THE NODULAR METROPOLITAN CONCEPT
TRANSPORTATION ASPECTS

by

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ABSTRACT

Rapid urbanization is one of the major problems facing the more developed nations of the world today. With technology making great advances and the needs and values of the people changing rapidly, elements of the cities are becoming obsolete and there is need to expand and build anew; bigger, better, and more beautiful cities. To do this, new and better planning tools need to be developed to understand urban structure and intelligently guide public investment decisions. One of the important aspects is transportation and the impact that changes in land use or the transportation system have on the total travel requirements of the city.

Prof. George C. Hemmens, Associate Professor of Planning, University of North Carolina, in a paper "Experiments in Urban Form and Structure" proposed a linear programming model to determine the minimum travel requirements of alternate landuse patterns. He takes as given alternate distributions among sub-regions of an hypothetical urban area of the following urban elements: work place, residence, alternate transportation systems, and an allocation rule which minimizes the total travel time between each residence and work place and a shopping place.

One of his main conclusions was that alternate transportation systems do not effect the relative efficiency of alternate landuse patterns.

The hypothesis of this thesis is that alternate transportation systems do effect the relative efficiency of alternate landuse patterns.

Two sets of experiments were conducted, with some modifications to Prof. Hemmens model, the results of which substantiate the proposed hypothesis. The first set of experiments, using a geometrically non-symmetric road network and a one mode transport system, indicate the relative efficiency of alternate landuse patterns remains constant regardless of the level of service or the geometric pattern of the transportation network. For the second set of experiments two modes of transport and modal split factors for the sub-regions were introduced. It is found that the relative efficiency of the alternate landuse patterns now varies with the level of service, the type, and the pattern of the transportation system. Thus there is just one transportation system most suitable for a given landuse pattern.

In general, the concentric ring with dispersed work and shopping (R2C2W2) pattern was found to be most efficient i.e.

for a weak commercial and work core the travel requirements were smaller in magnitude than for a stronger core and that changes in the commercial pattern had a greater impact on travel time than similar changes in the work pattern. Also, there exists a trade off between landuse and transportation i.e. landuse changes can be substituted for improvements in the transportation system, or visa versa, to achieve the same desired end result.

Because of the simplistic assumptions made, the hypothetical data used, and certain other limitations of the model, the validity of some of the conclusions may be questionable. But, if the results can be taken as conclusive, they are of great significance for planning. Time and locational priorities for all major renewal and new construction activity could be guided by the requirements of the R2C2W2 pattern. The highest priority being given to the restructuring of the commercial pattern and the lowest to the restructuring of the residential pattern. The model could also be used to determine changes in the travel requirements due to the construction of a new shopping center or a new freeway.

This thesis is part of a group study dealing with a concept

of urban growth and development; the "Nodular Metropolitan Concept." The results of the study substantiate that the "Nodular" pattern of urban structure (which by definition is analogous to the R2C2W2 pattern) has the highest efficiency i.e. the least travel requirements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

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SECTION I

THE NODULAR METROPOLITAN CONCEPT

THE GROUP STUDY

Basis of Study

A review of the following literature emphasises the unco-ordinated state of city development. If it is possible for mankind to anticipate (plan for) the future, it is important to discover the kinds of changes that may occur. The purpose of this study is to identify underlying variables that are shaping urban society and structure; specifically to explore a form of development which is becoming evident in the city today. From this analysis it is apparent that specific functional nodes have formed naturally within the present urban system. This study assumes that present growth trends in the city can be recognized and analysed. Based on this analysis, it is believed that the most desirable trends can then be reinforced to shape future form and structure.

Approach

The approach to this study has been inter- and multi-disciplinary. It is a postulate of this research that Community and Regional Planning must operate within a comprehensive and co-ordinated framework. In view of this, an attempt has been

made to construct a preliminary model (see matrix, figure no 1.1). Because of the limitations of time and personnel, only selected components of the conceptual model are explored. A more complete identification and analysis of all the model's components would result in a better understanding of the larger continuing urban growth process. The topics of individual studies are arbitrarily selected on the basis of individual researcher's experience and interest. It is only on this basis that a significant contribution to the theory and practice of Community and Regional Planning can be made.

The Problem

By the year 2000, the urban population of the United States is expected to be double.[1] Moreover, people are expected to be more affluent as their personal income in constant dollars increases by fifty percent.[2] While these anticipated changes have not yet been realized, the capacities of our cities are fast reaching their limits. For example, transportation facilities are already congested in the large metropolitan areas,[3] conveniently located land for housing is becoming scarce, and costs of providing public services and utilities are becoming prohibitive. The crucial problem arising out of this is

FIGURE NO. 1.1

INDEPENDENT VARIABLES \ DEPENDENT VARIABLES	quality	quantity	mobility diversification & specialization	ownership centralization & decentralization	privacy	power	time integration & segregation	culture	history	space	technology	location	form & structure	scale	density	design	amenities	shelter	climate	regionalism	convenience	urbanism	distribution	environment	movement patterns services & institutions	work	comprehensiveness	leisure	beauty	organization	congestion	efficiency	feasability	orientation	pollution
Political Science																																			
political theory																																			
public administration																																			
political parties																																			
leadership & decision-making																																			
power & influence																																			
Sociology																																			
social behavior										X																									
social structure										●																									
Economics																																			
Monetary & fiscal policy																															▲				
income distribution																																			
price theory																																			
economic growth																																			
Business Administration																																			
marketing																																			
finance policy & administration																															▲				
estate management																															▲				
public relations																																			
accounting																																			
Urban Form																																			
architecture																																			
landscape																																			
civic design																																			
land use & zoning	X												X																						
Law																																			
municipal law																																			
land & maritime law																																			
constitutional law																																			
torts																																			
corporation law																																			
Engineering																																			
utilities & services																																			
systems analysis																						●													
transportation													■																		■				
communication																																			
structural design																																			
Urban Geography																																			
urban systems																																			
urban processes							T																			T									
Social Psychology																																			
Statistics																																			

▲ Chang
x Cowie
● Lindeman
T Mann
■ Shahani

URBAN MATRIX VARIABLES

how to plan our metropolitan areas so that they can accommodate the anticipated growth and change.

It is estimated that by the 1980's or at least by the year 2000, we will have to rebuild our cities to accommodate the anticipated population increase and to satisfy the preferences of a more affluent society. By the year 2000, more urban homes, places of business and public facilities will have to be built than have been built since the first towns were started in North America. At least half of todays urban dwellings will probably require replacing because they will no longer serve the needs of families.[4] In addition, half of todays urban business and industrial buildings will require replacing because they will no longer serve changing production and distribution methods.[5]

It is likely that our cities will have to be restructured to accommodate radically new means of transportation. High density cities like New York have alrady found the cost of automobile travel to the city core prohibitive. In low density cities, such as Los Angeles, the cost in money, time and space of relying solely on the automobile is equally prohibitive. For example, two-thirds of Los Angeles' downtown is given over to the automobile - about one-half of this to parking lots and

garages and the rest to roadways and highways.[6] Most of todays cities have grown with little planning. Although they urgently need rebuilding and restructuring, they have neither the money nor the authority. Our larger cities are beset with problems of slums, traffic, congestion, sprawl, ugliness, housing; with the provision of inadequate open space; with air and water pollution; with outmoded forms of public administration and taxation. In addition, most cities have enormous problems with education, poverty and racial segregation.

Outdated, inflexible political boundaries have helped to encourage people and industry into the lower tax suburbs and to make planning extremely difficult. The wealthier families have excaped to the suburbs leaving the central city to deteriorate. Our cities continue to use a tax system that penalizes improvements and subsidizes obsolescence which inevitably leads to blight, sprawl and spread of slums.[7]

In spite of all these problems, which vary in degree across North America, our metropolitan areas continue to grow and cry out for imaginative solutions to making our urban environment more livable.

Planners like William Wheaton and Victor Gruen believe

that the essence of urbanism is variety, and that only a vibrant night-and-day "downtown" (city core) can support the variety of shopping, services, contacts, job opportunities, culture and recreation facilities needed to make a city an attraction.[8] Any viable city core needs people living within and adjacent to the area - not just daytime commutors. The provision through urban renewal of a functional and livable habitat for these central city dwellers is the focus of the group research effort described in this thesis.

Urban Growth

Metropolitanization

Before discussing the central core area of the city, it is important to mention the general forces which have contributed to the growth of our metropolitan areas. Peter Hall describes such forces.[9] The first is that total population has increased at a rapid rate and threatens to go on increasing. The second factor was the shift off the land into industry and service occupations in the cities. This, however, is no longer a major factor since over two-thirds of North Americans now live in urban areas. The third factor is that a large part of the urban growth is being concentrated in the already large metro -

politan areas. This concentration probably is a reflection of the more diverse economic and social opportunities available in the large centres.

Metropolitan areas have grown faster than the rest of North America in every decade since the turn of the century, except for the depression years 1930-1940. By 1960 almost two-thirds of the population of the United States lived in the Standard Metropolitan Statistical Areas delineated by the census. In Canada 87.5 per cent were classified as urban (non-farm) population. This is a 109 per cent increase from 1921-1961.[10]

Growth within the metropolitan areas has not been distributed evenly. The central areas of cities have grown relatively little, while the suburban rings have grown at a much higher rate. Some of the larger cities central areas have actually lost population during the last decade. Some of the many reasons for the loss of population include a lack of available space for further building, the obsolescence of housing and industrial plants in the core areas and the unavailability of rapid, cheap methods of communication and transportation.

The losses of population in the central areas do not necessarily reflect economic decline but rather the decentralization of

population and institutions to the suburbs. Historically the natural clustering of commercial, industrial and residential activities was due in part to the absence of a well developed transportation system. Mobility was limited since few people had a personal mode of transport. When mass production and ownership of automobiles became a reality, the form of the city began to change. Since people were not able to travel longer distances in a shorter period of time, they began to move to the outer fringes of the central city. Decentralization of the residence also brought with it many retail and service enterprises. In addition, there has been a trend towards the decentralization of manufacturing and wholesaling firms seeking to escape the congestion of the central core.[11] Another factor which has encouraged residential decentralization is the intervention of government in the housing market.[12] Through the U.S. and Canadian Housing Acts, long term, low interest loans made single family home ownership possible on a larger scale and encouraged the development of suburban sub-divisions.

It appears that the primary implications of increased mobility and government housing policy on urban form is a dispersion of activities. But while the city is becoming more

dispersed, specialized functional areas appear to be developing. The decentralization of retailing, wholesaling and industry has altered the function of the urban core. The core is evolving from a central business district to a central intelligence district.[13] That is to say, tertiary and quarternary economic activities are becoming the predominate land uses. Financial and administrative offices, research and consultative firms, entertainment and cultural facilities are increasing in the core areas of cities. Those retail firms which remain downtown are becoming increasingly oriented to the daytime working population and to those people who live in or adjacent to downtown.[14]

Within the core itself, specialized functional districts can be identified. For example, a financial district, a high order good shopping district, and an entertainment strip may be easily observed. This clustering of like activities reflects the desire for face to face interaction or, as in the latter cases, the desire for consumers for comparisons.[15]

Urbanism

Perhaps the first thing that strikes an observer of our cities is the tremendous change of rural to urban population during

the last few decades. Though change is constant it is the accelerating rate of change in the age of automation which has wrought havoc with the "good old times". Changing life styles are part and parcel of rapidly growing urban areas. The increasing acceptance of urbanism as a way of life has ushered in an urban society which exhibits an increasing affluence among the greater proportion of its members. The shorter work week, which is a consequence of automation, is making its appearance felt.[16] Increasing leisure time and recreational pursuits are bywords of a more affluent society. The impact this has had so far on the urban scene is the increasing emphasis that is placed on the development of leisure time amenities and urban open spaces.[17]

Another phenomenon of the age of automation is the increasing geographic mobility of the North American population. It is a fact that one out of five persons in the U.S. is now moving every year.[18] This means that a working person in his life is likely to change his residence eight times and two or three of them would involve moves to an entirely different community. One consequence of this greater mobility is the loss of personal contacts with relatives and neighbours who are left behind.[19]

In addition to urbanism as a way of life and increased geographic mobility, differences in urban residential location are becoming more pronounced. The growth of the city under a free enterprise system, or under any non-centralized system, is leading to a high degree of differentiation of residential areas by type of structure, quality of housing and levels of rental values. Under a market system of allocating housing, where people live depends in large measure on the rent or sales price they pay. A considerable degree of residential segregation results between persons in various income brackets and between persons in various occupations. However, recent findings clearly indicate that racial and ethnic residential segregation are more than just economic discrimination. They have also led to the high degree of differentiation of residential areas, because even where economic differentials are diminishing, racial residential segregation persists.[20]

Megalopolis

The large scale movement of population into the outer rings of metropolitan areas is, according to Jean Gottmann, ushering in a new phase of metropolitan development which he calls Megalopolis.[21]

In regions such as the north eastern seaboard of the United States the outer rings of metropolitan areas have expanded to overlap with outer rings of other metropolitan areas. The result is a continuous band of urban and suburban development. This phenomenon is also called "strip city", "city region" and "super-metropolis".

