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Environment-Influenced Zoning–E.I.Z.

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ABSTRACT

This paper explores the concept of environment-influenced zoning as a rational guide for the development of urban areas. Of all the regulatory powers that city government possesses, zoning is by far the most inclusive one which deals with our physical environment. To date its provisions and patterns have not been based upon predictive or testable theories. Rather, they have been based upon precedent and tradition. Zoning can be related to the fundamental energies of the environment, resulting in different patterns for cities of different latitude, topography, and street grids. The methodology proposed can apply to the design of new cities as well as the evolution of existing cities.

Introduction

A growing percentage[1] of people are relying on urban centers for vital life sustaining services as a result of population growth and industrial development.[2] This is creating a crisis which our cities are not able to meet. The demands of present urban and satellite populations can barely be met; future demands on the cities have yet to be faced.

One obvious answer which has been proposed is the establishment of a vast series of new cities–cities properly sited and designed. It is hoped that these can avoid the inappropriate condition for life and work now found in our cities. The setting forth of new cities is not a new occupation of man; virtually every city on this continent was a new city, consciously planned by man.[3] This has been true the world over, particularly when new undeveloped areas were settled. The cities resulting from Western colonialization were developed initially to imitate such "ideal" forms as the Greek

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and Roman Camps,[4] the presidios of the Spanish,[5] or the Bastide towns of France. More recently several new towns in England, India, and Brazil have been built.[6]

Traditionally, city or town planning consisted of the formulation of a physical pattern or "plan" to serve as a guide in the development of the town.[7] Plans were enforced by the founding authority—public or private. The obvious aim for any plan, or more generally a set of controls or prescriptions, is to make the place of habitation more serviceable and beneficial not only to the authorities but hopefully also to the people who will relate to and live in the town. In the case of a "democratic" town the benefit of the body politic is the overriding aim.

All cities have plans—usually, these are composed merely of set or prescribed streets with islands of land defined by these streets.[8] The layout dimensions and patterns of these streets determine many of the subsequent physical problems which the town will face. Included among these problems are sewage and drainage, light and air, noise and congestion, and control and defense.

The layout of the streets in relation to the terrain will drastically affect the degree to which these physical problems determine the basic aspects of city life. Time and time again towns have been laid out on paper and when they were transformed to the land the paper plans were found to fail because they did not take adequate consideration of the lay of the land.[9] This would lead to *ad hoc* modifications. Of course, many cities do not have a definite or influential terrain; but when there are significant topological factors, careful consideration of the properties of the surface can result in many benefits for the cities.

In the past, cities were laid out by rules of thumb. Little was known about the proposed area in which the city was to be located and there was little time to find out much about the site. Towns were located and the problems discovered later.

Today our capability to obtain knowledge is far greater and, in particular, our ability to *manipulate* essential information about an area is of tremendous advantage. The use of satellite or aircraft photographs, seismic recording, and other advanced devices enable us to quickly determine essential characteristics about vast areas. Operations research methodology provides a suitable framework in which an investigation of the consequences of zoning controls can be performed.

To objectively consider zoning controls is to ask the question, "Where and how is it appropriate to live?" and attempt to proceed intelligently in that direction. Where and how people live are left to the vagaries of our profit-seeking housing market system. While providing a greater percentage of the population with better housing than is found in most other countries, the results still leave much to be desired.

History of Zoning Controls—
Early Environmental Protection[10]

It was in response to the myopic exploitation and selfishness of the market forces that zoning controls were introduced into this country and have been upheld in the courts. Clearly the free market was not providing a desirable or even healthy environment.

Zoning controls have been instituted in the past to attempt to guarantee every man a better environment. They have been successful only to a small degree. All too often decisions of an economic and political nature have not clearly put forth the environmental impact associated with them. This failure has in part been due to the lack of appropriate models. Before we get to a discussion of what type of new procedures and controls may be more appropriate and successful in controlling the environment, we should like to review the nature of zoning controls.

The Nature of Zoning Controls

Existing cities have a fixed street pattern and topography which cannot be easily changed. As their population increases, density increases.[11] Thus, spaces that were appropriate for lower densities are stressed further by new buildings which are usually taller, and have greater coverage.

Zoning laws are employed as the prime means of controlling the arrangement of buildings in an attempt to benefit the city environment in two ways: the maintenance of minimum standards of light, air, and privacy within the buildings; the maintenance of some standard of "light and air" in the public domain–the street. This is usually done through a whole range of "measures" which, when combined, serve to regulate the distance between buildings, their bulk, height, setback, the number and arrangement of windows, and the resulting open space.[12] Again and again the terms *light* and *air* are mentioned as being the goal and hence the justification for these zoning requirements. Yet there has been little discussion of what *light* and *air* actually mean. Further, little effort at constructing even rudimentary models to study the effects of zoning controls has been made before.

