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The Role of Spatial Configurations in Urban Dynamics

An Analytical Model for Urban Design and Development

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ABSTRACT

The thesis explores the role of spatial configurations on the development of city form and the influence of these configurations on specific economic variables which govern the development of cities. It is argued that there are pervasive interconnections that seem to link the nature of society and economics with its spatial form and that economic theories must have some basis in a spatial theory. Based on this premise, this work investigates the logic of spaces and their network to derive an analytical spatial theory of intelligibility which is then built into a spatial-economic model of land values and densities.

In urban land dynamics, location plays a significant role in determining the land values and density of development. Two important models namely Space Syntax and Ricardian rent mode, have been developed based on this assumption. This thesis adapts these models to generate a comprehensive dynamic spatial-economic model of cities. This new model will have predictive applications in spatial design as well as in urban development. It is proposed that the location in urban areas is determined by spatial configurations as well as commuting distance which is often used as a variable in economics to determine location. Relative asymmetry is proposed as a measure of relative location of a street segment in the system with respect to every other segment and as a function of intelligibility in any given physically contiguous configuration. Segments that are accessible and intelligible have location advantage. The differences in location value are then used to develop an econometric relationship between land values, density and relative asymmetry in a city. This yields a quantitative measure of an individual's preference for location and density.

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[11] Acknowledgements**[13] Chapter 1: Introduction**

- [13] The inquiry
- [15] Mode of Study
- [15] Thesis Outline

[17] Chapter 2: Cities as Means-Ends System

- [18] Cities as Means-Ends System
- [19] Spatial Configurations
- [20] Culture
- [23] Economics
- [27] The Interaction
- [29] Complexity of Physical Form
- [32] Rationality and how we understand cities:

[35] Chapter 3: State of the Art

- [37] Ricardian Rent
- [40] Space Syntax

[55] Chapter 4: Spatial-Economic Model

- [55] Location - Densities and Land Prices
- [59] Spatial Design: Accessibility and Intelligibility
- [65] Procedure for Spatial Analysis
- [71] Application of the Model in Design
- [74] Rents and Land Prices
- [77] Density
- [80] Interaction: Externalities and Gravity
- [81] Land Rents

[89] Chapter 5: Towards a Spatial-Economic Theory**[93] Select Bibliography****[95] Source of Illustrations**

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1

INTRODUCTION

1.1 The Inquiry

The thesis explores the role of spatial configurations on the development of city form. Furthermore, it is aimed at discovering the relationship between these configurations and the economic variables that determine the development of cities. However reflective of everyday experience, the relationship between space and urban dynamics is either poorly understood or very little studied. While on the one hand, parameters such as density and commuting distances are limited in their capacity to explain the phenomena of city form, on the other, the lack of understanding of urban design as a dependent variable is a major obstacle in producing better designs. It is intended to develop an analytical model that will integrate the spatial and economic variables to explain the dynamics of cities holistically. The aim of this model is to detect the impact of changes in spatial structure of cities that occur due to changes in demand on land value and density.

The fundamental economic model of urban housing and land markets is that housing and land are more expensive at better locations and cheaper at less advantageous sites. Ricardian rent model, developed in 1817 explains why land uses and different

types of households tend to be separated spatially. Since sites go to those offering the highest rent, spatial separation occurs naturally in these markets. The model suggests that the residential rental values in a city decline linearly with distance from the employment center.

Ricardian Model has been the fundamental basis for many urban economic theories since its inception more than 150 years ago. It has proven to be an accurate predictor of metropolitan housing rents. However, like other economic models this one too is removed from spatial reality and is unable to capture variation at a micro level such as rental variations in locations that are equidistant from the center. The thesis argues that it is possible to identify these variations through modeling the spatial configurations and that modeling is effective in addressing the issue of rents and land prices more holistically.

Space Syntax is a configurational analysis model that has pioneered new, proven techniques for regenerating urban areas through urban design. These techniques focus specifically on making physical connections to integrate people and places. Conceived at the Bartlett School at the University College of London, by Bill Hillier and his colleagues in 1980s, space syntax is now used around the world as a tool to simulate the likely effects of urban design on physical movement.

This thesis hence explores both spatial configurations and economic variables as mutually dependent variables. The task is two fold: one, exploration of the logic of spaces and their network to develop a spatial theory , two developement of a spatial-

economic model that is based on the spatial theory.

1.2 The mode of study

The thesis bases its arguments on two theories namely space syntax and Ricardian rent model. It adapts them to generate a comprehensive theory that integrates spatial and economic realms of city design. No empirical analysis has been conducted due to the short term of the thesis. However, it is recognized that further development and empirical validation of the thesis is essential. The author hopes to carry on the task beyond this thesis to develop practical applications of the methodology. Process of empirical analysis of cities using this model is expected to substantiate and inform the spatial model itself. For now, conceptual examples of how each assumption and nuance of the model works is presented.

1.3 Thesis outline

The thesis consists of four chapters beyond this introduction. Chapter 2 describes city as a means-ends system. Means are described here as physical and ends as functional. The chapter sets out a theoretical framework for developing a dynamic relationship between architecture, urban design and the economic rationality.

Chapter 3 is a discussion of various attempts made in the past to model spatial configurations and economics. This chapter critically discusses two models, namely Space Syntax and Ricardian Rent model, and concludes with an identification of problems involved in these approaches and with a proposition to integrate the two models.

Chapter 4 proposes a new spatial economic model. It lays out a methodology for measurement of configurations and develops an econometric model. Relevant graphic and numerical examples are used wherever necessary. Chapter 5 concludes by discussing the limitations and the application of this model, and sets out a framework for future development.

2

CITY AS MEANS-ENDS SYSTEM

The first sentence in any discussion about the science of cities usually contains the word 'complexity'. One of the most obvious forms this takes is the sheer physical and spatial complexity of the city as an object. There is, however, in most urban research, a strange silence on this aspect. The reason is simple: no one knows how to control the physical complexity variable. There is no formal language in which differences between one form of complexity and another can be described with the required rigor and consistency, and without controlling the variable we cannot measure its effects. What we cannot measure we prefer not to discuss.

†Hiller, c2001, *The Common Language of Space: A Way of Looking at the Social, Economic and Environmental Functioning of Cities on a Common Basis*

Hillier, 2001†

The building of cities is one of the greatest achievements of mankind. Cities are the largest and most complex artifacts that mankind makes. Cities are a result of complex processes and determined by a multiplicity of decisions made by numerous individuals and stakeholders involved in the city design and development process. Cities are about people and their actions, the way they inhabit, absorb, consume and detest them. The role of architecture or urban design is that of understanding and

representing the contemporary human condition. The goal of these disciplines is the facilitation of its actions and to make human life meaningful. By human condition we mean not only social and cultural behavior, but also the economic conditions and technological advancements of the time.

2.1 City as means-ends system

The condition of any goal-seeking system is explained by Herbert Simon† as connected to the outside environment through two kinds of channels: the afferent, or sensory, channels through which it receives information about the environment and the efferent, or motor, channels through which it acts on the environment. Similarly cities can be interpreted as functional entities and city design is the motor or channel through which the functionality or rationality is manifested. In effect, means are physical and ends are functional. By physical we mean the spatial configurations and by functional, culture and economics (a detailed discussion follows). It is important for means to be informed by the nature of the ends in order to be able to produce the desired end.

One of the principle aims of urban research is to discover what comprises these means and ends and the causal linkages between these in an urban system. One of the salient features of our current society is the all pervasive belief in rationality. We are in an age where society is more fascinated by stock markets, cyberspace, information technology and virtual reality. The utopian ideas of the pre-war period or the notion that architecture or urban design are independent variables is no longer relevant without pragmatic rationale. Under such circumstances, there is a

†Simon, c1996, *The Sciences of the Artificial*

strong need for research that can explain multiple phenomena involved in city design.

2.1.1 The nature of urban design

Current theory and practice of spatial design is not appropriately integrated with the other disciplines involved in the city design process because of its qualitative nature. However, this is the most distinct feature of spatial design, and makes it more sensible to the cultural and social behavior of individuals as well as to climatic and environmental considerations. This qualitative process can be described as cognitive rationality. Cognitive rationality is the ability to think without bounds or limitations. Instrumental rationality on the other hand can be described as the conditions of work carried out by the sciences in that they involve substantial amount of internal validity. Cognitive rationality insists more on external validity. Johannes Albrecht† argues that the insistence in value-free conduct by the sciences furthers the trend in society to abandon qualitative for quantitative concerns. Meanwhile, scientific knowledge transformed into technology helps to produce means for which ends have to be found, surely this is the inversion of any real rational behavior. It is important for spatial design to maintain a value basis in society. This would enable us to add meaning to quantitative disciplines such as economics. Thus, the means and ends mutually contribute to each other's behavior which is real rational behavior.

†Albrecht, *Architecture: An Inquiry into the Human Condition*

2.2 Spatial Configurations

Human societies are spatial phenomena in that they occupy a geographical space. Spatial configurations carve out a portion of the geographical space for human inhabitation. This process

entails two different motives. First, configurations arrange people in space in relation to each other, with a greater or lesser degree of aggregation or separation, based on the social and economic conditions of the people. This results in variation in terms of intensity of use and hierarchy of land uses. This is called 'spatial allocation' and can be classified as the work carried out by economists and planners. Secondly, configurations arrange spaces themselves rationally based on the same dynamics that determine their organization. This is topological and can be described as the design of physical environments, or 'spatial design', that architects and urban designers practice. In both cases, society acquires a definite spatial order.

2.3 Culture

Spatial patterns contribute significantly to the identity of any society. It is through realization of space that we can realize that a society exists. Furthermore these spatial patterns are an outcome of the lifestyle, ways of building and inhabiting space and climate of a society. To explain why people behave in a particular way is not in the domain of architecture, but the understanding of that behavior and relations to spatial patterns is particularly relevant to architects and urban designers. It is critical to understand that different cultures produce different spatial patterns, i.e. spatial logic is not universal. The diversity in city forms can be found despite the fact that the elementary generators of space are almost the same everywhere. According to Bill Hillier†, spatial order is one of the most striking means by which we recognize the existence of the cultural differences between one social formation and another. That is, differences in the ways in which members of those societies live out and reproduce their social existence.

†Hillier, Hanson, c1984, *The Social Logic of Space*

The possibility of meeting someone randomly and being comfortable while moving through the physical environment is an essential feature of cities. Physical form and spatial patterns are critical to movement, the interface between the individual and the physical environment and between the individual and strangers. For decades, social scientists have tried to explain this phenomenon by explaining the cultural and social behavior of individuals in the city. In these explanations the role of the physical environment seems to be trivial. Herbert Gans† dismisses the physical environment as a factor in human situations: “the physical environment has much less effect than city planners imagine, the social environment has considerably more effect” . Stanford Anderson† points out that social scientists may discourage inquiries into more subtle concepts of the interaction of people with the physical environment, ruling out a search for the

†Anderson, c1978, *The Urban Ecology of Streets*



Figure 2.1: Plan of Perrotet in Southern France

interaction of physical with social, cultural, and cognitive factors as nonsense is dogmatic. However, during the 20th century, some architects have attempted to use design as a determinant of cultural behavior. Because these architects failed to understand the existing spatial patterns that reflected cultural behavior, these efforts have not only failed to transform cultural behavior, but have also created numerous social problems.

2.3.1 An Example

To demonstrate the complimentary relationship between culture and spatial logic, let us examine the simple example extracted from Social Logic of Space†. Plan of Perrotet in Southern France is presented in figure 2.1. It appears irregular in shape at first

† Hillier & Hanson, c1984, *The Social Logic of Space*

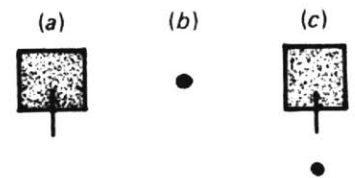
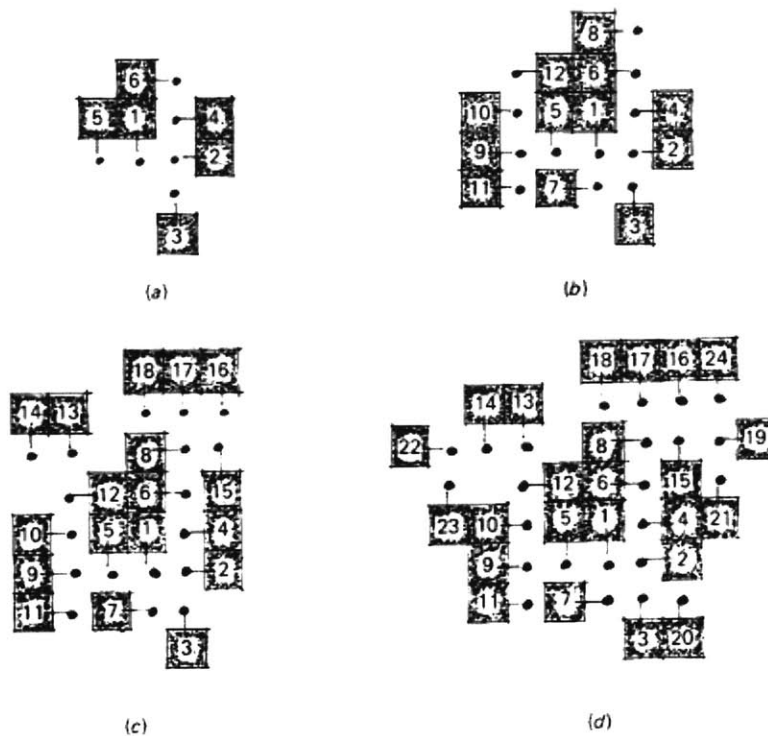


Figure 2.2

Figure 2.3: Four stages of a computer-generated beedy ring structure

glance and lacks any formal geometric properties we normally associate with spatial order. If we examine the plan closely, the underlying order is manifested.

For example:

- a. each individual building fronts directly on the open space structure of the hamlet without intervening boundaries (Figure 2.2 a-c)
- b. two individual buildings are joined full face wise on the entrance face to form a doublet (Figure 2.3 a)
- c. The open space structure is not in the form, for example, of a single central space with buildings grouped around it, but is rather like beads on a string: there are wider parts, and narrower parts, but all are and linked together direct;
- d. The open space is eventually joined to itself to form one major ring and other sub-rings, the main beady ring of space being the strongest global characteristic of the complex (Figure 2.3 b-d)

A similar pattern was found in all the surrounding settlements of Perrotet. An understanding of spatial logic can contribute to an understanding of the social logic of space.

