a type of GIS used urban planning) have some applicability to operational planning by giving the state of several urban infrastructures like bus stops, metro stations, road arterials, etc... Examples of transportation operational planning are bus route scheduling, traffic lights timetables and delivery trucks scheduling.

Relevance of GIS in Transportation / Land Use Planning

An efficient urban planning process should consider the three global levels of planning and should begin at the strategic level. When the strategic goals are identified, the emphasis drops to the tactical level where more specific problems are dealt with. The operational level is used to answer logistical problems of the transportation system. The use of each planning level depends on the goals and in some cases only one planning level is required. For instance, with a previously given strategic planning goal, like the construction of a ring road to decongest the central city, only tactical planning is needed for the location of that road and its impacts on spatial interactions. Operational planning should be used if there is a need to assess infrastructures like traffic lights or bus stops. However, we must underline that a distinction between planning levels is often not clear, particularly between strategic and tactical planning.

Table 2: GIS and Transportation / Land Use Planning

Aspect \ Level	Strategic	Tactical	Operational
Time Period	Long (+2 years)	Average (1-2 years)	Short (<1 years)
Information Gathering	Average	Difficult	Very Difficult
Data Requirement	Low	High	Very High
GIS Complexity	Average / High	High	Very High
GIS Utility	Very High	High	Low

The relevance of GIS in transportation / land use planning (see table 2) can be summarized by the following points: 1) The major weakness of a GIS in transportation / land use planning is that few GIS can perform network analysis. However, vector based digitizing and storage is easily done in a GIS, and could be used for network definition and analysis (Shaw, 1989). Several existing GIS packages are now integrating transportation network analysis and some are specializing on transportation. The integration of a GIS and a package that deals with strategic planning of transportation networks and multimodal route optimization (see Crainic, Florian, Guélat and Spiess, 1990) would provide a powerful environment for transportation / land use planning. However, we are still far from modelling meta-systems and modelling in a decision analysis environment (see table 1). 2) A GIS is not very useful for tactical planning, and over some aspects of operational planning, it is nearly useless. Packages doing operational transportation network planning are available and their underlying methodologies in traffic affectation on transportation networks have come to maturity (Florian, 1986, 1984; Babin, Florian, James-Lefebvre and Spiess, 1982).

Considering the current weaknesses of GIS and GIM, we use those methodologies in strategic and tactical planning through the assessment of a utility value to land use. That methodology is static, deterministic modelling because it uses a simple arithmetic manipulation of geographical data represented as map layers. However, we show how the utility level can be used in simulation modelling of land use and in modelling the interactions between transportation and land use.

Land Use: Utility Value *versus* Land Rent Value

Land use is the joint level of spatial accumulation of interactions, transportation infrastructures, economic activities and population in an area. Even if the variables representing land use are discrete, land use is strictly a qualitative term associated with the function of the land. In classic notions of land use planning and economic geography, the assessment of a quantitative value to land use was done by using the land rent theory. Planning was done according to rent value. This notion is one of the oldest in modern economic geography (Isard, 1955). According to this theory, each type of land use (economic activity) occupies areas where the land rent corresponds to the value that it is able to pay. The basic assumption of land rent theory is that each type of land use maximizes its welfare (Alonso, 1960; Muth, 1969), so:

$$\text{Max}: u = u[z, q, s] \qquad \mathbf{1}$$

Where: u= Welfare.
z= Composite good.
q= Quantity of land.
s= Distance from the city centre.

Equation 1 is subject to a set of constraints like transportation costs and the available quantity of land. This assumption is still the base of recent developments of land rent theory such as the consumption theory of land rent (Thrall, 1987). It is presently argued that the distance from the city centre plays a less important part in the assessment of land rent value. The polycentric state of several metropolitan areas underlines that problem (Huth, 1983). Therefore, land rent is the perceived economic value of land use, not its effective value.