In 1929, New York City attempted to prepare zoning controls related directly to the amount of sunshine received.[13] They did not examine the effects of reflected light nor did they deal with the density and scale of structures found in Manhattan.[14] They also lacked the ability to examine the variables in a dynamic system model. The task is overwhelming to perform manually. A zoning control related to the way the sun moves and shines upon objects and surfaces requires the use of mathematical models and computers. The British have a more advanced system of location of structures in relation to the sun, but they, too, fall far short of any system which relates to the actual movements and properties of light and air.

An operations research approach would entail a model which can relate building controls to independent variables.[15] Controls can then be manipulated to achieve a clearly defined environment, one that can be agreed upon by popular referendum or by experts (it does not matter inasmuch as a range of specified environments is possible whatever the system).

Considerations of an Operations Research Model

Any discussion of light must make the distinction between direct and indirect sunshine. There are distinctly different considerations which apply in each case. The existing regulations involve discussions about entities such as "setbacks," sky exposure planes, angle of light obstruction, light access units, etc.

The Behavior and the Effect of the Uncontrollable Variables

Let us begin our discussion of the uncontrollable variables with how the sun actually moves and what effect it has upon different types of surfaces, some of which combine to comprise the local environment. Let us make some very general statements about the sun and its effects.

The sun is high in the sky during the summer. It rises early, sets late, and gives more hours of sunlight than at other times of the year. In the winter the sun rises late and sets early. Thus, it shines for only a little while. Its position is low in the sky, giving less heat.

The sun shines upon the earth and upon man-made objects on the surface of the earth, such as buildings. Buildings are composed of vertical walls. The light they receive varies in duration and intensity depending upon the position of the sun and which way the wall faces. We have all heard about the benefits of a southern exposure, but what do we know about other exposures and how they relate to the zoning concern with light and air? Further, such questions as "What effect does the sun have upon surfaces separated by a street width in different exposures?" must be answered if a useable model is to be constructed.

We have built a computer simulator for the movement of the sun and its effects upon surfaces of any inclination and exposure. The ability to see just what these effects are, easily and quickly, generated some new ideas for the reformulation of building form and appearance, so as to guarantee a predictable quality of light within an apartment or on the street. With such a simulator, each city can adapt its regulations to the exact sunlight conditions it has by virtue of its latitude, as well as understand which parts of the city should have different regulations stemming from different environmental conditions.

Sun and Topography

The surface of the earth is rarely flat. Where there are slopes, the sun will shine upon these different slopes with varying intensity and for a varied length of time, depending upon what orientation the slope has.

Street plans are typically drawn as a regular geometric pattern and then applied to the terrain, modifying the terrain where necessary to make the streets work.[16] In the case of San Francisco, where the hills cannot be leveled, a street plan is made to work, anyhow.[17] The only other alternative would be a different street plan.

The effects of having the sun shine differently upon different slopes of the earth are many. If street widths are constant, buildings along a street built on a north slope will have a dramatically different shading effect than on a south slope. What types of activities are to be located on which streets is a question that can be related to the movement of the sun. Parks, recreation, and shopping can be located so that they will be using the desirable sunlight at a time of day when more people will desire to use them.

Another result of knowing how and when the sun will shine on different slopes and exposures will be a description of which streets will warm or cool at which times, a prime consideration in the maintenance of the street system. Some streets will be far more susceptible to frost heave, rapid freeze, and thaw. The effects of the sunshine on different slopes at different times and intensities provide a basic overall pattern that will be different for each city. This primary pattern can then be further modified by regulations of the placement, size, and type of development allowed by zoning ordinance. This primary pattern is a clearly established phenomenon in no way arbitrary and is established by clearly set procedures that are applicable everywhere. This satisfies one of the prime requirements that zoning must meet.

Starting from the basis of a clear understanding of how light behaves in these different slopes and exposures, building controls can be modified to accentuate or nullify desired characteristics. That is, where the sun shadow pattern is shortened by slope, buildings can be allowed to be taller and still maintain a desired lighting standard. Similarly, where the shading situation is more severe, lower buildings or greater spaces between the buildings will be called for. In a similar manner, bulk and surface regulations will vary depending upon the area on a slope and what exposure the slope has. Thus, the effect of the gross shape of the city surface could be recognized.