2.4 Economics

Economics has the power to explain most phenomenon with a required precision. It deals with the optimal allocation of scarce resources. Because scarcity is a central fact of life (land, money, fuel, time, attention and many other things are scarce) it is a task of rationality to allocate scarce resources. Herbert Simon† describes the role of economics as illustrating well how outer and inner environments interact and, in particular, how an intelligent system's adjustment to its outer environment (its substantive

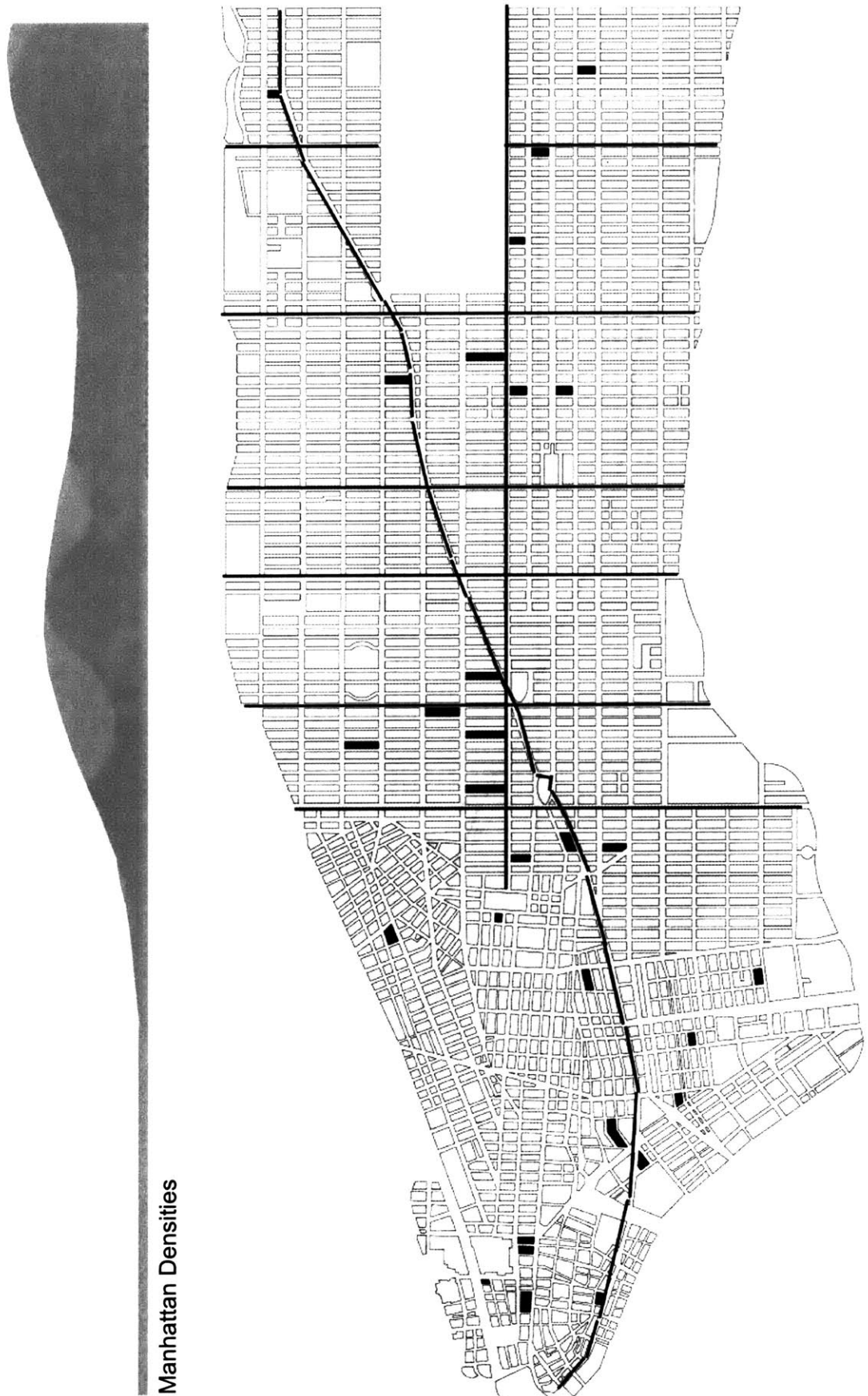
†Simon, c1996, *The Sciences of the Artificial*

rationality) is limited by its ability through knowledge and computation, to discover appropriate adaptive behavior (its procedural rationality). The outer environment is defined by the behavior of other individuals, firms, markets or economies. The inner environment is defined by an individual's firm's, market's or economy's goals and capabilities for rational, adaptive behavior.

It is argued in this thesis that economic rationality and economic theories are far removed from the actual spatial, configuration and cultural realities. Economic and planning theories concern themselves with intensities of use, residential density, land use and land value without reference to spatial and configuration patterns. Densities and land values are decided based on commuting distances and land uses are determined based on economic benefits. Life style choices are measured against quantitative variables mentioned above, even though there is a significant contribution made by the qualitative variables, such as spatial qualities. Let us examine a simple example to demonstrate the importance of spatial configurations. This is a simple thought experiment and shall not be construed as having any empirical evidence.

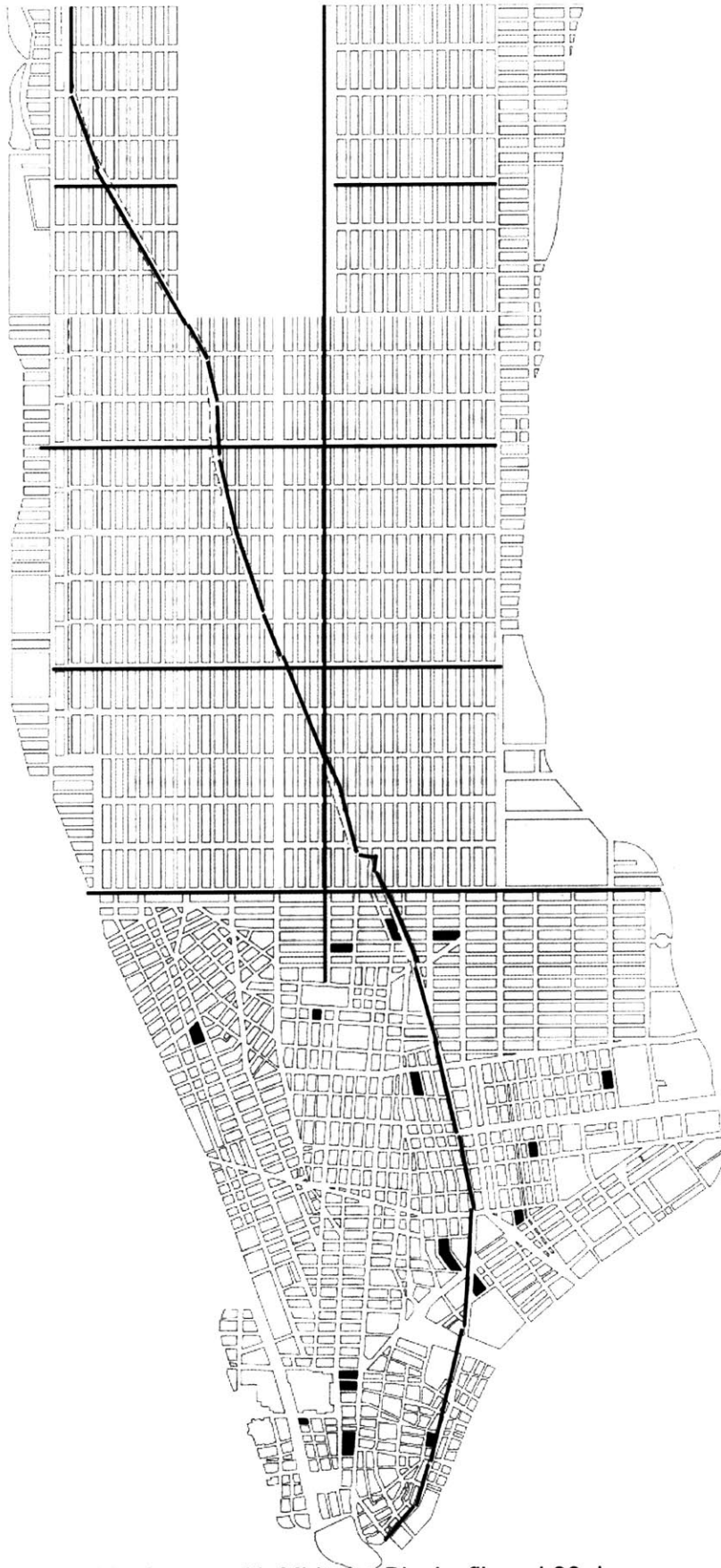
2.4.1 Manhattan Speculation

Why is Manhattan so dense? One would not hesitate to answer by saying that it is land constrained. Why is Manhattan equally dense all along its northsouth access except for few bumps over the island? This is an intriguing phenomenon. One could perhaps give the same answer as above. Another argument could be the shallowness of the island along its east-west axis and its north-south axiality. The current configuration of Manhattan blocks



Manhattan Densities

Figure 2.4: Manhattan Street Network



Manhattan Densities as per the speculation

Figure 2.5 Manhattan with Midtown Blocks flipped 90 degrees

(Figure 2.4) with its shorter face facing the avenues establishes a rhythm of east west streets. This is specific to Mid-town and one could see 14th, 27th, 34th, 42nd, 57th, 72nd and so on occurring after every few blocks. The interface with Broadway is interesting too. This frequent incidence of east west streets renders all locations advantageous that is reflected in uniform residential densities along north-south axis (in terms of street networks, besides Manhattan has extensive subway network). This is truly a function of the way the city is configured.

What if the grid of Manhattan is flipped 90 degrees in a way that avenues become streets and streets become avenues. The density of grid along the north-south axis is reduced because of the longer blocks. A flip would disrupt the rhythm of east west streets and their occurrence would be much farther from each other (Figure 2.5). The intuitive measure of the occurrence of these streets is not the distance but the number of blocks. This is because intersections create friction. An intense use requires a minimum amount of friction or number of blocks of catchment. We could hence speculate that the segregation of these east-west main streets creates hills and valleys in terms of density by rendering the locations along east-west streets highly advantageous and the locations in between less advantageous.

2.5 Interaction

The current interaction between spatial design and economic rationality is illustrated in figure 2.6. As was explained earlier, spatial allocation and spatial design are the two most important components of city design and development, and spatial allocation decisions are made without reference to spatial configurations or

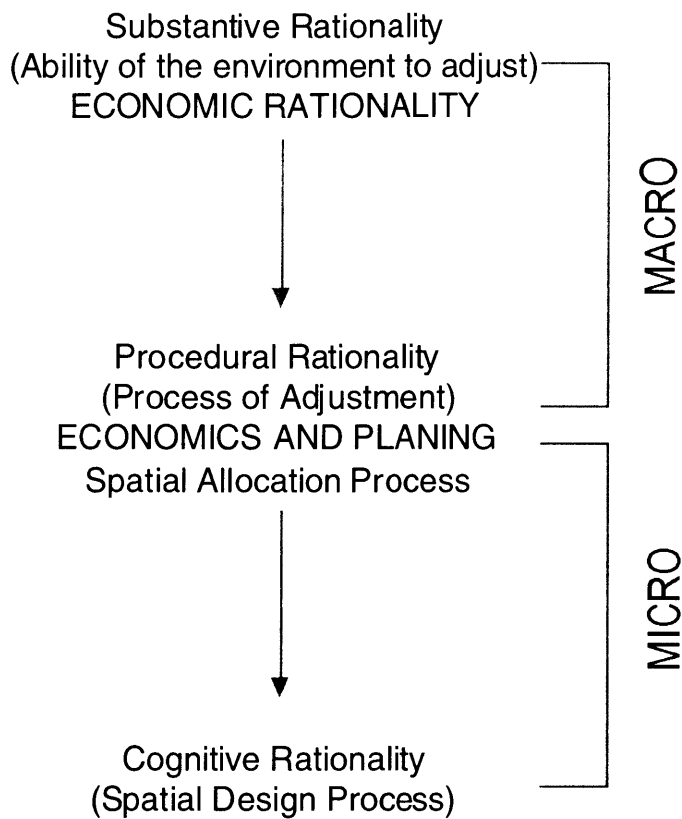
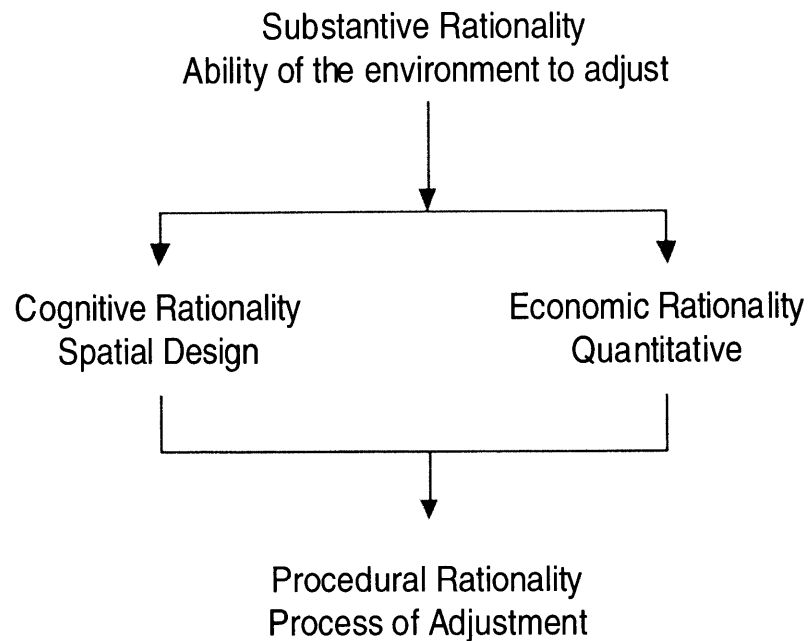


Figure 2.6: Current interaction between spatial allocation and spatial design

the design of cities. Spatial allocation decisions are made using quantitative variables while discarding the potential of spatial configurations to determine the allocation. The reasons are discussed in detail later on.

As argued earlier in the Manhattan example, there are pervasive interconnections that seem to link the nature of society and economics with its spatial form and economic theories must have some basis in a spatial theory. It is proposed in this thesis that the urban models should entail both spatial design as well as economic variables as represented in the figure 2.7. A detailed methodology to integrate spatial and economic realms is proposed in Chapter 4.



ECONOMIC and SPATIAL PROCESSES

Figure 2.7: Proposed interaction between spatial allocation and spatial design processes

2.6 Complexity of Physical Form

An important factor that led to the separation of spatial design from economic rationality is the absence of configurational models that can explain the complexity of spatial design. There is no formal language in which differences between one form of complexity and another can be described with the required rigour and consistency, and without controlling the variable we cannot measure its effects. Research that aims at integrating the two disciplines must establish a common ground for understanding and analysis. A spatial variable has to be developed that can be controlled to understand the role of spatial configurations in economics with required precision. The question that needs to be

addressed is what components of spatial configurations address the issues that economics is concerned with. A proposition has been made in this thesis that location in urban areas is a function of spatial configurations, that economics is highly connected with this reality, and that a dynamic relationship should be developed to integrate the two disciplines. This would enable us to understand cities more holistically.

2.6.1 Scale of Operations and Compartmentalization

Another gap between the spatial design and economics is their scale of operation. While planning and economics deal with the larger and more comprehensive scale of cities, urban designers deal with buildings or groups of buildings. Most efforts are made at a gross level, far from where actual interventions are made. The nuances of space do not feature in the economic or planning analysis. Neither approach is sufficient to explain the city as a spatial and functional whole. Urban models require an analysis of structural and dynamic complexities of the spatial realm.

Also there appears to be a fine line between spatial and non-spatial disciplines of cities today. There is a compartmentalization of people who are preoccupied with analysis and control of the social and economic process and those who are concerned with physical and spatial synthesis in the city. This is a split between thought and action. If we look at urban designers, we find their interest in matters such as creation of places as rich and complex as those founding the traditional cities, but little analytic endeavor to understand what gave rise to the creation of that place. This information would have a different impact on the process as well as the output of designing these places.

The lack of understanding of places as having global effects is another obstacle for design. Not understanding how a (re)configuration at a local level could affect the global system, both qualitatively as well as quantitatively is a handicap of current practice. There exists an imaginary and assumptive attitude towards these issues in Urban Design and every site an architect/urban designer designs ought to produce significant global changes. The issue of product-differentiation is totally misunderstood. Product-differentiation is the characteristic of land in urban economics. This distinguishes the nature of land type based on certain economic variables like location.