Without denying the relevance of the land rent theory, we stress the need to evaluate the utility value of land use in terms of what it is worth for the performance of an economic system and not for the owners of land. The performance of an economic system is an abstract concept, but it could be expressed by low congestion levels, by an equitable distribution of economic activities and of spatial accumulation, and by a structured pattern of movements for all modes. Therefore, the utility value is the potential economical output value of the land use of an area. It is defined according to concepts of accessibility level, spatial accumulation and spatial interactions. Accessibility defines the capacity of an area to convey movements of several modes, more simply the transport supply. It is also expressed by the accessibility level to intermodal infrastructures. Spatial accumulation is the value of the infrastructures built on an area and its productivity level. An infrastructure can have a monetary, a functional and a cultural value. For example, some residential areas can have a high land rent because of factors like prestige and history, but the utility value of those same residential areas can be low. Spatial interactions are the set of movements of people, goods and information between spatial entities.

The land rent value of an area is quite independent of the infrastructures built on it, but the built infrastructures are directly related to the land rent value. The whole theory of urban rent value is based upon that fact (Alonso, 1960). The user of land is supposed to pay a rent according to the perceived value of the land. On the contrary, the utility value of an area is directly related to the nature of the built infrastructures because it partly represents the economic output of those infrastructures. The more a land use zone have a high utility value, the more that zone is important in the performance of the overall economic system. With the same land rent, a highly productive industrial facility has a higher utility value than a less productive one. It is similar to the land rent value of an airport compared with its utility value to an economic system. The infrastructures of an airport are more expensive than the land they are built on in term of construction, maintenance and operation. Also, the economic output of an airport for an economic system is very high. For the tertiary and quaternary sectors, their high level of productivity place them at the highest utility value.

The basic assumption of the utility value theory, like the land rent theory, is that each type of land use tends to maximize its utility level according to a set of constraints. Both notions partly depend on the relative position of a land use zone in the economic system. The relative position is based on distance such as from downtown (an aspect less significant than before), from transportation facilities (modal and intermodal), or from other economic activities (economies of agglomeration). Each type of land use occupies areas where the utility level corresponds to the required levels of territorial accessibility, so the utility value is highly related to the density of land use. The utility value of a zone *i* (U_i) is defined by:

$$U_i = v\, u_i \qquad \textbf{2}$$

where the utility level u_i is defined by:

$$u_i = f\ \{A_i, E_i, T_i\} \qquad \textbf{3}$$

where:v= Value by level of utility.
u_i= Utility level of zone *i*.

A_i= Accessibility level of zone i.
E_i= Economic level of zone i.
T_i= Interaction level of zone i.

The utility level of zone i is a function of its accessibility, economic and interaction levels. The more a zone will have a high density of those concepts, the higher will be its utility value. Equation 2 stresses the difficulty in giving a monetary value by level of utility. How to give a value to utility? Is this value in dollars, in economic output, in tons of good or in bytes of information? Those questions raise complex notions of land economics that have not yet been answered and are likely to require the development of an index of output value by types of land use. Therefore, the value by level of utility will not be discussed in this article. The utility value is proportional to the utility level, so we can remove v from equation 2:

$$U_i = u_i \because U_i \propto u_i \qquad \textbf{4}$$

For the remaining of this paper the utility value of land use will be addressed as the utility level because we cannot give a value by level of utility. An utility level considers both the demand and the supply of the transportation system. If the difference between the interaction level and the territorial accessibility level of a zone is negative, there will be a tendency towards a higher density of land use (spatial accumulation). This underlines a potential for spatial accumulation and economies of agglomeration. On the contrary, if the interaction level exceeds the territorial accessibility level, there are congestion costs that initiate a loss of density process. External costs overcome the advantages of the location. Equation 3 shows that the utility level is an overlay of specific utility levels related to accessibility, economic and interaction levels. Geographic information systems offer tools to handle that aspect with map overlays. Considering the difficulties of assessing a discrete quantitative utility level, the use of an ordinal utility level is more recommended. In overlay analysis, the utility level is defined by a weighted sum of maps:

$$\begin{gathered} U_i = \sum_x M_i^x w^x \\ \sum_x w^x = 1 \end{gathered} \qquad \textbf{5}$$

where:M_i^x= Utility level of zone i for attribute map x.
w^x= Weight of attribute map x on the overall utility level.