> The words megopolis and megalopolis are being heard with increasing frequency, usually applied to an almost continuous string of cities running from Washington, D.C. to Boston. . . .
>
> The pattern does not consist of a string of metropolitan areas standing shoulder to shoulder, fighting for space like a crowd in a subway, but of metropolitan areas in a functioning group, interacting with each other. In the same manner that economic development has made the size of the typical nation inadequate and has called for super-nations, it seems that soon - at least in historical time - urban units will go beyond the scale of the metropolis to the scale of the megalopolis. And just as the metropolitan area is not made up of an accumulation of little cities complete in themselves but on a system of specialized and therefore dissimilar areas, the various metropolitan units of megopolis will specialize and become more different from each other than they are today.[22]

There are over a dozen areas in North American that could develop the same urban megalopolation form as the north eastern seaboard. For example, in California most of the population is in the densely populated San Francisco Bay areas and in sprawling Los Angeles. Indications now are that people

eventually will fill an almost solid population belt running between the two areas through the Central Valley of California.[23]

Urban Form and Structure

There have been many efforts to analyse the form and structure of cities. "Form" means the physical pattern of land use, population distribution and service networks, while "structure" signifies the spatial organization of human activities and inter-relations.[24] Ideas such as Ebenezer Howard's Garden City movement and Frank Lloyd Wright's Broadacre Concept have had considerable influence in the decentralization argument while opposing views have reflected the "Save the Central Cities" movement. An example of a scheme developed for the retention of the central city was put forward by L. Hilberseimer during the early 1940's, based on a "settlement unit".[25] Such a unit contains all the essentials of a small community within itself and each unit is in turn connected to other units to create an overall system of self-contained centres. Hilberseimer's study applies such a system to the City of Chicago. Recent efforts to analyse urban form and structure have focused attention on basic theories similar to Hilberseimer's appraoch instead of being largely intuitive as in earlier concepts. More scientific

methods of analysis using computer techniques have been developed. With the use of models, many alternative forms of growth and change can be examined. Emphasis on transportation analysis has led to schemes such as the Year 2000 Plan for the National Capital Region[26] and more recently to the Penn-Jersey Trasnportation Study, where future growth possibilities have been presented with clear alternatives. In the Penn-Jersey Study, since transportation policy was the factor most directly under the influence of the study's policy committee, alternative transportation systems were taken as the starting point for investigating different possible regional growth patterns.[27]

Many theoretical studies of transportation and urban form have been made by planning teams, such as the proposal for North Buckinghamshire in England,[28] and by architects such as J. Weber in his "Linear City Development" in 1965,[29] but few of these radical ideas have been implemented.

On a more academic basis there have been approaches to the theoretical studies of urban form and structure by use of models as exemplified by Melvin Webber and Kevin Lynch. Webber[30] suggests that most of the models used currently are based on "static descriptive" relationships such as density gradients of population, rates of decline of manufacturing and

other relationships observed in existing spatial patterns. These models concentrate on the results rather than on the cause of urban form. He stresses the need for analysis of the "dynamic behaviour" aspects of urban structure. Lynch and Rodwin suggest in their model,[31] which deals with physical form, that this approach should be followed by studies of the "activity pattern" and its effect on urban form. Recent studies for the New Town of Columbia in the State of Maryland takes this approach and offers a better understanding of models in integrating transportation and urban form.[32]

Theoretical Concepts

There are many choices for future urban form and structure. Catherine Bauer Wurster outlined four broad alternative approaches.[33]

(a) Present Trends projected. Region-wide specialization with most functions dispersed but with a push toward greater concentration of certain functions in the central cities. Perhaps unstable, likely to shift toward one of the other alternatives. . . .

(b) General dispersion. Probably toward region-wide specialization of certain functions but a considerable degree of sub-regional integration might be induced.

(c) Concentrated super-city. Probably with a strong tendency toward specialized sectors for different functions.

(d) Constellation of relatively diversified and integrated cities. With cities of differing size and character, a range from moderate dispersion to moderate concentration would be feasible.

Any one of these four alternatives could probably apply in North America, depending on differing local conditions.

The city of Los Angeles has recently carried out a study on urban form and structure and the following four alternative concepts for urban growth were outlined:[34]

(a) Centres Concept. This concept envisions large regional concentrations of residence and employment, which would be the focal points for solidifying new growth in the metropolitan area. It proposes a city of a highly urban character, while preserving single-family residential areas and natural amenities. It attempts to minimize travel distances between home and places of daily occupation. . . .

(b) Corridors Concept. This concept proposes a highly urbanized metropolis, with concentration of employment, commercial services, recreational favilities and high density apartments located in corridors extending outward from the . . . . metropolitan core. This concept would require a mass transit system. . .

(c) Dispersion Concept. This concept seeks an even distribution of activities, which would accommodate growth while preserving the characteristics that make Los Angeles unique among major cities; decentralization, owner occupied homes, and the automobile with its flexibility of movement. This concept attempts to keep travel distance from home to work and other daily activities at a minimum, by having jobs, consumer services, recreation and public facilities located close to the resident population. . . .

(d) Low Density Concept. This concept seeks to preserve the present residential patterns and life styles of Los Angeles. It emphasises the single-family detached house with low rise apartments in about the same proportions as now. The automobile would continue as the predominant means of transportation. . . .

The four alternative concepts for the urban growth of Los Angeles are not unlike Catherine Bauer Wurster's four theoretical alternatives.

Nodular Metropolitan Concept

The Nodular Metropolitan Concept is another alternative for urban growth and development. This concept, which is the basis of the group study, is found to combine elements of both the Centers and Corridors Concept as outlined in the Los Angeles Study.[35] For purposes of clarification at this stage of the study the following assumptions are made:

(a) Located in a large North American metropolitan region, containing a broad base of varied land use and widely diversified employment and offering a range of residential types.

(b) A region of highly urban character with a concentrated central core.

(c) Developed as a concentration of growth nodes at intervals along major transportation corridors. These

nodes become centres for mixed usage or single uses of large proportions.

(d) Preservation of outer single family residential areas and existing natural amenities.

(e) Development of large areas between nodes as public recreation and open space.

(f) Development through a comprehensive plan which co-ordinates the tools of capital budgeting, proper enabling legislation and programmed phasing.

It is envisaged that this system will bring about a higher standard of living, create more opportunities for the enjoyment of the city and provide an environment which will stimulate and support present and future generations.

To achieve this desirable urban condition for the city, the need for increased participation by public and private sectors has been acknowledged.[36] It is likely that totally new means of land use control and administration would be needed. The enormous problem of rebuilding our cities will most certainly require the most advanced technology, especially in transportation and building.

Transportation Technology

There have been in recent years many innovations and research

into modes of travel that, if implemented, could possibly play a significant role in making our cities more livable. Three recent innovations are:

(a) Conveyors or moving sidewalks

(b) Automated electric roads

(c) Mini-cars.

(a) Conveyors. The first proposal for implementing the moving sidewalk was in 1893 for the Columbia Exposition at Chicago and later at the Berlin Exposition in 1896 and Paris Exposition in 1900.[37] Because of the problem of low speed and other practical difficulties in its day to day use, the moving sidewalk has not come into extensive use as an integral part of the urban transportation system. Its application seems particularly suitable where large numbers of people have to move between two levels or along corridors, e.g. at big airports (Los Angeles, San Francisco, Montreal) to save the passengers from a long walk, and in department stores where it can be used conveniently by trollies and prams. Along with escalators, the conveyor has potential for use in high density nodular developments.

(b) Automated Roads. The General Motors Laboratories and Radio Corporation of America have been experimenting with automated roads with considerable success. A single cable is buried in a shallow trench just beneath the surface of the road and this cable, when energized, gives guidance through an electronic apparatus connected to the vehicles steering system. Secondary cables and detection loops adjust the speed of cars, keeping them at safe distance behind the one in front. General Motors estimate that vehicles could cruise in groups safely at a controlled speed of 70 m.p.h., giving a capacity of 9,000 vehicles per lane per hour, the equivalent of building five additional lanes of motorway.[38] The cost of construction of such a system, would compete favourably with contemporary highway construction.[39]

(c) Mini-cars. Mini-cars have come to the forefront only in recent years. Their sudden importance can be attributed to:

i. A critical shortage of parking space in the central core

ii. The extremely high costs involved for providing additional parking

iii. An increasing concern for air pollution in our cities.

Although no "on the road" model has yet been developed, many companies have produced prototypes. The most widely known mini-car is the StaRRcar (for self transit rail and road) invented by William Alden. The StaRRcar can be driven along streets until the driver requires a faster speed in which case he merely drives up a ramp to an elevated track joining, say, a 60 m.p.h. train of vehicles. On pressing a dash-board button the vehicle is automatically ejected at its pre-selected exit. A mass shift to the use of StaRRcars would help alleviate the congestion on the road network and would also decrease the problem of inadequate parking spaces in the central core of the cities as three StaRRcars can fit into the space previously occupied by one conventional car.[40]

Other modes of transportation include the monorail, cushion craft, vertical takeoff and landing and helicopters. In recent

years millions of dollars have been spent on development but their application has been limited to special purposes like the mini mono-rails for secondary transportation at Expo '67 and the helicopter service between Kennedy Airport and downtown Manhattan. For mass passenger transport they apparently still lack the economies necessary to provide a truly cost competitive corridor service.[41]

Building Systems

There are numerous illustrations of advanced ideas in building systems that could possibly provide for high density core living for the future city dweller. Three recent illustrations are:

(a) Habitat. With the advent of Canada's Expo '67, the development of Habitat became a possibility. Moshe Safdie, the designer of the project, has used a basic building unit in various combinations to develop a number of housing types. Habitat has developed vertical and horizontal circulation systems creating three-dimensional spaces.[42]

(b) Intropolis. A. Watty, the designer, has developed Intropolis as a system of multi-use blocks that can be connected in various ways to create higher or

lower density of living spaces which are organized on a rational basis to give maximum flexibility and interaction. Three-dimensional spaces and circulation systems are evident as in Habitat.[43]

(c) Urbanisme Volumetrique. This system is based on expanding structures leaving the ground free. A three-dimensional tubular structure with a series of slabs provides terraces for various builders to erect buildings, or to lay out roads and open spaces to create artificial landscapes.[44]

The detail description of any single land use and related building technique as it could be applied to the nodular metropolitan concept of urban growth is beyond the scope of this study (see matrix, Figure 1).

Urban Pattern

With few exceptions, the form of North American cities is based on the grid pattern.[45] Chicago, New York, San Francisco, Montreal and Vancouver are all examples of grid layout used to subdivide land and in providing services. It has been a quick solution to rapid development in any direction and a direct result of large scale surveying emphasis. Depending

on local physiographic features, the access to all properties is nearly equal, and theoretically the only factor that affects a property's locational value is its relationship to the central core. The grid has been applied to such varied terrains as flat prairie and steep hillside. San Francisco is a good example of the latter.

Social and Spatial Systems

It appears that the changing urban form and structure is a process of continuous urban growth and development. This growth and development is an expression of the existing socio-cultural system.[47] There are certain social indicators, which are not only demographic in nature, but also of a social behavioural nature. Demographic characteristics are generally an expression of the growth, size and age composition of a population. But underlying this are social behavioural characteristics, namely the practices of a society, which are expressed in activities and responses of the population. These practices of a society to some extent determine the spatial characteristics of the land.[48] Thus, a relationship between social and spatial characteristics exists.

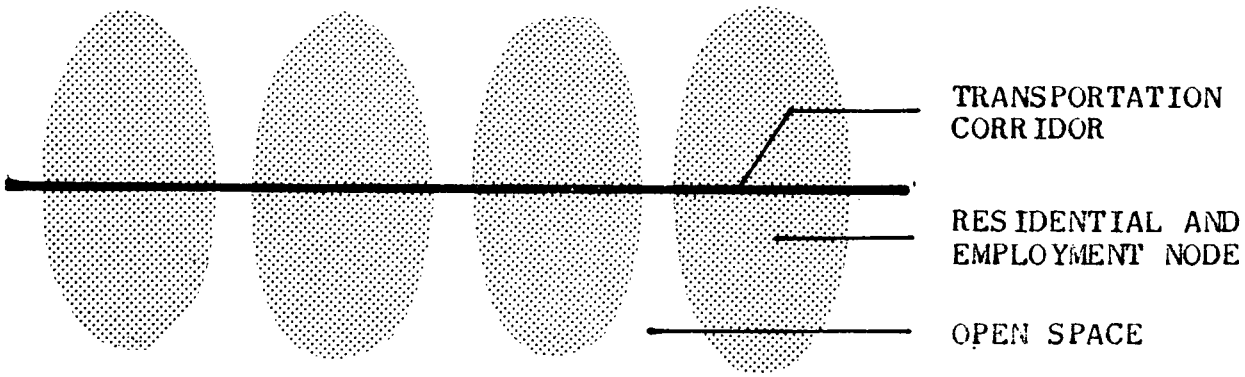
When changes are introduced in the urban growth and

development process, they usually have an impact on the internal social and spatial relationship of the urban system.[49] These incremental changes of the internal state of the urban system may range from "fixed" to "variable" states. Any shifts of the internal system from one state to another occur over time. These shifts represent incremental changes, depending on social reference structures and environmental manipulation. While there may be a number of external conditions which affect the urban system, there are at least two which should receive close attention in urban growth and development analysis; namely those as a result of chance, where change is due to aggregate individual action.

Group Hypothesis

A review of the preceding concepts indicates that the nodular concept should be studied. Therefore the following hypothesis is formulated.

> That a Nodular Metropolitan Concept provides a useful basis to initiate a study of urban living and planning.



Scale

Approx. 1m.

