URBAN FORM AS A TRANSPORTATION INTERCHANGE:

A FORMAL THEORY

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Architecture.

Massachusetts Institute of Technology July, 1966

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Dear Dean Anderson:

This thesis, "Urban Form as a Transportation Interchange: A Formal Theory", is submitted as partial fulfillment of the requirements for the Degree of Master of Architecture.

Respectfully,

Gary Arthur Dunbar

ABSTRACT

This thesis states and develops a theory concerning the forming of boundaries by movement pathways. A hypothetical test case of a maximum movement boundary in the City of Boston is used for demonstration. This test case is analyzed within the limits of the theory. The result is a three-dimensional matrix of urban activities, structure, and movement.

CONTENTS

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Anna Dunbar
Joanne Horgan

INTRODUCTION

The impetus of this thesis is the problem of transportation in the urban environment. In attempting to define this problem, the particular aspect which drew my attention is the tendency of movement pathways to divide the earth's surface into a number of smaller areas. The specific question is how do adjacent areas relate to, and interact with, each other across a boundary.

The statement sought herein is a generalization of the nature of interaction and separation. Some of the notions of the more exacting sciences of physics and biology have been adopted in the attempt to establish this generalization. In order to maximize the value of this crossing of ideas, care has been taken to concentrate on general attitudes toward problems rather than specific solutions to problems. It is intended that this emphasis on attitude or approach will insure the generality of the statement and avoid the extrapolation of specific ideas into inappropriate situations.

In architectural terms, the theoretical statement of this thesis is concerned with generalizations leading to form. The discussion does not deal directly with the more traditional architectural notions of form, function, and scale. The intention and goal here is the establishment of a generalized framework in which certain questions of form, function and scale are easily definable. This generalized framework is not meant to be a complete theory of architecture in any way, but is intended to shed new light on traditional ideas.

CHAPTER ONE

The objective of this chapter is to outline a language that deals with general synthetic relationships and limits, or concepts of how things fit together. The intention is to bring certain synthetic notions to a useful and respectable communicable level. First, in order to establish a spatial frame of reference, the spatial system that was derived by Minkowski and is used in the general theory of relativity is outlined. Four notions of synthetic form are developed from the intrinsic synthetic limits of this spatial system. Secondly, from considerations of what constitutes a discrete object and various biological notions, an idea of boundary operation is developed. Boundaries, or the areas considered as separating discrete objects, are given operational modes of interaction. These operational modes are intended to establish a framework within which any interaction or separation may be described. The combination of these two ideas, spatial systems and boundary operations, constitutes a general synthetic theory of form.

PART I - DIMENSIONS

The first task is the establishment of a spatial frame of reference in which events may occur. The frame must be general enough to be applicable to a large number of real situations or phenomenon and still describe synthetic limits in specific terms. The term synthetic limits will be defined later. The frame must have the inherent capability of describing the spatial characteristics of the order or structure of all real phenomenon. Any such frame implicitly assumes that phenomenon are orderly and this assumption is easily confirmed with regard to repetitious phenomenon.

The spatial frame of reference will be a four-dimensional "world" space[1] as defined by Minkowski and uses a Gaussian coordinate system to quantify or "map" that space. The important thing for purposes of this paper is that this generalized spatial system uses four dimensions. Although in theoretical problems there is no limit to the number of dimensions which can be assumed, real situations or phenomena appear easily described in terms of four dimensions. If a four-dimensional space is a valid generality, then it establishes definite synthetic limits.

Synthetic limits may be though of as concepts, structures, forms, or orders which describe the way the various parts of any situation fit together and interact. Any generalization inherently contains synthetic limits. The recognition of these limits and their correspondence with reality is the test of a generalization. For synthetic limits to be valid they must adequately describe existing situations and predict major characteristics of future situations.

The term situations is used as a generalized notion of any kind of occurrence. In this portion of the discussion it is necessary to avoid the specific and maintain the general. Therefore, situations may be thought of as referring to such things as ideas, physical objects, forms, physical phenomena, social groups, etc.

The synthetic limits intrinsic to a four-dimensional space may be discussed by simplifying the mathematician's rigorous definitions. In rigorous terms, the four dimensions are pure numbers which locate points in space and have no real physical significance. But for purposes of conceptualization, they may be considered as space and time dimensions without damaging the more rigorous theory. A synthetic form or concept statement within any frame is one which simply states the principal order of a given situation. A spatial system containing four dimensions must intrinsically contain four synthetic statements of form.

The terminology "degrees of complexity" is used in the list of synthetic statements to define the properties of each synthetic statement. This terminology denotes properties which are both observable and predictable in a given situation. In a problem situation where order is sought, the observance of certain degrees of complexity can lead to the appropriate synthetic form; or the assumption of a synthetic form establishes the degree of complexity which must be accounted for.

LINEAR FORM: Situations in which events occur one after another in chain-like fashion can be described as linear. In linear situations, events can be located with one number like rooms along a corridor. Linear forms have two degrees of complexity: the link or what occurs along the line, and the termination, or how the line ends or joins other situations.

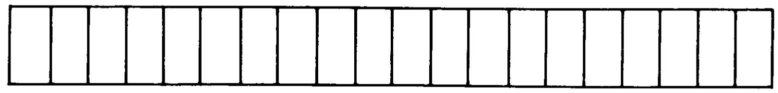
PLANAR FORM: Planar form describes situations in which events occur primarily in a surface and can be located with two numbers. In a linear form, by comparison, an event can affect other events only on either side of it, but in planar form, an event affects other events on either side and in front and in back of it. The planar form has three degrees of complexity: edges, corners, and surface interiors.

SPATIAL FORM: Situations which are described in terms of volume and may be "mapped" with three numbers are of spatial form. The spatial form has four degrees of complexity: edges, corners, surface interior and volume interior.

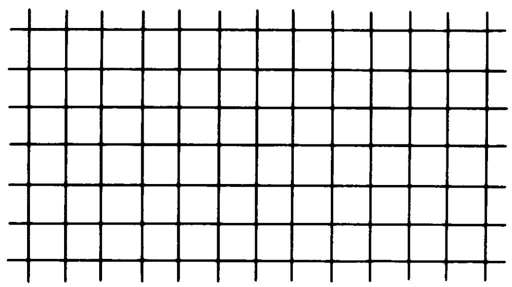
"WORLD" FORM: The "world" form uses all four dimensions in a temporal space. Rigorously, "world" form is the only one which can completely describe real situations, but it is rare when this is the simplest description possible. All the degrees of complexity attributed to spatial form apply to universal form plus the notion of rate or time.

Note that for conceptual purposes, the notion of time was introduced only in the most complex synthetic form, but that it is equally valid to introduce the time dimensions at any level. Thus, one may speak of planar form being composed of a spatial dimension and time as is the case with situations like "velocity".

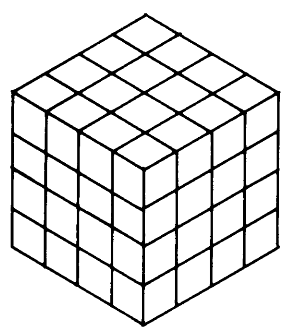
LINEAR FORM
- **LINK**
- **END**



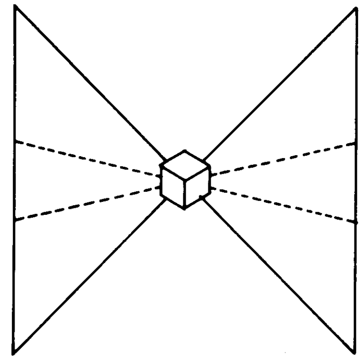
PLANAR FORM
- **EDGE**
- **CORNER**
- **SURFACE INTERIOR**



SPATIAL FORM
- **EDGE**
- **CORNER**
- **SURFACE INTERIOR**
- **VOLUME INTERIOR**



"WORLD" FORM
- **EDGE**
- **CORNER**
- **SURFACE INTERIOR**
- **VOLUME INTERIOR**
- **RATE**



DIMENSIONAL SYNTHESIS

PART I - NOTES

1. The four-dimensional "world" space of German mathematician H. Minkowski is described by G. Gamow in his Biography of Physics. "If time is to be considered as a legitimate fourth coordinate, it must first of all be measured in the same units as the three space coordinates. This can be done by multiplying time, originally given in seconds, by some standard velocity which leads to the distance expressed...the same as the three space coordinates...the best choice will be the velocity of light in a vacuum,..." But because time cannot be reversed, the mathematical unit (i) is used in its definition. The coordinates are x, y, z, etc. "The result is a diagram...where space coordinates x and y (and z) axes are in horizontal plane (in respect to the reader) and the imaginary time axis runs vertically. Each point in this diagram represents an event, i.e., something that happened in a definite place at a definite time. Events which are simultaneous---are represented by the points in plans perpendicular to the time axis. Events which occur at different times but in the same place---are on straight lines parallel to the time axis. The conical surface with a 90 degree opening, known as a 'light cone', corresponds to events which can be connected by a light signal". Therefore, a cone of less than 90 degrees describes a time "space" which is limited by a velocity smaller than the speed of light. Thus, at least in the theoretical sense, we may speak of the time cones of the pedestrian, the automobile, or the airplane. It is conceivable to develop a notion or an urban time cone.

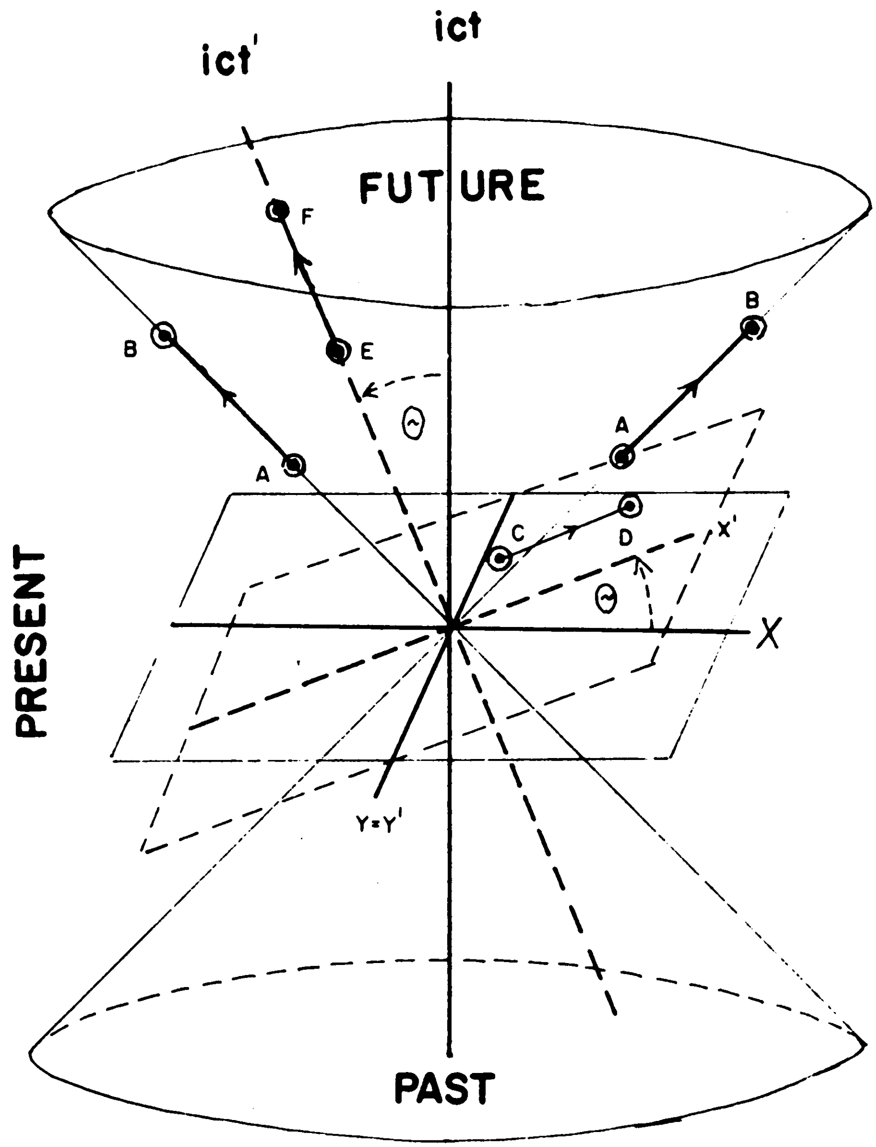


FIG. VI–11.