An example of a map overlay could be the overlay of population density, of employment density and of road accessibility maps. The result, a utility level map, can be used for transportation / land use optimization.

The utility level can be a very flexible concept depending on what planners view as useful and less useful. For instance, some authorities might view the same area from different point of view. Environmentalists may assign an area a high utility level because it contains some rare ecosystem, while an industrial development board could assign the same area a high utility level because of its location relative to transportation infrastructures. Therefore, utility is viewed as a purpose.

Transportation / Land Use Optimization

In existing urban areas a great deal of resources (human, capital and infrastructures) and energy are spent in maintaining and improving movements between economic entities. With the raising costs of energy and resources, planners look upon means to lessen the costs of movements generated by economic activities. Optimizing transportation and land use is such a mean. It implies a spatial pattern that will reduce the cost of movements and raise the synergy between economic activities. Transportation and land use relationships occur in a complex urban system where an optimal level cannot be reached. The required changes to attain an optimal level would be too important considering constraints like limited resources and existing spatial patterns. The optimal is a theoretical spatial pattern that the existing spatial pattern must aim to optimize transportation and land use. The optimal spatial pattern would be a "perfect" city where there are no congestions, an equitable distribution of economic activities and of spatial accumulation and a structured pattern of movements. This is unrealistic and we suggest that reaching a functional level is not necessarily done by aiming at an optimal one.

The main objective of the decision thinking process is to find a functional level of the transportation / land use system given a set of constraints that cannot be bypassed. Optimization is considered as a set of process to attain a functional state, not a perfect one. Constraints are of three general types: spatial, infrastructural and social. Spatial constraints are related to the geographic distribution of infrastructures, labour and land use pattern, that is the fixed character of places. Infrastrastructural constraints are the capacity of existing transportation infrastructures and the density of land use zones. This is the potential to overcome the fixity of places. Social constraints are the most difficult to express. Some locations have a high historical and cultural significance where a value is very difficult to assess. Existing planning strategies are social constraints in the sense that most of the time they do not consider the transportation / land use optimization has an explicit goal.

Over the past, transportation models have been used by transportation planners to solve transportation problems that considered land use as given. It has been the same for land use planning that considered the transportation system as given. At the beginning of the 80s the emphasis has shifted over the relationships between transportation and land use. This is considering whole meta-system instead of two separate ones (Los, 1979). We suggest that the overall objective of transportation / land use optimization is to minimise the cost of the movements for all modes between land uses and to maximize the utility level of land uses. This seems simplistic but implies several complex planning processes. By reducing the costs of movements, friction is lessened and by raising the utility level, the economic output of land use is increased.

Thus, we assume that transportation / land use optimization considers first, the minimization of the transportation costs between spatial entities (*C*) (Wilson and al., 1981):

$$\text{Min}: C = \sum_i \sum_j \sum_k c_{ij}^k T_{ij}^k \tag{6}$$

subject to:

$$T_{ij}^k \geq 0 \; (\forall\, i, j, k) \qquad \sum_j \sum_k T_{ij}^k = O_i^k \tag{8}$$

$$\sum_i \sum_k T_{ij}^k = D_j^k \tag{7}$$

where: T_{ij}^k= Spatial interaction of mode *k* between zones *i* and *j*.
c_{ij}^k= Transportation cost of mode *k* between zones *i* and *j*.
O_i^k= Net trips of mode *k* leaving zone *i*.
D_i^k= Net trips of mode *k* arriving a zone *i*.

Equation 6 specifies a minimum cost of movement considering the existing transportation network.

Transportation / land use optimization considers second, the maximization of the utility level of land use (*U*):

$$\text{Max} : U = \sum_{i} v\, u_i \qquad \mathbf{9}$$

subject to:

$$u_i \leq M_i \qquad \mathbf{10}$$

where: u_i= Utility level of zone i.
v= Value by level of utility.
M_i= Maximum utility level a zone i can have.