2.6.2 Current Theories

Let us step back for a minute and talk about the theoretical framework of the spatial patterns and city planning itself. Charles Daviler, a French seventeenth-century theorist, defines a town in his dictionary of architectural terms as 'an ordering of blocks and quarters disposed with symmetry and decorum, of streets and public squares opening in straight lines with a fine and healthy orientation and adequate slopes for the draining of water. Definitions like this are very common in the theory of city planning. A rather contradictory statement can be found in the article 'Idea of a Town' by Joseph Rykwert†, "always it is the conceptual model and its relation to the place and the plan shape which interests me, rather than the material remains, definite patterns, definite, assertive configurations of streets and squares, private and public buildings, which will not yield their meaning to the common means of urban analysis". We understand that there is a constant contradiction or varying thinking in the profession of city planning. This leads to a sharp questioning of the profession of city planning

†Rykwert, c1975, *The Idea of a Town*

or urban design which we see everyday. The attack is more fundamental and is on the adequacy of the assumptions on which planning doctrine is based.

Most theories of urban design are strongly normative in that they emphasize how buildings and environments should be, while neglecting how the buildings and environments actually are.

To date, theories have only been able to explain geometric properties in limited cases. For example proportioning systems like Le Corbusier's Le Modulor[†] explore the relationship of universal human proportions to the geometry of building. Where human proportions vary and cultural behavior does not have any relationship with human proportions, the applicability of this theory becomes limited.

[†]Corbusier c1954, *The Modular*

2.7 Rationality and how we understand cities

The way we design cities depends on the way we understand them. Natural Sciences are concerned with how things are, where as design is concerned with how things ought to be. The question we might pose is whether the forms of reasoning that are appropriate to natural science are suitable for design. This understanding is myopic in a sense.

Herbert Simon[†] points out that Darwinian evolution is completely myopic. At each incremental step the evolving organism becomes fitter relative to its current environment, but there is no reason for the progress to lead to a global maximum of fitness of individuals, separately or severally. If we are considering this kind of system, whose environment has a multitude of local maxima, we can not

[†]Simon, c1996, *The Sciences of the Artificial*

understand the system unless we know something of the method and history of its evolution. Nor is there any reasonable sense in which such a system can be regarded as 'fittest'.

Traditional cities are physical interpretations of their implicit social, cultural agendas and complexities. They are a labyrinth of spatial networks that create hierarchies for different land uses. These networks emerged through conscious decisions made by individuals. The development of city form depends on the direction and meaning accorded by the structure of the existing city. Furthermore, the configuration of the space in the existing city provides cues to the development of the newer parts of the city. The plan of a town forms a spatial framework for development because it provides the physical link between the built form, the site, and the town's past existence. It constitutes a morphological construct to which subsequent development must conform.

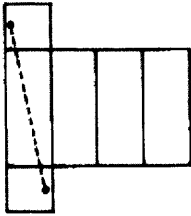
The fact that physical environment is increasingly controlled and designed in its own right presents numerous problems and issues for consideration, both in terms of theory and practice of urban design. Great emphasis is rested on designing physical environments that are vibrant and articulated. It is a legitimate assumption that how we design cities depends on how we understand them. The understanding of them and designing newer parts in the right way however is critical to producing cohesive and legible cities.

Our understanding should not be restricted to physical space but also to economics. This exchange would enable us design cities that are coherent as well as functional entities. In this way we

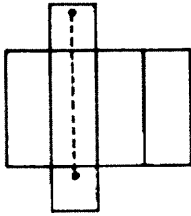
would be able to bring rationality to our design process and qualitative thinking to economics. This approach could be compared to the technology used in radio voice transmission. Radio signals are originally voice signals that are converted to radio signals for transmission. These signals get converted into voice signals once they arrive at the radio transistor. The philosophy of this thesis is the same. It is proposed that the qualitative components of spatial design be converted into quantitative information. This will be combined with the other quantitative theories. The outcome of this combination is used to inform spatial design.

3

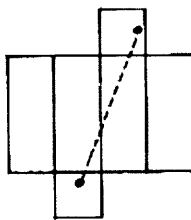
STATE OF ART



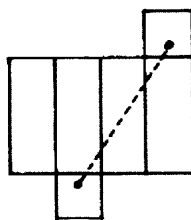
a 43.2 ft



b 42 ft



c 40.7 ft



d 40 ft

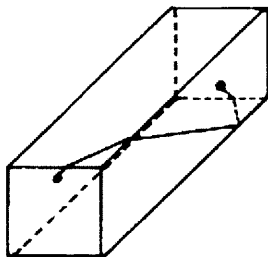


Figure 3.1

In a room 30 feet long, 12 feet wide and 12 feet high, there is a spider in the center of one of the smaller walls, 1 foot from ceiling; and there is a fly in the middle of opposite wall, 1 foot from the floor. The spider has designs on the fly. What is the shortest possible route along which the spider may crawl to reach his prey? If he crawls straight down the wall, then in straight line along the floor, and then straight up the other wall, or follows a similar route along the ceiling, the distance is 42 feet. Surely it is impossible to imagine a shorter route! However, by cutting a sheet of paper, which when properly folded, will make a model of the room and then by joining the points representing the spider and the fly by a straight line, a geodesic is obtained. The length of the geodesic is only 40 feet, in other words, 2 feet shorter than the 'obvious' route following straight lines.

There are several ways of cutting the sheet of paper, and accordingly, there are several possible routes, but that of 40 feet is the shortest; and remarkably enough, as may be seen from d, this route requires the spider to pass over five of six sides of the room.

Kasner and Newman, 1940†

Geometry provided the first means of interrogating the spatial world in a language whose own structure was consistent and fully explicit. Herman Weyl† writes, "nowhere do mathematics, natural sciences and philosophy permeate one another so intimately as in the problem of space". The analysis of understanding cities using geometry is derived largely from a British tradition. A variety of efforts have been made to explain the logic of space using geometry and other means. Lionel March† and Philip Steadman†, among others, have explored the relevance of mathematics in

architectural design. March and Steadman argued that geometry and architecture have been seen to have much in common. Further work and application to urban structures was carried out by Lionel March with Leslie Martin†. In 'Grid as Generator' Martin explores simple interrelationships between street pattern, plot size and building form and the patterns of living which elaborate that there is in fact a framework which itself offers choice and within which a plurality of choices can operate. Christopher Alexander on the other hand sought to understand architecture in a non-mathematical, but structured way. Disenchanted with computer-driven design, but more than ever interested in what made certain places work both spatially and psychologically, Alexander developed a theory of "fit" in terms of what he called "patterns". This theory suggested a means for creating successful places that blended application of logic with collective experience. Bill Hillier belongs to the same tradition and has been instrumental in applying this methodology to the development of analytical theory of architecture and urban design. Bill Hillier and his colleagues at the Bartlett at the University College of London, conceived a methodology called "Space Syntax" in early 1980s. The methodology relies on physical movement as a measure of the success of an urban space. It is a configurational model based on individual's movement in a city to find out the most integrated areas in a city based on intelligibility.

For the purpose of this thesis two important models namely Space Syntax and Ricardian rent model are examined. These are adapted in this thesis to generate a comprehensive dynamic spatial-economic model of cities. These models are presented below.

From Previous Page
†Weyl, c1950, *Space, Time, Matter*
†Kasner, c1940, *Mathematics and the Imagination*
†March & Steadman, c1974, *The Geometry of Environment*

†March & Martin, c1972, *Urban Space and Structures*

3.1 Ricardian Rent

Rent for housing and land is determined according to the compensation principal. This rent is referred to as Ricardian rent because Ricardo (1817) developed the approach. In the city, commuting or access to a place of employment is used as a measure of the locational advantage. Rent refers to either to the payments that a tenant would offer for housing, or, alternatively, to the annual amount that an owner would be willing to pay for the right of occupancy or use†.

†Dipasquale & Wheaton, c1996,
*Urban Economics and Real Estate
Markets*

3.1.1 Assumptions

- ◇ There exists a single employment center to which households commute.
- ◇ Households are identical and the number of workers per household is fixed.
- ◇ Housing has fixed and uniform characteristics at all locations.
- ◇ Housing occupied by households who offer the highest rent, and land is allocated to the use yielding the greatest rent.
- ◇ With a growth in population, boundary extends outwards.
- ◇ Rents decline linearly from the employment center of the city.

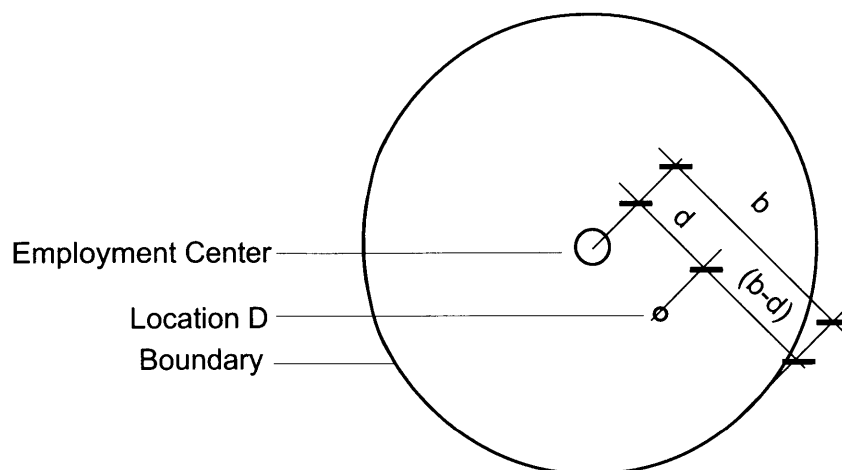


Figure 3.2: Ricardian Rent Model

3.1.2 Rent Model

According to Ricardian rent model, moving from the edge of the city, rents must rise as commuting costs decrease in order for all locations to be in spatial equilibrium. Hence housing rents will be equal replacement costs plus the difference between commuting costs at the urban edge and those at the location in question.

Figures 3.2 and 3.3 illustrate the Ricardian Rent Model.

$$R(d) = r^a q + c + k(b-d)$$

$R(d)$ = rent per unit per year

r^a = agriculture rent

q = land per unit

k = commuting costs

b = boundary of the city/town

d = distance from the boundary towards the center

v = land available for development

$(b-d)$ = savings in commuting by living in any location d

$$b = (nq/Pv)^{1/2}$$

$$r(d) = r^a + k(b-d)/q$$

$1/q$ = density

3.1.3 Modifications to the Model

The model has proved to be a reliable indicator of housing rents at the metropolitan level. The model is conceptual in a sense and the issue of location is open for interpretation. The commuting costs should represent how arduous the commute is rather than just representing the radial distance and cost per mile. The following modifications are a different interpretation of the locational advantage presented in the Ricardian Rent Model.

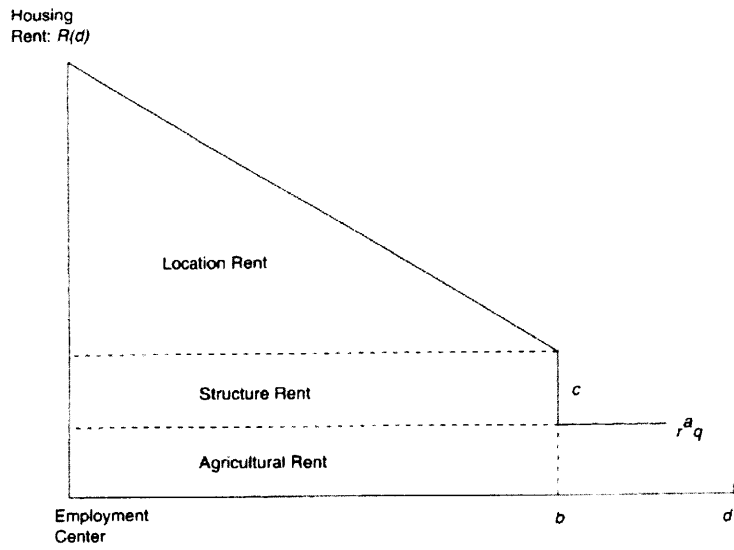


Figure 3.3: Components of Housing Rents

For example, rents may not vary at a city or town level exactly with the distance, but also with integration or separation of a street or an area with respect to the whole system. If an area is easily accessible to all the other points, then it becomes a more desirable area than an area that is less accessible, even though these areas are equidistant from the center. The example presented in

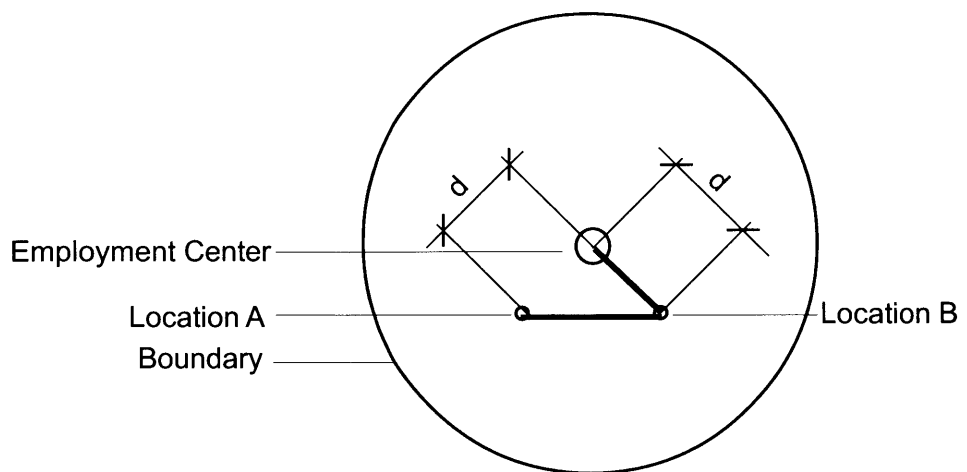


Figure 3.4: Arduousness of commute

figure 3.4 explains the rationale for a spatial theory to complement the economic theory. Two locations A and B are linearly equidistant from the Center. According to the Ricardian model, both should have the same rents as they are located at same distance from the center. However, in the above example, to get to the center from A one has to pass through B and many other intervening places. This makes A farther to the center than B and hence have lesser rents. The following analogy can be used to explain this phenomenon. In American cities transit stops are located on the best-integrated streets in the system. As one moves away from the transit stops, rents decline. One can imagine B having a transit stop and A as a place from where one walks to the transit stop to get to the other areas of the city. This is a function of the configuration and it is only possible to understand these effects by modeling them.

3.2 Space Syntax

Society can only have lawful a relationship to space if it already possesses its own intrinsic spatial dimension. Like-wise space can only be lawfully related to society if it can carry these social dimensions in its very form†. This is the premise of a theory of space as an aspect of social life that was set out by Bill Hillier and Julienne Hanson† in 1984. The intention is to understand spatio-temporal and spatio-social contexts, rather than simply reducing the spatial patterns of the city to an object that can be submitted uniquely to economic, functional and cultural analysis.

Since then, the Space Syntax has pioneered new, proven techniques for regenerating urban areas through urban design. These

†Hillier & Hanson, c1984, *The Social Logic of Space*

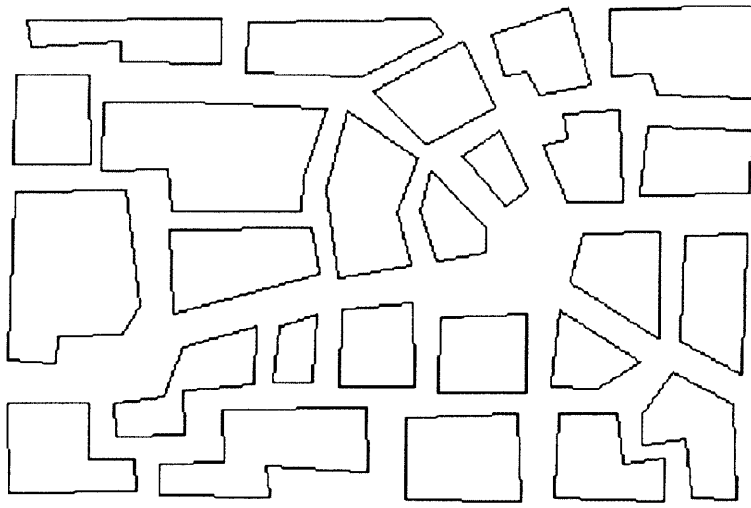
techniques focus specifically on making physical connections to integrate people and places. Conceived at the Bartlett School at the University College of London by Bill Hillier and his colleagues in 1980s, space syntax is now used around the world as a tool to simulate the likely effects of urban design on physical movement.