Space-time continuum containing two space coordinates (x and y) and the time coordinate (ict). The conical surfaces representing the propagation of light ($x^2 + y^2 - c^2t^2 = 0$) divide the continuum into "present," "past," and "future."

PART II - BOUNDARIES

The arguments as to whether the physical universe is composed of a continuous substance fluctuating from mass to energy or of discrete objects is largely a matter of the scale of perception. In general, the larger the scale of perception, the more continuous the observed situation appears and conversely, the smaller the scale, the more discrete the situation appears. There is, then, an appropriate scale for each situation, i.e., one does not examine molecules in terms of miles. If discreteness as a physical phenomenon occurs over a wide range of scales, it may then be qualitatively general and offer some significant synthetic limits. Therefore, an orderly description of what constitutes discreteness in real situations at any scale and for any function could provide a synthetic framework equally applicable to atoms, cities, or galaxies.

In order to examine the phenomena of discreteness, the type of situation in which discreteness makes sense must be determined. Obviously there is no vital concern with zero number of discrete objects. There may be some possible concern with one singular discrete object, singular meaning that there are no sub-parts. If any real physical knowledge of this object is to exist, then the object's existence must in some way be confirmed. If the confirmation is to take place by some form of observation, then in addition to the object an observer and a message-carrying device such as a photon or sound wave are required. Therefore, our imaginary universe must contain at least three objects to confirm the existence of one. If the object could confirm its own existence, which is somewhat like an eye seeing itself, then still no communicable knowledge would exist because there is no means of communication and there is nothing to communicate with. Therefore, any meaningful examination of discreteness must include two or more objects. The point is that the notion of discrete objects is determined by the relationships and interactions of those various objects.

The notion of discreteness may be discussed in terms of boundary where boundary denotes the restraints of interaction which cause the perception of discrete objects. A boundary is the area in which two or more objects interact. In order to come to some kind of understanding of the idea of boundary, a specific definition must be determined. The definition may be stated in terms of dimension, function, or operation. Dimensional and functional definitions apply to specific events. Operational definitions describe general situations in which functional and dimensional events may occur. An operational definition is a synthetic framework and has synthetic limits. The definition of boundaries must then operationally describe the limits and controls of interaction and separation.

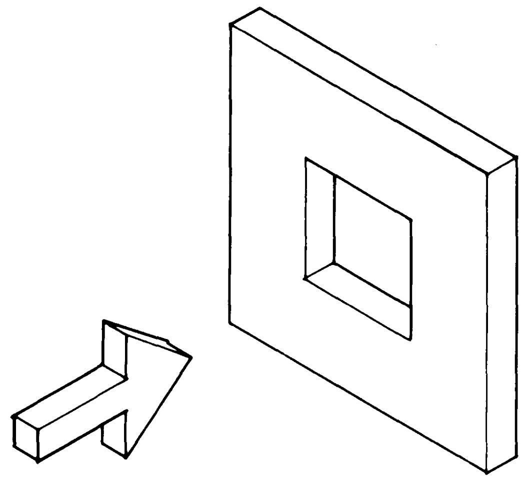
The problem of determining generalities is that very often there is no higher or more general statement readily available to which reference can be made. There exists a certain comfort in a postulation which may be tested in terms of the statements from which it is derived. When no previous statement exists, however, a postulate can only be tested in terms of what may be derived from it. Therefore, as is often done in mathematics, one states a postulate and tests it within itself and downwards with the only higher authority being the rationale of man and the reality of the situation. The presentation of operational boundary definitions is in these terms.

The following definitive classifications are extrapolated from the biological processes of a cell membrane.[1] In evolutionary biological terms, the membrane is the first physical requirement for the possibility of the existence of life. The cell membrane, by separating a bit of matter from the universe as a whole, provides the fundamental order of life.[2] The critical control of a cell membrane in isolating its interior from the surrounding environment is of vital concern to biological science. Therefore, the notions of boundary operation used in biology may be pertinent to a more general notion of boundaries.

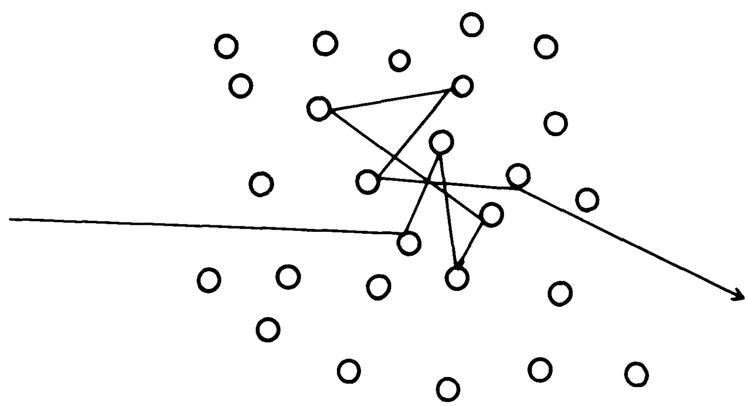
MECHANICAL:	Physical form is the determinant of interaction. When the interaction or separation can be best described in terms of the physical form or the dimension of the various objects, the boundary is mechanical in operation.
OSMOTIC:	When objects interact by becoming interwoven or by conglomerating or in some way becoming integral parts of each other, the boundary operation is osmotic.
SERIAL:	If a series of change conditions occur during the process of interaction or separation, the boundary operation is serial.

The three boundary operations are to establish a framework within which the interaction of any discrete objects may be described. There is no exclusiveness or hierarchy, and in any given situation it may be assumed that all would be required for adequate description. In any given situation, one or two modes of operation may be found dominant, but the other(s) may be present also.

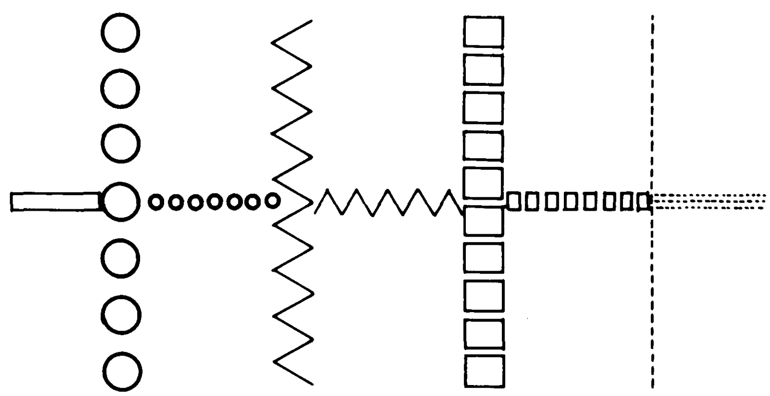
MECHANICAL



OSMOTIC



SERIAL



BOUNDARY SYNTHESIS

PART II - NOTES

1. In Transport and Accumulation in Biological Systems,by E. J. Harris, there are three ways listed in which material can enter a cell:

(1) Movement through pores whose dimensions are greater than those of the material (sponge-like).

(2) Leave the water by dissolving in the membrane, re-dissolve into the water.

(3) By "...a series of steps along a chain of absorption sites situated along the length of the pore."

(The material is acted upon at each step before it is passed to the next).

2. In Division of Labor in Cells, G. H. Bourne states: "The secret of the complex activity of the living cell lies in the isolation or partial isolation or even the timed isolation of its various activities. This is achieved by the presence of various membranes."

CHAPTER TWO

A test case is defined in this chapter. The purpose of this test is to demonstrate and develop the logic of the theory as stated in the first chapter. The test case is a hypothetical urban situation developed out of a general urban form, a technological proposal, an economic prediction, and the special character of the site. The test case is a general test in order to evaluate the logic and clarity of the theory and not to demonstrate practical applicability.

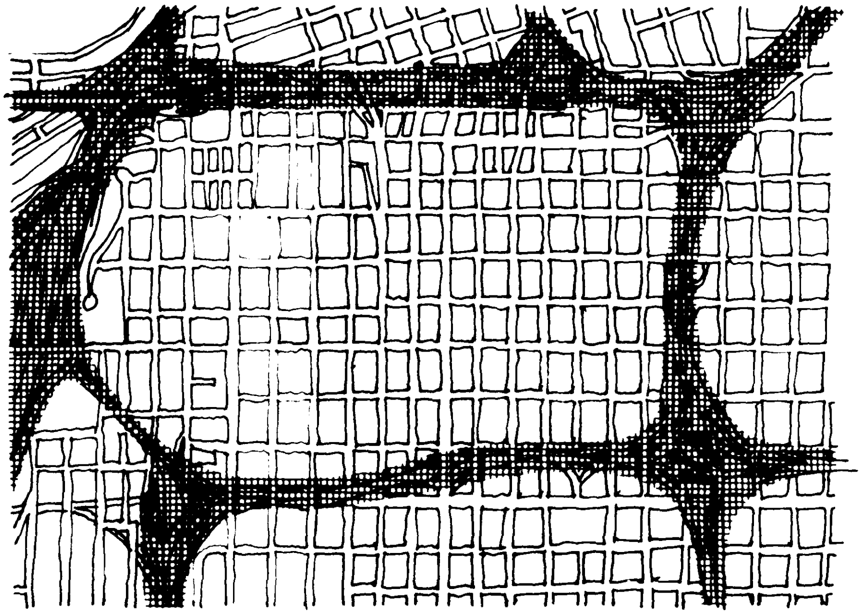
The test or demonstration case for this theory of dimensions and boundaries will be carried out using the boundaries formed in urban spaces by movement pathways. Streets, sidewalks, railroad tracks, expressways, shall be considered as forming some pattern of boundaries in the urban environment. The major interest is how this theory will help establish the relationship of spaces across such pathways.