Equations 6 and 9 enable us to underline the main link in optimizing transportation and land use; accessibility. From the planner's point of view, raising the transportation supply of a zone will lower the transportation cost (minimizing *C*) and raise the utility level (maximizing *U*). The relationships between transportation and land use are not that simple considering the important feedbacks of congestion costs and externalities like environmental degradation and circulation accidents. Joining equation 6 and equation 9 and including the concept of externalities will produce the general transportation / land use optimization (maximize *TLU*) equation:

$$\text{Max} : TLU = \text{Min} : C \ \cup\ \text{Max} : U \ \cup\ \text{Min} : X \qquad \mathbf{11}$$

Where *X* are the external costs, or externalities. This equation is difficult, if possible to apply to transportation / land use planning. Facing that problem, a strategy often employed is to optimize only one part of equation 11. For instance transportation planners only attempt to minimize the transportation costs while land use planners try to maximize the utility level of land use (most often according to the land rent theory). Externalities are often ignored in the planning process and considered as unavoidable and unpredictable costs.

Equation 11 does not identify the level of relationship between transportation and land use. Our contribution to the development of transportation / land use optimization methodologies is to propose that the state of transportation / land use optimization can be measured by the degree of relationship between the utility level and the land use type. A simple statistical method, the contingency coefficient, can measure the level of relationship between the utility level and land use. It is a measure of association between two non parametric variables (Norusis, 1983). A contingency coefficient between utility level *u* and land use *L* (*CC(u,L)*) is expressed by:

$$CC(u, L) = \sqrt{\frac{\chi^2(u, L)}{\chi^2(u, L) + N}} \qquad \mathbf{12}$$

and where:

$$\chi^2(u, L) = \sum_{\forall u} \sum_{\forall L} \frac{\left(O(u, L) - E(u, L) \right)^2}{E(u, L)} \qquad \mathbf{13}$$

where: $\chi^2(u,L)$= chi square statistic between utility level *u* and land use *L*.

$O(u,L)$= observed surface by utility level u and land use L.
$E(u,L)$= expected surface by utility level u and land use L.
N= total surface.

The expected surface by utility level and land use assumes that this surface is uniformly distributed. The more contingency coefficients tend to 1, the more the utility level is associated with land use. This express the degree of transportation / land use optimization. However, it is not likely that any urban system will have a value of the coefficient somewhere near 1. To test the developped methodology, the next section will evaluate the utility level of land use in Shanghai.

Utility Level Assessment to the Land Use of Shanghai

Shanghai is the largest city, the most important port and the hearth of the industrial production of China. The city is experiencing population and industrial relocation changing the land use of entire areas. The economy and the transportation system are affected by a growing importance of the informal sector. There is also an increasing importance of the international trade in the economic production (Comtois and Rodrigue, 1991; Comtois, 1989). The complexity of the urban system of Shanghai requires efficient tools to help the decision thinking process to have an overview of the situation. Geographic information systems provide a geographical database that could help the management of available information on Shanghai and represent more efficiently the state of the transportation / land use system. To assess a utility level to land use in Shanghai, several variables were used. Each variable represents a layer of information in a GIS. The procedure is a simple arithmetic operation (see equation 5) representing the first level of complexity of Geographic Information Modelling (GIM).