3.2.1 Movement and Interface: Intelligibility

The notion that spatial layout itself generates a field of probabilistic encounter is central to Space Syntax theory. Bill Hillier observes that an urban system is made up of two elements: a fixed system of spaces in a particular configuration and a set of mobile 'individuals' superimposed on that configuration†. He argues that this produces an urban system which has both static and dynamic properties. Consider the two layouts are presented in Figures 3.5 and 3.6†. In the second layout the blocks in the first layout are slightly displaced. Both layouts are a form of 'deformed grid' in that they both are composed of linear and axial axes (one-dimensional spaces) that do not continue through the system but are obstructed by buildings or blocks. Both layouts are composed of different sizes of two-dimensional spaces (squares), however, the quality of both one and two-dimensional spaces in both layouts differ. The first layout seems to be much more intelligible than the second layout because the visibility field caused by the composition of one and two dimensional spaces. In other words, the sequence of the varying visibility fields in the first layout creates a much more continuous system than that of the second layout. Thus, movement through space is enabled or enhanced by intelligibility of the environment, which will result in more potential interactions (i.e. the more the system is intelligible, the more potential for interactions and vice versa). Intelligibility is a

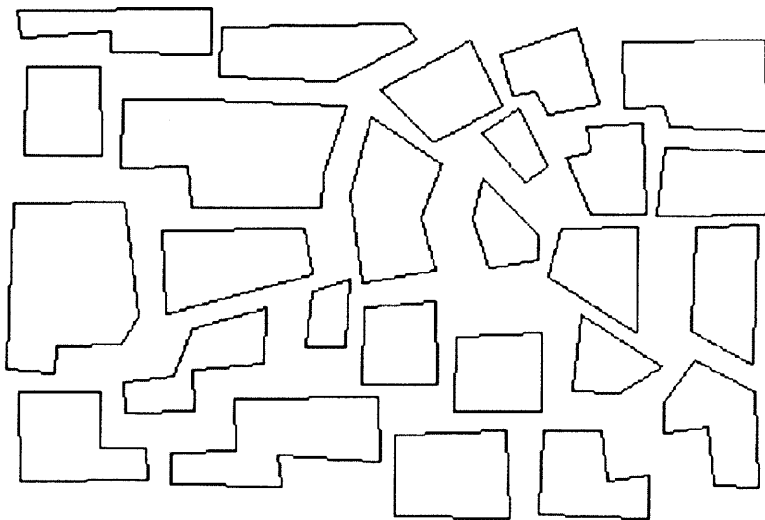
†Hillier & Hanson, c1984, *The Social Logic of Space*

†Hillier, c1996, *Space is the Machine*



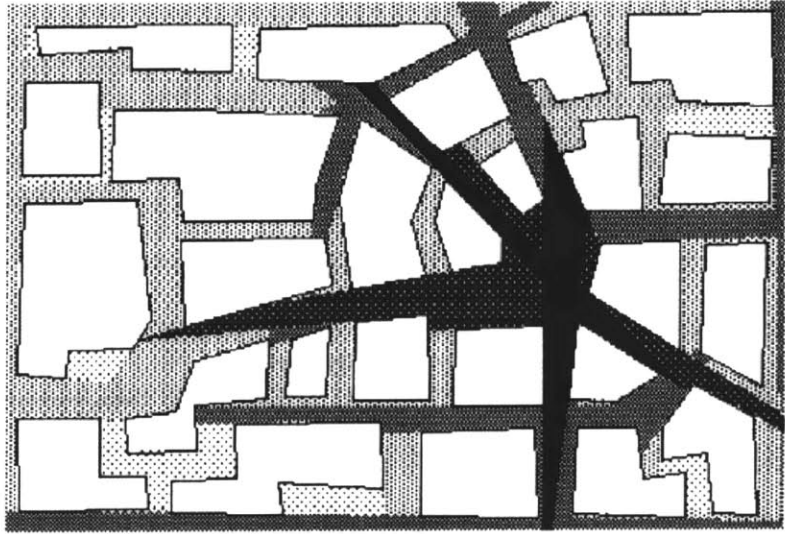
a

Figure 3.5



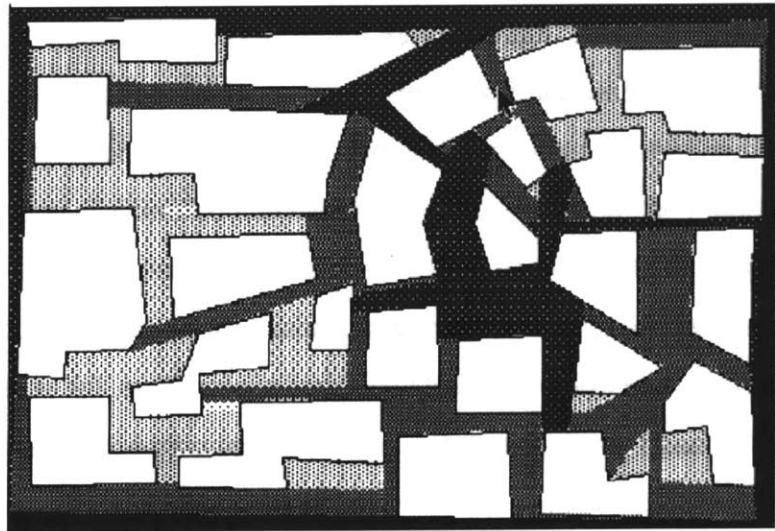
b

Figure 3.6



c

Figure 3.8



d

Figure 3.9

function of connectivity and integration. This is because it indexes the degree to which the number of immediate connections a line has which can therefore be seen from that line. This is a reliable guide to the importance of that line in the system model (Figure 3.7)



Figure 3.7

3.2.2 Connectivity and Integration

Of the first order of measures, 'the local state' measure is connectivity: how many other lines are only one step away from a particular line (ie immediately connected to it) This measures convexity or the two dimensional space. The "global" measure is 'integration': how many other lines are up to n steps away from each line. This is the measure of the axiality or the one dimensional space. Second order measures reflect the relationships between first order measures, and take the form of Pearson product moment correlation coefficients r . The most important of these is the correlation between connectivity and integration. This is 'intelligibility', as a whole. If locally well-connected lines are also integrating lines, then the correlation will be strong, and the system will have intelligibility. Thus, the whole can be read from the parts. Conversely, if well-connected lines are not also integrating lines, then the correlation will be poor, and the whole will not be readable from parts.

3.2.3 Integration analysis

Figures 3.7 and 3.8 clarify the usage of Space Syntax technology. The figures present integration to segregation shown from dark to light. In the first layout, the integration core is located in the center that happens to be the market place of the settlement. In contrast, the second layout does not depict a strong focal point, but rather a blurred system. One could also find some of the highly integrated cores in the periphery of the second layout. In other words, the marginal rearrangement of blocks leads to a difference in the intelligibility of the system and produces quite different distributions and degrees of integration

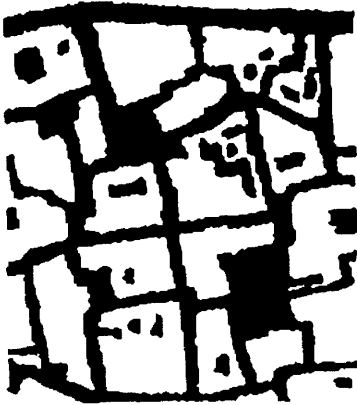


Figure 3.10
The Open Space of an
Irregular Grid

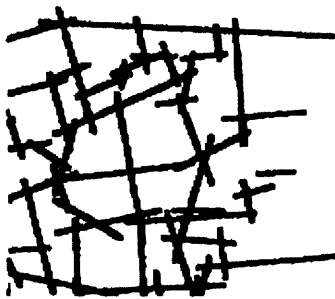


Figure 3.11
The Axial Map of the Irregular
Grid

3.2.4 Methodology

Configurational models of space syntax quantify the pattern properties of street networks in cities by breaking up the pattern of continuous open space through which individuals or automobiles move into the fewest and longest lines of sight and access that pass through all circulation routes. This is called an axial map (Figure 3.10). Next each line in the map is represented as a node in a graph with each intersection between lines represented as a node in a graph with each intersection between lines represented as a link in the graph (Figure 3.11). Once a graph has been constructed, it is a simple matter to measure the properties of the graph and then to use statistical methods to see whether there are any detectable correlations between the pattern properties of the network and observed behavior†.

3.2.5 Global Integration

One of the most useful measures is the mean depth of a node within the graph. This assigns a significance value to a street or

†Penn, Hillier, Banister & Xu, c1997, *Configurational Modelling of Urban Movement Networks*

node and is called global integration. This is taking every move along a link to add a step depth and normalizing the figure according to how deep it could possibly be with that number of nodes in the graph, producing a measure of relative asymmetry of the node in the graph according to the formula;

$$RA = \frac{2 * (MD - 1)}{k - 2}$$

MD = Mean depth of the system from the space obtained by assigning a depth value to each line according to how many spaces it is away from the original line, summing these values and dividing by the number of lines in the system less one (the original space).

The number of spaces a line is away from the other line is measured by the number of turns to reach to that line.

K = number of lines in the system

In other words, the above formula is measuring how accessible a street or a node is from all the other streets or nodes in the system.

3.2.6 Analysis of Washington DC

A global integration analysis of Washington DC is presented in Plate 1. This analysis shows Constitution and Independence avenues and 13th and 7th streets as the most integrated streets in the system, followed by 9th Street and Connecticut Avenue. Two observations can be made about this analysis. First, the analysis tends to capture the longest streets in the system as the most

integrated streets. This is true because the streets that traverse the system are usually close to every other street in the system. To the trained eye, the results of the analysis are very obvious. Infact, this is a major criticism today against Space Syntax methodology. Secondly, and most importantly, the analysis fails to capture variations along a particular street. Space Syntax model considers a street as one indivisible segment. In reality however, streets vary in their characteristics along their length. This is important since rental and land values at different locations along the same streets vary significantly. Although space syntax may be accurate in its predictions of individual's movement in the city, it is not adequate to explain the economic variability of locations.

3.2.7 Modifications to the Model: Segment Syntax

Based on the above observations it is proposed that an analysis of the smallest possible segments should be carried out in order to get finer results of a system. This is called Segment Syntax.

3.2.8 Measurement of Steps

Measurement of steps is another shortcoming of Space Syntax model with respect to the location values. Space Syntax assumes two streets or nodes to be separated by a number of steps that are equal to the number of turns between them. However, the value of a place with respect to other spaces or streets depends on the number of intervening spaces or streets. So it is necessary to modify the measure of steps in order to obtain a correct measure of land values. Segment Syntax proposes to use the simple notion of city blocks and to measure how many blocks or intersections on average a segments is away from the system on the whole. A simple configuration is presented in figure3.12, and

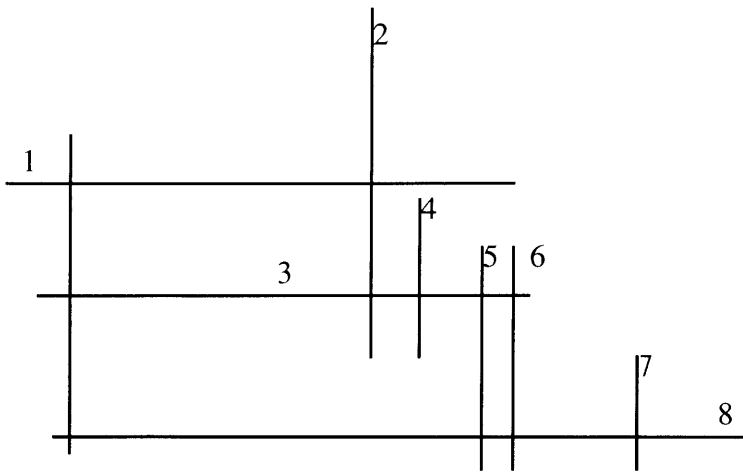


Figure 3.1: Axial map of a Town

the measurement of steps using Space Syntax is presented in figure 3.13. There are two possible distances between street 7 and Street 1, 4 steps and 5 steps away. Intuitively the option of 4 steps away can be thought of being less interesting than that of the option that is 5 steps away because of the number of intervening blocks in between.

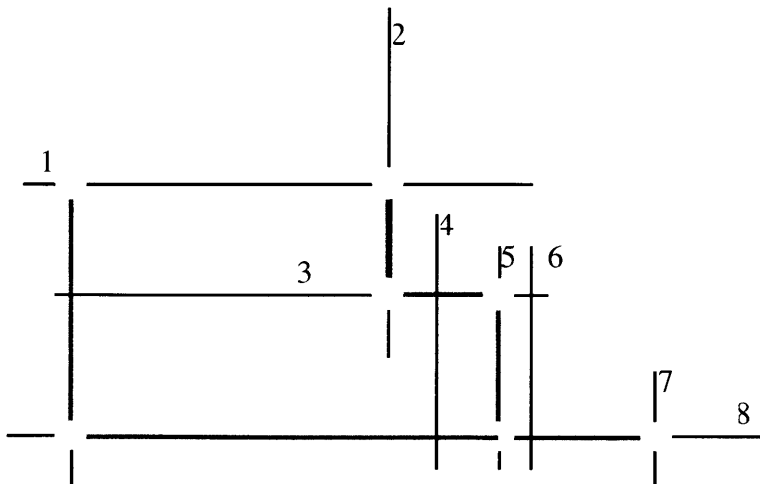


Figure 3.13: Mean Depth Analysis According to Space Syntax

In figure 3.14, the measurement of steps using Segment Syntax is presented. In this analysis all the nodes in between the two nodes are counted as steps. Now the number of steps between 7 and 1 is 7.

The important feature of Space Syntax is that the number of steps between any two nodes always remains constant. This is a similar measure to distance. But introduction of more cross streets in between the two segments or nodes, makes one node less desirable with respect to the other nodes and the new segments or nodes in between more desirable.

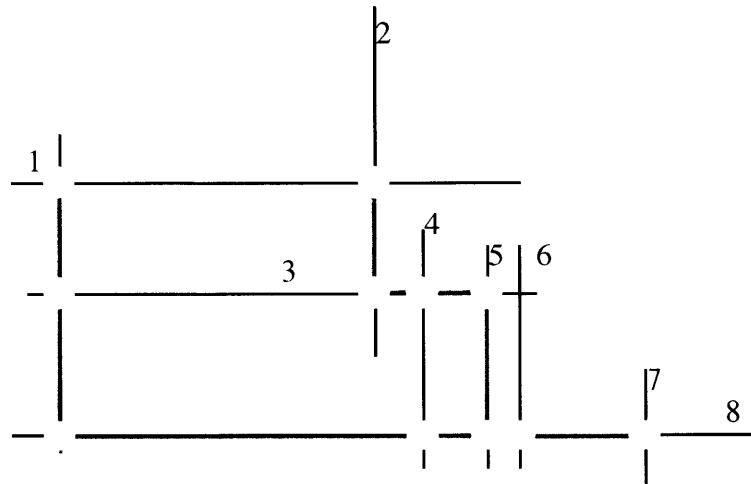


Figure 3.14: Mean Depth according to Segment Syntax

Segment Syntax proposes that all the other streets intersecting the path should be considered as steps. This is a reliable measure of distance, since increase in number of intersections mostly accounts for an increase in the distance in general. This notion is substantiated in later Chapters.