The evaluation of a theory by the use of a test case must be done in terms of either utility or validity. To demonstrate the utility of a theory, the test case must exhibit a relevance to real and practical situations. The test of validity is a test in a limited and hypothetical situation. The validation test yields more immediate and general results for the evaluation of the applicability of the theory. The test case demonstrated in this thesis is a validation test.

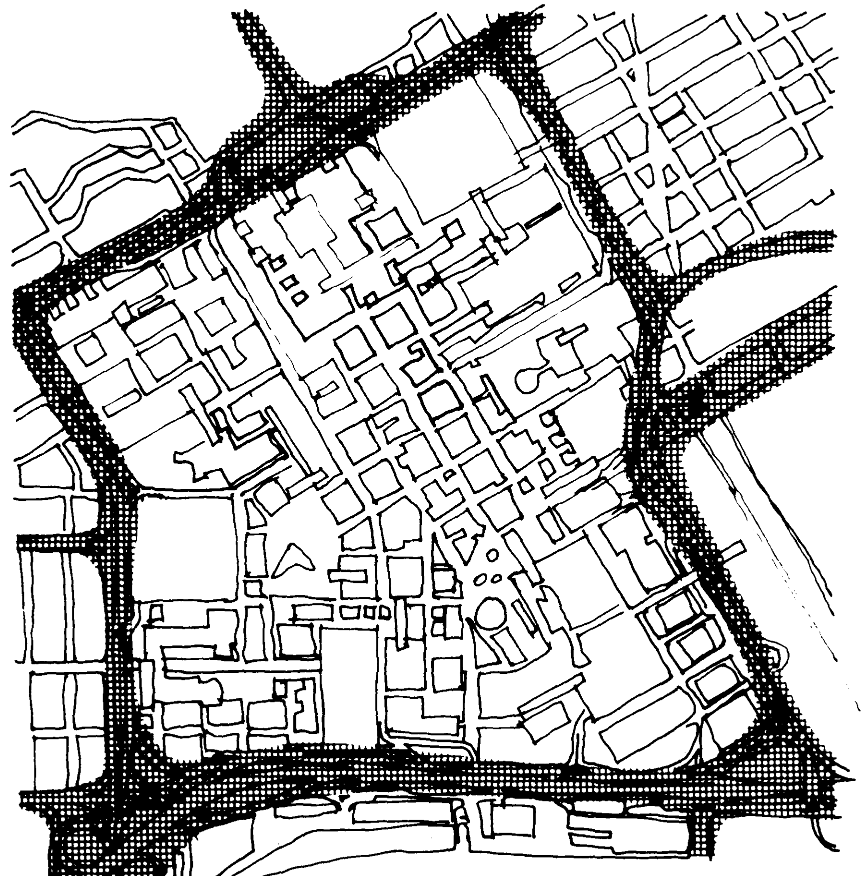
In contemporary cities the most formidable movement boundary is the access ring of expressways which is built or being built around a number of city cores. In terms of boundary operational modes, this access ring is primarily a mechanical boundary for the urban form. This expressway of access is simply a swath cut through the urban form whose dimensions are determined by the needs of the automobile. Holes are poked through above and below the ring which are just big enough for automobiles and trucks to pass through. The adjacent activities and forms have little or no direct bearing on the forms of the access ring. Some attempts have been made to integrate this ring with the urban pattern, but such attempts are severely limited by traditional notions of two dimensional land use planning.

For convenience, the city of Boston, with its inner belt access ring, will be used. The inner belt is cut by an extension of the Massachusetts Turnpike.

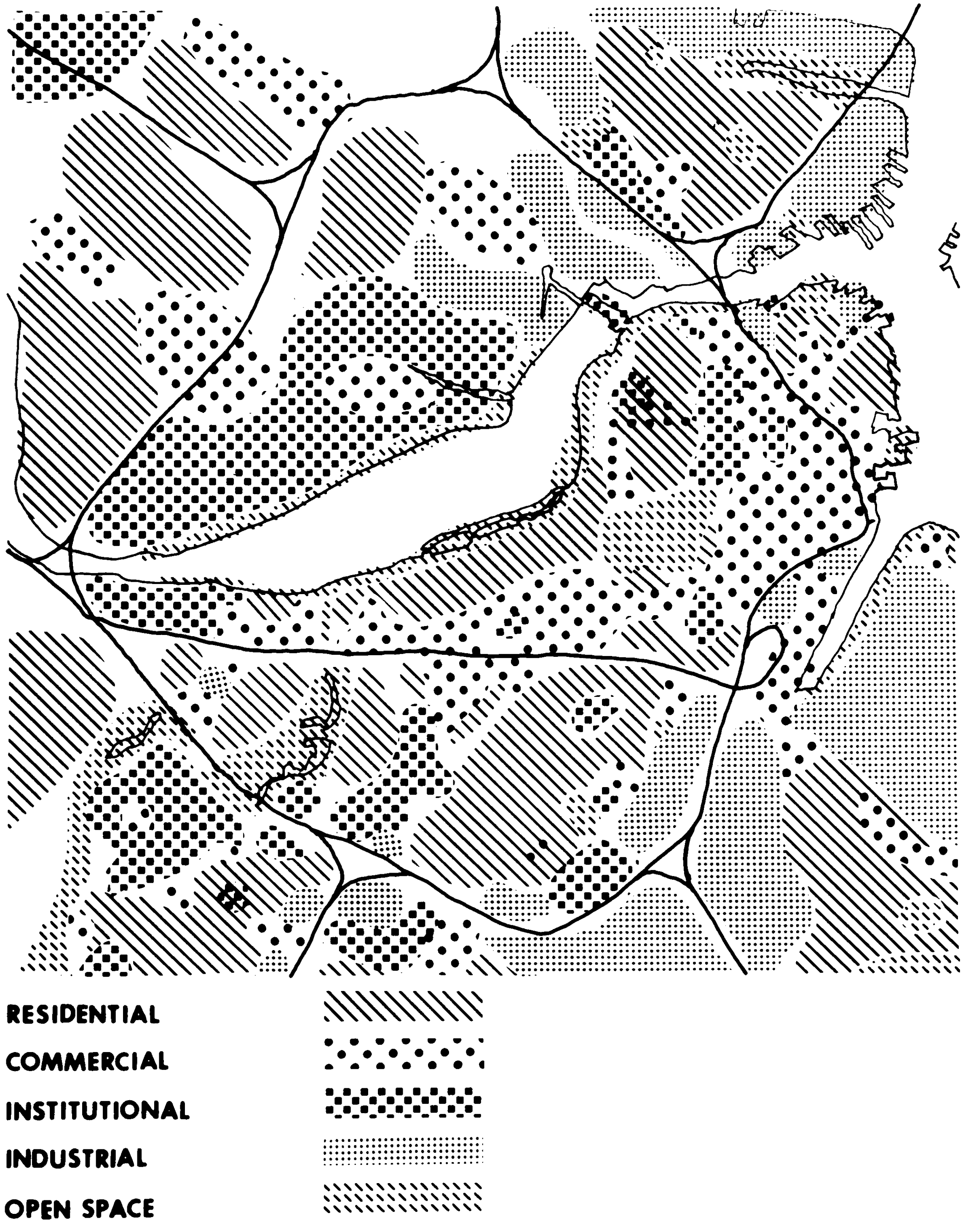
KANSAS CITY



FORT WORTH



EXISTING URBAN BOUNDARIES ACCESS RINGS



BOSTON:
ACCESS RING & ACTIVITIES

Therefore, there are two access rings adjacent to each other. The northern and largest ring, which is triangular in shape, is divided in the center by the Charles River. The northern side of the Charles is dominated by the Massachusetts Institute of Technology and various research facilities. The southern side of the Charles is dominated by the commercial core of the Boston Metropolitan Area. The southern ring is of mixed use with the largest area being a semi-slum residential neighborhood. The large ring formed by the inner belt is approximately a square of 2.25 miles on a side.

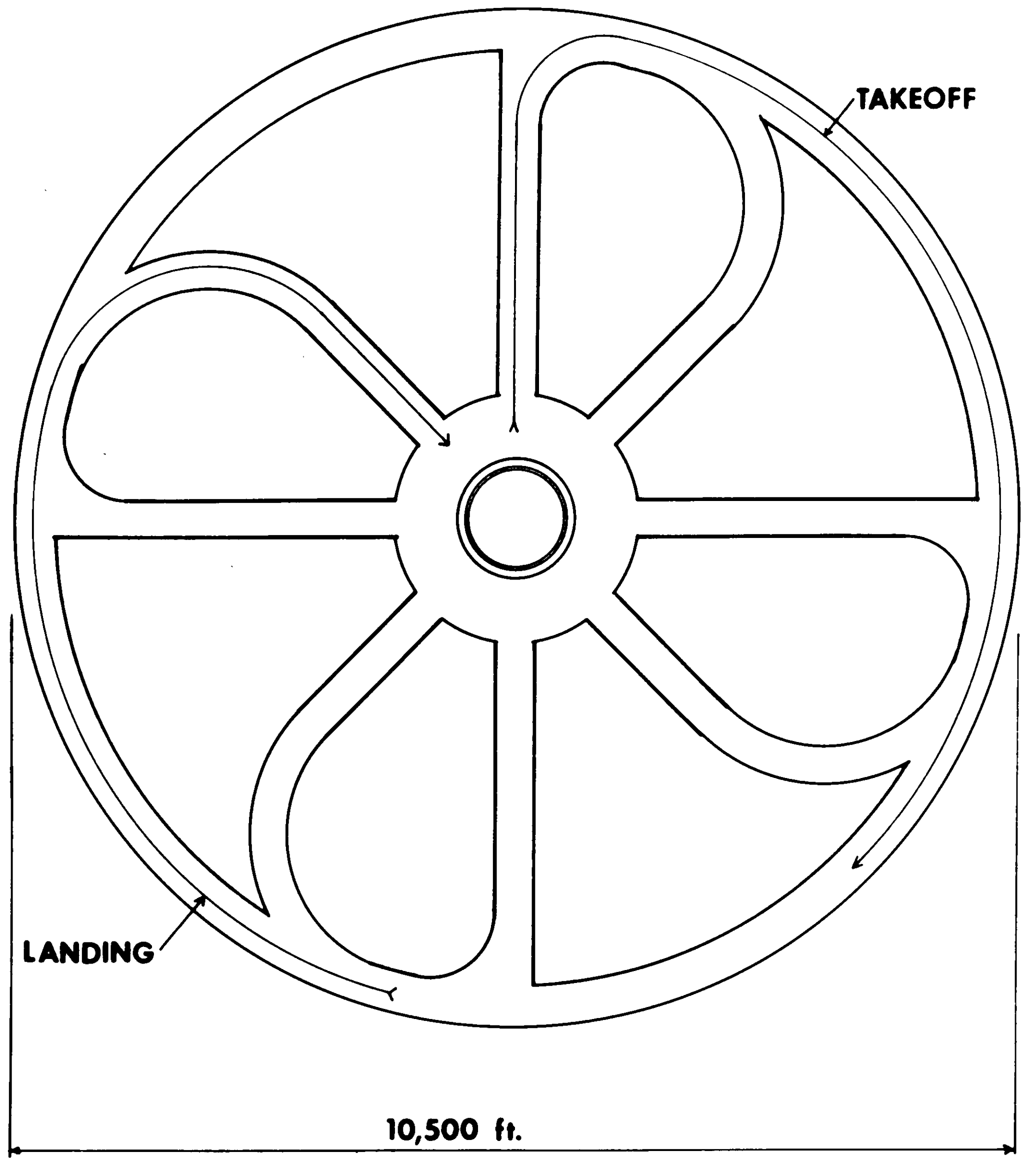
Two considerations lead to the next diagram:

1. Cities have a tremendous capital investment in the access ring. The return on this investment in terms of usage may be increased or maximized by incorporating other modes of transportation in the same basic land space and structure.