Map Layers and Weights

Equation 3 defines three types of variables used to assign a utility level to land use: accessibility, economic and interaction levels. We assign each variable to a map layer with a class range. For the first type of variables, the accessibility level, four map layers were digitized. On the first layer, the road transportation network of Shanghai was digitized and a class was assigned to each type of road. The class range from 1 to 4, were class 1 represents the primary roads and 4 represents small urban roads of less than 4 lanes. The transportation network was digitized as vectors, but vectors do not have a width. A 1 km large corridor was therefore calculated for class 1 roads and a 0.5 km corridor for class 2 roads. Class 3 and 4 roads were discarded. The result is a map layer of the general road accessibility in Shanghai. The second map layer representing accessibility is a corridor of 0.5 km starting from the shore of important waterways such as the Wusong and the Huangpu rivers. This is justified by the fact that Shanghai is the most important port of China and that zones near such waterways are very accessible. So that layer has one class. The third layer is a concentric circle map representing the distance from the central area of Shanghai as defined by the planning authorities. Even if Shanghai does not have a central business district, there is a central area that has an important concentration of commercial activities along road axes like Nanjing Lu. The first circle (class 1) as a radius of 1 km that encompasses the whole central area. The following circles (classes 2 to 10) have a radius gradient of 3 km. The fourth layer is a concentric circle map representing the distance from the Hongqiao international airport that was recently renovated (10 classes).

For the second type of variables, the economic levels, two map layers were digitized. The first layer represents a map of the density of population per square kilometres. This map is the result a contouring procedure based on the population density for the economic zones of Shanghai (8 equidistant class intervals).

They are over 100 economic zones in Shanghai. A centroid was assigned for each economic zone and contouring was done according so. The second layer represents a map of density of employment in the industrial sector that was obtained using the same procedure as the population density layer.

For the third type of variables, the interaction levels, three map layers were digitized. The first layer is the attraction for persons by transit for each economic zone. Attraction is the sum of all the movements going in an economic zone. Interaction layers were obtained using the same contouring procedure than economic layers (10 equidistant class intervals for each layer). The second and the third layers are the attraction for persons by bicycle and by car. Table 3 presents the map layers used for the assessment of a utility level to land use in Shanghai and the number of classes per layer.

Table 3 : Map Layers Used to Assign a Utility Level to Land Use in Shanghai

Accessibility Layers	**Classes**	**Economic Layers**	**Classes**	**Interaction Layers**	**Classes**
Road accessibility (A^1)	2	Density of population (E^1)	8	Attraction by transit (T^1)	10
Waterway accessibility (A^2)	1	Density of employment (E^2)	8	Attraction by bicycle (T^2)	10
Distance from urban centre (A^3)	10			Attraction by car (T^3)	10
Distance from airport (A^4)	10				

Map layers used in our analysis will produce a specific type of utility level, which is not the only type that could be assessed. For Shanghai, the availability of information was very limited. No social variable is used except in some way the density of population. Equation 5 requires the use of weights in the assessment of a utility level to land use. As a part of a map overlay procedure, each variable is given a weight according to a model of weight distribution by variable. In this study, we limit ourselves to three models of weight distribution that are presented on table 3.

Table 4 : Map Layers Weights for Three Models

Map Layer	**Model A** w^X	**Model B** w^X	**Model C** w^X
Road accessibility (A^1)	0.2	0.3	0.1
Waterway accessibility (A^2)	0.1	0.15	0.05
Distance from urban centre (A^3)	0.1	0.15	0.1
Distance from airport (A^4)	0.05	0.1	0.05
Total Accessibility Weight	**0.45**	**0.7**	**0.3**
Density of population (E^1)	0.1	0.05	0.1
Density of employment (E^2)	0.1	0.05	0.1
Total Economic Weight	**0.2**	**0.1**	**0.2**
Attraction by transit (T^1)	0.2	0.1	0.25
Attraction by bicycle (T^2)	0.1	0.05	0.15
Attraction by car (T^3)	0.05	0.05	0.1
Total Interaction Weight	**0.35**	**0.2**	**0.50**
Total sum of Weights	**1.0**	**1.0**	**1.0**

The distribution of weights amoung variables for the three models is heuristic. Model A is our basic assumption of the weight of each map layers in the assessment of a utility level to land use. Accessibility is the most important concept, followed by interaction and the economic level. Model B puts more weight on accessibility variables representing transportation infrastructures, that is the supply side. This is based on the assumption that the utility level of land use is more depending on the level of accumulation of transportation infrastructures. For model C, the emphasis is on the attraction potential for transit, bicycle and car modes. In this case we assume that the utility level of land use is depending more on its capacity to attract movements. In all models, the interaction weights put more emphasis on attraction by transit and attraction by bicycle, than on attraction by car. Considering the characteristics of traffic in chineses cities, especially in Shanghai (see Comtois, 1991), this is well justified.