Consider two more layouts presented in figures 3.15 and 3.16. Figure 3.15, is the measurement of the shortest path between street 1 and 9. The two streets are 2 steps away according to Space Syntax. That is, all the nodes on street 1 are only two steps away from 9.

In Figure 3.16 Street 1 is divided into four segments based on block sizes. Each intersection is measured as one step. The number of steps from 9 to different nodes is different. This measure reflects the actual friction between two nodes. This frames another basis for the Spatial-Economic Model presented in Chapter 4.

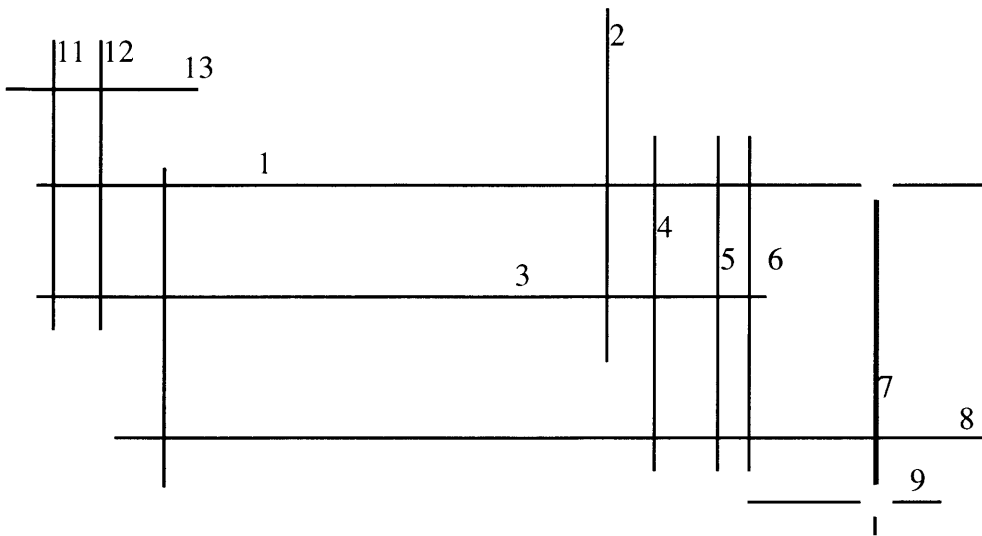


Figure 3.15: Mean Depth analysis between nodes 9 and 1 according to Space Syntax

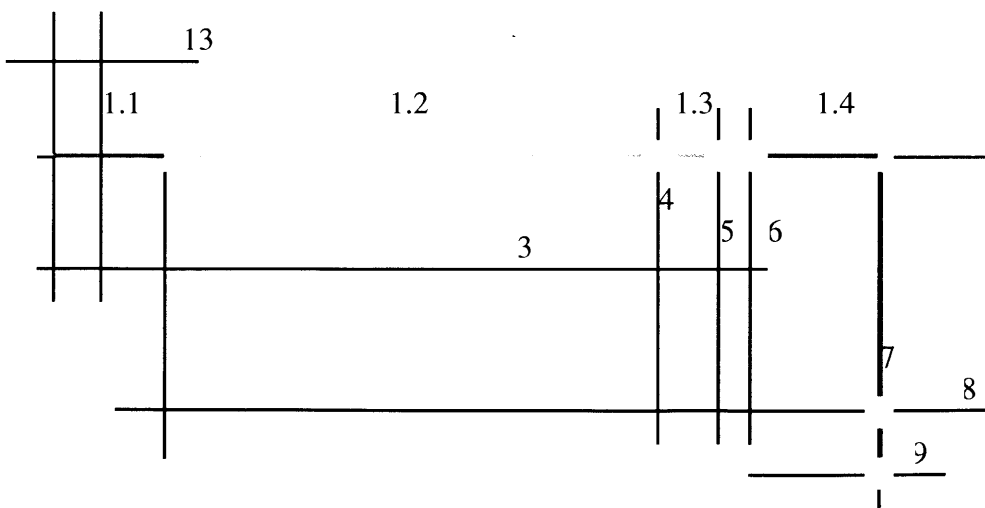


Figure 3.16: Proposed Mean Depth analysis between nodes 9 and 1

3.3 Synthesis

As stated in the earlier chapters, there appears to be a fine line between the spatial and economic realms today. On the one hand, space syntax lays out a methodology for analytical spatial analysis, but its applicability in economics is limited. On the other hand, Ricardian rent model has extensive applicability in economics, and is open for interpretation of the location variable. It explains the metropolitan rents to a great precision. However, when it comes to a physically contiguous city, it requires reinterpretation. This thesis seeks to combine the two models by modifying them to produce a comprehensive spatial economic model. This is presented in the following chapters.



Plate 1

Global integration analysis of Washington DC. Streets that are integrated to segregated are presented in red, orange, yellow, green and blue

4

SPATIAL ECONOMIC MODEL

The notion that the spatial layout in itself generates a field of probabilistic encounter presents a very powerful argument. The possibility of meeting someone randomly and being comfortable while moving through the physical environment is an essential feature of cities. Spatial configurations are critical to movement and the interface between the individuals and the physical environment and between individuals and strangers. This is the singular idea behind multiple hierarchies created by the spatial patterns, and results in vibrant streets that support land uses like commercial and high density housing to quieter, segregated and controlled residential neighborhoods. These hierarchies render urban land product-differentiated.

4.1 Location – Densities and Land Prices

Locations in the city are advantageous or disadvantageous for various land uses. As we observed in the Ricardian rent Model, location in urban areas is a predominant contributor to land values and densities. This can be seen in several cities where densities and land values are higher in central locations compensating each other and they decline as one moves away from these areas. This is called 'factor substitution'. By central areas we mean areas that



Figure 4.1: Land rent variations in the city

are business or commercial districts, transportation terminals, and so on. High densities can be found not only at the center of cities, but also at different places in the city and rent gradients in cities usually follow the pattern of hills and valleys as presented in figure 4.1.

Colin Clark† provided the first systematic empirical analysis of these density gradients and suggested the use of the negative exponential function to describe the decline of population densities with distance from the urban center. This notion is similar to gravity models which describe, and hence help predict, spatial flows of commuters, air-travelers, migrants, commodities and even messages. They are one of the oldest and most widely used of all the social science models. The appeal of these models can be attributed both in the simplicity of their mathematical form and the intuitive nature of their underlying assumptions. Garin-Lowry proposed a gravity-based model that generates urban population

†Clark, c1951, *Urban Population Densities*

and service employment distributions for a given pattern of basic employment. These laws are based on the Newton's laws of mechanics that states that the force of attraction between two heavenly bodies is proportional to the product of their masses and reciprocal to the square of their distance. George Kingsley Zipf† suggested the use of just distance instead of second power of distance.

†Zipf, c1949, *Human Behavior and the Principle of Least Effort*

There is a substantial evidence that land values are different at different locations, because urban land is product differentiated. Brennan, Cannaday and Colwell† found that the office rents in Chicago CBD (Central Business District) were highest at the intersection of LaSalle and Madison Streets (Figure 4.2) . The

†Brennan, Cannaday & Colwell, c1984, *Office Rents in Chicago*

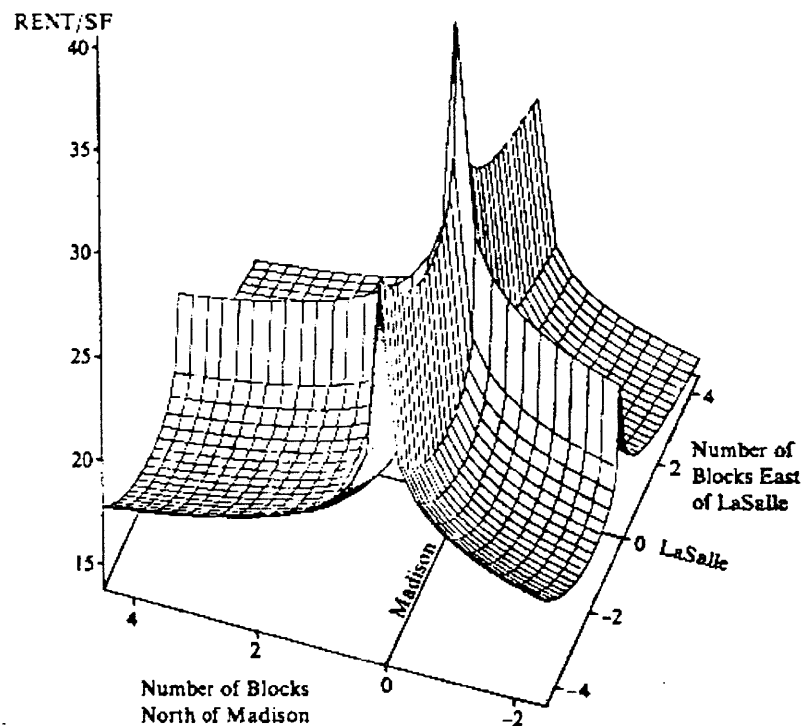


Figure 4.2: Rent surface in Chicago CBD

rents declined from the intersection with distance along north south and east west. It was found to be because of the location advantage of the intersection of LaSalle and Madison, where four out of six transit lines of Chicago have stops. This was found to be a significant advantage in terms of location of this intersection.

An important location determinant in economics is the distance from the Central Business District and rents vary by the amount of commuting costs incurred. The requirement for configuration analysis as a variable in place of commuting distances is presented in Chapter 3. The notion of commuting costs and distance has been elusive and is open for interpretation. It should essentially represent how arduous the commute is, but not just a product of linear distance and commuting costs. In this chapter it is argued that a modeling of the configurations should enable us determine what locations are most accessible in the system with respect to every other location in a physically contiguous city. This should in turn enable us to determine the land values and densities at different locations of the city and predict the variations in the above two variables with a variation in spatial configurations of the city. This can be used as a tool not only to rationally distribute densities, land values and uses, but also to produce cities that are cohesive and intelligible.

This thesis explores economic variables as dependent variables of spatial configurations to develop a dynamic relationship between land values, densities and spatial configurations. The task is two fold in that it explores the logic of spaces and their network to develop a spatial theory, and it develops a spatial-economic model that is based on the spatial theory.

4.2 Spatial Design: Accessibility and Intelligibility

The structure of urban grid is strongly determined by the natural movement densities of individuals in the city. Cities have grown over time by this notion while creating hierarchies of natural movement. These movement patterns created land uses in a way that is demanded for various functions. Commercial land uses can be found where the natural movement densities are higher, quieter neighborhoods can be found where these densities are lower.

4.2.1 Accessibility

Accessibility is an important component of location advantage of various blocks in the city. In this model an alternative approach to the origin and destination (O-D)† models is suggested.

Conventional traffic models use relatively simple representations of road network coupled to quite complex cost functions which are calibrated with data on origins and destinations of trips and observed flows on the networks. There are number of areas in which these models appear to have limitations. These models are seldom constructed to represent the finest scale structure of the street network and their performance at this scale is not well understood. Models are generally developed based on the travel to work trip, for which the best O- D information is available.

However, there is often little information available on their trip types and for other modes. In particular, O- D information is lacking for the pedestrian mode and this is where it seems likely that the fine-scale network will be of most relevance†. The new method is based on the use of a detailed representation of the configuration of space through which people move. It is proposed that the location advantage of any site or a block is determined by

†Penn, Hillier, Banister & Xu, c1997, *Configurational Modelling of Urban Movement Networks*

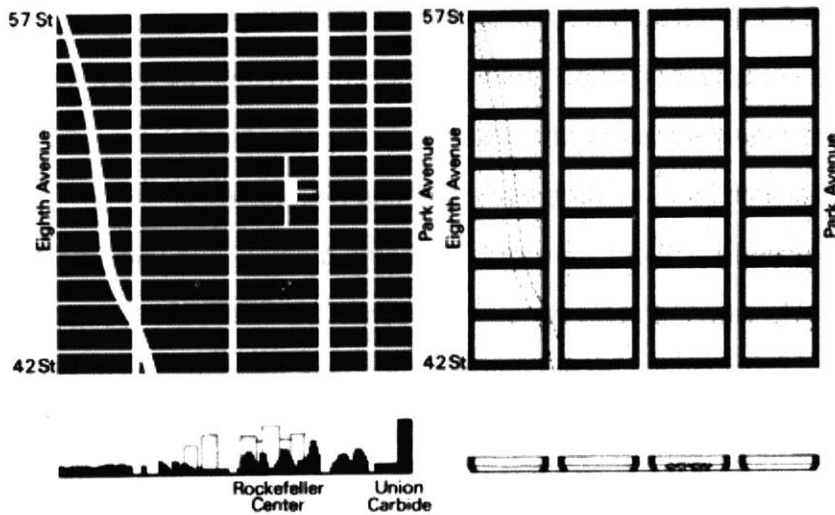


Fig. 1.8

Figure 4.3: New York as it is and as it is proposed by Martin

the ease of access to all the other blocks in the system.

Traditional models have always used distance as a measure of accessibility. The proposition now is topological and is a measure of friction.

4.2.2 Why Blocks (segments)

In urban spatial design and configuration, the primary generator is the city block. Not only the size of the block, but also orientation (results in intelligibility) and accessibility are basic concerns of design. The role of urban blocks in determining physical structure as well as spatial structure can not be overemphasized. While the organizing principles of urban blocks determine the configuration of spatial networks, and influence the physical form of cities, they also determine the streets and their characteristics. Leslie Martin's† explorations of Manhattan grid show how reorganization of block sizes transform the grid structure of the island as well as physical form (Figure 4.3). However, locations and land pressure are not considered as a part of this speculation. We also

†Martin, c1972, *Grid as Generator*

discussed in the Manhattan example in the earlier chapter how the reorganization of blocks could effect the functionality of the city. This model treats the constitution of space within the block as an exogenous variable for the time being.

4.2.3 Segment

According to this model, a segment is defined as a linear segment of a street between any two intersections. This is the segment of the street that is equal to the length of a block. In this model, it is proposed that the measure of accessibility of a segment in a system is dependent on how many number of blocks away on an average that segment is from every other segment in the system. A segment that is the least number of blocks away from the system is not only highly accessible from every part of the system, but also can be accessed easily by every part of the system. That means these segments are highly integrated in the system. A segment that is the highest number of blocks away from the system are segregated.

4.2.4 Intelligibility

Intelligibility contributes significantly to natural movement in the cities. Natural movement in turn determines land uses and values. Intelligibility can be defined as the quality of a system being clear and easily understood. It is an outcome of visual and physical connections between any two points in a system. Perception is considered exogenous to the model. With reference to spatial patterns, a street or a segment of a street is highly intelligible if it can be viewed from all the other points in the system. The axially and orientation of a segment with respect to the system determines its intelligibility.

It is proposed that a combination of accessibility and intelligibility determine the relative location of segments in the spatial structure. A quantitative methodology to measure this combination is presented in the following section. We call this Mean Depth analysis and the relative measure as Relative Asymmetry.

My graduate thesis at the University of Illinois in 1998 proposed a crude model that described the relationship between spatial patterns and human behavior (Figure 4.4). This model, which I called the 'vibrancy triangle', measured the success of urban design based on the physical movement of individuals in space and the ability of the built environment to facilitate this movement. An intuitive analysis of this question established intelligibility and physical movement as the basis of this model. Intelligibility is the quality of being clear and easily navigable in space. The model proposes the following dimensions of spatial interaction: the first vertex is produced by the physical forms designed by architects and urban designers which facilitates a certain basic type of physical movement in space. This movement coupled with the second vertex, the opportunity for visual connections to other spaces and events, should generate a third vertex of psychological freedom in the mind of the individual. This third vertex generates a new set of physical movement patterns which adds new dimensions to the first vertex.