2. For purposes of this test case, the development of a maximum urban boundary seems to offer the best validation test.

The increased utilization of existing land space plus the maximization of an urban boundary generated by movement establish the basis of the hypothetical test.

The circular airport is an idea of James R. Conrey that has been tested by the Navy.[1] The airport has the advantages of being independent of wind direction, self-correcting in terms of directional stability at high landing speed, and more efficient in terms of length of runway and number of planes taking off and landing. While the Navy report is optimistic, the Federal Aviation Agency has a more conservative attitude. The FAA believes additional construction costs may outweight the advantages. A circular airport 12,000 feet in diameter with a maximum bank of 23 degrees would have an optimum landing speed of 195 m.p.h. The

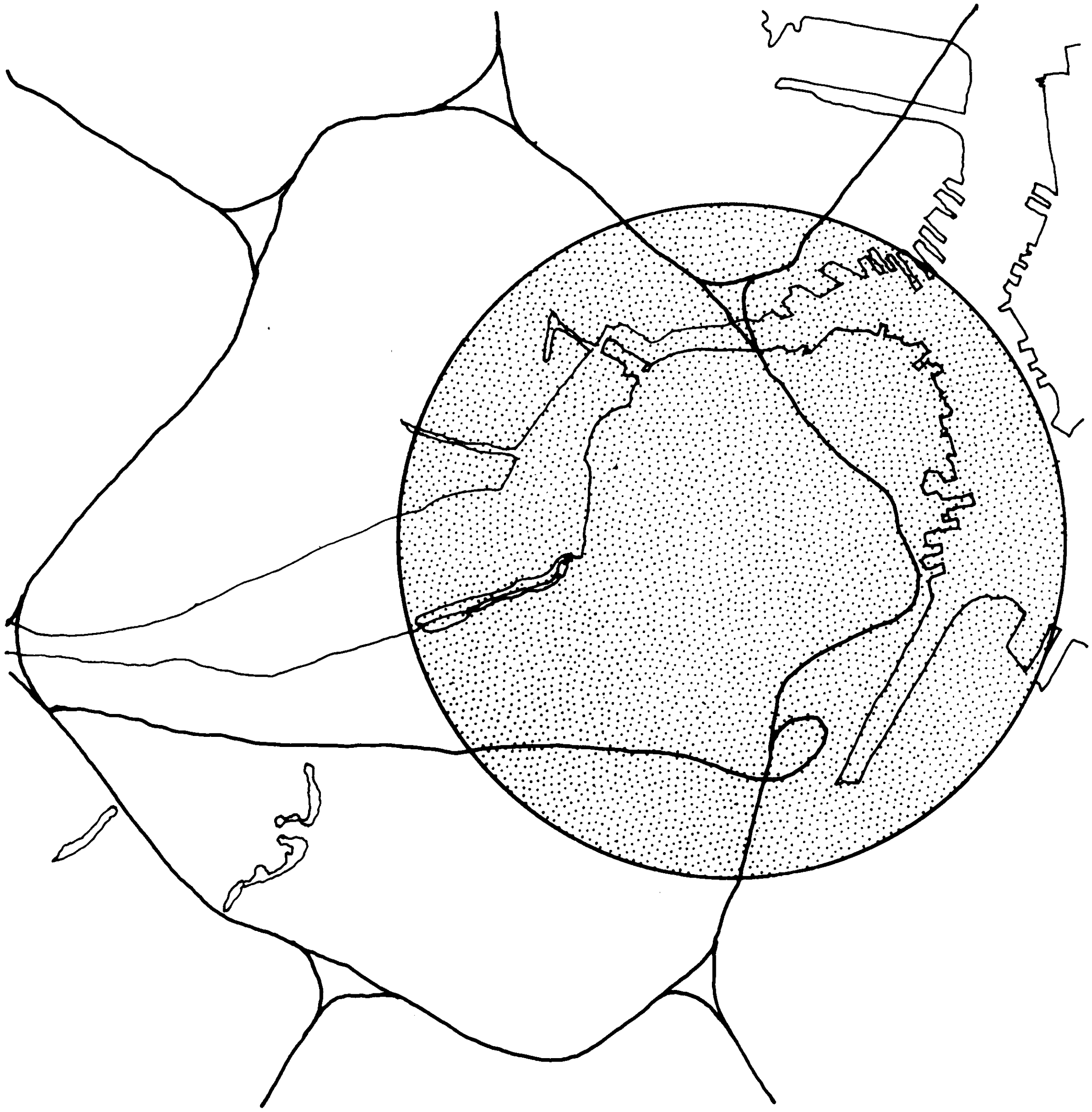


CIRCULAR AIRPORT

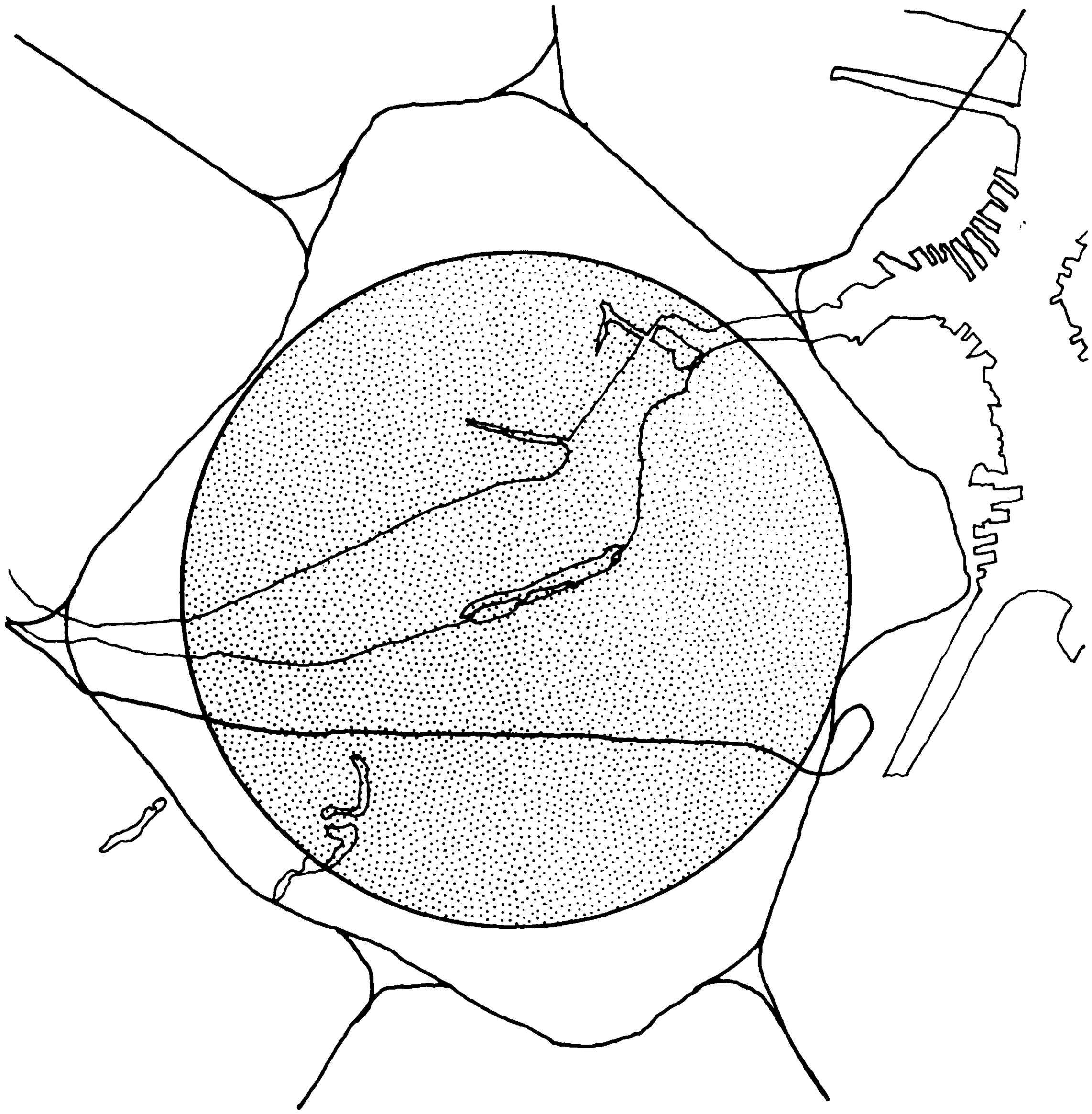
super sonic aircraft, XB-70, which is currently being tested, has a landing speed of 300 m.p.h.

A circle 12,000 feet in diameter, the access rings of the inner belt and the turnpike extension, and the land and water masses of Boston are shown in three diagrams. In the first diagram, the circle is centered around the land area of the old Boston center. There is no inherent coordination of the access ring and the circle. A circular airport in this position might reinforce the island-like quality of the old Hub, but it would create additional confusion in terms of transportation systems. In this geometry, a high speed ground transportation ring could either go with the airport, the access ring, or in a third location. This first diagram spreads the movement boundaries over the urban landscape, creating a number of irregular pockets of cells. A cellular breakup of this kind may be desirable and have some interest in terms of urban form, but it is not efficient land use and it tends to negate the idea of a maximum boundary.