Table 4 underline that the utility level of land use is not fixed, but depends on its perception by planners, which is consistent with our previous reasoning on the relativity of usefulness. In that context, the use of a GIS can provide an environment to elaborate several alternatives (or scenarios) in the assessment of that value by changing overlay weights of layers, and even map layers themselves.

The Utility Level of Land Use in Shanghai

Using the weights of table 4 with equation 5, a GIS was able to produce, through map overlay, three utility level maps. For instance, the utility level of model A is defined by:

$$\begin{aligned} U_i = A^1 \bullet 0.2 + A^2 \bullet 0.1 + A^3 \bullet 0.1 + A^4 \bullet 0.05 + \\ E^1 \bullet 0.1 + E^2 \bullet 0.1 + \\ T^1 \bullet 0.2 + T^2 \bullet 0.1 + T^3 \bullet 0.05 \end{aligned} \tag{14}$$

The utility level produced through map overlay ranges from 1 to 8, where 1 is the highest utility level for the urban area, and 8 the lowest. Figures 1, 2 and 3 present the geographical distribution of utility levels in Shanghai for the three models. There are good examples of what kind of output to expect from a GIS. Table 5 shows the surface occupied by each level of utility and figure 4 shows the distribution of utility levels for each model.

Table 5 : Surface Occupied by Utility Level Class

Utility Level	Model A		Model B		Model C	
	Area (KM^2)	%	Area (KM^2)	%	Area (KM^2)	%
1	1.285	0.20	1.770	0.28	6.314	1.00
2	16.713	2.65	11.085	1.76	55.975	8.88
3	97.115	15.41	46.997	7.45	97.012	15.39
4	148.714	23.59	143.743	22.80	147.953	23.47
5	151.189	23.98	175.690	27.88	139.171	22.07
6	144.170	22.87	224.949	35.68	89.016	14.12
7	71.232	11.30	26.184	4.15	94.978	15.06
8	0.039	0.00	0.039	0.00	0.039	0.00

Several preliminary conclusions can be advanced from the utility level maps. First, the highest utility levels are not near the central area of Shanghai. This confirms that there is no central business district like the ones that are usually found in occidental cities. The most plausible factor explaining this, is that the neighbourhoods in Shanghai are planned to be relatively self sufficient to limit the movements within the city. Another reason is since 1949, the chinese socialist economy did not require much office space as decisions, policies and the economy were centrally planned. Also, commercial activities in chinese cities were not very important until recently. Second, the three models show that areas with the highest levels of utility are in the western part of the city along the Wusong river, which corresponds to an industrial district. This reflects the status of Shanghai as a centre of industrial production. Another area of high utility levels corresponds to the Yangpu industrial district (specializing in steel production) where the main port facilities are located. To a lesser extent, the Wusong industrial district has an average utility value, even if it is located far from the central area. Third, few areas have a high utility level and the distribution tend to be normal like (see figure 4). This means that in Shanghai, a limited number of land use zones have characteristics of a high level of spatial accumulation, and no zone have the optimal. Fourth, model A have the most normal-like distribution of the surface occupied by utility levels (see figure 4). This favours that model as the best choice of weights distribution in the assessment of a utility level to land use in Shanghai.

To find the utility level by land use type, utility level maps were overlayed with the land use map of Shanghai and contingency coefficients were calculated. By overlaying the utility level distribution of figure 1 (model A) with the land use map of Shanghai, table 6 was obtained.

Table 6 : Surface Occupied by Land Use and Utility Level Class in Shanghai, Model A.