An individual walking from the subway stop to his office on one side of a street in Manhattan serves as a very simple example of this phenomenon. While walking, the individual notices street play across the street, which creates a new opportunity and perhaps frees the mind of the individual to think something that he would

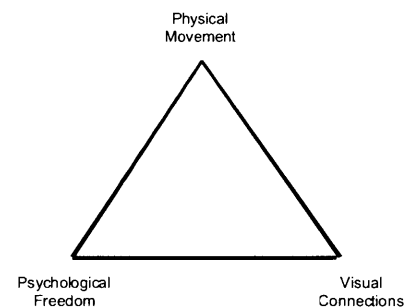


Figure 4.4
Vibrancy Triangle

not otherwise. Provided that there is a physical connection that exists between the two sides of the street, the individual can create a new movement pattern and watch the play. This new movement pattern allows the individual to further notice that there is a coffee shop, which offers another possibility for movement, and so on and so forth.

This example demonstrates two points: first, the subject of this case has his own intrinsic psychological system that determines his movement patterns in the city. This psychology could be an outcome of his specific culture or the culture of the city. Second, the physical form can facilitate or inhibit the individual's movement patterns in cities. It is argued that the more intelligible a space is with respect to the whole system, the more attractive it is.

It is hence proposed in this thesis that the measurement of steps should vary based on the angle of incidence of the subsequent segment. This is presented in the Figure 4.5. At a configuration level, segments that are linear are more intelligible to each other than segments that are perpendicular. The spatial intelligibility reduces as the angle between the segments changes. That is, if the subsequent segment is linear to the segment, then it is considered to be only 0.1 steps away. And if it is a perpendicular turn, it is 1 step away. For all the intermediate angles, the following step values should be assigned. This applies to both NE and NW quadrants. It can be understood that segments that are linear are more intelligible than segments that are perpendicular. Another interesting proposition is made in terms of the angle of incidence and steps in SE and SW quadrants. Segments in these quadrants are argued to be less intelligible than the segments in

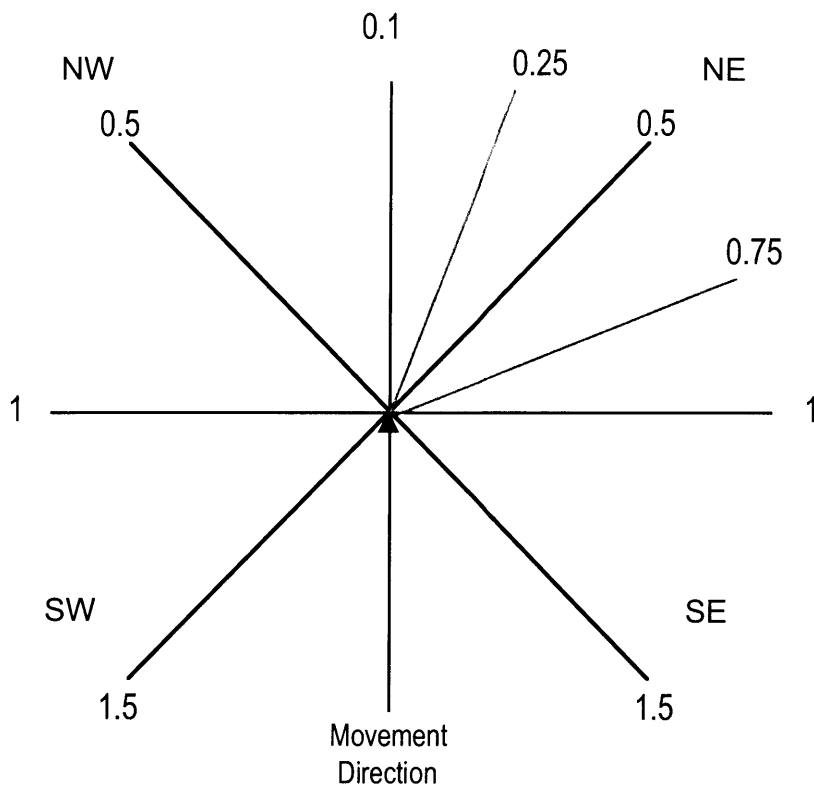


Figure 4.5: Coefficients for different angles of turns.

Angle	Coeff.
0	0.1
10	0.2
20	0.3
30	0.4
40	0.5
50	0.6
60	0.7
70	0.8
80	0.9
90	1

Table showing the coefficients for different angles of turns

the NE and the NW quadrants. It is based on the simple notion that a person does not go back on himself. Hence it is proposed that the steps in SE and SW quadrants vary from 1 to 2 in the clockwise direction.

Nick Dalton† of the Architectural Association, London, proposed a similar approach to the angle of streets, while suggesting modifications to space syntax approach. In what is called fractional angular analysis, Dalton argued for incorporation of fractional values while measuring steps in Space Syntax configuration analysis. An analysis of Manhattan conducted by Dalton using this methodology is presented in Plate 2. In the first diagram normal mean depth approach (original Space Syntax approach) is presented and in the second the analysis is

†Dalton, c2001, *Fractional Configuration Analysis and a Solution to the Manhattan Problem*

conducted using fractional mean depth. It is noticeable that while in normal mean depth, Broadway underperforms and in Fractional Mean Depth analysis it comes up as the most integrated street in the system.

4.3 Procedure for Spatial analysis

4.3.1 Axial Map

The first step to spatial analysis is procurement of the street network of the city in the study. An axial map is prepared by finding the longest straight line that can be drawn in the configuration linking all intersections in the system, then the second longest, and so on. Mostly these axial lines follow the street networks for the purposes of land value evaluation. For purposes of pedestrian movements however, all the pedestrian access networks should be drawn. Hence axial lines are the ones that connect two intersections, both visually and physically. That is, if the same street changes its angle, then it should be treated as a different axial line. This is, true since the visual connections that are broken lead to a change in intelligibility of the system, and it is central to the methodology.

Number the axial lines in the system beginning from 1 in an order that is convenient. Then each axial line is divided into segments. A segment is the axial line between any two intersections. This corresponds to the segment of a street along a block. This is the segment map of the system. Number each segment in the following format. If the number of the axial line is 1, then number the corresponding segments as 1.1, 1.2 and so on. Figure 4.6 represents the axial map with segment numbers of a hypothetical small configuration.

Number the axial lines in the system beginning from 1 in an order that is convenient. Then each axial line is divided into segments. A segment is the axial line between any two intersections. This corresponds to the segment of a street along a block. This is the segment map of the system. Number each segment in the following format. If the number of the axial line is 1, then number the corresponding segments as 1.1, 1.2 and so on. Figure 4.4 represents the axial map with segment numbers of a hypothetical small configuration.

4.3.2 Mean Depth

The location of a segment is determined by counting the number of intersections between two segments. These are “steps”. The number of steps a segment is away from every other segment is measured. Then an average number of steps to all the segments is taken. This is the Mean Depth of the system.

$$MD_i = \frac{S_1 + S_2 + S_3 + \dots + S_n}{N - 1}$$

MD_i = Mean Depth of a Segment i

S₁, S₂, S₃, ..., S_n = the number of steps to each of the segments

(S_i = 0)

N-1 = number of segments in the system minus the segment under consideration

The Number of steps between 1.1 and 9.1 is presented here.

1.1 – 9.1 (90 degree turn) = 1 X 1

9.1 – 3.2 (90 degree turn) = 1 X 1

3.2 – 3.3 (0 degree turn) = 1 X 0.1

3.3 – 3.4 (0 degree turn) = 1 X 0.1

Total Steps = 2.2

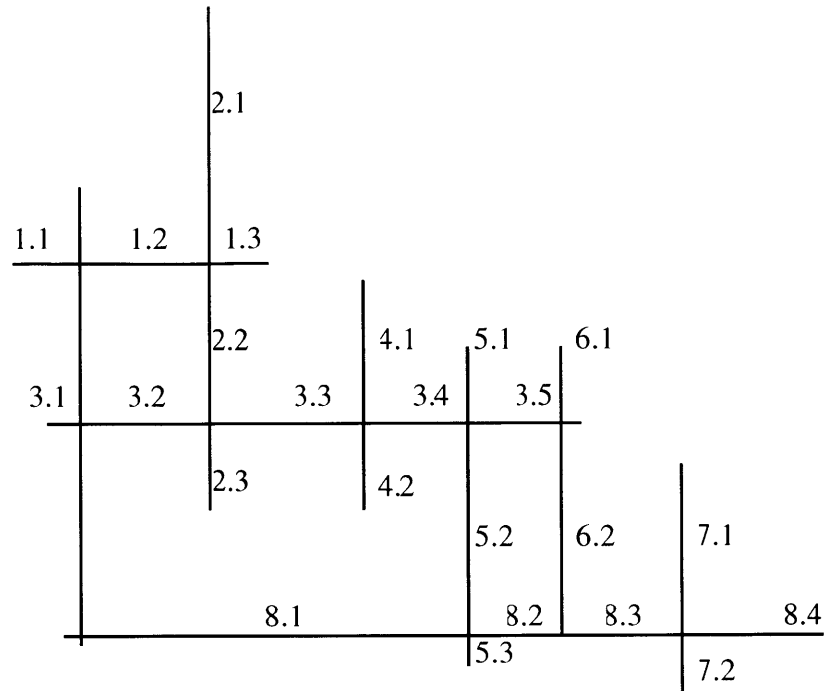


Figure 4.7: Axial Map with segments

4.3.3 Relative Asymmetry and Density of grid

The model so far is topological in that it models only configurations of space. It is essential to introduce at least a quasi notion of distance in this model. Currently the number of steps between any two points is the same in a configuration, but different density of grids is the same. This is not true, because in reality, the distance between the two is higher in a finer grid than that of a coarser grid because of large block sizes. Refer to the logic presented in figure 4.9. To introduce the quasi notion of distance, it is proposed to normalize the mean depth by the density of grid network. This is called Relative Asymmetry.

$$RA_i = \frac{MD_i}{\text{Grid Density}}$$

RA_i = Relative Asymmetry of segment i

MD_i = Mean Depth of segment i

Grid Density = Total number of intersections in the town

That is if the grid is coarse, the number of intersections per acre are greater, and this results in a lower Relative Asymmetry. This is high integration. And if the grid is finer, the number of intersections per acre are smaller, and this results in a higher Relative Asymmetry. This is low integration.

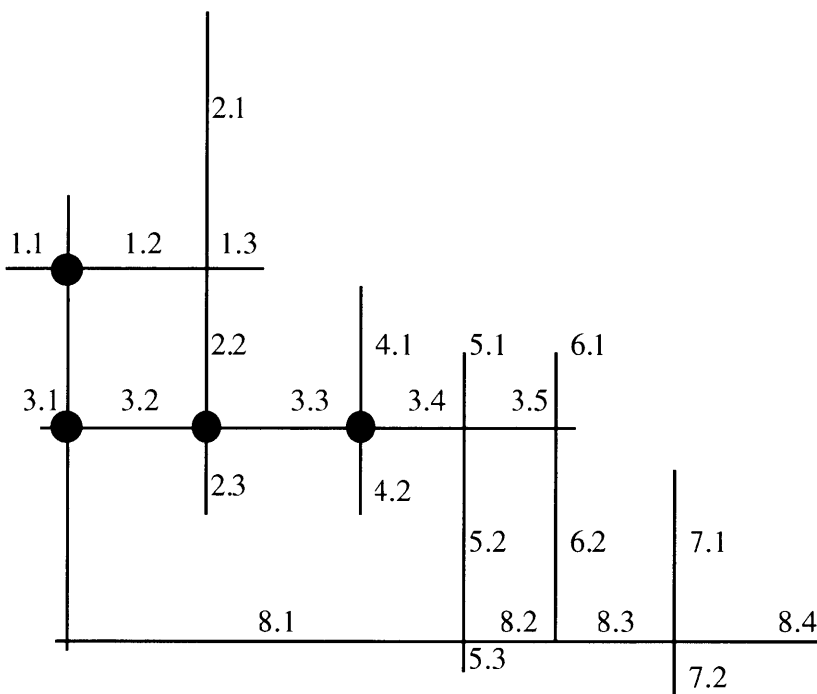
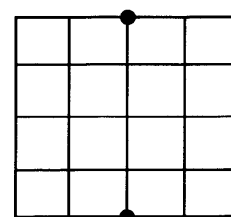
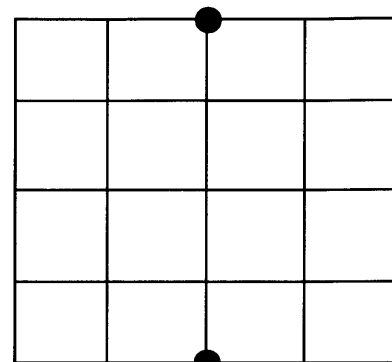


Figure 4.8: Number of steps between segment 1.1 and 3.4 for the hypothetical configuration. Black dots indicate steps.

Relative asymmetry is defined as the relative location of a segment in the system with respect to every other segment, as a function of intelligibility in any given physically contiguous configuration of a city. The Integration map of a sample town configuration is presented in figure 4.10 and the integration values are presented in figure 4.11.



Configuration 1



Configuration 2

Figure 4.9

Two configurations are presented above. Configuration 1 is topologically the same as Configuration 2. However, it is half the size of Configuration 2.

Two points in both layouts are considered and Mean Depth is measured. The Mean Depth in both layouts is same: 2.3. However, since the two configurations are different in size it is imperative that in configuration 1 the two points are much closer to each other than in Configuration 2. To account for it the Mean Depth is divided by the Grid Density (Relative Asymmetry). The Relative Asymmetry of Configuration 1 is 0.092 (2.3/25) and that of Configuration 2 is 0.184 (2.3/12.5)

4.3.4 Example of Central Boston

Axial maps of Central Boston in 1895 and 1995 are presented in Plates 3 and 4. It is visible from the two that the grid became finer in 1995. Two different applications of the model are presented using these two maps. Firstly, the number of steps between Old State House and the Tip of Bulfinch Triangle have increased from 2 in the 1895 to 2.7 in 1995. One would expect the number of steps to reduce as the grain got finer. However, this model indicates that they have increased mostly because of the reduced intelligibility between the two points. As we can observe, the axial link between both places that existed in 1895 is missing in 1995. Secondly, one could observe that the actual distance between the two points has increased more than the difference between 2 and 2.7. This is because of a reduction in number of blocks or intersections over the same area that led to an increase in mean size of a segment. Hence, we divide 2 by 7 (the number of intervening intersections in 1895) to get 0.28 steps and 2.7 by 4 (the number of intervening intersections in 1995) to get 0.68 steps. This indicates that these two places are segregated in 1995 when compared to 1895. This is a true measure of accessibility and intelligibility.

4.3.5 Friction

In effect, Relative Assymetry is a measure of friction, that is, how difficult or easy it is to get to a point from every other point within the system. Newton's second law of motion states that an object in motion tends to stay in motion unless the object is acted upon by an external force. This external force or friction contributes to the modulation of motion in our real life. Spatial patterns constitute different degrees of friction that can be explained by intelligibility.