Figure 2

Nodular Metropolitan Concept

Individual Thesis Topics

The topics chosen for individual research are as follows:

1. Ian W. Chang - "The Problem of Private Investment in Urban Redevelopment".
2. Ashok G. Shahani - "The Nodular Metropolitan Concept: Some Transportation Aspects."
3. Monica H. Lindeman - "The Nodular Metropolitan Concept: Some Social and Spatial Aspects."
4. Ronald E. Mann - "The Role of the Time Element in the Urban Renewal Process."
5. Arthur R. Cowie - "The Provision and Distribution of Local Open Space in Urban Residential Areas."

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(2) Lowdon Wingo, Jr., Cities and Space, (Baltimore: John Hopkins Press, 1963), p. 11.

(3) Wilfred Owen, The Metropolitan Transportation Problem, (New York: Doubleday & Company Inc., 1966), p. 1

(4) "What Kind of Cities Do We Want", Nations Cities, (Vol. 5, No. 4, April, 1967), p. 18.

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(6) Los Angeles City Planning Department, "Major Issues for Los Angeles" May 2, 1966, p. 4.

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(12) W.R. Thompson, Op. cit., p. 355.

(13) Interview with Dr. Edward Highbee, Vancouver, B.C. November, 1967.

(14) Interview with Dr. Walter Hardwick, Vancouver, B.C. April, 1967.

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SECTION II

THE NODULAR METROPOLITAN CONCEPT

TRANSPORTATION ASPECTS

CHAPTER I

INTRODUCTION

General Statement of the Problem

With the prospects of the population in America and Canada doubling by the year 2000 A.D. and the urban wealth increasing almost fourfold,[1] the world in general and planners in particular, are faced with a problem of considerable magnitude: that of providing shelter and other urban facilities for the people at standards that will be socially, economically and aesthetically acceptable to them. The magnitude of this problem is more vividly understood when it is expressed in terms of figures and numbers.

Homer Hoyt in his paper "Changing Patterns of Urban Growth, 1959-1975" suggests that "between 1958 and 1975 the population is expected to increase by fifty million or approximately fourteen million new households will have to be constructed."[2] This, he says is not all. Because of the changing habits of living, new innovations in the technology of transport, and new inventions in other related fields, buildings tend to become obsolete after

a physical life of fourty to a hundred years. To balance the physical obsolesence of buildings, he estimated, will require the construction of at least another ten million new households. In all, he estimated that, ". . . by the year 2000 A.D., . . . , there would be a demand for fifty million additional units in excess of the present supply."[3] In terms of capital investment there is no doubt that almost astronomical sums will have to be spent. "Between now and the 2000, someone will have to put up close to one thousand five hundred billion dollars for new and renewal nonfarm housing alone: One thousand billion dollars for new replacement commercial, industrial and utility construction; and at least another thousand billion dollars for all of the new and better community facilities needed to go with the new and better housing."[4]

Our problems would be hard enough to solve in a static urban economy, with a static urban population, a static social mix, and a static transportation method and system - but our urban economy and population is anything but static and is undergoing great simultaneous changes. But, regardless of the magnitude of these difficulties, the problems have to be overcome and within the next generation we will not only have to

build new towns and expand our existing ones, but, also to some extent, reconstruct and restructure segments of the existing ones to suit changes in technology and human values. The approach taken will have to be an all inclusive comprehensive one because we want the cities of the future to be far better places to live in than the cities of today.

The planner then, before he sets out on this tremendous task of designing for the future, must fully understand and be aware of the people he is planning for, their needs and desires, and what makes them and their city tick. To achieve the desired results he must also understand the existing trends and factors influencing and shaping urban structure and growth. As interesting as this may be, it is too vast a topic to be satisfactorily dealt with under the existing limitations of time and space.

The role that transportation plays in shaping the urban environment is no doubt a very major one. It is also realized that economic, technological, topographical and certain other factors play an important role too. To investigate fully the impact of the several facets of transportation on urban form is once again too vast a subject to be covered in this thesis.

The fact that traffic attraction and generation is a function of land use, factors like car ownership, family income, family size, residential density, etc., has been well documented by Voorhees, Blumenfeld, Mitchell, Rapkin and others. But what has not been researched and sufficiently documented is the influence that transportation facilities have on urban structure and urban growth.

Purpose of the Thesis

Professor G.C. Hemmens, Ass't. Prof. of Planning, University of North Carolina, in his paper "Experiments in Urban Form and Structure",[5] has developed a linear programming model for studying the impact of alternative transportation systems on different urban structures. One of his conclusions is ". . . Alternative transportation systems do not effect the relative efficiency of alternate land use patterns [and so] spatial patterns of land use and the patterns of transportation service can be planned somewhat more independently than is commonly thought".[6] These conclusions appear to be contradictory to the widely accepted relationship that the supply and demand of transportation services is a function of the land use (the activities).

This thesis, using the model as developed by Prof. G.C. Hemmens, will try to show that the above conclusion is questionable and that in fact alternate transportation systems do have a differential effect on the efficiency of alternate land use patterns.

Hypothesis: "Alternate transportation systems do effect the relative efficiency of alternate land use patterns."

Definitions

To achieve a certain amount of consistency in expression, a few of the terms used often in the thesis are defined below:

Cities:	is used synonymously with metropolis.
Land use:	when used refers to the activity and not the physical use.
Accessibility:	is used as function of travel time.
Transportation facility:	when used with reference to Prof. Hemmen's paper implies the road network.
Urban form:	is the physical arrangement of residences, work places, etc.

Urban structure: is the pattern formed by the connection of these elements in the daily activities of the area's residents.

Urban Growth: involves an increase in size and also an adjustment to size. It may be measured in the following ways -

i) Increase in population density

ii) Increase in dwelling units/acre

iii) Increase in business units/acre

iv) Increase in employment.

v) Increase in retail sales.

Efficiency: is used in the context of minimizing travel line.

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(3) Ibid., p. 3.

(4) Nation's Cities, op. cit. p.20.

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(6) Ibid., p. 9.

CHAPTER II

HISTORICAL ISSUES IN URBAN TRANSPORTATION

Impact of Transportation Systems on Urban Structure

Transportation has always played a very important role in the growth and development of this world. Were it not for an extensive and efficient system of roads the great Roman empire would never have become united.[1] Were it not for revolutionary developments in the technology of shipping, man's horizon may still have been limited to his near surroundings and the treasures of the 'new world' evaded him forever. Were it not for the development of fast automated transport, like the streetcars and the automobile, our settlements would not have been the large, diverse, and exciting cities that they are today.[2] The role that transportation (railroads, air, roads and pipelines) has played is nowhere more evident than in Canada where the Canadians have succeeded in building a nation in defiance of all the facts of geography, of history, of economics, and ethnic and cultural differences.

Transportation has played an equally important role in uniting and sustaining the city and helping to serve the reason

for its (the city's) existence; mutual accessibility-primarily, though by no means exclusively, mutual accessibility of place of residence and place of work. Each new innovation in the technology of transport, from the days of walking as the only means of locomotion to the present days of the automobile, has had a revolutionary impact on the form and structure of man's settlements and its location. The following paragraphs will discuss the impact of transportation on urban structure and not its influence on the location of cities.

In the early days when walking was the only means of transport, the settlement was limited to a size which could conveniently be covered by walking within a reasonable period of time. People lived where they worked or at least very close to it and the settlement tended to be uniformly dispersed and the land uses mixed.[3] The streetcars, from their horse-drawn origin in the first half of the nineteenth century, were an inexorable force in moulding the American city. With an average speed of four miles an hour the practical radius from the core of the city to its outermost built-up point increased to roughly two miles during the horse-car period.[4]

The electric streetcar with an average speed of ten miles an hour permitted expansion out to a distance of about five

miles from the city core.[5] This expansion was not uniformly dispersed in all directions and was in fact restricted to narrow strips on both sides of the streetcar lines and with spaces of undeveloped land in between, resulting in finger like patterns of development. The coming of the suburban railroad brought another change in urban structure. As the technology of steam railroad dictated few and widely spaced stations, a pattern of small settlements developed, strung out over a considerable length of railroad line with a small commercial center at each station.[6] This is to some extent evident in Chicago where residential areas grew up along the suburban railroad routes and also in New York where the commuter trains led to the development of suburban homes in Montclair, the Oranges, Maplewood in Jew Jersey, Bronxville in Westchester, and Hampstead on Long Island.[7] With the electric streetcar, stops were far more frequent, so the dots merged into solid and short bands with commercial concentrations at their intersections.

With the coming of the automobile the mobility of the people increased considerably and the structural pattern of developed and open-land, which had begun to emerge in the railroad and streetcar eras, was submerged in universal sprawl.[8]

In cities where car ownership and roads are so universal as to make accessibility merely a function of a straight line distance, the impact of the location of transportation facilities on the structure of land use becomes quite modest and limited and any substantial modification of the pattern of ubiquitous sprawl can be brought about only by considerable changes in public opinion and public policy.

Thus it seems that the role that transportation systems have played in determining the specific shape of a metropolitan area has depended on the number of different types of transport modes that have served the area and the difference between their speeds. Where the difference has been very great, a pattern of isolated developments has resulted. But whenever a means of individual transport has predominated, and accessibility has been uniform in all directions, urban growth has also tended to be uniformly distributed. Residences and industries have tended to scatter out and occupy all the available land. Of course, economic considerations and social, technological, geographical and climatic factors also play their due role in influencing their choice of location. In fact, these factors have become increasingly more important in this day and age of affluence and increased mobility and flexibility which the automobile has provided.

To conclude this discussion without mentioning the role that the inherited urban pattern has played in shaping the present day American and Canadian city would be a gross mistake. Perhaps, one of the most significant factors which has influenced the urban form of present day American cities is the inherited gridiron system of streets.[9] But, on the whole, the present urban form is not the result of any single factor but of several interacting forces and the superimposition of urban forms of the past eras.

Metropolitan Transportation Crisis

Alvin Hansen, a prominent economist, in assessing the economic problem likely to confront the United States during the next twenty years felt that the most important ones would be those created by the rapid increase in urbanization.[10] The truth of this observation is even now being borne out by the ever presence of numerous street congestion, traffic deaths, transit strikes, housing shortages, racial riots and the problems of pollution and destruction of the natural environment. The important role of transportation in moulding the urban environment was recognized by President John F. Kennedy in his message to the Congress on transportation, April 6, 1962.

> Our national welfare. . . requires the provision of good urban transportation with the proper use of private vehicles and modern mass transport to help shape, as well as serve, urban growth. . . .[11]

It is perhaps not inappropriate at this stage to stress that although the metropolitan transportation problem is a critical one facing cities today, it is actually just one of the several problems arising from rapid urbanization. The sheer variety of needed urban services reflects the fact that the sources of urban problems are much more complex than a clear-cut inadequacy of transportation facilities. Even the metropolitan transportation problem is multi-dimensional and in itself a set of several problems.

One facet of the problem is the rapidly increasing urban population and their increasing affluence and car ownership rates. This has increased the mobility of the people and also their freedom in the choice of location of households and industry. Residences, offices and industries have been moving out of the congested central cities and to the suburbs. Open countryside has rapidly been replaced by single family residential subdivisions resulting in what has come to be called "urban sprawl". This separation of the place of residence from the place of work has resulted in heavy pendulum like uni-directional traffic flows, often far in excess of the street

capacities, resulting in severe peak hour congestion problems. And often, for the remaining part of the day these facilities are under-utilized. Also, the road network being used is of the pre-automobile era and was never designed for the automobile. In short, these roads are often outdated, outmoded and inadequate, and wrongly used for both local circulation and through traffic.

Another facet contributing to the problem has been the decreasing patronage of the public for mass transit. This has had a four fold impact on the problem. One, that of increasing the traffic and so the congestion on the roads; two, increase in the demand of terminal parking facilities; three, that of under-utilizing the greater capacity of transit for carrying traffic; and four, making it more difficult for the transit companies to replace old stock because of financial problems. The transit industry is therefore facing a serious financial crisis and many transit companies have had to close down and others are not making enough to even cover operating costs leave alone replacing old stock. Very often demands are made for the transit companies to be self-sustaining and at the same time restrictions are imposed on them against raising fares so as to enable them to meet costs. On some occasions when fares

have been increased the ridership has decreased, thus, extending the "second-order" effects.

There are of course some cities where the transit companies are not facing a crisis. The transit authorities in Houston and Dallas are making profits. But this is attributed to the rapid increase in their population since 1940. This has led to the increased transit patronage.[12] Cleveland is another city where the transit authority is financially well off. To some extent this success can be attributed to the high parking rates in downtown Cleveland and to the timely purchase of the transit system by the city at a low price in 1942. The heavy war-time traffic that followed helped to write off the debt by 1952. Later, in 1958, the transit authority was exempted from paying taxes and it also appropriated thirteen miles of electrified track at a very low rate.[13] In addition to these boosts the transit authority has made considerable efforts to provide for the convenience of the riders. Suburban stations have been provided with convenient and adequate park-n-ride facilities and simplified and automated ticket vending machines have been provided for the passengers. An important factor, but one that has been difficult to explain, is the cultural conditioning of the people of Cleveland which makes them quite willing to travel

by transit.