Utility Level	Non Urban	Built Area	Industrial	Institutional	Utility	Park	Airport	Warehousing	Total
8	0.033[*] (0.01)	0.005 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.039 (0.01)
7	65.349 (10.37)	3.955 (0.63)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	0.000 (0.00)	1.892 (0.30)	0.037 (0.01)	71.232 (11.30)
6	127.14 (20.17)	9.573 (1.52)	0.323 (0.05)	0.609 (0.10)	0.565 (0.09)	0.080 (0.01)	5.021 (0.80)	0.856 (0.14)	144.170 (22.87)
5	119.09 (18.89)	14.840 (2.35)	5.388 (0.85)	1.378 (0.22)	1.588 (0.25)	1.154 (0.18)	7.190 (1.14)	0.556 (0.09)	151.189 (23.98)
5	87.250 (13.84)	39.299 (6.23)	12.281 (1.95)	1.496 (0.24)	4.226 (0.67)	0.637 (0.10)	1.815 (0.29)	1.710 (0.27)	148.714 (23.98)
3	29.004 (4.60)	50.246 (7.97)	9.357 (1.48)	2.070 (0.33)	2.989 (0.47)	2.205 (0.35)	0.098 (0.02)	1.146 (0.18)	97.115 (15.40)
2	2.556 (0.41)	9.639 (1.53)	2.196 (0.35)	0.627 (0.10)	0.665 (0.11)	0.452 (0.07)	0.000 (0.00)	0.579 (0.09)	16.713 (2.65)
1	0.179 (0.03)	0.690 (0.11)	0.368 (0.06)	0.000 (0.00)	0.000 (0.00)	0.047 (0.01)	0.000 (0.00)	0.000 (0.00)	1.285 (0.20)
Total	430.61 (68.30)	128.25 (20.34)	29.91 (4.74)	6.18 (0.98)	10.03 (1.59)	4.58 (0.73)	16.02 (2.54)	4.88 (0.77)	630.46 (100.0)

[*] Note: The first value is the area in square kilometre, and the second is the percentage of the total area of Shanghai.

Table 7: Measures of Association between Utility Level and Land Use in Shanghai.

Measure	Model A	Model B	Model C
Contingency Coefficient	0.4781	0.3957	0.5009
Cramer's V	0.1721	0.1362	0.1830

Tshuprow's T	0.1486	0.1176	0.1580

Table 7 suggests a relationship between the utility level and the land use type with a contingency coefficient of 0.4781 for model A. Model B and C show similar contingency coefficients (0.3957 and 0.5009 respectively). Figure 5 illustrates that non-urban land use have lower levels of utility than urban land use. This is particularly true for the distribution of the utility level of industrial, institutional, utility and park land uses that are located in the central part of Shanghai where the concentration of economic activities, transportation infrastructures and movements is higher. Airports and warehousing land uses, with their peripheral location have a lower utility level distribution. Parks have a surprisingly high distribution of utility level that can be explained by the fact that they are mainly located in central areas and are benefiting from the locational utility level of surrounding land uses.

An high association of utility levels and land use types underline an adjustement of the transportation system with the land use pattern. This means that high utility levels must correspond to specific types of land use like commercial and industrial, and that lower utility levels must correspond to land use types like residential and non-urban. Small contingency coefficients in Shanghai suggest that transportation supply does not respond effeciently to the mobility demand of land uses. Other measures of association like the Cramer's V and the Tschuprow's T show even less relationships between the utility level and land use.

Variations in weight assignments give different contingency coefficients. If more weights were assigned to interaction layers, growth in the contingency coefficient is expected. Empirically, if all the weights were assigned to interaction layers, the level of association would be around 0.7. However, we would have demonstrated an association of spatial interactions with land use that does not consider the transportation supply. When we put more weights on accessibility layers (model B), we have the lowest level of association. Jointly considering the supply (accessibility layers), the demand (interactions layers) and the economic output (economic layers) with land use shows how the spatial structure corresponds with the economic structure. Therefore, results underline that the status of transportation / land use optimization in Shanghai is far from being efficient. Depending on what measure of association is considered (contingency coefficient, Cramer's V or Tshuprows' T), the level of transportation / land use optimization in Shanghai range from 15 to 50%, so the most plausible value is likely to be around 30%.