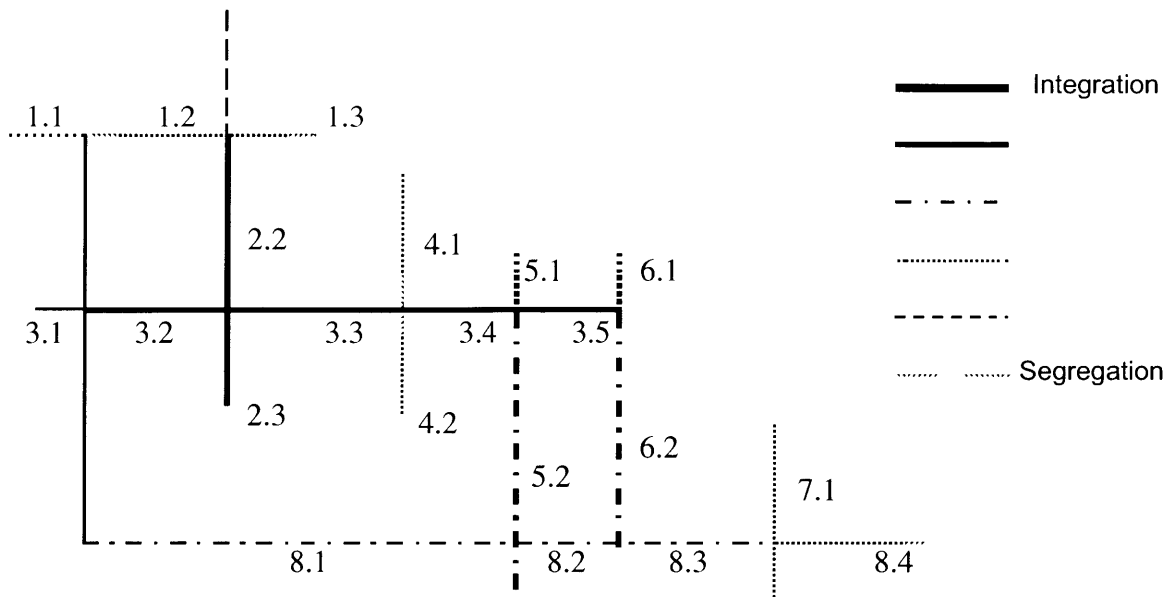


Figure 4.10: Integration map of the small hypothetical town

3.3	0.11033	1.1	0.15333
3.5	0.112	6.1	0.15433
3.2	0.11233	5.1	0.156
3.4	0.116	2.2	0.15633
3.1	0.12233	2.3	0.15767
9.1	0.12567	2.1	0.16833
9.2	0.12933	1.3	0.17433
8.1	0.14133	1.2	0.17467
5.2	0.14233	8.4	0.18167
5.3	0.14467	4.1	0.18567
8.3	0.14567	4.2	0.18567
8.2	0.14767	7.1	0.219
6.2	0.15033	7.2	0.219

Figure 4.11: The integration values (Relative Assymetry) of different segments from the highest to the lowest are presented below.

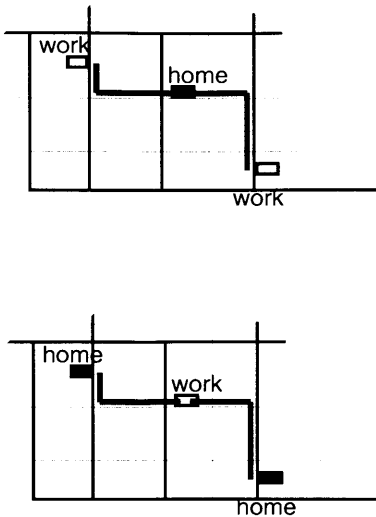


Figure 4.11

4.3.6 Jobs and Homes

If relative asymmetry is lower it means that a segment is much closer to all the segments in the system. In economic terms these locations would be highly desirable and have the highest demand for uses. In these locations one could change jobs without changing residence and one could change residence without changing job (figure 4.11).

4.4 Application of the Model for Design

The sample configuration in Figure 4.7 is subjected to design changes to observe the performance of the model. It can be understood from the integration analysis in figure 4.10 that the integration core of the settlement is along the street 3. This means that this area is the most accessible to the whole system.

Two different design reconfigurations have been proposed as shown in figures 4.12 and 4.13. In the first layout 4.10, the north south streets were extended to meet street 8 and horizontal street 10 is introduced. As a result the integration core of the settlement shifted outwards to the edge. This has two different inferences:

1. This proves that the model does not find the geometric center of the city, but truly the most accessible points in the system. If we take a close look at the layout, one could draw an analogy to Chicago, whose integration lies on the lake front. In this layout the two parallel and most integrated streets, 8 and 10, can be compared with South Michigan and State Streets. Streets 2 and 9 can be compared to Madison and Congress Parkway.

2. The original center (figure 4.7) is along street 3. If this were a real town, it is understandable that the commercial center of the city or the main street would be along 3. This design proposal leads to a shift of that center, by making another portion of the city more intelligible and accessible. This may or may not be good for

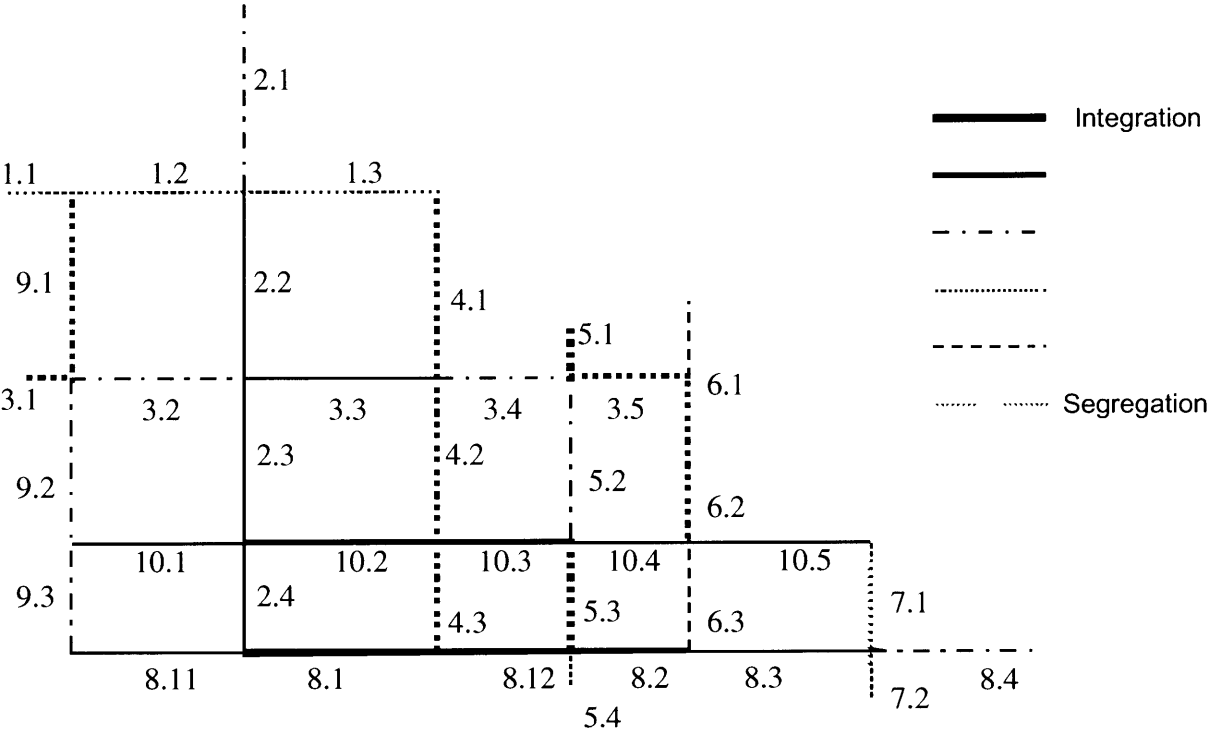


Figure 4.12: Design Simulation 1

the city. This model is able to show the likely affects of these configurational changes and the local planners can decide whether this suits their agenda

In the second alternative that is presented in figure 4.13, a diagonal street is introduced instead of a horizontal street. This is in addition to the extension of North South streets up to street 8. It is interesting to observe how the diagonal changed segment 7.2

and street 4 into a better integrated than before. This is due to the the introduction of diagonal that not only shortens the distance between two points, but also makes the two intelligible. It is curious that segment 10.2 is not a highly integrated street in the system despite its proximity to the most integrated parts of the system. This can be explained by its orientation with respect to the system.

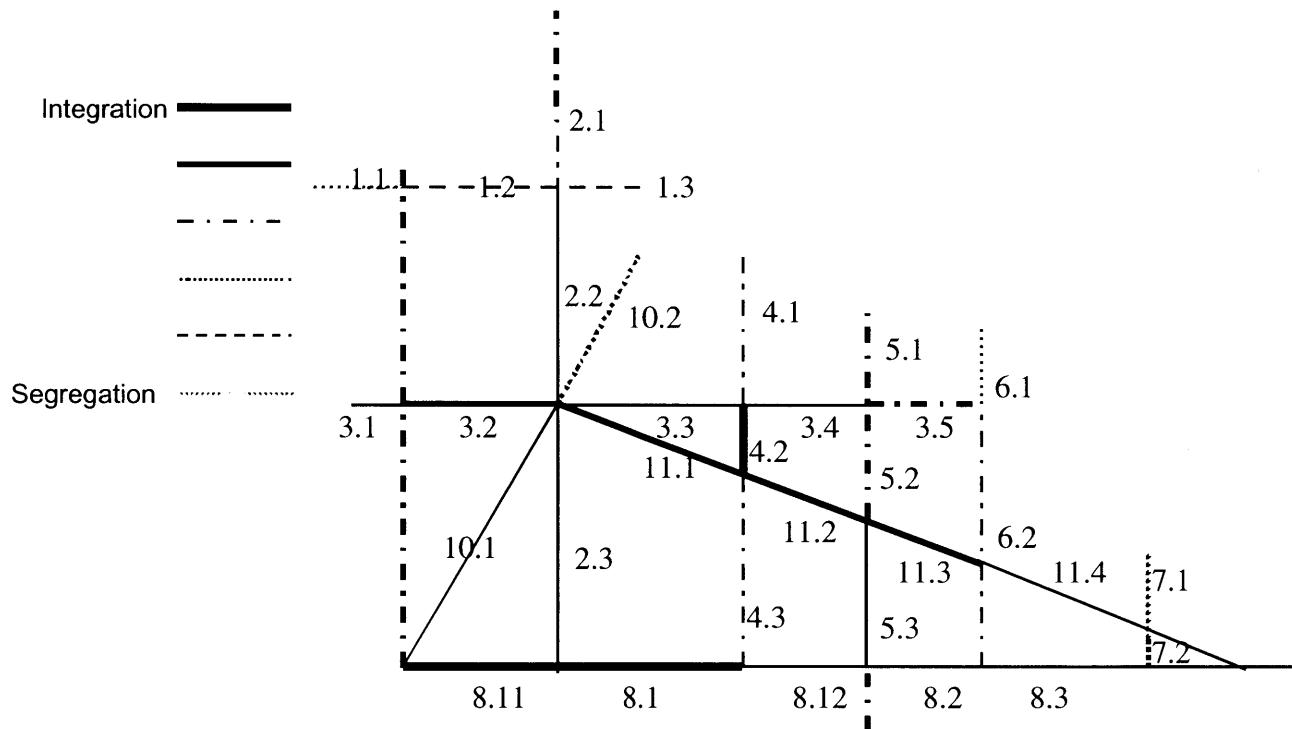


Figure 4.13: Design Simulation 2

In both the cases the tendency of the center to move southwards is noticeable. The reason is that most of the design interventions have been made on the South of the configuration. This is a very important inference that would lead into the next sections, where spatial interventions render certain areas in a city more advantageous than the others.

4.5 Rents and land prices

Bill Wheaton† argues that in economics, the markets for different land uses are often referred to as completely product differentiated. Commodity or automobile markets for example, are completely contrasting to this and are largely uniform. Product-differentiation for these markets is partial and only occurs if there are multiple producers of the same product. In these markets, there are large numbers of substitutes with almost the same quality. The lack of availability of similar land for substitution makes urban land product-differentiated.

The fact that urban land is differentiated product makes it difficult to speak about the supply or demand for sites at any particular location. By definition, the supply of land at each location is fixed; hence, it is quite price inelastic. The demand for a particular site, on the other hand, is likely to be quite sensitive, or elastic, with respect to its price. This results from the fact that numerous competitive sites, or substitutes exist at adjoining locations.

For almost two centuries, economists have recognized these distinctive features of the land market and have developed a simple approach for determining land prices based on t locations. This approach argues that land must be priced at each site so that its occupant is charged for the difference in location. Ricardian model of rents (explained in Chapter 3) is an example of determining land values or housing rents based on commuting distances.

In this model we substitute the location value of a site in a physically contiguous city by the value created by spatial

†DiPasquale, Wheaton, c1996,
*Urban Economics and Real Estate
Markets*

configurations. A methodology to determine the relative significance of different segments in the system is presented in the spatial theory earlier in this Chapter.

4.5.1 The location Advantage

The advantage of a location is the difference between its Maximum Relative Asymmetry and the Relative Asymmetry of the location itself. Maximum Relative Asymmetry is the asymmetry of the farthest segment in the system. The difference indicates how much better off one is by locating at that particular location with respect to the farthest location in the system. That is the location advantage at the farthest point is zero. This is presented in the following regression expression for rents:

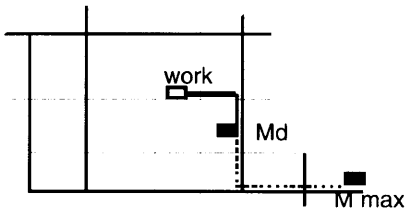


Figure 4.14

Solid line is M_d and the dotted line is $(M_{max} - M_d)$, the gain.

$$R_i = a + b (M_{max} - M_i)$$

R_i = Rent per unit or square feet at location i

a = uniform base rent per unit all over the city. This can be termed as a combination of agriculture rent and structure rent.

b = location coefficient

M_{max} = Maximum Relative Asymmetry

M_i = Relative Asymmetry at location i

Do not include locations that are not residential in regression analysis.

4.5.2 Assumptions in the Model

◇ For the time being:

1. All households are identical.
2. All Housing has fixed and uniform characteristics at all locations.

More variables to describe the phenomenon comprehensively can be added later on.

- ◇ Housing occupied by households who offer the highest rent, and land is allocated to that use yielding the greatest rent.
- ◇ With a growth in population boundary does not necessarily extend outwards, there may be spatial reconfigurations that may change the rental levels with in a city.
- ◇ Rents declines non-linearly from the employment center of the city.
- ◇ Employment center or other non residential land uses that demand centrality and natural movement, coincides with the best integrated segments of the city.
- ◇ Segments that are highly accessible from all the other Streets in the system are the most desirable locations.

4.5.3 Procedure for obtaining the real values

Rents per unit or per square feet of built up area should be collected from each of the segments in a city. Relative Asymmetry of the respective segments is computed using the constructs of the Spatial Theory. Arrange the data in an ascending order of Relative Asymmetry. This arranges segments from highly integrated to segregated. Mean Depth gain for each location is computed by deducting the Relative Asymmetry of that particular location from the Maximum Relative Asymmetry, ie, the Relative Asymmetry of the segment that is at the bottom of the table. The difference at this last segment would be zero. That is there would be no location rent. A sample data is presented in the following table.

Coefficients are estimated using Regression analysis under the condition that serial correlation was found. Future configurational changes can be analyzed to obtain the Mean depths that in turn can be used to predict the rents using the above expression. Configurations can be rearranged and manipulated for desired rents. A sample regression expression obtained from regression analysis would look like this.

$$R(d) = 456.25 + 141.81(M_{max} - M_d)$$

4.6 Density

When rents per unit at different locations are computed, a significant difficulty is encountered, because the basic characteristics of built form or housing, namely density or FAR, is not considered as a variable. It is conceivable for rents per unit in the most integrated or central areas at times being lesser than

- a. rents per unit of housing units that are in segregated areas
- b. rents of the units of housing in similar location.