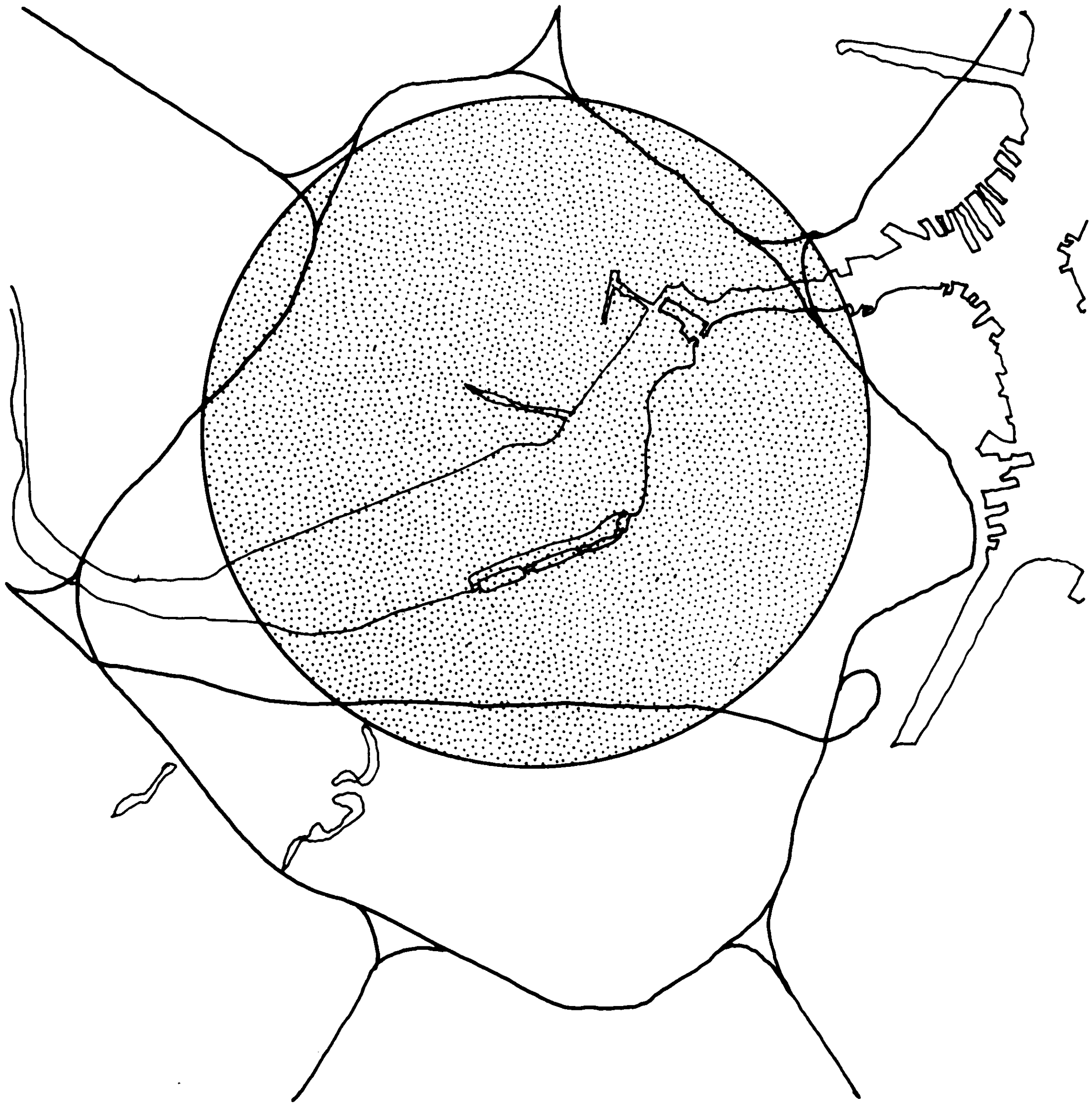
In the second diagram, the circle is balanced in the square of the inner belt. This diagram has geometric qualities which offer the possibility of the coordination of various transportation modes. The possibility of developing a maximum boundary condition is almost present in this position. The biggest drawback is that the urban form within the ring is divided by the Charles and the turnpike extension into three nearly equal land areas. An examination of the Boston activities diagram does not offer any kind of a clear concept of what the relationship between three such units would be.



BOSTON:
ACCESS RING & CIRCULAR AIRPORT 1



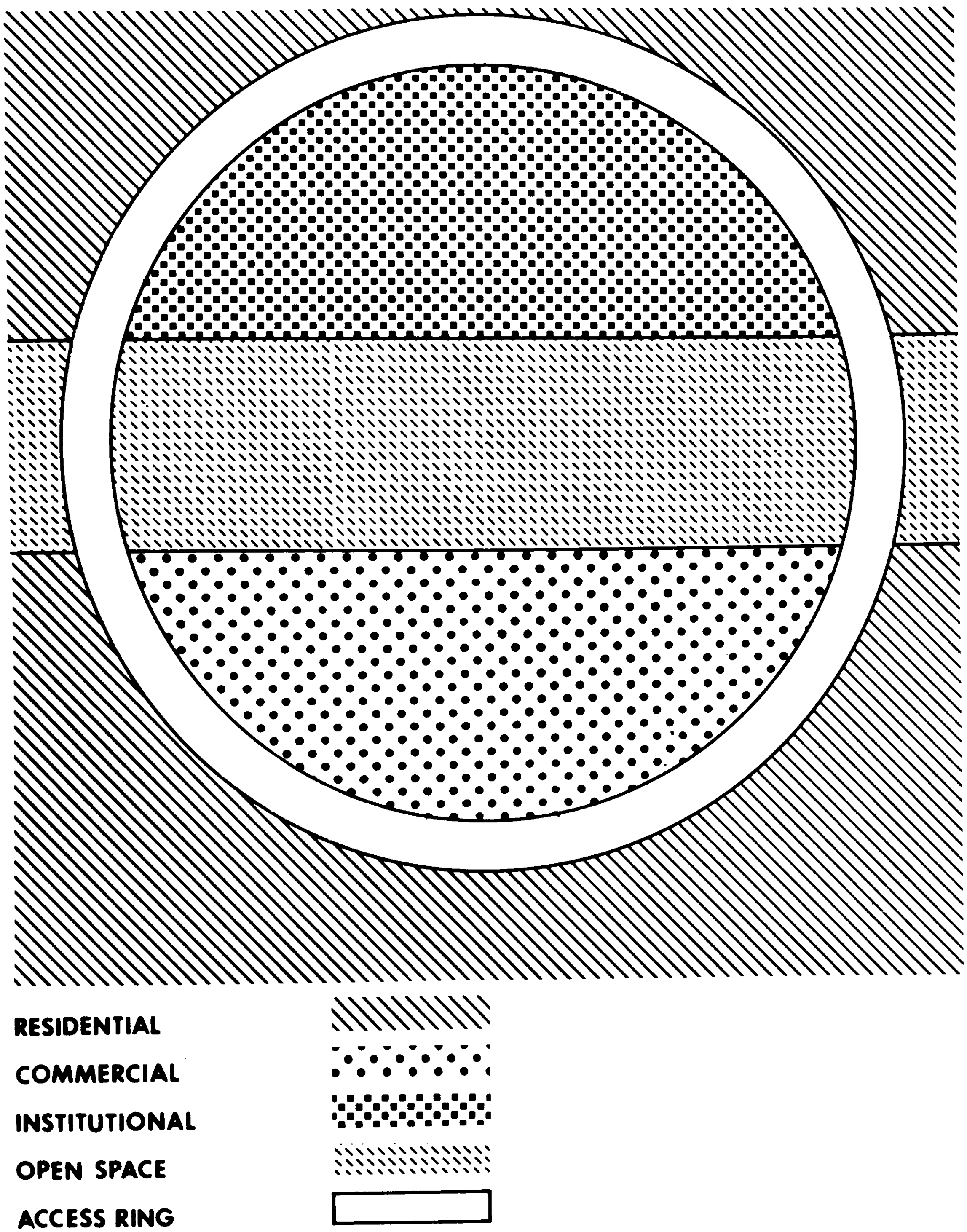
BOSTON:
ACCESS RING & CIRCULAR AIRPORT 2



BOSTON:
ACCESS RING & CIRCULAR AIRPORT 3

The third diagram has the circle centered in the triangle formed by a portion of the inner belt and the turnpike extension. The overlapping offers an optimum land usage for the transportation modes. The geometry offers the potential of developing a coordinated transportation system of automobile expressway, high speed ground transportation, and airport, thereby creating a maximum movement boundary. The Charles divides the urban form into two banks, one primarily commercial and the other educational. Thus in conceptual terms we have a bi-nuclear city centered around a large leisure space in the form of a river and served by a highly sophisticated access ring. This seems to suggest a total city form of a very dense and highly mechanized city core surrounded by a much less dense support area which is predominantly residential. This third diagram is carried on as the test case.

The schematic activities plan shows the primary concept of the urban environment that is indicated by the (BOSTON: ACCESS RING AND CIRCULAR AIRPORT - 3) diagram. This kind of bi-nuclear condition of the institutional and commercial activities is somewhat reinforced by economic predictions concerning the role of a post-industrial society. According to some economists a post-industrial economy will maintain a core activity of producing, controlling, and dispersing information. This differs from an industrial or pre-industrial economy which is primarily concerned with the distribution or production of goods. In this particular case the Boston area is a world education center. Hence the integration of educational and commercial facilities into a preceivable whole has a degree of feasibility in view of the special character of Boston and the economists predictions.



SCHEMATIC ACTIVITIES PLAN

The test case can now be formulated.

Develop a hypothetical urban form composed of a boundary generated by movement and surrounding a dense core housing education, leisure, and commercial activities. The movements generating the access ring boundary includes a full range of movement scales from walking to 2000 m.p.h. The primary problem is how the urban and sub-urban activities interact through the access ring boundary.

CHAPTER TWO - NOTES

1. In *Time* magazine of December 31, 1965, the idea of a circular airport as developed by Navy pilot James R. Conrey is reported. Conrey developed this idea and persuaded the Navy to test it at the General Motors test track at Mesa, Arizona. In a report of the test in 1964 the Navy stated that the circular airport has "a definite and vital place in future aviation".

CHAPTER THREE

In this chapter, the problem as stated is analyzed within the synthetic framework of theory. The analysis should produce the prime criteria for a working and vital solution.

Now that the problem is defined, the first step is the application of dimensional synthesis to establish a basic order upon which a solution may be developed. The problem as defined has three basic components: the activities of the core, the different scales of movement which generate the boundary, and the structure which houses these two.