Comparing the results with the planning goals in Shanghai reveals inadequacies between the existing utility level of land use and the projected land use. Zones of high utility level coincide with actual industrial zones, more specifically heavy and labour intensive industrial zones. The planning strategies of the authorities of Shanghai consists in 1) Upgrating road sections that have already reached congestion levels at their present design standards to face the potential demand from a new economic infrastructure. 2) Optimizing road and transit network for a better level of efficiency. 3) Changing the land use pattern of the municipality towards a more efficient spatial organization (Comtois and Rodrigue, 1991). Those strategies will reorganize the land use pattern of Shanghai by establishing a hierarchical urban structure composed of the central city, satellite towns, county markets and suburban counties. The authorities plan a shift towards the light industrial sector with value added production and the creation of a commercial district starting from the central area and extending towards the eastern bank of the Huangpu river in a new development zone named Pudong (see figure 6). If so, major changes in the urban structure that will modify the utility level of whole districts are forecasted. This will be achieved through land use changes, population relocation, new industrial and commercial zones and the construction of two ring roads with bridges crossing the Huangpu river (one already completed and another under construction). As the existing industrial infrastructures age and the plan is progressively applied, a new pattern of utility level of land use will emerge. It is likely that the utility level of the central area of Shanghai will raise, also the one of Pudong area and that the utility level of old industrial areas along the Wusong creek will drop. Is the urban structure of Shanghai in a process of change from a polynuclear state towards of a nuclear city? Other evidences suggest that the new urban structure will be linear because heavy investments are done along main commercial roads, especially between the central area and the international airport. Changes at an other scale are also occuring. Shanghai is integrating a vast economic area by acting as an intermodal centre and the hub of a corridor of economic development towards Hangzhou and Nanjing.

Conclusion

The utility value of land use is a more comprehensive notion than the land rent theory. It illustrates the general level of spatial accumulation of transportation infrastructures, economic activities and spatial interactions. High utility levels of land use are an indicator of the importance of a zone in the overall economic performance of an urban system. Starting from our initial definition of utility value, we have stressed the difficulty to give a monetary value by level of utility, so we have limited ourselves to the notion of utility level. In this article, a utility level angled towards the transportation supply and the spatial distribution of interactions was assessed to represent the value of land use zones in Shanghai. Areas with the highest utility level are not in the central district like we would expect it in other urban areas, but in a part of the city corresponding to heavy, labour intensive industrial activities. This tends to confirm that there is no central business district in Shanghai. However, recent changes in the economy of Shanghai let forcast the emergence of a linear commercial corridor from the actual downtown towards the international airport. We must keep in mind that the utility level is a very flexible concept that depends on what is viewed as useful and on what kind of variables are used to represent it. To illustrate this, the weights that give a utility level through map overlay have been changed to produce three models of utility levels. Different weight assignments have produced different levels of association between utility levels and land use, which are increasing if more weights are assigned to spatial interactions.

From the aspect of transportation and land use optimization in Shanghai, the utility level enables to point out areas where more transportation infrastructures could be added if a raise of the utility level is required. This is likely to occur because major changes in the urban structure are forecasted. The utility level must be consistent with the land use type otherwise problems of insufficiencies of transportation infrastructures appear and the effeciency of the urban system drops. The measures of association between the utility level and the land use in Shanghai underlines the weak capacity of the transportation system to answer to transportation demand of land uses. Therefore, the relationship between transportation and land use in Shanghai is far from being efficient and measures suggest an efficiency level of around 30%. A efficiency level of 100% is conceptually impossible. It would be relevant to compare the utility levels and land uses of different cities to better assess what is a low efficiency level, and how high the relationship betwen the utility level and land use can go in efficient cities. However, considering the heterogeneity of available information, this is not an easy undertaking.

Geographic information systems are efficient tools to help transportation / land use planning that includes decision thinking and decision making processes. The utility level is part of a strategic and tactical planning process, which aims to acheive a better levels of transportation / land use optimization for urban areas.

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