These are some of the problems of urban transportation. They call for a consolidation of the transit industry under a metropolitan wide organization and for financial and administrative reforms.[14] Equally important, they call for an over-all comprehensive approach towards transportation planning and full coordination with all other aspects of urban planning. . . "the traffic engineer who only tries to accommodate the private auto is doomed to inevitable failure. . . the better he does his job the greater will be his failure."[15] Constructing freeways, expressways, and the necessary terminal facilities is extremely expensive and they invariably get used to full capacity, and more, long before the design period of the facility. This should not mean that mass transit alone is the answer to the problem. The different types of transport modes are suitable for different circimstances. For the total metropolitan transportation system all modes, the auto, the transit and walking must be used in a balanced fashion. And, balance is said to be achieved when ". . . each of the several transportation modes yield the greatest net benefits after the capital and operating costs of the particular transportation modes are deducted from the value of user and non-user benefits that can be realized. . ."[16]

(1) Lee, Norman E., Travel and Transport Through the Ages, Cambridge University Press, (1951), p. 50.

(2) This is also expressed by A.M. Carr-Saunders in his Forward to Dr. Kate Kieppmann's "The Journey to Work", London, Kegan, Paul, Traubner & Co. Ltd. (1944) p. v.

(3) For further discussion refer to: Lewis Mumford, The City in History, Harcourt, Brace & World, Inc., New York, (1961).

(4) Smerk, G.M., "The Streetcar: Shaper of American Cities," Traffic Quarterly, volume XXI, number 4, (October 1967), p. 570.

(5) Ibid., p. 572.

(6) Blumenfeld, H., "The Urban Pattern", The Modern Metropolis, ed., P.D. Spreiregen, The M.I.T. Press, (1967), p. 56.

(7) Hoyt, Homer, "The Pattern of Movement of Residential Rental Neighborhoods," Readings in Urban Geography, Ed. H.M. Mayer and C.F. Kohn, The University of Chicago Press, (1959), p. 505.

(8) Blumenfeld, op. cit., p. 55.

(10) Hansen, A.H., Economic Issues of the 1960's, McGraw Hill, New York, (1960), pp. 181-182.

(11) Meyer, J.P., Kain, J.F., Wohl, M., The Urban Transportation Problem, Harvard University Press, Cambridge, Massachusetts, (1965), p. 1.

(12) Owen, Wilfrid, The Metropolitan Transportation Problem, The Brookings Institute, Washington, D.C., (1966), p. 108.

(13) Ibid., p. 109.

(14) For a further discussion of the crisis facing the transit industry refer to:
Wilfrid Owen, op. cit.

(15) Blucher, W., "Moving People--Planning Aspects of Urban Traffic Problems," Virginia Law Review, Vol. 36. (November 1950), p. 849.

(16) Wilbur Smith and Associates, Transportation and Parking for Tomorrow's Cities, New Haven, Connecticut, (1966), p.

CHAPTER III

MODELS IN PLANNING

Introduction

As the urban planning profession matures, the need for revision, improvement and refinement of techniques is becoming increasingly evident. Experience has indicated that the planning techniques of the past are not always reliable and have often misled the planner. Recent research indicates that people's behaviors assume limited patterns and often mathematical formulae can be developed to express travel behavior and forecast land use patterns.[1] This has encouraged the development of the new field of 'models' and its application to several disciplines e.g. city planning, traffic engineering, regional science, economics, sociology, etc. People in these fields have reacted differently to this new technique. Some, suspicious and unable to fully comprehend the mathematics and technical jargon, have rejected it on the argument that 'models' are not realistic. Others, fascinated by the computer hardware used and the mechanical simplicity of solving long tedious problems, have got carried away. The real value of course lies somewhere in between,

and professionals are beginning to realize the advantages offered by the use of models in city planning and related disciplines. What is important is to fully understand the limitations of the process, the input data and the assumptions before evaluating the output from the model.

Definition and Purpose of Model

The term 'model' seems to mean different things to different people. Britton Harris defines a model as ". . . in general a somewhat simplified abstraction of the real world".[2] More specifically, a model can be defined as ". . . a way to express significant causal and structural relationships stripped of the irrelevancies and complexities of the real world, so that they may be more readily understood."[3] Thus, models do not necessarily have to be mathematical equations. Block diagrams, flow charts, and activity analysis diagrams can also be considered as models.

Models can be of several types and an attempt to classify and explain all the different types in an orderly manner is beyond the scope of this chapter. Nevertheless, a simplistic approach as shown in figure 2.1 has been suggested.

At the most general level models can either be mathematical or non-mathematical in nature. "A mathematical model

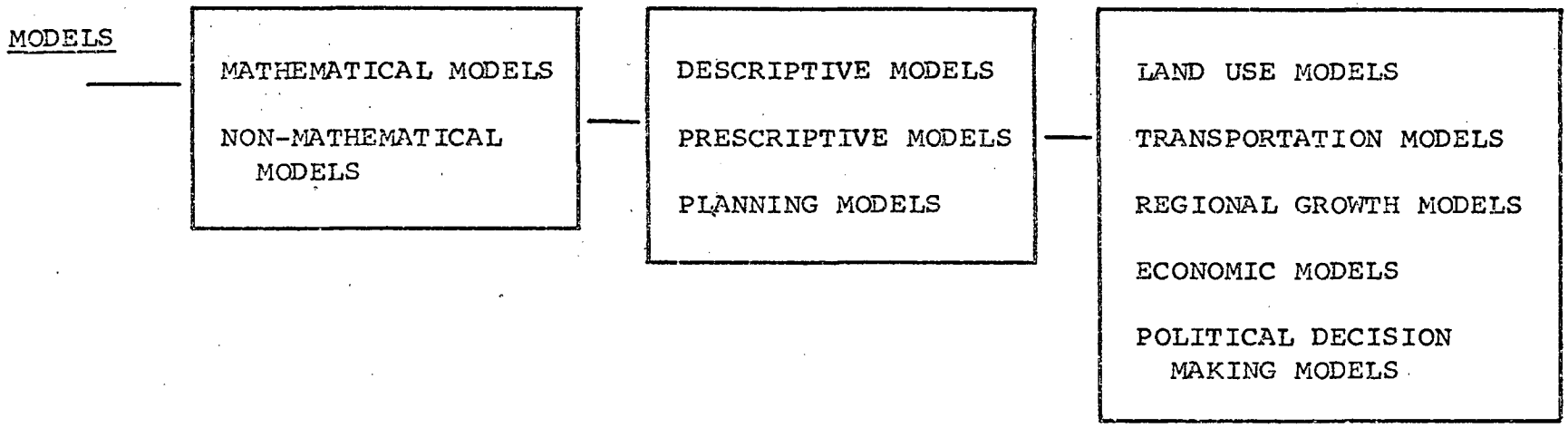


FIGURE NO. 2.1 A SIMPLE CLASSIFICATION OF MODELS

is a set of quantitative relationships expressed in the language of mathematics and describing the interaction of phenomena."[4] Whereas, a non-mathematical model expresses relationships between events verbally in the form of statements or graphically in the form of diagrams. Models can further be classified as descriptive models, prescriptive models and planning models.[5] Descriptive models are used only to help simulate the relevant features of an existing urban environment or of an already observed process of urban change. They are therefore static in nature. The prescriptive models deal with the important relationship between urban form and the urban process. The model specifies a causal sequence and knowing the future value of the "cause", the future value of the "effect" can be predicted. Planning models go a step further and evaluate the "effect" in terms of the planner's goals. Finally, there are land use models, traffic models, regional growth models, economic models, and political decision making models.[6]

Limitations

John Dakin in his article "Models and Computers in Planning" states that "the purpose of such models is to discover order in the data obtained so that some understanding of the structure

and functioning of the region can be reached."[7] Here, of course, he is referring only to descriptive models. In a broader sense models can not only help us to understand the interrelationship between several variables, but also to highlight the more significant ones, and the impact changes in these variables will have on urban growth and structure. For example, models can help us to predict fairly accurately the consequence of varied governmental policies on land development. Such a model has been developed by Prof. S. Czamanski.[8] They can help us to evaluate the impact that rising income, improved transportation services, extension of sewer and water systems, zoning laws, etc., will have on land development.

Appropriately set up and applied, models give the planner a factual basis for planning and help him evaluate and test alternate plans.[9] Thus, he can estimate traffic volumes and patterns resulting from different arrangements of land use or for various transportation solutions. In short, with the intelligent use of models, the planner can outline alternatives more clearly and develope plans which are cognizant of changes in technology, urban structure and human values, and, at the same time, are explicit, dependable and complete in all respects.

Their use also results in substantial economies because of the lesser time and man-power requirements.

The superficial simplicity of models is often misleading. Their results must be evaluated with intelligence and caution. "The fact that any model is imbedded in judgement, intuition and guess-work should be remembered when we examine the results that come (with high precision) from the model."[10] Often, social factors because of their non-quantifiable nature cannot be included in the mathematical equations of the model. The results of the model have therefore to be suitably modified by the planner and their quality will depend on the individual planners judgement, experience and biases. At times, to make the model less cumbersome, a certain amount of accuracy is lost by using linear instead of non-linear relationships. And also, since past date is generally used as the input for the model, the danger of perpetuating existing trends always exists. It is therefore of critical importance to remember that the quality of the output from the model will only be as good as the quality of the data fed in, and "regardless of the machinery used it is to the assumptions and the limits of the problem that we must turn to when we ask for an explanation of the results of the

model".[11] In addition, an adequate knowledge of the mathematics and mechanics of the model is necessary to be able to find its weak links, for a single unsatisfactory element in the chain of reasoning will be enough to call into question the value of the whole model.

(1) Voorhees, A.M., The Nature and Use of Models in City Planning, Journal of the American Institute of Planners, Vol. XXV, No. 2, (May 1959), p.

(2) Harris, Britton, New Tools for Planning, Journal of the American Institute of Planners, Vol. XXXI, No. 2., (May 1965), p. 90.

(3) Wingo, Lowdon, Jr., Transportation and Urban Land Resources for the Future, INC., Washington, D.C. (1961). p. 9.

(4) Ibid., p. 9.

(5) Lowry, Ira. S., A Short Course in Model Design, Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May 1965), p. 159.

(6) For a detailed discussion of the several types of models refer to:
(a) Journal of the American Institute of Planners, Vol. XXV, No. 2, (May 1959).

(b) Journal of the American Institute of Planners, Vol. XXXI, No. 2, (May 1965).

(7) Dakin, John, Models and Computers in Planning, PLAN, Vol. 6, No.1, (July 1965), p. 12.

(8) Czamanski, S., and Chatterji, M., Regional Planning Model of of Nova Scotia Economy, Institute of Public Affairs, Dalhousie University, Halifax, Canada (August 1967).

(9) The approach of developing alternate transportatin plans and evaluation each using a set of models was used by the Penn-Jersey Transportation Study group in preparing an over-all regional transportation plan for the Camden-Philadelphia-Trention area.
For details about the approach and techniques used refer to:
(i) Penn-Jersey Transportation Study: Prospectus, Philadelphia, Pennsylvania, (Dec. 1959).
(ii) Penn-Jersey Transportation Study, PJ Reports, Volumes 1 to 3. Philadelphia, Pennsylvania.

(10) Specht, R.D., The Why and How of Model Building, Analysis for Military Decisions, Ed., E.S. Quade, Rand Corporation, Santa Monica, California, (1964), p. 77.

(11) Ibid., p. 77.

CHAPTER IV *

A LINEAR PROGRAMMING MODEL

Introduction

The model developed by Prof. Hemmens in his paper "Experiments in Urban Form and Structure" tries to examine the impact of changes in the components of urban form on urban spatial structure.[1] He takes as given the alternate distributions among sub-regions of an urban area of each of the following urban elements — work-place, shopping-place, residence; alternate systems of transportation service; and an allocation ~~site~~ rule which specifies the way in which residences will be linked up with work places and shopping places. He then asks what is the impact of changes in the components of urban form on urban spatial structure? The allocation is done by a simple linear programming formulation to minimize total travel time required for establishing a linkage between each residence and a work-place and a shopping-place. The criteria for evaluating the alternate urban forms are:-

(a) The efficiency of alternative urban forms in terms of minimum travel time requirements.
(b) The equity of alternative urban forms in terms of the locational advantages of residence location.

For the experiments conducted to substantiate the hypothesis proposed in this thesis the model is used in basically the same form as set up by Prof. Hemmens. But, due to certain limitations of the computer programme used[2] the number of residences in the hypothetical urban area have been reduced to 10,000 from 300,000. This however will not change the nature of the results.

In the first set of experiments conducted the approach differs from Prof. Hemmens in that the transportation systems superimposed on the twelve alternate urban forms are not geometrically symmetric. For the second set of experiments an attempt is made to refine the model. This is done by introducing two modes of transport (the private auto and transit) and modal split factors for all the residential zones of the hypothetical metropolitan area. Although this is a refinement on the model as proposed by Prof. Hemmens but it is still very simplistic in nature.

Mathematical Statement of the Problem

Find the Xij such that

$$\sum \sum C_{ij} X_{ij} = \text{Total travel time} = \text{a minimum} \quad (1)$$

Subject to: $\sum_{j=1}^{n} Xij = Oi \qquad i = 1 \ldots m \quad (2)$

$$\sum_{i=1}^{m} Xij = Dj \qquad j = 1 \ldots n \quad (3)$$

$$Xij \geqslant 0, \qquad Cij \geqslant 0$$

and $$\sum_{i=1}^{m} Oij = \sum_{j=1}^{n} Dij$$

where : Cij = travel time from zone i to zone j

Xij = trips from zone i to zone j

Oi = trip origins in zone i

Dj = trip destinations in zone j

The Dual Proglem is:-

$$\sum_{j=1}^{n} rjvj - \sum_{i=1}^{m} si\ ui = \text{locational advantage} = \text{a maximum}$$

where the constraints are:

$$vj - ui \leqslant Cij \qquad i = 1 \ldots m,\ j = 1 \ldots n$$

and

$$ui,\ vj \geqslant 0$$

si = trips sent from zone i

rj = trips received at zone j

ui = rental value of locations in zone i

vj = value to the trip maker of activities in zone j

Note: The 'Dual' is not dealt with in this thesis.