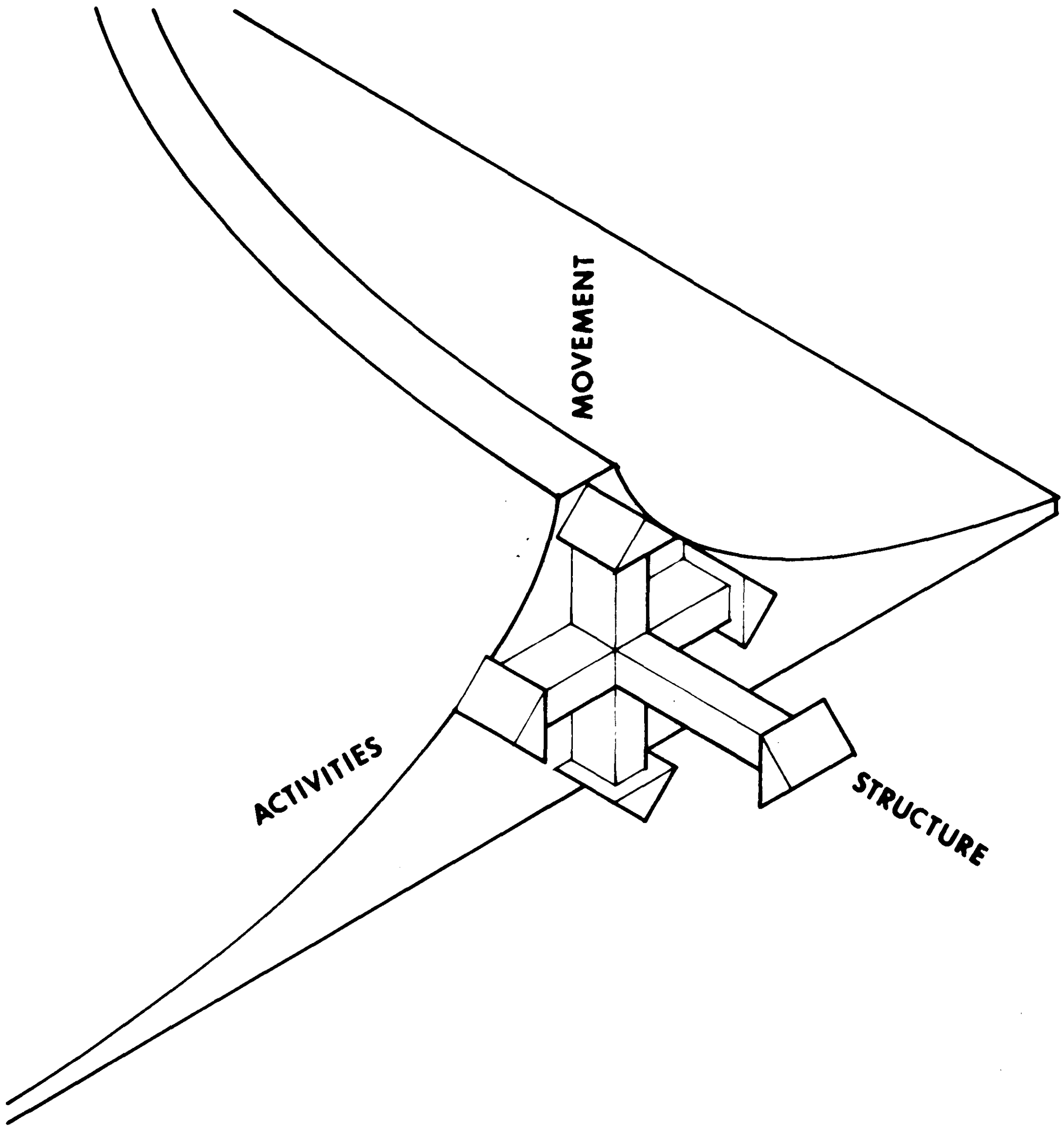
The activities as shown in the schematic activities plan are basically planar, but the order of the activities may be described by a radial line. Therefore, a cross-section through the schematic activities plan would show the variance of activities as a function of a single dimension.

The movement scales have as extremities walking on the ground and flying in the air. The basic order is described with a vertical line.

The structure is a result of the activities and the movement and is a third dimension. The direction of the line describing the structure is perpendicular to the plane defined by the intersection of activities and movement.

The form described by the dimensional analysis is three dimensional. In this case, the dimensions have conceptual names which will be of great help in ordering the problem but are not intrinsic requirements of the theory as stated. The role of the fourth dimension does not appear critical to the analysis of the problem. The fourth dimension will be discussed in the evaluation as a criticism of the test case.

Now that three dimensions have been designated, the boundary synthesis may be applied. Each dimension must be able to assume qualitatively any one or a combination of the operational modes of the boundary synthesis in order to



DIMENSIONAL ANALYSIS

perform at any scale any specific function at or through the boundary.

Activities: Activities may be considered as being composed in terms of quality or type and intensity or density.

1. Osmotic: Shopping might be continuous through the boundary along a shopping mall perpendicular to it. As the boundary is generated by the ingegration of modes of movement the shopping may intensify at the boundary because of the increased accessibility for both goods and people.

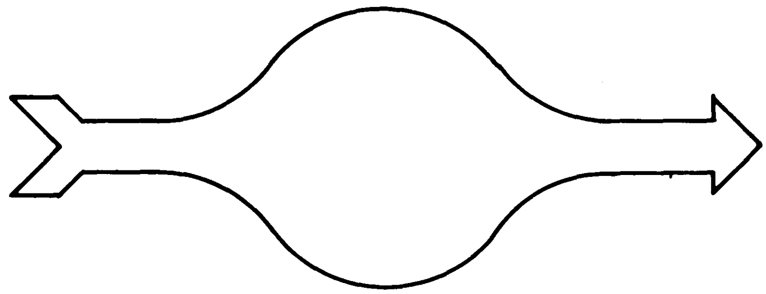
2. Mechanical: Activities may maintain both quality and intensity as relatively constant through the boundary. In the schematic activities plan in the preceding chapter, the Charles River, indicated as open space, is treated in this way. This type of interaction would indicate that the activity as a function is somewhat independent of the boundary function.

3. Serial: A serial interaction indicates a primary change in quality. This may also be accompanied by a change in intensity, but that is not critical. It may be said that the essential activity remains the same but the functions change. One might think of a university constructed about the boundary. On one side would be the residential facilities, the center would contain student activities and the primary connecting movements, and the other side would principally be classroom facilities.

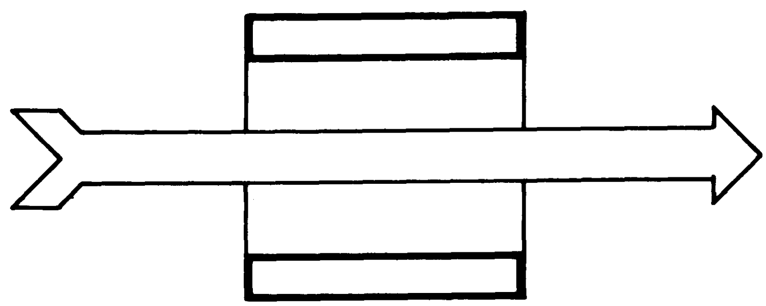
Movement: Movement may be thought of as either a pathway, a capsule, or continuous flow which interacts with or through the boundary in some way.

1. Osmotic: A movement may in the process of interacting with or through the boundary become part of the boundary. A transportation network

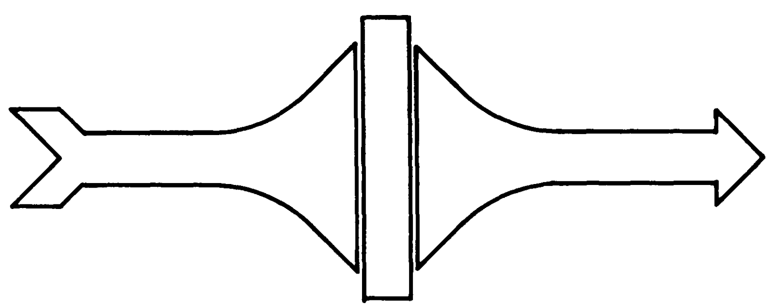
OSMOTIC



MECHANICAL

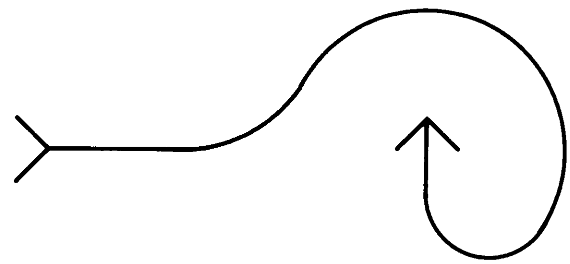


SERIAL

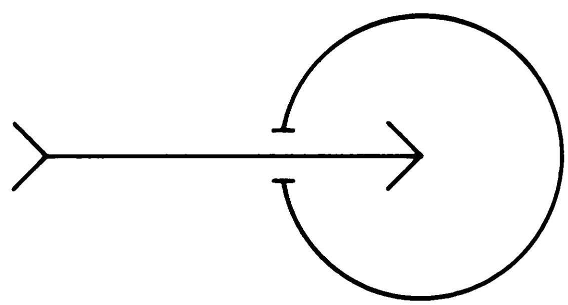


ACTIVITIES
BOUNDARY ANALYSIS

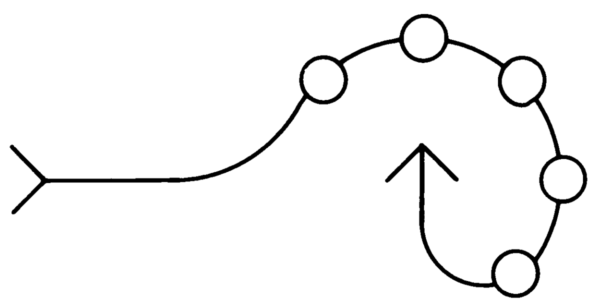
OSMOTIC



MECHANICAL



SERIAL

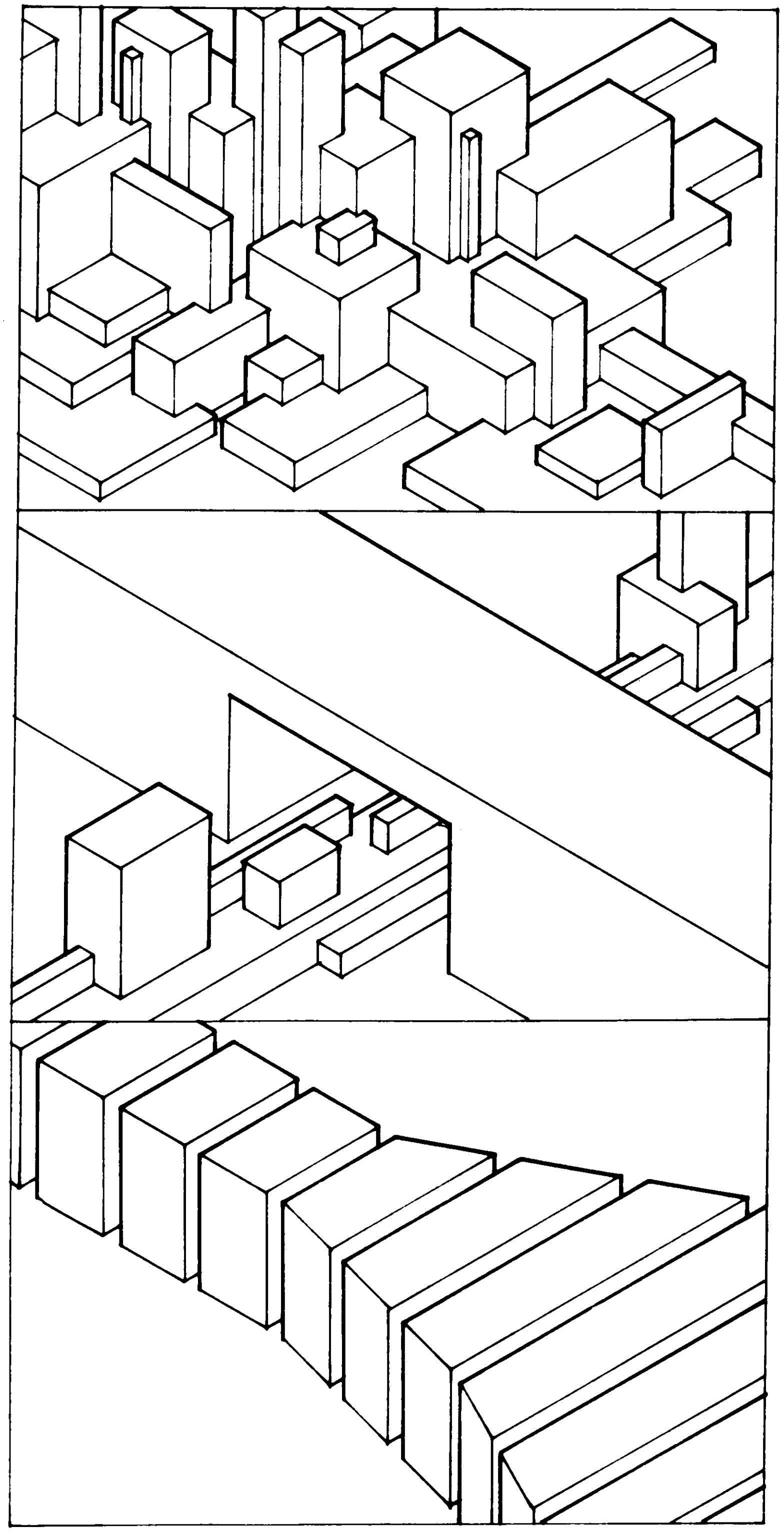


MOVEMENT BOUNDARY ANALYSIS

OSMOTIC

MECHANICAL

SERIAL



STRUCTURE BOUNDARY ANALYSIS

upon interacting with the dense core may become part of the boundary. This is the case of the present expressway system which becomes the access ring surrounding the urban core.