Construction of a Model to Develop Environment Influenced Zoning

As we have mentioned, the present controls used to shape the physical environment and guarantee a certain quality of light and air do not relate in a measurable way to the way the sun moves. (They were not really ever intended to be this sophisticated.) Neither do they relate to the way the sun's light and heat react with the forms of buildings to generate more heat, drafts, and other elements of a definable microclimate.

Just how does one go about establishing a zoning which is influenced by the environment? What kind of controls can be applied which relate to the basic dynamics of an environment, be they natural or man-made? To answer these questions we must have a model capable of predicting the impact of zoning actions upon the environment in question.

There is some basic information which must be known about the existing environment in order to construct the desired model. An accurate topographical map of the area (preferably with 2- to 5-foot contour intervals) must be available. This map will be used to determine not only important considerations such as drainage patterns, but also slope, exposures, and slope/exposure maps.

From this basic piece of information a classification of the area into various slope categories, that is, what areas are flat, have 10%, 20% or 30% slope, can be determined. The classification should be chosen so that the slopes are relevant to other physical planning considerations–slopes which prohibit certain building types, grades which trucks cannot easily negotiate, or slopes which are prone to erode, if denuded. They can be expressed in per cent of slope, degree of slope, or as a ratio of length to rise. Areas that are flat are distinctly different natural resources from sloped surfaces.

Also vital to the model is an analysis of the terrain in terms of exposure relative to north. The number of categories here is arbitrary but should be large enough to show the differences between northern, eastern, and southern exposures. The direction of the slope of the land is a prime determinant of its microclimate. Each exposure can be considered as a natural resource available to the city.

A combination of slope and exposure, a slope-exposure map serves to define the basic characteristic of a local area. Similarly, an area of the same slope but different exposure will also have a fundamentally different microclimate due to the way the sun shines on it. The slope-exposure map, therefore, represents a breakdown of the area into areas which have or contain definable different environmental properties–properties which one can choose to maximize or minimize depending upon the needs and requirements being faced.

In addition to topographical data for the area being considered, a knowledge is necessary of how the sun actually falls upon the land as a function of the latitude of the area. Similar surfaces located at 45°N latitude and at 20°N latitude would have fundamentally different interactions with the sun due to their differing positions relative to the earth's equator.

An accurate description of the regional climate may also be incorporated into the model. This might include annual temperatures, humidities, deviations, precipitation, winds, and percentage of possible sunshine available. For areas that are already established and have built fabric which cannot be changed, there should also be a street analysis–a description showing when the sun will be on the axes of which streets.

The street system should also be characterized in terms of the width of the streets, for this will have a strong effect upon the type of controls to be applied–how high the buildings can be before the street is shaded for an unacceptable amount of time, what uses could best be related to sunshine at what time of day, in what direction traffic should flow so as not to blind drivers, and so forth.

These then are the basic data required for the construction of a model:

1. slope,
2. exposure,
3. slope/exposure,
4. sun pattern,
5. climate,
6. street width and
7. street axis

Controllable Variables (Zoning Actions) to be Tested by the Model

Zoning as it exists today relates only to the width of the street. Of the existing array of controls used in zoning, only some come in for model investigation in this paper: height limits and setbacks. Other components of zoning: floor area ratios, open space requirements, lot area per room, are not examined here. Concepts such as sky exposure planes and angle of light obstruction are replaced with new concepts more directly related to the way the sun actually shines upon surfaces. One control which is somewhat similar to a sky exposure plane is an angle of inclination. Another concept which has been modified is that of required spacing between buildings. An entirely new control involves light reflectance of a structure and an angle of reflectance for various surfaces. The proposed controls relate directly to the way that the sun shines.

Since it is a goal of zoning regulations to guarantee a certain amount or quality of natural light in the street and in buildings, it follows that if and when it is impossible to obtain direct light, as on northern slopes or northern facing sides of the street, it would be legitimate to regulate the manner in which reflected light reaches the street or apartments. Surfaces which receive direct light will automatically reflect some of that light away. The manner in which this reflection takes place and the direction of the reflection is of importance in the illumination of areas in shadow.

One could simply require that a shaded surface receive a certain amount of reflected light from adjacent surfaces, which would then be a design requirement for new buildings that would be constructed. This might require that the surfaces of adjacent buildings be improved as part of the design and construction of a new building, or one could specify the degree, diffusion, and possible direction of reflection required for a building in a given location. The exact method of realization would not be specified, this being up to the designer and owner. Such a regulation could be universally applied without requiring specific materials, and hence not be an aesthetic judgment. Zoning is not to be based upon aesthetic considerations but legitimate functional concerns of the city. There is no reason why sun shading devices often used on buildings might not also help illuminate shaded areas of other buildings or the public space.