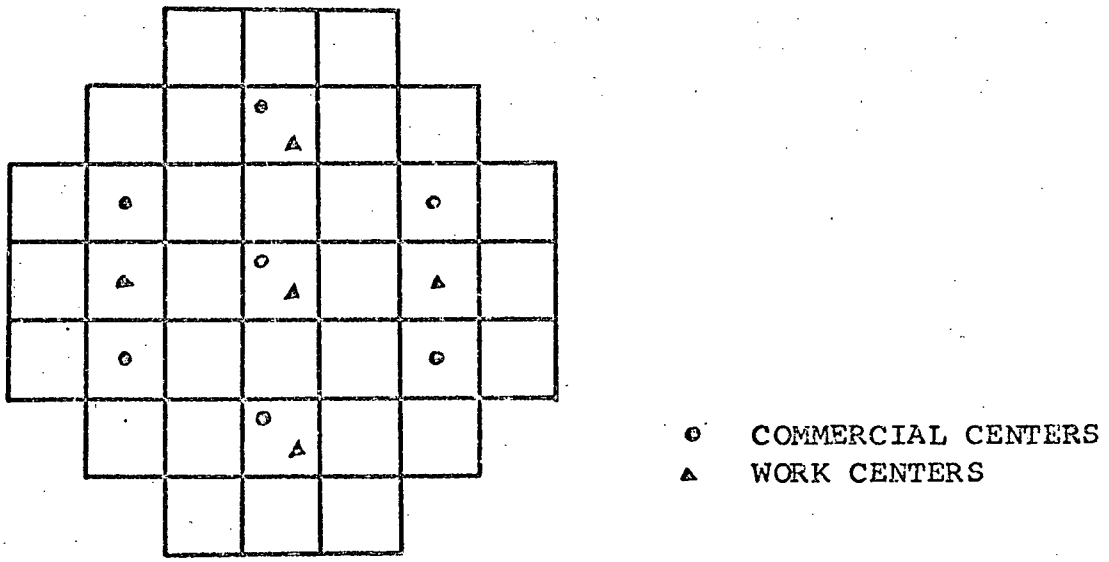


FIGURE 2.2 EXPERIMENTAL URBAN FORM

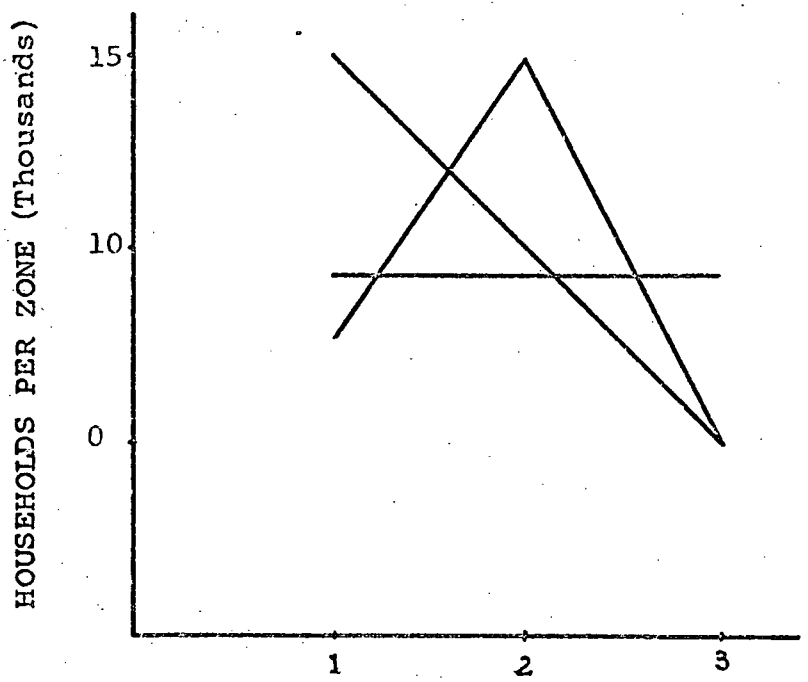


FIGURE 2.3 ALTERNATE RESIDENTIAL DENSITY PATTERNS

Elements of the Model

For the purpose of the experiment Prof. Hemmens chooses a hypothetical urban area as shown in figure no. 2.2. There are thirty seven zones of equal size and only thirty two of these may contain residences. There are five work centers. One is in the center of the urban area and the others are regularly spaced around the center. No residences are permitted in zones containing work-centres. Similarly, there are seven commercial centers. One is in the center of the urban area and the other six are distributed regularly around the center. There are three zones which contain both work-centers and commercial-centers.

There are three alternate residential density patterns, two alternate patterns of commercial-center and work-center capacity and three alternate systems of transportation service. The alternate residential density patterns are:

R1 - uniform density throughout the urban area.

R2 - high central density declining regularly with distance from the center, and

R3 - crested density, rising from a low value in the center to a highpoint and then declining (See figure No. 2.3)

The alternate patterns of work-center and commercial-center capacity are:

W1 and C1 - 70% of the jobs and 70% of the shopping opportunities are in the (geographic) center zone. The remaining 30% each of job and shopping opportunities are equally divided among the four outlying job-centers and six outlying shopping-centers respectively.

W2 and C2 - This is reverse of the above alternative, with 30% of the jobs and shopping opportunities in the center and the remaining 70% being equally distributed among the outlying centers.

The three alternate transportation systems are:-

T1 - Uniform level of transportation service through out the urban area. The travel cost of all zone to zone links is given the same arbitrary value of 2 time units. It is assumed that sufficient capacity to maintain this level of service will be provided. (see figure no. 2.4)

T2 - Superimposed on T1 are north-south and east-west links through the central zone from the periphery with a travel cost of 1 time unit (see figure no. 2.5)

T3 - Further superimposed on T2 is a ring of high service level also having a travel cost of 1 time unit (see figure no. 2.6)

The three residential alternatives, two commercial-center alternative, and two work-center alternatives can be combined into 12 different urban forms:

R1, C1, W1 - spread city with strong core
R1, C1, W2 - spread city with spread employment but strong commercial core
R1, C2, W1 - spread city with spread commercial but strong employment core
R1, C2, W2 - spread city

R2, C1, W1 - concentric city
R2, C1, W2 - concentric city with dispersed employment
R2, C2, W1 - concentric city with dispersed commercial
R2, C2, W2 - concentric city with dispersed commercial and employment
R3, C1, W1,- Ring city with strong commercial and employment core
R3, C1, W2 - Ring city with commercial core
R3, C2, W1 - Ring city with employment core
R3, C2, W2 - Ring city with weak core

These twelve urban forms along with the three transportation system alternatives result in thirty six different cases.

The population of the hypothetical urban area is assumed to be one million persons (300,000 residences) and one trip is made from each residence to a work-place and to a shopping-place. For the sake of convenience it is also assumed that roads are the only elements of the transportation system and all travel is done by individuals in private vehicles. Also, the only routes permitted are in the north-south and east-west directions from the center of one zone to the center of an adjacent zone. So a diagonal path through the area is composed of zig-zag right angle links. The travel time ~~of~~ or cost of travel from one zone to another is defined in terms of level of service provided rather than in terms of the design capacity and speed of physical facilities.

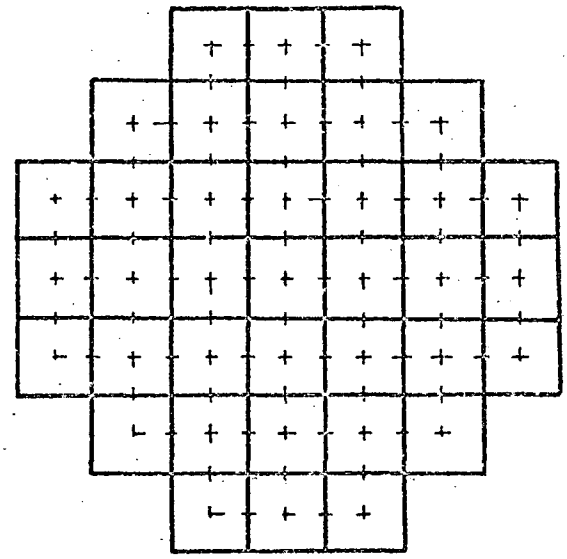


FIGURE 2.4 TRANSPORTATION ALTERNATIVE 1

TRAVEL TIME ON EACH LINK = 2

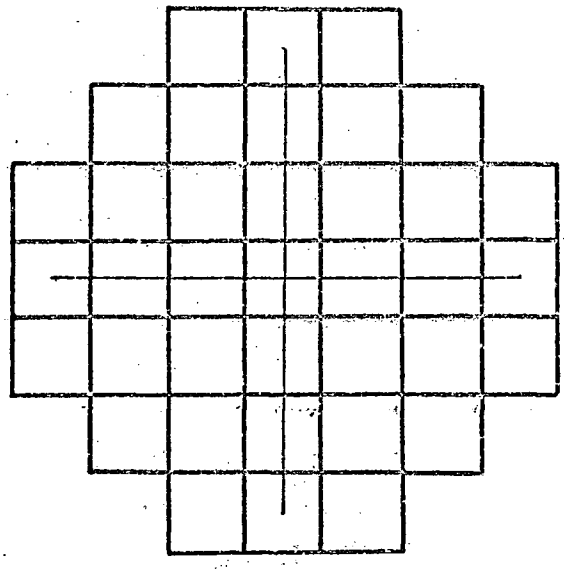


FIGURE 2.5 TRANSPORTATION ALTERNATIVE 2

TRAVEL TIME ON MAJOR LINKS= 1

ALL OTHERS = 2

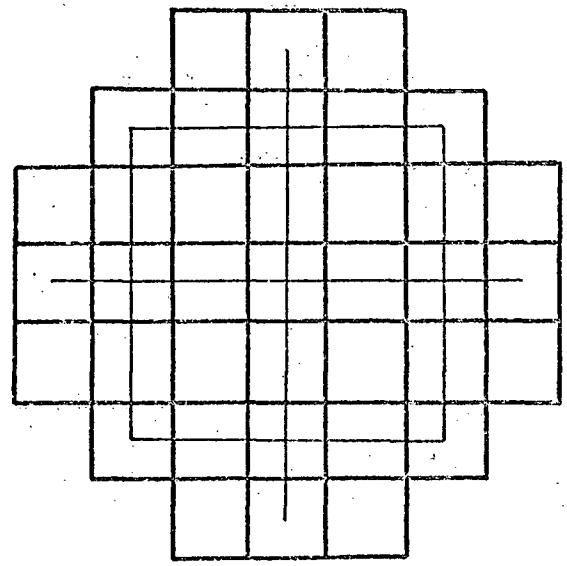


FIGURE 2.6 TRANSPORTATION ALTERNATIVE 3

TRAVEL TIME ON MAJOR LINKS=1

ALL OTHERS =2

Experimental Results and Conclusions

The impact of the three alternate transportation systems on the different urban forms in terms of minimum travel requirements, is given in table no. 2.1. The impact of the first transportation system (T1) on the twelve different urban forms is also sketched in figure no. 2.7.

On the basis of these results Prof. Hemmens feels that the most important finding is that the general ranking of urban forms by travel requirements found with uniform transportation service holds for all transportation alternatives. This means that at least for the particular alternatives examined the system of transportation service has little influence on the relative efficiency of alternate urban forms. He also feels that the obvious implications for urban planning is that the spatial pattern of land use and the pattern of transportation service can be planned somewhat more independently than is commonly thought. The results do not imply that land use pattern and the transportation system are not interrelated. They imply that the evaluation of alternative land use patterns may be considered without reference to particular transportation systems.