2. Mechanical: When physical dimensions allow direct movement through without requiring any substantial involvement with the boundary, the interaction is mechanical. The relationship between two raodways using an overpass at their intersection is a mechanical interaction.

3. Serial: When the process of interaction between two areas requires the movement to undergo a number of changes, the interaction is serial. Such would be the case with a truck (capsule) loaded with cartons of goods in one interacting through the boundary with the consumers in another area. At the boundary would occur the change process taking the goods from a bulk state to a consumer state.

Structure: In ways very similar to activities and movement, the structure can vary with the conditions of interaction.

1. Osmotic: The structure may maintain itself as a basic system, but vary its quantity in the boundary area. Existing urban structure may be generally described as a combination of rectilinear forms set in a matrix of pathways. As a structure this tends to lessen in quantity as it nears the access ring, which is one possible form of osmotic interaction.

2. Mechanical: If two or more clearly distinct structural systems intersect without becoming integrated in any way, the interaction is mechanical. A structure supporting the access ring running over the structure housing a shopping

mall without the two becoming involved would be a mechanical interaction.

Serial: When the structure evolves in a step-by-step fashion to account for some condition it is a serial interaction.

This essentially comples an outline analysis within the synthetic frame established in the first chapter. The second chapter stated the problem, and this chapter states the specifications of the solution.

> In order to build an access ring as a working and living part of the urban form, the ring must have a minimum of three dimensions. Each dimension may behave in three ways. There are nine basic modes of interaction, each of which may join with any combination of the others to perform a specific function.

CHAPTER FOUR

A set of ten components and their pattern of relationship and interaction according to the solution specifications of chapter three are stated in this chapter. The key element of this chapter is the final pattern of relationships which is described as a three-dimensional matrix.

In order to propose a viable solution for a maximum access ring as an urban form, a set of components in terms of scale and function must be developed. The components must be devised so that in combination they meet the analytical specifications. Therefore, the synthetic theory and the analytical specifications act together as a framework for the more specific elements of scale and function.

The boundary is generated by various scales of movement ranging from walking to flying. The fastest and most technical movement is flying in airplanes. At this level of movement, the boundary acts as a connection of the adjacent areas with the whole of the world. With the advent of 2,000 m.p.h. passenger-carrying aircraft, the circular airport at the boundary would be a point of interaction of the city core and surrounding area with a world movement network.

The serial process of landing and taking off is the prime internal determinant of the airport form. The capsule which is the aircraft does not lend itself technically to transferring to other transportation networks; therefore, process interactions of the osmotic or mechanical type will take place primarily at the level of the passenger or goods. This means that a physical facility is required for passengers or goods to leave the aircraft and connect with other modes of transportation or activity.

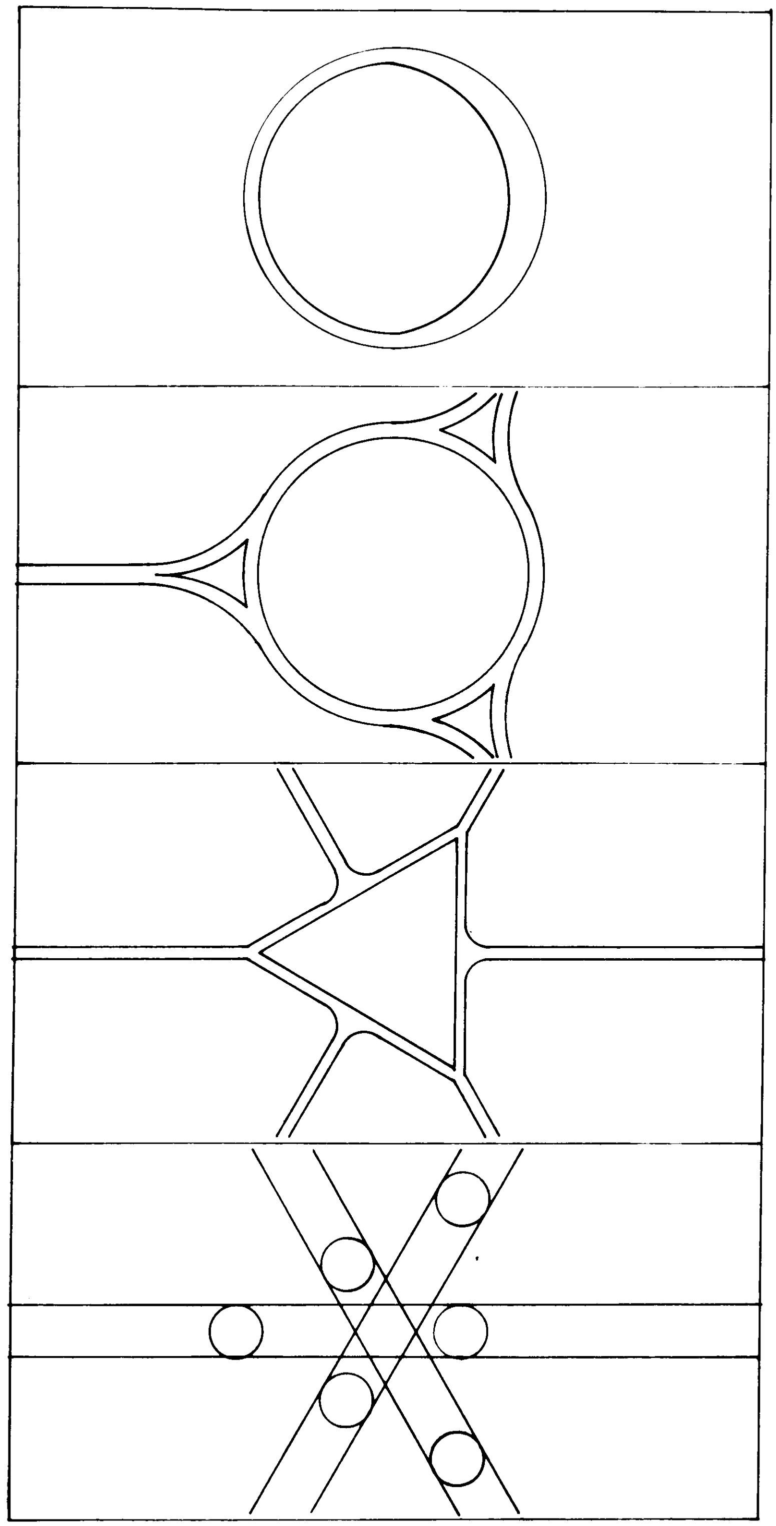
In scale terms, the next lower transportation mode is a regional connector with speeds in the range of 150 to 300 m.p.h. The vehicle here would be some sort of ground supported capsule, and in this aspect could be transferrable to other transportation modes. Therefore, facilities for capsule transfer are required. The capsule interacts serially through a slowing down and speeding up

WORLD
AIR VEHICLE
200 to 2000mph

REGION
GROUND VEHICLE
150 to 300 mph

METROPOLIS
GROUND VEHICLE
40 to 80 mph

CITY
GROUND VEHICLE
20 to 50mph



MOVEMENT BOUNDARY SCALE

process in the boundary. The capsule may interact osmotically by becoming involved in the internal movement process of the boundary or move directly in a mechanical way to a predetermined destination.

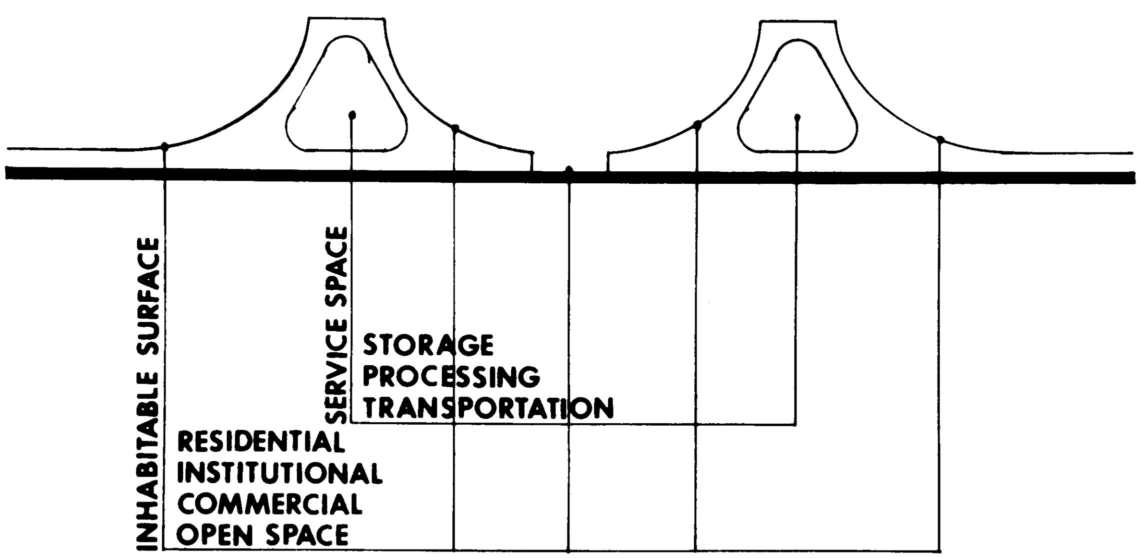
Below the regional network are the metropolitan, city and neighborhood networks of ground vehicle movement. In terms of capsule and network, these four modes must be able to interact with each other serially by connection through their scale hierarchy, mechanically by direct connection from one to the other, and osmotically by being connected integrally with the boundary's internal movement system. Furthermore, the capsules and the networks must be able to interact in all three modes with the activities and the structure.

At the lowest scale and highest dominance is the movement of walking. All scales and functions of movement must be able to connect in all three modes to walking pathways. All activities must have all forms of interaction with walking. Walking is the common denominator of the movement components. Walking is primarily predominent in the ground plane.