Spacing requirements for buildings usually involve rear yards, side yards, light wells, distances of windows away from walls, etc. We have changed these considerations and provided for such light by the use of reflection from existing surfaces. Given an adequate model, the city could examine a given building or set of buildings to see whether the expected reflected light off of the surfaces meets the amounts required by law. This would be far less restrictive on the design and arrangement of new structures and would address the controls to maintaining a given quality, whatever the forms involved.

Spacing controls would be used for fundamentally different purposes—as the height and size of a building gets larger, its shadow will be cast over a greater area. As the sun moves, the shadow moves. The longer the shadow, the faster the end farthest from the base of the building will move in absolute velocity. Closer to the base, the shadow moves more slowly (but still at the same angular rate). Depending upon the size and proportion of the structure, the shadow will take different amounts of time to pass over a given point. The amount of time will decrease the further away from the base one gets. At some locus of points there will be continual shadow cast by the structure.

Certain activities find some structures to be more or less economical than others. An ideal apartment floor plan in New York would be about

70-feet wide by 120 feet, a tower about 100 by 100 feet. When larger than this, service and other costs increase disproportionately.

Presently there is great pressure to construct high density luxury apartments in Manhattan. Existing zoning patterns allow large buildings to be constructed on the wider streets. Each block can be built on, creating a wall of tall buildings. This pattern is allowed by present zoning. The effect of such geometry of building upon the actual light available in the environment has not been studied. The philosophy is to build and see what it is like, then to change the regulations if the resulting environment is deemed unfit. The locations of buildings of this size ought to include a detailed study of the effect of shadow on the street and on each other. If necessary, such buildings might be allowed every other block. Alternatively, they might best be located in the mid-block area rather than on the street frontage area.

The buildings of the Wall Street area show the environmental effect of tall buildings constructed without limits. The present zoning regulation requires either setbacks or the construction of towers.

The net result is:

1. the form of the street is not related to the sun.
2. the setback principles and spacing requirements create a discontinuous street experience, with the buildings being discontinuous towers, or the plazas destroying the sidewalk, continually.

Implications of Environmental-Influenced Zoning

A street axis noted as being 30°E of N would mean that the sun would be on axis of the street at approximately 1:00 p.m. summer, at an altitude of 73°. In the spring the sun would be on axis at 2:00 p.m., at an altitude of 42°. And in the winter it would be on axis at 3:00 p.m., at an altitude of 12°. At these times there would be little or no shadow in the street, posing possible problems for traffic traveling into the sun or making the experience of walking on the street more pleasurable for pedestrians. The 30° axis of the street makes the difference between the sun shining on the street at 3:00 p.m. in the winter or at noon (which is the case for a 0° axis).

In a similar fashion, if a cross-street has an axis of 120° (300°), the sun would be on axis at 10:30 a.m. in the summer, at an altitude of 65°. In spring and fall this street would have no shadow at 9:00 a.m., with the sun at an altitude of 30°. In the winter, the sun would rise on axis with the cross-street. In the summer the sun would set on axis.

Given the width of the street, its axis and slope and height of the buildings along it, one can easily determine how long the street would receive direct sunlight. On a 30°(210°) axis street, the east and west side would receive direct light for different amounts of time. The western side would receive more hours of light than the eastern side. The situation is even more dramatic on the 120°-300° axis street. Sunlight on the northern side would vary from several hours a day to no sunlight, depending upon the season. The south-facing side receives sun in equal amounts throughout the year.

The question arises whether or not there are activities which would more ideally suit one or the other type of environment. For the latitude of 40°N and New York's climate it would be desirable to maximize the light and heat of the sun in the winter and minimize it in the summer during the hours when the heat and light intensity is greatest.[18] To do all this all the variables of Environment Influenced Zoning can be employed.

The placement of structures can be such that the shade in the summer hours will keep the street or specific activity area cool. The use of shading devices which shade direct light in the warmer hours of the summer but which allow direct light in the winter can be used to reflect indirect light into shaded areas. For other areas of the earth one might choose to reduce direct light but not reflected light, or to receive direct light at all times, depending upon the local climate.

Any structure will create shade. The question is, how much. Where and when the sun is low the shadows are long. The taller the buildings the longer the shadows. We have indicated shadow length as a function of the height of the building (i.e., a shadow length of 1 would be as long as the building is high. A shadow length of 0.5 would be one-half as long as the building is high, and so forth.)