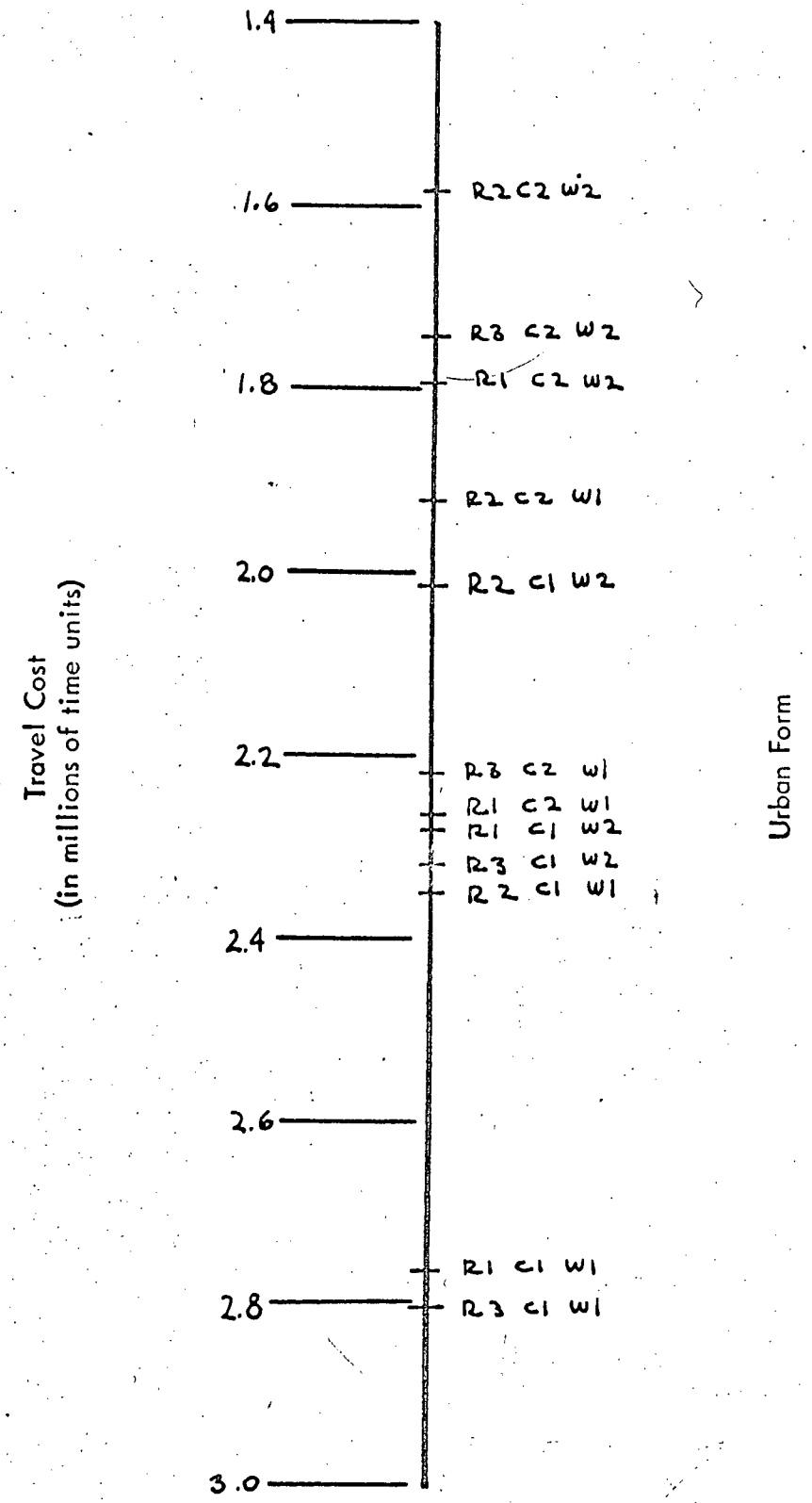
Table No. 2.1

TIME UNITS REQUIRED FOR MINIMAL LINKAGES IN URBAN FORM EXPERIMENTS *

URBAN FORM EXPERIMENT	COMMERCIAL	WORK	TOTAL	RANK
T1 R1 C2 W2	827,500	960,000	1,787,500	3
T1 R1 C2 W1	827,500	1,440,000	2,267,500	7
T1 R1 C1 W2	1,320,000	960,000	2,280,000	8
T1 R1 C1 W1	1,320,000	1,440,000	2,760,000	11
T1 R2 C2 W2	680,000	900,000	1,580,000	1
T1 R2 C2 W1	680,000	1,240,000	1,920,000	4
T1 R2 C1 W2	1,112,000	900,000	2,012,000	5
T1 R2 C1 W1	1,112,000	1,240,000	2,352,000	10
T1 R3 C2 W2	760,000	980,000	1,740,000	2
T1 R3 C2 W1	760,000	1,460,000	2,220,000	6
T1 R3 C1 W2	1,340,000	980,000	2,320,000	9
T1 R3 C1 W1	1,340,000	1,460,000	2,800,000	12
T2 R1 C2 W2	629,375	742,500	1,371,875	2
T2 R1 C2 W1	629,375	982,500	1,611,875	5
T2 R1 C1 W2	894,375	742,500	1,636,875	6
T2 R1 C1 W1	894,375	982,500	1,876,875	9
T2 R2 C2 W2	580,000	700,000	1,280,000	1
T2 R2 C2 W1	580,000	880,000	1,460,000	3
T2 R2 C1 W2	815,000	700,000	1,515,000	4
T2 R2 C1 W1	815,000	880,000	1,695,000	8
T2 R3 C2 W1	612,000	1,040,000	1,652,000	7
T3 R1 C2 W2	545,000	592,500	1,137,500	2
T3 R1 C2 W1	545,000	832,500	1,377,500	7
T3 R1 C1 W2	772,500	592,500	1,365,000	6
T3 R1 C1 W1	772,500	832,500	1,605,000	9
T3 R2 C2 W2	460,000	540,000	1,000,000	1
T3 R2 C2 W1	460,000	720,000	1,180,000	3
T3 R2 C1 W2	690,000	540,000	1,230,000	4
T3 R2 C1 W1	690,000	720,000	1,410,000	8
T3 R3 C2 W1	495,000	800,000	1,295,000	5

* From: Hemmens, C.G., Experiments in Urban Form and Structure, A Paper Presented at the 46th Annual Meeting of the Highway Research Board, Washington, D.C., (January, 1967).

Fig. 2.7 Minimum Travel Requirements of Alternate Urban Forms [3]



* This chapter presents the salient features of the model and the experimental results extracted from Prof. H.G. Hemmens paper, "Experiments in Urban Form and Structure."

(1) Here the meaning of the terms "Urban Form" and "Urban Structure" is as defined in Chapter I.

(2) UBC Library Programme, UBC TRAN, The Transportation Problem, Restrictions:. . .
(ii) The maximum cost of shipping a unit amount of goods is 999.
(iii) The maximum size of any source or

(3) From: Hemmens, G.C. Experiments in Urban Form and Structure, A Paper presented at the 46th Annual Meeting of the Highway Research Board, Washington, D.C., (January 1967)

CHAPTER V

CASE STUDY: THE MODEL APPLIED

To substantiate the proposed hypothesis that "alternate transportation systems do effect the relative efficiency of alternate land use patterns" two sets of experiments were conducted with the linear programming model described in Chapter IV. The minimum travel time for each of the twelve alternate land use patterns was tested, with different transportation systems and different levels of service as variables. (These issues were tested and analyzed with the aid of Computer Program UBCTRAN found in Appendix 2.A)

Input Data

It must be emphasized that the data used for the model is entirely hypothetical and so not truly representative of the real world. Although the exact numerical values chosen are debatable, they are nevertheless quite rational.

For all the experiments the hypothetical metropolitan area consisted of thirty seven square zones. Twenty-eight of these were solely residential, two solely office zones, three office-

cum-commercial zones, and four being residential-cum-commercial zones. For all cases, the geometric shape of the metropolitan area and the location of office and commercial centers has been fixed.

The variable inputs for each set of experiments are the three alternate patterns of residential density distribution, the two alternate patterns of office capacity distribution, and the two alternate patterns of shopping center capacity distribution. Details of the numerical values are given in table No. 2.2 and table no. 2.3 respectively.

Two alternate transportation systems T1 and T2, as shown in figure No. 2.9 and figure No. 2.10 respectively, were used for the first set of experiments. And for the second set of experiments, another two systems of transportation T3 and T4, as shown in figure No. 2.11 and figure No. 2.12, were used. The time cost of travel, modes of transport, and the different levels of service offered by each one of the alternate transportation systems is given in table no. 2.4.

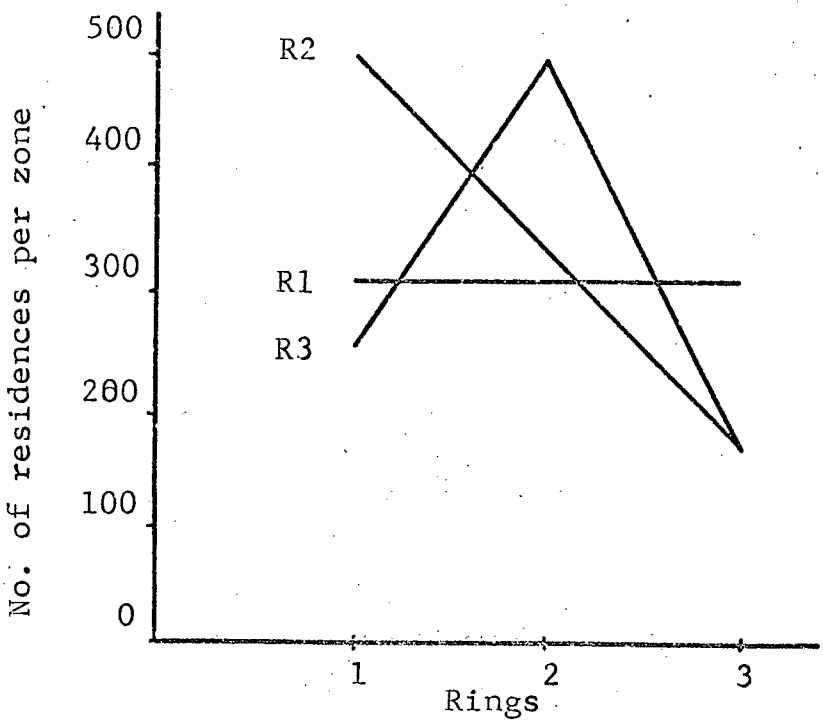


FIGURE NO. 2.8 ALTERNATE RESIDENTIAL DENSITY DESTRIBUTION PATTERNS

TABLE NO. 2.2 ALTERNATE RESIDENTIAL DENSITY DESTRIBUTION PATTERNS

Residential Patterns	Total Number of Residences	Number of Residences per Zone		
		Ring 1	Ring 2	Ring 3
R1	10016	313	313	313
R2	10000	500	334	166
R3	10004	250	500	167

TABLE NO. 2.3 TRIP ATTRACTING CAPACITIES OF OFFICE AND SHOPPING ZONES

Patterns		Zonal Trip Destributions								
Residential	Commercial	B4	D4	F4	C2	D2	E2	C6	D6	E6
R1	W1	752	7008	752	-	752	-	-	752	-
	W2	1753	3004	1753	-	1753	-	-	1753	-
	C1	502	7004	502	502	-	502	502	-	502
	C2	1168	3008	1168	1168	-	1168	1168	-	1168
R2	W1	750	7000	750	-	750	-	-	750	-
	W2	1750	3000	1750	-	1750	-	-	1750	-
	C1	500	7000	500	500	-	500	500	-	500
	C2	1167	2998	1167	1167	-	1167	1167	-	1167
R3	W1	750	7004	750	-	750	-	-	-	-
	W2	1750	3004	1750	-	1750	-	-	-	-
	C1	500	7004	500	500	-	500	500	-	500
	C2	1167	3002	1167	1167	-	1167	1167	-	1167

TABLE NO. 2.4 - TRAVEL COSTS FOR ALTERNATE TRANSPORTATION SYSTEMS.

Transportation System	Levels of Service	Time Cost of Travel Auto	Transit
T1, T2	Collector Streets	2	
	Freeway	1	
T3, T4	Collector Streets	4	6
	Major Arterials	3	4
	Freeway	1	2

The transportation systems used are geometrically non-symmetric with respect to the center of the metropolitan area. This has been done deliberately in order to determine what impact, if any, it has on the relative efficiency of the alternative land use patterns. Also, for the second set of experiments, six residential zones (C4, D3, D5, D7, E4, G4) are assumed to be predominantly transit oriented. For these six zones eighty per cent of the work trips and shopping trips are done by transit and the remaining twenty per cent by auto. For the remaining twenty six zones eighty per cent of the trips are done by auto and twenty per cent by transit.

Limitations of Data

As a result of the hypothetical nature of the experiments the data used obviously has many short-comings. These have to