The physical locations of the extremities of the movement components, walking and flying, are determined by their internal requirements. The walking pathways must be predominantly on the ground and the airport must be in the air. Because the airport must have free accessibility to the air, anything which intersects it must pass under the runway. The locations of the various ground vehicle networks are determined by a combination of internal and external relations as these networks must interact with various serial and osmotic processes within the boundary. It would be helpful in terms of braking and accelerating for the regional network to run up grade when approaching the access ring and down grade when leaving the access ring. A vertical location of the various networks within the boundary area, as determined by a hierarchy of scale, is a strong possibility. In this case the ground plane would contain walking pathways and ground vehicle networks for the neighborhood and the city. The next level above grade would hold the metropolitan network's access ring and the activities requiring direct accessibility. Above the metropolitan ring and below the airport would be the regional ring with its high speed ground transportation system and related facilities. This physical distribution of movement components provides a skeleton for a transportation interchange ring.

Activities may be considered as being composed of a duality of service activities and people activities. Service activities are primarily oriented around the handling of goods. Functions like storage, processing, and mechanical transportation compose service activities. The areas allocated for service activities would house things like fabricating and packaging facilities, storage warehouses, parking garages, hangars, fuel and energy storage and processing facilities, and mechanical maintenance areas. Service activities have a high accessibility requirement.

People activities occur in inhabitable areas which have light, air, and a supply of whatever goods are necessary for the specific function. In the diagram, the inhabitable space flows over and under the service space. A portion of the inhabitable space over the service space has direct accessibility to sun and air on one side and service, goods, and transportation on the other side.



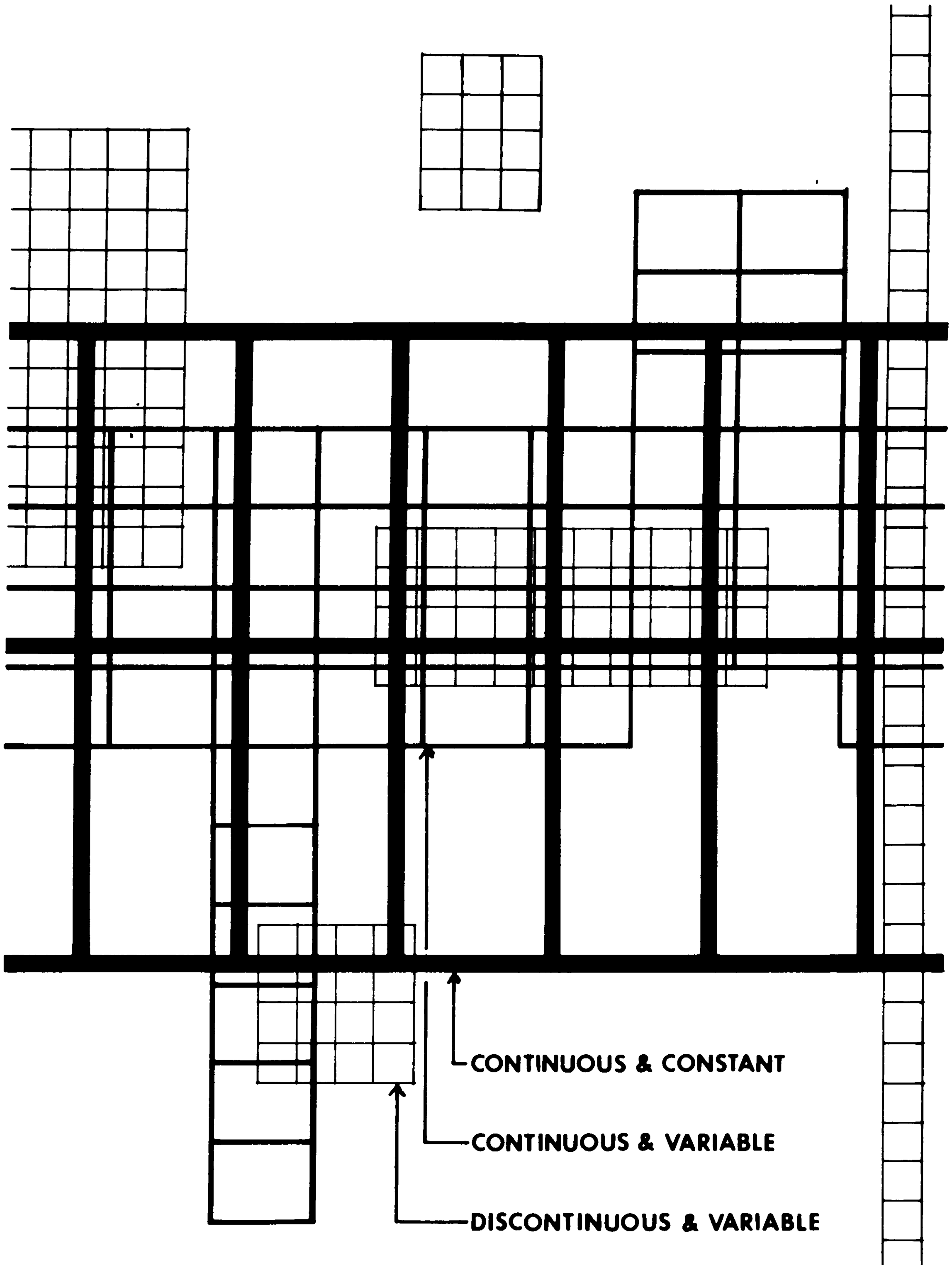
ACTIVITIES
BOUNDARY SCALE

Also the diagram indicates that the ground plane is held as inhabitable space in agreement with the notion that the movement of walking is predominant on the ground plane.

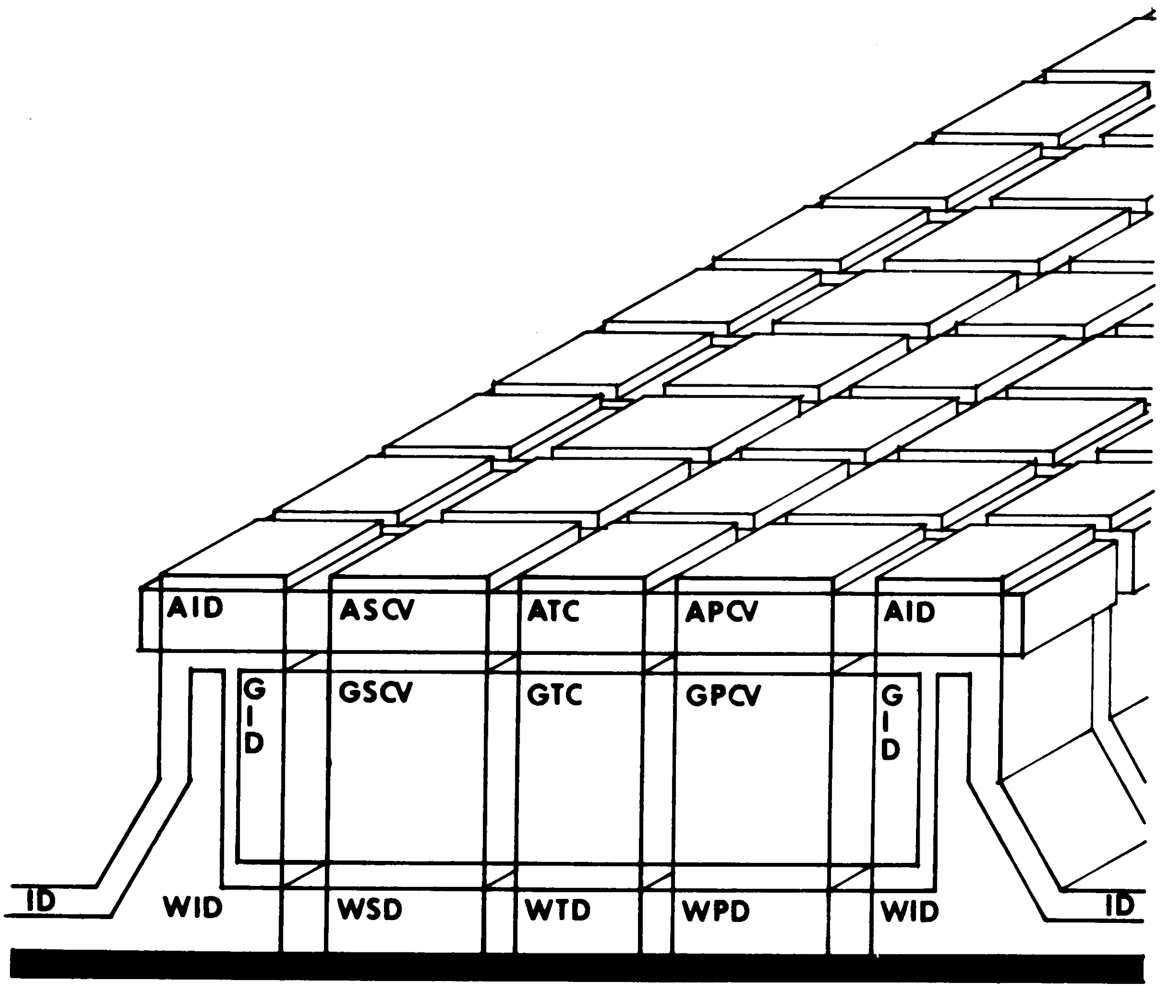
The activities diagram is intended as a cross-section through the schematic activities diagram. This indicates the bowl-like area housing institutional and commercial activities as well as the open space of the Charles River. The outer slopes of the bowl house residential activities.

As stated previously, structure is the result of movements and activities. Hence, the prime determinants of structure are the various support and closure requirements of the functions which result from the interaction of movement and activity. When the function is continuous and constant over the area being examined, the structure follows the same pattern. A street grid is an example of this type of structural pattern. The three types of structural patterns shown are a logical classification system determined by the requirements of each situation. This kind of situational logic means that there is no requirement for the structure which supports the airport to also house the corner newsstand.

A synthesis of the ten components listed into a formal relationship is illustrated by the three-dimensional matrix diagram. This diagram is an expression of the relationships between the components and not of the architectural form. The key to the three-dimensionality of this matrix is found in the continuous, discontinuous and constant, variable classifications. These classifications are a description of the structure but are arrived at through considerations of activity and movement. Therefore, any point marked as discontinuous and variable is



STRUCTURE
BOUNDARY SCALE



A AIR VEHICLE
G GROUND VEHICLE
W PEDESTRIAN
I INHABITABLE SURFACE
T TRANSPORTATION
S STORAGE
P PROCESSING
C CONTINUOUS & CONSTANT
CV CONTINUOUS & VARIABLE
D DISCONTINUOUS & VARIABLE

THREE DIMENSIONAL MATRIX SYNTHESIS

potentially unique both in the cross-section and along the chain of relationships. If the dimension of time is included, the points which are continuous and constant will have the lowest rates of change while the discontinuous and variable points will have the highest rates of change. This matrix of relationships is dependent upon the interaction of movement and activities and independent or a priori to any specific form. Therefore, as a form, the boundary of the access ring and circular airport must be designed to intrinsically contain these relationships if it is to be a vital urban form.

These components and their three dimensional inter-relationships constitute an outline of a solution for the problem. The remaining problem is the design of a physical facility which provides a living framework wherein these components may interact.

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