The important determinant of the above phenomenon is density.

Density of residential real estate frequently varies widely within a metropolitan area. The underlying reason for variation in density is simple. As location rents increases the price of land, a substitution occurs between land and structure. Economists call this process 'factor substitution'. At locations where land is more valuable, development tends to use less land per housing unit and relatively more structural capital. In other words the above model predicts inherently higher densities in highly integrated or

central areas of the city. This is understandable and can be seen in most cities. The metropolitan densities of Boston are presented to demonstrate this in figure 4.16.

4.6.1 Rents Densities and Mean Depth

Hence, to explain the phenomena of rents per unit more comprehensively we should endogenize residential densities. The new regression expression is:

$$R_i = a - b_1 F_i + b_2 (M_{max} - M_i)$$

F_i = Number of units per acre of land

The negative coefficient on density variable is important. Coefficients are obtained (positive or negative) using regression and it is a stylized fact in economics that an increase in densities reduces rents per unit. At any location this is true. If a parcel of land is developed with 10 units, rents will be shared by 10 units against a parcel of land that is developed with 1 unit, where rents will be shared by only 1 unit. Both sites will have same the rent/acre as they are in similar locations. This also can be explained in a tenant's perspective that a tenant would pay less if there are more units, since people prefer open space to neighbors.

However, this may vary with different types of population groups. For example, elders and youngsters may value low rents and high densities more than open space. Families with children value open space more than density. The user variable is exogenous to this model for the time being.

4.6.2 Demand and Supply

In this model, demand is considered as location exogenizing the other demand variables such as household formation and interest

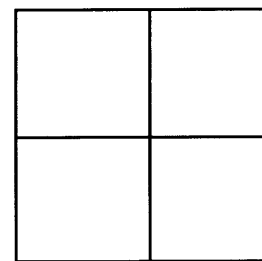
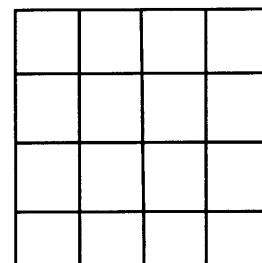


Figure 4.15
Density of development

In two diagrams presented here, the same area of land (block) is divided into 16 and 4 plots. If they are at the same location, the rent per unit in block 2 is lower than that of block 1 because the same amount of area is shared by more units in block 1.

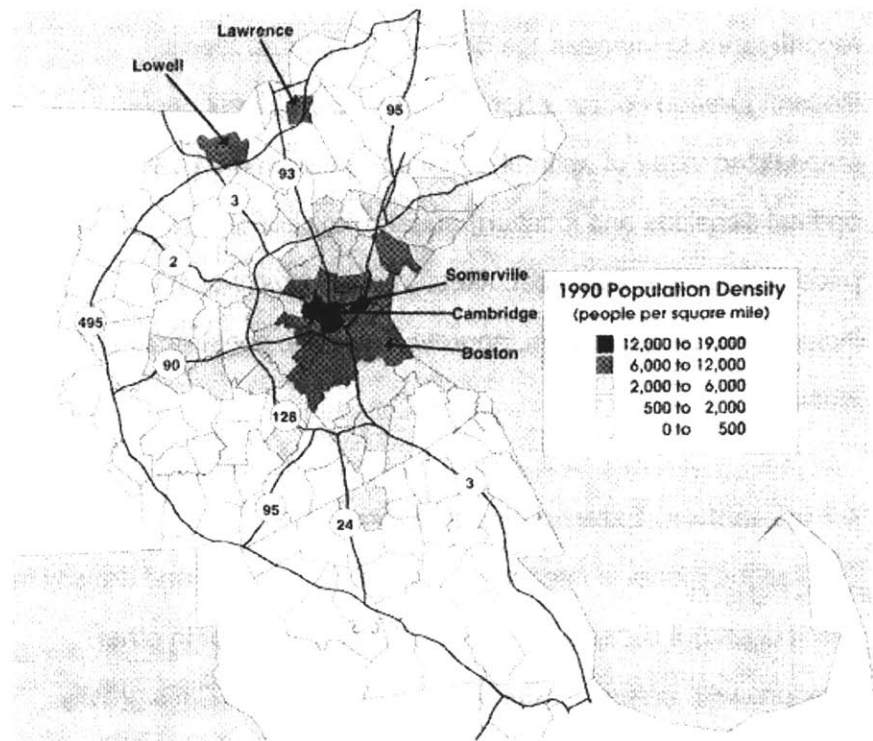


Figure 4.16: Densities in Boston Metropolitan Area

rates. These exogenous variables are excluded because they have the same impact relatively and proportionately on all the locations. For example an increase in interest rates increases the rents uniformly at all locations. However, household formation does not have the same impact on all locations. In this sense, this model is supply based. This largely depends on the frequency of new development. In the Ricardian rent Model, we observed that an increase in rents is high at the edge of the city due to an increase in households in the city. The model assumes that the boundary of the city is going to extend outwards with an increase in number of households. However, in the current model it is argued that there could be certain internal reconfigurations in the city. These configurations are often referred to as "land use succession". They arise at locations that are underutilized (lower densities and rents than optimal levels) and which are

reconfigured to increase the density to optimum levels.

Reconfigurations occur when the projected optimal prices (capitalized value of optimal rental stream based on our model of optimal densities and location) equal or exceed the sum of current price and replacement cost. Replacement cost would typically include demolition, design, approval process, construction and leasing.

4.7 Interaction: Externalities and Gravity

Till now the model is internal to a particular location and density in that it does not consider the impact of development in other locations with respect to density. As explained in Zipf's gravity model presented in Section 4.1 of this Chapter, the interaction between every two places is also important to the performance of each place relative to the other.

Let us observe a simple example. There are two adjacent lots at the same location. Densities of one location negatively effect the rents of a neighboring location, just as densities of a location effect its own rents negatively. This is a stylized fact in economics. That is, if location A has a lower density, the rent per unit will be higher. However, if the neighboring location is developed at a much higher density, there would be a negative impact on the rents of the existing location because the high-density development next door reduces the attractiveness of your location. This is because people prefer open spaces to neighbors. This applies not only to ones own site, but also to the neighboring site. This impact would be an inverse function of mean depth. That is, the density of a location that is farther away or more number of steps away will have less impact on the rents of location A (Figure 4.17).

Gravity Interaction $F_{ij} = \hat{A} F_j * (1/R_{ij})$

The new expression for rents is:

$$R_i = a - b_2 F_i + b_2 (M_{max} - M_i) - b_3 F_{ij}$$

4.8 Land Rents

Land price in economics is considered residual of total asset price and cost of construction. We are interested in rents or prices per acre instead of per unit in order to compare different locations.

Land Rents/acre (land) = rents/unit * units/acre-Structure rent

That is

$$r_i = F_i \{a + b_2 (M_{max} - M_i) - b_3 F_{ij} - C\} - F_i^2 \{b_2\}$$

C = Structure rent

4.8.1 Optimal Density

The land value at every location in a city ought to be highest if all else is constant. Optimal densities and land rents occur at the peak of the curve, where the rate of change of land rent with density is zero. Using calculus it is possible to construct a direct relationship between densities and mean depth, if we try to maximize rents at every location ($dr/df = 0$)

$$F_i = \frac{a + b_2 (M_{max} - M_i) - b_3 F_{ij} - C}{2 * b_2}$$

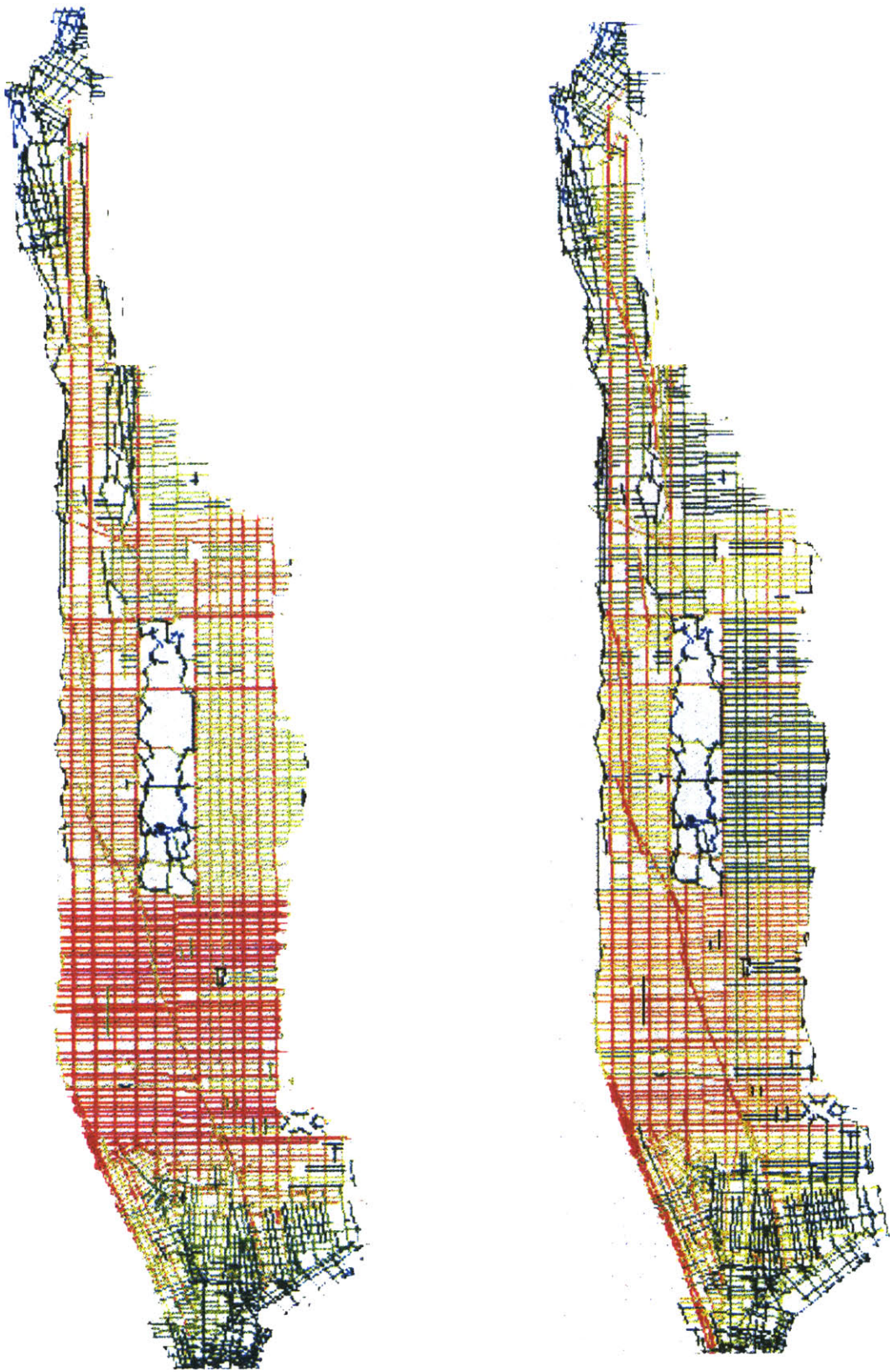


Plate 4
Space Syntax and Fractional Angular analysis of New York



Plate 3

Map of Boston in 1895 showing the relationship between State House and West End



Plate 4

Map of Boston in 1995 showing the relationship between State House and West End

5

TOWARDS A SPATIAL- ECONOMIC THEORY

If there are no objective regularities in the real world of urban form and space which link the configurational aspects of cities with behavioral and economic outcomes, then there are no grounds whatsoever for seeking to build an analytical theory. However, as demonstrated in this thesis, there are such regularities inherently in very form and spatial configuration, and these regularities can be the fundamental basis for developing analytical models of cities. What is explored in this thesis is perhaps of limited consequence. One could potentially argue against the basis of this model, the physical movement of individuals. In the contemporary society both means of navigation(intelligibility) and means of movement have changed. While technological advancements have made urban navigation much easier, the automobile made the relevance of contiguous form of cities itself insignificant, and locations that were not considered accessible are now accessible. Unfortunately these are the ends that our value-free technology produced and this behavior is unsustainable. For the past 25 years urban population trends have been increasing in American cities. Inner cities have started to grow in their population with young professional seeking vibrant urban life. American cities are going through a renaissance. If we continue to see this trend, we

need to locate thousands of people in our cities. Land use succession will lead to reconfiguration and redevelopment of underutilized or abandoned land in our cities. The spatial allocation, i.e, where to locate people with respect to each other is an important task in bringing meaning to human life. The meaning is in understanding social, economic and spatial concerns of a society. Rationality will continue to be an everincreasing belief and our acts should have a firm grounding in it. Under such circumstances, it is important for us to be conscious of the morphology of existing cities and the social and economic values built into it. It is too costly to make mistakes that were done in 1960's renewal.

Cities are dynamic and are not once-for-all planned objects in a stable end-state, but are complex global structures which emerge from innumerable local decisions over a long time scale. In seeking to describe and analyse cities, the Spatial-Economic Model presented here seeks to understand the emergent structure of the physical city on the one hand, and to account for both its constructive functional logic and its functional impacts on the other. The Model is convincing in its own right. It has the ability to understand the morphological construct of contemporary cities, as well as to determine the economic potential of urban land based on morphological issues. Supplemented with relevant variables that affect urban development phenomena, the model could produce cities that are not only economically sustainable, but also physically cohesive.

The model's similarity to relevant transportation, economic and spatial models is an important arguement for its application in

urban policy. The assumptions and ideas built into the model are in validity with the models mentioned above. With the inclusion of more variables and empirical validation, the model could become a tool of common understanding between city planners, architects and developers.

Three potential application areas of this model have been identified. First application is in terms of urban analysis, similar to the build-out analysis conducted to understand the potential of urban land based on intelligibility and accessibility. The current process of build-out analysis only involves environmental and legal issues as a measure of build-out analysis. This model would have tremendous applications in land use zoning in cities. Secondly, it can be used as a design tool with predictive capability of not only related spatial and topological issues but also economics. Various design proposals for reconfigurations and newer parts can be tested with this model, and spatial modifications can be used to achieve social and economic goals, for there is a strong interconnection between spatial configurations and social and economic behavior. The third application is a combination of the two. Using this model it is possible to understand the impact of not only economic decisions but also spatial decisions made at certain locations on the whole of the city.

Two challenges remain that need to be addressed. One, the Space Syntax Institute and similar thinkers whose model has been adapted here with significant changes. Two, economists who are little concerned with the configurational aspects of space. The model proposed here is a preliminary speculation. To meet the above challenges there is a considerable amount of future work

that the author anticipates. The immediate task is to collect empirical evidence. It is proposed that the model be run on few sample American cities. This is intended to give a substantial feedback to Spatial Model proposed. Appropriate corrections are then proposed to be made to the Spatial Model. This will be a beginning of the subsequent task of building an analytical tool for various applications.

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SOURCE OF ILLUSTRATIONS

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[2.1] - [2.3] **Hillier**, *The Social Logic of Space*, c1984

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[3.5] - [3.9] **Hillier**, *Space is the Machine*, c1996

[3.10] - [3.11] **Penn**, *Configurational Modelling of urban movement networks*, c1997

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[4.2] **Brennan**, *Office Rent in the Chicago CBD*, c1984

[4.3] **Martin**, *Urban Space and Structures*, c1972

[4.16] **DiPasquale**, *Real Estate Economics*, c1995

[Plate 1] **www.spacesyntax.com**

Plate 2] **www.spacesyntax.com**

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