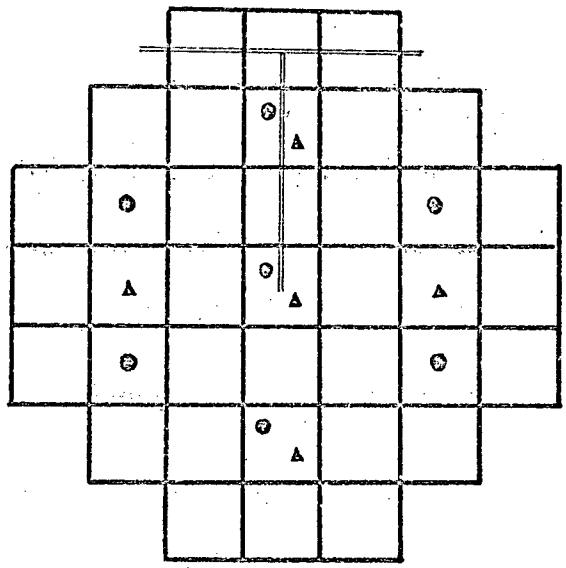


FIGURE NO. 2.9

TRANSPORTATION SYSTEM T1

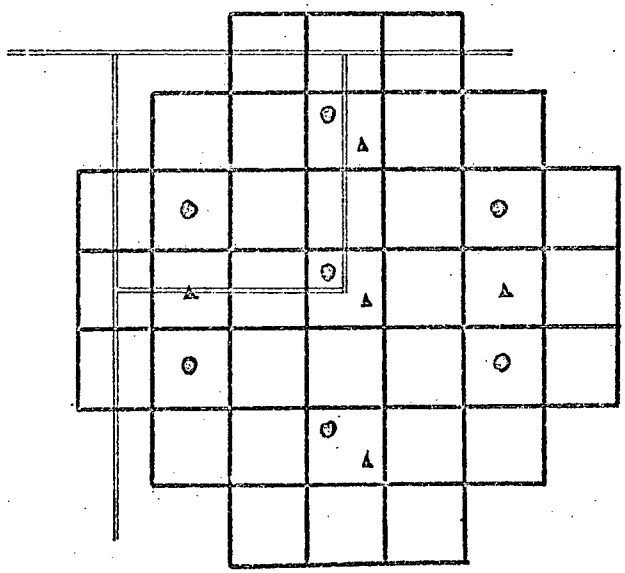


FIGURE NO. 2.10

TRANSPORTATION SYSTEM T2

Freeways
Local Roads
Office Complex
Commercial Complex

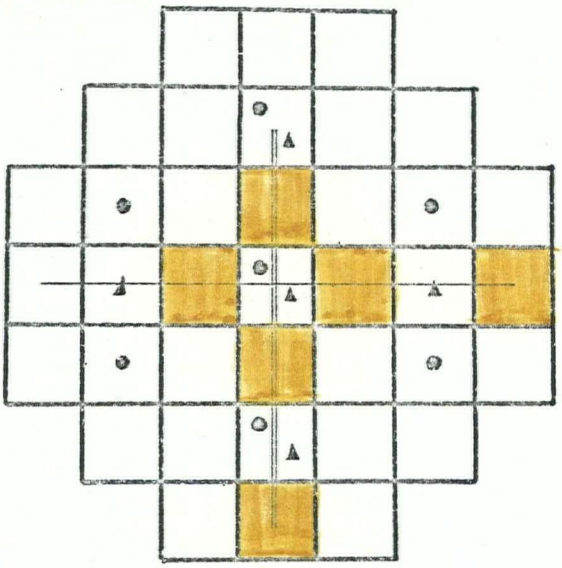


FIGURE NO. 2.11

TRANSPORTATION SYSTEM T3

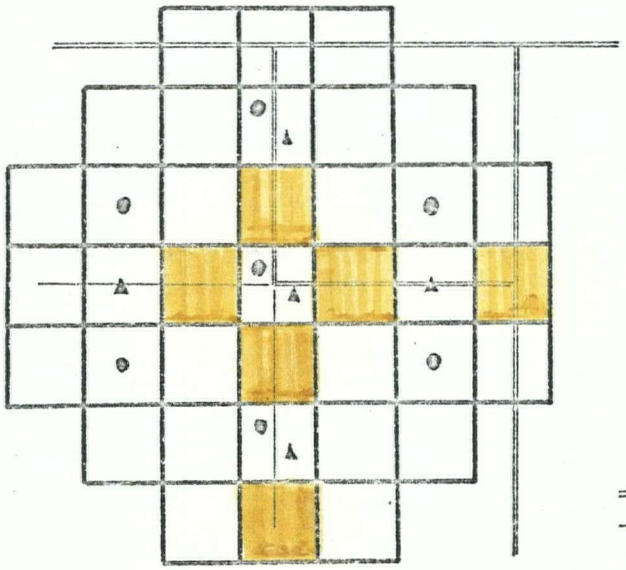


FIGURE NO. 2.12

TRANSPORTATION SYSTEM T4

Freeway
Major Artery

Transit Oriented Residential Area

Commercial and Office Complex

be thoroughly understood to safeguard against any misinterpretation of the results.

To start with, the metropolitan area is divided into a very small number of relatively homogeneous zones. There are just thirty-two zones of origin and nine zones of destination (considering only out bound trips from residential zones). No competition for trips exists between similar land uses, i.e. all the five offices offer the same range of jobs opportunities and similarly the seven shopping centers provide exactly the same goods and services. A homogeneous topography has also been assumed for the entire metropolitan region and so there is no one particular residential zone more attractive than any other zone. Such unique zones (like the West End of Vancouver, for example) exist in almost every city attracting to them a special group of people with a special set-of-travel characteristics, adding to the city's diverse and hetrogeneous character.

Secondly, it is assumed that one work trip and one shopping trip originate from each household. This may not always be true and more often the number of work trips originating from a residential area are larger than the number of shopping trips from the same area. In addition, trips are also made for

business, social and recreational purposes. These trips have been neglected in this model, although they account for approximately fifty per cent of the trips starting from a residential area.[1]

Thirdly, the question of modal choice has been greatly simplified. For the first set of experiments, travelling is done only by automobiles, an assumption which has not been proved valid even for the auto oriented city of Los Angeles. For the second set of experiments, transit as a second mode of transport, has been introduced and six of the thirty-two residential zones assumed to be transit oriented i.e. eighty per cent of all trips are done by transit and twenty per cent by auto. For the auto oriented zones twenty per cent of the trips are done by transit and eighty per cent by auto. These modal split factors are constant for all the zones. In actual fact these factors will change from zone to zone and be a function of family income, car ownership, length and purpose of trip, availability and cost of parking at destination, availability and convenience of transit service, etc.

Lastly, the road network and the transit system are assumed to have infinitely flexible capacities. Thus, some routes carry a very large proportion of the traffic whereas certain other

routes do not carry any traffic at all. In effect this assumption means that the level of service offered by the transport facility does not fall with an increase in the traffic beyond the "service volume" i.e. the time cost for travel also does not increase as traffic volumes rise. This is a very critical assumption and only valid up to the point where the "service volume" for the transportation facility has been reached.[2]

Limitation of the Model

The drawback of this linear programming model, when used to evaluate the efficiency of alternate land use patterns, lies in its allocation rule. It subsumes that people will work at the closest job opportunities and shop at the nearest shopping center. This is clearly not the case as people often work and shop at places which are not the nearest to their residence.[3] In fact, as shown in figure No. 2.13, a non-linear relationship exists between travel time and the location of work place.

Thus the allocation rule of minimizing the linear cost function Cij Xij is unrealistic and will distort the results.

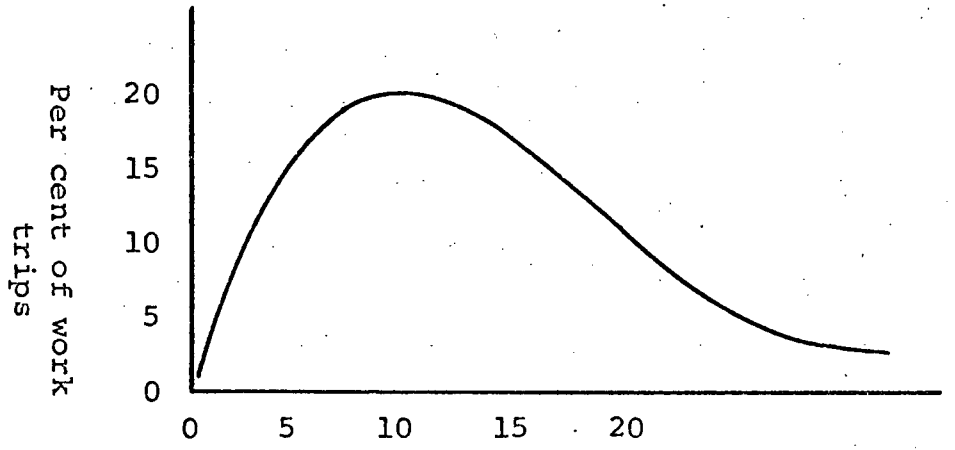


FIGURE NO. 2.13. RELATIONSHIP BETWEEN TRAVEL TIME AND LOCATION OF WORK PLACE

Experimental Results

The minimum travel time computed for the four alternate transportation systems and twelve alternate land use patterns was obtained from the computor output sheets and reported in table No. 2.5 and table No. 2.6. These results were further reorganized and for each transportation system the twelve land use alternatives were ranked according to their efficiency in table No. 2.7

Interpretation of the Results

Within the restraints of the model and the nature of the assumption the results are encouraging and support the hypotheses that alternate transportation systems do effect the

TABLE NO. 2.5 MINIMUM TRAVEL COST FOR THE FIRST SET OF EXPERIMENTS

	T1			T2		
	Work	Shopping	Total	Work	Shopping	Total
R1C1W1	41430	37589	79019	36987	33461	70448
R1C1W2	28794	37589	66383	26353	33461	59814
R1C2W1	41430	22773	64203	36987	21582	58569
R1C2W2	28794	22773	51567	26353	21582	47935
R2C1W1	35830	32164	67994	32500	29000	61500
R2C1W2	26998	32164	59162	25168	29000	54168
R2C2W1	35830	19324	55154	32500	18325	50825
R2C2W2	26998	19324	46322	25168	18325	43493
R3C1W1	42275	38608	80883	38438	34938	73376
R3C1W2	29356	38608	67964	27770	34938	62708
R3C2W1	42275	20932	63207	38438	19764	58202
R3C2W2	29356	20932	50288	27770	19764	47535

TABLE NO. 2.6 MINIMUM TRAVEL COST FOR THE SECOND SET OF EXPERIMENTS

	T3			T4		
	Work	Shopping	Total	Work	Shopping	Total
R1C1W1	69725	61448	131200	65116	57440	122556
R1C1W2	56240	61448	117688	49852	57440	107292
R1C2W1	69752	44384	114136	65116	41006	106122
R1C2W2	56240	44384	100624	49852	41006	90858
R2C1W1	60829	51989	112818	59746	51672	111418
R2C1W2	52333	51989	104322	49616	51672	101288
R2C2W1	60829	38709	99538	59746	36288	96034
R2C2W2	52333	38709	91042	49616	36288	85904
R3C1W1	70194	61198	131392	69658	61091	130749
R3C1W2	57688	61198	118886	54456	61091	115547
R3C2W1	70194	39618	109812	69658	38082	107740
R3C2W2	57688	39618	97306	54456	38082	92538

TABLE NO. 2.7 RELATIVE EFFICIENCY OF ALTERNATE LANDUSE PATTERNS

Ranking	T1	T2	T3	T4
1	R2C2W2	R2C2W2	R2C2W2	R2C2W2
2	R3C2W2	R3C2W2	R3C2W2	R1C2W2
3	R1C2W2	R1C2W2	R2C2W1	R3C2W2
4	R2C2W1	R2C2W1	R1C2W2	R2C2W1
5	R2C1W2	R2C1W2	R2C1W2	R2C1W2
6	R3C2W1	R3C2W1	R3C2W1	R1C2W1
7	R1C2W1	R1C2W1	R2C1W1	R1C1W2
8	R1C1W2	R1C1W2	R1C2W1	R3C2W1
9	R3C1W2	R2C1W1	R1C1W2	R2C1W1
10	R2C1W1	R3C1W2	R3C1W2	R3C1W2
11	R1C1W1	R1C1W1	R1C1W1	R1C1W1
12	R3C1W1	R3C1W1	R3C1W1	R3C1W1

efficiency of alternate land use patterns.

The first set of experiments show that for a one mode transportation system the relative efficiency of the twelve alternative land use patterns remains constant regardless of the level of service or the geometric pattern of the transportation network.[4] This indicates that, under the given assumptions, there appears to be just one land use pattern most suitable for a given transportation system. As expected, this pattern is the concentric ring, with dispersed work and shopping (R2C2W2).

The results of the second set of experiments show that for a two mode transportation system the relative efficiency of alternate land use patterns is not constant.[5] It varies with changes in the level of service, and the type and pattern of the transportation system. Therefore, different land use alternatives will require quite different transportation systems.

A closer look at the ranking of the alternate land use patterns for the four transportation systems reveals that the variations in relative efficiency are local in nature, with the extreme ends of the spectrum remaining unchanged. This

is because of the aggregate nature of the data and other limitations of the model which dampen the effect of changes in the transportation system on the relative efficiency of alternate land use patterns.

A study of table No. 2.7 also reveals that with the transportation system remaining constant, a weaker commercial and office core (a C2W2 pattern) is more efficient that a concentrated core (C1W1 pattern). Further, with the residential pattern and the transportation system remaining constant, a change in the commercial pattern from dispersal (C2) to concentration (C1) increases the travel requirements more than a similar change in the work pattern (i.e.a change from W2 to W1). Therefore, changes in the pattern of commercial areas seem to have a greater impact on the total travel requirements than changes in the pattern of work locations. Whereas, changes in the residential distribution patterns appear to have the least impact on changes in travel requirements. Although these conclusions are borne out by the experimental results, because of the limitations of the model, their validity is questionable.[6] Finally, the results indicate that there exists a trade-off between land use and transportation. At times, land use changes

could be substituted for transportation improvement to achieve the same desired end result.

(1) Voorhees, A., A General Theory of Traffic Movement, The 1955 Past President's Award Paper, Institute of Traffic Engineers, Connecticut, (1955), p.8

(2) Cleveland, D.E.. Ed., Manual of Traffic Engineering Studies, Institute of Traffic Engineers, Washington, D.C., (1964), p. 103.

(3) Voorhees, A., Op. cit.

(4) The efficiency of the alternate land use patterns for transportation systems T1 and T2 are given in Table No. 2.7. As can be seen, the ranking of the land use patterns for both these cases in the same. It is also similar to the ranking obtained by Prof. Hemmens (given in table No. 2.1).

(5) The efficiency of the alternate land use patterns for the transportation systems T3 and T4 are given in Table No. 2.7. As can be seen, the ranking of the alternatives for these two cases is not the same, This ranking also differs from that for T1 and T2.

(6) This may be because the number of commercial centers assumed (7) is greater than the number of work centers (5).