In considering the light falling on the street, one obvious natural measure of shadow would be to have shadows cast so that the whole street would be shaded. The shortest shadow would be the perpendicular distance across the street. Call this 1. The secant function of the angle with reference to the perpendicular line will give the length of shadow to fill the street at any angle other than 90°. These can then be related to the shadows cast by a structure. Where the shadow length is greater, the building would have to be shorter than the street is wide or one would have to accept the shadow falling on a building across the street. Thus, when the length is shorter, the structure can be taller. For different street orientation of various widths and slopes, different height buildings will be required to fill a street of a given width. Alternately, one can require structures to be set back from the street, effectively making the street wider and allowing taller structures. With this kind of analysis, the amount of setback would be different for different sizes of structures, or different slope orientation and exposures.

A critical aspect in the control of effect of shadow, is the size, length and movement of the shadow. Since the sun moves through the sky at approximately 15 degrees per hour, the angular rate of movement of shadows around the base is the same 15 degrees per hour. However, the far end of the shadow will move much faster in relation to the ground; the width of the shadow is small in relation to the distance it must cover. At this distance the shadow covers a given width rapidly. Thus, the more distant the sun from an object casting a shadow, the faster the shadow will pass a given point. This is particularly important when considering the placement and spacing of tall buildings.

It is now possible to determine what effect a new structure will have upon the existing environment. Existing activities that would be shaded out by having the new structure in a particular location can be determined. The location of taller structures can now be related to their effect upon each other and upon the existing fabric. The patterns of placement for structures of different sizes would vary not only because of the effect of their shadows, but also because of the different effects that slope and exposure would have on these shadows. The provision for setbacks is still useful up to a point. It provides for wide sidewalks and effective width of street to allow more light in. Setbacks also change the scale and proportion of a street, but should be limited in use to where they improve the scale of a street and improve pedestrian circulation. They should not be the prime means for compensating for shadows cast by large structures, but for the creation of a better proportioned street.

An examination of the shadows cast by a large structure would have that large structure placed near the middle of the block or on a side of the block so that the shadow that did reach the street would sweep across other properties as fast as possible. Those areas that would be in shadow a great amount of time should be zoned to encourage the location of light insensitive uses, i.e., theaters, department stores, garages, etc.

Since the city is allowing space to be created with a certain minimum of light and air, it would be appropriate to attempt to encourage uses that would best utilize the light quality created: artist lofts with north light; relaxation or recreation where there is direct light. This reconsideration of what activities should be where can be further refined to relate to activities which would better use sunlight at one time of the day than another. Parks with afternoon sun, as opposed to morning sun, etc.

Another result of knowing the way in which light interacts with existing and new structures is a direct and positive control of indirect light. As buildings get larger or closer together, or are built on slopes with little sun, there are always areas that will be in shade most of the time. Any light they receive will be indirect light from the sky or reflected from another surface in the area. Where areas receiving direct sunlight are far removed from the street and the space is narrow, little reflected light reaches the street.

A north-facing wall of a building receives almost no sunlight at all. Buildings built on a street with an east-west axis will have one side of the street facing north. In such situations it would be legitimate for a city to require a certain percentage of reflected light to reach the street from surfaces that do receive direct light. The shaded surfaces should also reflect light so that light will bounce back and allow a greater percentage to reach street level.

Such a requirement does not specify aesthetics for there is no mandate for exact building material nor its precise arrangement in space. However, if the designer accedes to this mandate, he must choose a combination of material and arrangement which will yield the prescribed amount of reflected light. Such controls would be linked to a design review. Yet another mode of relating the physical forms of cities to the way the sun actually shines would be to allow buildings to penetrate the air space above the streets.

By allowing buildings to penetrate street airspace, several advantages would accrue:

- The effective shading of the structure would be decreased.
- With proper guides, both front and rear of structures could receive direct light.
- Buildings would protect sidewalks and part of the street from rain and foul weather.
- Streets would be sunny, allowing for better growth of trees and plants.
- Sound control would be enhanced.

Thus there are several independent controls operating in concert with Environment Influenced Zoning.

Those relating to gross shade:

- slope
- exposure
- slope/exposure

Those relating to the street pattern:

- setback
- use/location
- air rights penetration

Those relating to sizes of structures:

- inclination
- spacing
- reflectance
- height

All of these controls are integrated around:

1. the information about gross shape of the city (slope, exposure, slope/exposure)
2. the sun's movement
   environmental standards (decisions)

One and two above form the basis for evaluation of any given physical situation and the application of appropriate controls based upon stated standards.

If these controls prove effective, then existing cities can evolve into more satisfactory environments and new cities can be laid out from the very first plan with these considerations as part of their structures.

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