CHAPTER VI

CONCLUDING COMMENTS

Recommendations for Improvement of the Model[1]

To this date little work has been done on trying to understand urban structure and analyze the impact that changes in land use have on the total urban system. This is necessary to help plan for better cities in the future and also improve the quality of public investment decisions. Because it is relatively difficult to reconstitute cities or change the behavior of the people in order to evaluate unexplored alternatives, the problem can be approached through a form of laboratory experiment rather than by observations or trend estimates alone. This model presents a technique which helps to understand and evaluate the impact that changes in land use (or the transportation system) will have on the traffic pattern and travel requirements of the entire metropolitan region. Thus, not only can alternate urban forms be evaluated for their travel requirements, but changes in the traffic pattern due to a new shopping center or the construction of a new freeway can also be estimated.

This model is very easy to understand and also very easy to apply to an urban area. This is the main advantage of the model. But, it also has its drawbacks. The two important ones are:

a) The model does not reflect competition for trips between similar land uses i.e. the trips are distributed linearly in accordance to travel costs only. And,

b) There are no capacity restraints on the transportation network.

Thus, refinements are necessary to increase the sensitivity of the model and improve the quality of the output.

The first drawback could be overcome by using a trip allocation rule that relects competition for trips between similar land uses. One such allocation rule would be the gravity principle which distributes trips from any zone to all other zones in accordance with[2]:

a) The number of trips originating in that zone,

b) The attractive force of the other zones, and

c) The travel cost (resistance) between the corresponding zones.

This allocation rule is obviously more realistic than the one used and will yield better results while still not making the model too complicated.

To overcome the second drawback, capacity restraints on the transportation network will have to be introduced. This could be done in an indirect way by assuming that only a certain percentage of work trips and shopping trips are done during the peak hours, the remaining being spread out over the rest of the day. A higher travel cost could then be assigned to all peak hour travel to account for congestion costs and capacity limitations. It is also true that the level of service and trip length being the same, the travel costs will be different if the purpose of the trip is different i.e. a shopping trip from A to B would probably have a lower travel cost than a work trip from A to B done at the same time. Thus, travel costs should be a function of:

a) mode of travel (auto or transit),

b) road facility used (collector street, major artery or freeway),

c) time of travel (peak hour or non-peak hour),

d) purpose of trip (work or shopping).

Other refinements that could be quite easily incorporated in the model are:

a) increase the number of zones and land uses in the hypothetical metropolitan area. Thus, in addition to residential, shopping, and work areas, parks and other other recreational sites could be introduced.

b) Topographic features such as:
   i) Rivers, thus restricting cross movement to bridge locations, could be introduced. Also,

   ii) prestige zones with special trip production and mode split characteristics could be introduced. In fact, trip generation and mode split factors could be made to vary between zones as desired.

c) The transit service could be restricted to certain fixed routes. Major transfer points could also be located along these routes and a certain percentage of the trip assumed to be a combination of auto and transit travel. This percentage could also vary between zones.

Implications of the Study

A significant fact that people have often failed to recognize is that "transportation planning is not so much a link in a chain as it is a strand in the unseparable multi-dimensional web of urban planning".[3] The inability of the human mind (in this case the planners) to comprehend and deal with this vast "unseparable multi-dimensional web" at the metropolitan level is probably one of the factors which has led to the uncoordinated fashion that planning, be it land use or transportation, is being done today.

An analysis of some of the literature reviewed along with the experimental results of this study leads to the following conclusions which are of considerable importance to planning:

That land use and transportation are interrelated and as such each should compliment the other. Also, changes in the land use pattern can be traded-off against changes in the transportation system, or visa-versa, to achieve the same level of improvement in the minimum travel requirements.

That the impact of changes in the land use pattern or the transportation system are not local in nature, only. And that the dispersed ramifications must also be recognised and planned for if the desired overall community objectives are to be achieved.

That the model provides a simple tool for research and analysis, on a comprehensive basis, of the interrelationship between the transportation system and the land use patterns of a metropolitan area. Thus, alternative locations for offices, shopping centres, urban freeways and interchanges can be evaluated for their efficiency in terms of their travel requirements and for their influence on the overall traffic flow pattern. This would give the planner an analytic tool for establishing a trade-off between transportation efficiency and social benefits. He could then choose that alternative which would make the maximum contribution towards furthering the desired overall community objectives.

The model could help to establish comprehensive policies for the development of land use and transportation facilities for the metropolitan area, i.e. for land use and transportation planning. These would act as a common ground to coordinate and integrate the activities of the different agencies involved in the planning and development of the metropolitan area.

The experimental results of this study also show that the concentric ring with dispersed office and commercial pattern (R2C2W2) is the most efficient with respect to total travel requirements. They, therefore, suggests a land use structure

for a future metropolitan area. Thus, with the objective of restructuring the metropolitan area to this efficient pattern, these results serve as a guide-line for making the necessary changes in the existing land use pattern and transportation system, i.e. in setting priorities for the timing, selection, and location of new construction and other redevelopment activities.[4]

Since a change in the pattern of commercial areas has been shown to have a greater impact on travel requirements than a change in the work location pattern, first priority should be given to the restructuring of commercial areas to the dispersed (C2) pattern. Next priority should be given to the reorganization of work centers and finally to the restructuring of residential areas. At each stage the alternate choices could be evaluated for their efficiency and the more beneficial one adopted. Also, each change would have to be accompanied by appropriate complimentary changes in the transportation system.

With reference to the "Nodular Concept" discussed in Section I of this thesis, one of the basic criteria of such an urban system is:

> ". . . a concentration of growth nodes at intervals along major transportation corridors. These nodes become centers for mixed usage of single use of large proportions."[5]

On the basis of this criteria the 'nodular concept' would be analogous to the concentric ring with dispersed work and shopping pattern (R2C2W2) as used in the second set of experiments. This nodular system of urban structure (shown in figure No. 2.14) would therefore be more efficient, in terms of travel requirements, than most of today's metropolitan areas. Thus, if this is the type of future urban environment that people want, the job of formulation of the appropriate guiding policies is greatly clarified and simplified.

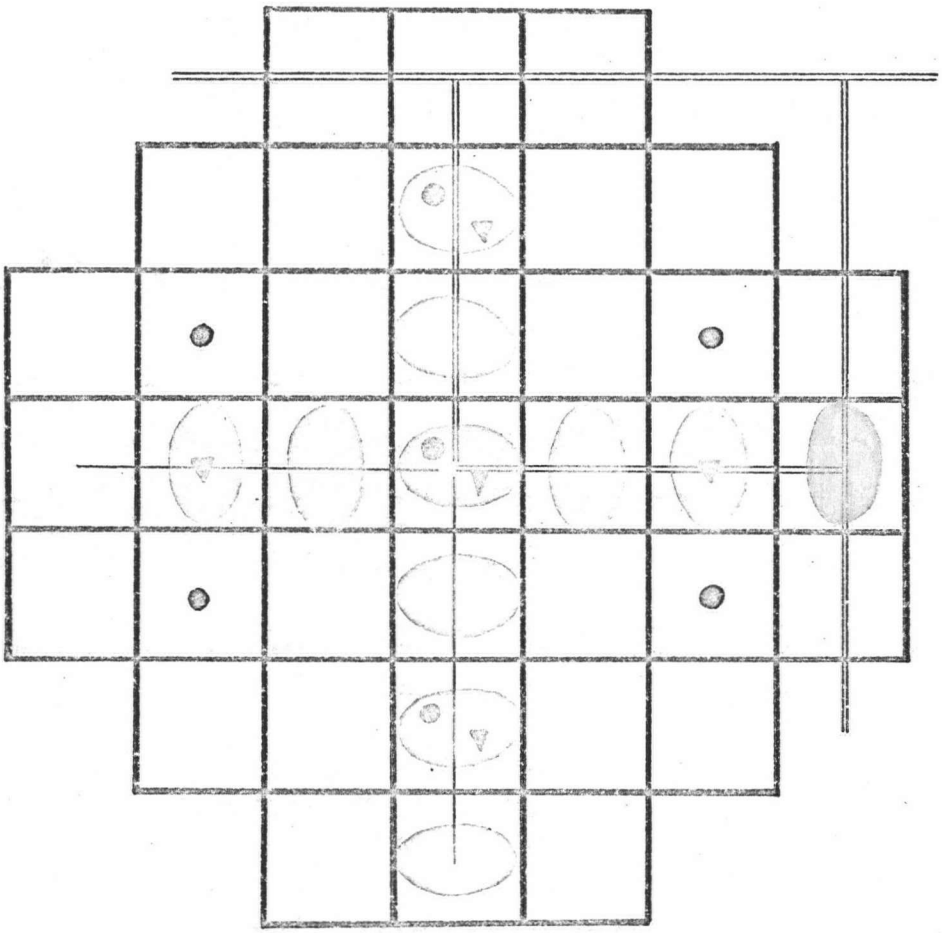


FIGURE NO. 2.14 THE NODULAR CONCEPT

Residential Node

Office Node

Office/Commercial Node

(1) Because of the limited time available, the practicality of these recommendations has not been tested. Although it is felt they can be quite easily incorporated without making the model very complicated and cumbersome.

(2)

$$Tij = Ti \frac{\dfrac{Sj}{Dij^x}}{\dfrac{S_1}{Di1^x} + \dfrac{S_2}{Di2^x} + \dfrac{Sn}{Din^x}}$$

Where Tij = present trips between zone i and zone j (i,j,= 1, 2, ... , n) due to an attractive force located in zone j.

Ti = present vehicle trips originating in zone i,

where

$$\sum_{j=1}^{n} Tij = Ti$$

Sj = the attractive force on zone j (size depends upon land use characteristics of zone j and trip purpose under consideration).

Dij = the travel time or distance between zone i and zone j.

X = distance exponent (value dependent upon trip purpose).

(3) Fagin, Henry, Comprehensive Urban Planning, Transportation Design Considerations, Transportation Research Conference, National Academy of Science, National Research Council, Publication 841, Washington, D.C. (1961).

(4) This should not in any way imply an "end state" plan.

(5) Section I, p. 17-18.

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APPENDIX 2.A

UBC COMPUTING CENTRE
VANCOUVER 8, B.C.

H3 UBC TRAN
September, 1967

THE TRANSPORTATION PROBLEM

Wilson Baker
(Modified by A.G. Fowler and G. Allard) UBC Computing Center

Type of Program: Self Contained FORTRAN IV program.

Purpose: To compute an optimal solution of the transportation problem, a special case of the general linear programming problem.

Method: See Ref. 1. All calculations are done using integer arithmetic.

How to Use: Let:

M = no. of rows (surplus or sources)
N = no. of columns (shortages or sinks)
K_{ij} = the cost of shipping 1 unit of goods from source i to sink j.
A_i = the amount of goods initially at source i
B_j = be the amount of goods needed at sink j

The input required by the program is M, N, A_i, B_j, K_{ij} as well as a Title Card.

(See also Data Preparation).

Print-Out:

1. The Title or Heading (this is input information).

2. The cost Matrix K_{ij} and the values of A_i and B_j (again this is input data).

3. The total cost associates with the optimal solution.

4. The optimal solution.

Restrictions:

1. Both the number of sources and the number of sinks are limited to 100.

2. The maximum cost of shipping a unit amount of goods is 999.

3. The maximum size of any source or sink is 9999.
(These last two restrictions can be removed by modifying the output format of the program).

4. All input must be in integer form.

Timings: Sample: Execution time (including printing)

20 rows (sources by 25 columns (sinks)=4.7 secs.

Core Storage: Essentially all of core storage is used.

Data Preparation: In describing how the input must be recorded on the data sheets the number of columns allotted to each number (called the field width) will be given. It is implied that the number put in these columns must be placed in columns as far to the right as possible (this is called right justified). Thus, for example, when it is stated that the value of N is to be recorded in columns 6 to 10, and if N = 7, then the number 7 must be recorded in column number 10. (If it were put in column number 9 the computer would interpret it as 70 rather than 7).

DATA CARD # 1 Heading Card, should contain a description of problem being solved.

	Columns	Format	Variable Name	
DATA CARD # 2	1 to 5	15	N	No. of Sources (No. of rows in the Cost Matrix)
	6 to 10	15	N	No. of Sinks (No. of columns in the Cost Matrix).

DATA CARD #3	1 to 5 6 to 10, etc.	1615	S_i	Amount of surplus at the ith source (if M 16 there will be more than one Data Card #3)
DATA CARD #4	1 to 5, 6 to 10, etc.	1615	T_j	Amount of Shortage at the jth sink (if N 16 there will be more than one Data Card #4)
DATA CARD #5	1 to 5, 6 to 10, etc.	1615	K_{ij}	Transportation cost from the ith source to the jth sink (if N 16 there will be more than one data card per source).

Repeat DATA CARD #5 for each source (each row of the cost Matrix)

<u>NOTE</u>: Always start a new row of the cost matrix on a new Data Card.

Example: Assume that the transportation charges from the 4 sources to the 6 sinks are as follows:

SHORTAGES	3	3	6	2	1	2
SURPLUS						
3	5	3	7	3	8	5
4	5	6	12	5	7	17
2	2	8	3	4	8	2
8	9	6	10	5	13	9

TRANSPORTATION COST MATRIX

The deck set up including data cards would be:

Col.1	Col.8	Col.16
$JOB	JOB NUMBER	Your name
$EXECUTE		TRAN

	Col.5	Col.10	Col.15	Col.20	Col.25	Col.30
CARD #1	SAMPLE TRANSPORTATION PROBLEM					
CARD #2	4	6				
CARD #3	3	4	2	8		
CARD #4	3	3	6	2	1	2
CARD #5's	5	3	7	3	8	5
	5	6	12	5	7	17
	2	8	3	4	8	2
	9	6	10	5	13	9

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