ON THE USE OF THE GARIN-LOWRY ACTIVITY ALLOCATION MODEL IN METROPOLITAN AREA PLANNING: THE CASE OF WINNIPEG

by

Robert J. Crews

A Thesis

submitted to the Faculty of Graduate Studies

in partial fulfillment

of the requirements

for the degree

of

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ABSTRACT

The current debate concerning the potential utility of large-scale, quantitative simulation models to the predicting of urban development processes is familiar to urban planners and analysts alike. This research examines the operation of the Garin-Lowry activity allocation model, and its ability to describe the structure of the Winnipeg urban system for a 'base-year' of 1971. A doubly-constrained gravity submodel is used to simulate work and shopping-trip behaviours as the foundations for the allocation of employment and population to subareas of the bounded metropolitan spatial landscape. A second economic base submodel is operated on functional-economic criteria via the minimum requirements technique. The zone system partitions the landscape into 9 superzones and 125 zones whereupon spatial resolution is increased relative to other similar research on the model; this design then constitutes a comparatively rigorous test of the model's capabilities.

The definition of the economic base, and the sensitivity of the associated multiplier, are found to be vital determinants of model performance. Winnipeg's spatial isolatedness and the nature of its role as regional service centre, introduce certain unique elements into the 'base' concept wherein the criticality of manufacturing, transportation, financing, and administrative functions to the metropolitan economy is suggested. Although the minimum requirements technique derives the most conceptually satisfying description of the base, the associated subdivision of individual industrial sectors into

basic and service components is largely incompatible with the nature of the interaction data governing the internal allocation of employment.

It is suggested that the economic base be realigned in accordance with a method, on either functional or locational criteria, wherein individual sectors are wholly classified as basic or service. This would be proved the most immediately fruitful means of effecting improvement on the comparatively poor correspondence in activity distributions derived in this case.

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Models are undeniably beautiful, and a man may justly be proud to be seen in their company. But they may have their hidden vices. The question is, after all, not only whether they are good to look at, but whether we can live happily with them.

(Kaplan, 1964:288)

CHAPTER ONE - INTRODUCTION

A plethora of new methods in the analysis of urban systems have been employed in geography in recent years, many of which are based on analogies with other disciplines, especially the more advanced sciences. This constitutes a shift from the view of geography as essentially descriptive scholarship and interpretation to a view which recognizes the need to explain phenomena of interest by building theories and models, and ultimately to develop a predictive capability. In such fields as urban and regional planning, there has been generated a substantial demand for predictive capability which in turn, makes increasing demands on geography both as an essentially synthesizing discipline and as the only discipline which makes a direct attack on spatial analysis. This all adds to the pressure to produce theories and models which can assist prediction (Wilson,1969B:5).

An important aspect of the new methodology is the development of comprehensive activity allocation models. The allocation of activities to subareas of a bounded region is an important aspect of urban modelling as it provides major inputs to land use and transportation planning and in addition, it offers a means through which changes in the urban system can be better monitored and understood (Batty, 1971). Apart from using these models for evaluating change in spatial systems, it is important to recognize that any urban model is a translation of an hypothesis about the organization of the urban system into a form which can be manipulated and tested against observations in the real world (Harper, 1973:63).

This research examines one activity allocation model originally developed by Lowry (1964) and modified by Garin (1966) as it applies to Metropolitan Winnipeg. Emphasis is placed on considerations in model preparation and internal methodology towards maximizing the model's description of the Winnipeg urban system for 1971.

1.2: Literature Review and Research Objective

The model structure is comprised by an economic base submodel for determining total employment and population levels, and a gravity-type submodel for determining the probability of inter-zonal interaction with respect to workplace to residence, and residence to 'service' facility allocation. The framework has been developed and used extensively in the United Kingdom and North America at both the regional and metropolitan scales of enquiry. Its role within the planning function is visualized as one of many facets, including 1.) impact analyses, wherein model input variables are manipulated to reflect alternative economic policy or structural design alternatives, 2.) the continuous use of the framework as a means of monitoring the strengths and weaknesses of existing programmes, 3.) its use as an exploratory tool in the generation of alternatives as a primary planning exercise, and 4.) its use as an educational tool whereby the planner's and decision-maker's knowledge and awareness of system behaviour is heightened. In short, urban models should be capable of generating insights into the functioning of spatial systems as well as providing a means for simulating urban phenomena (Batty, 1976:233). It is also evident however, that they should be used with caution, until they are fully tested and justified empirically (Reif, 1974:45).

> In choosing a model to use in a particular study area, it will of course be necessary to ensure that the model can provide a 'reasonably' accurate description, and forecast, of the relationships and interdependencies of reality (Massey, 1973:11).

The first stage of the model evaluation process concerns a test of the model's capabilities to adequately describe the system under consideration. The specific objectives applying in this case then include the investigation of 1.) data base requirements, in relation to the availability and form of information from existing sources as the compiling and/or realigning of data are factors in the convenience and cost of model preparation, 2.) the relationship between zone system design and 'base-year' goodness-of-fit, 3.) the operational consequences deriving from alternative definitions of the economic base within the model, and

4.) problematic issues in the measurement of goodness-of-fit between empirical and model-generated activity destributions.

1.3: Organization

Chapter two begins with an introduction to the model concept and the perceived roles of quantitative models and the scientific method in relation to urban spatial analysis. The structure of the original Lowry model is then presented so as to introduce the 'parent' framework from which the Garin model is derived. The chapter closes with the presentation of the Garin derivative wherein its theoretical and practical strengths and weaknesses are contrasted to alternative modelling techniques.

Chapter three presents a survey of the related literature. This section begins with a definition of the planning function and a summary of the visualized roles of simulation models therein. The discussion then focuses on the proposed utility of the Garin model in prediction and policy-making with selected North American and British examples. The remainder of the chapter deals specifically with the objectives of this research in relation to Metropolitan Winnipeg.

Chapter four deals entirely with the procedure of preparing the data base and computer package. The chapter opens with a discussion of problematic issues in the acquisition and alignment of data for purposes in the model. This is followed by an account of the gravity model and interaction data adopted for purposes here from the 1971 Winnipeg Area Transportation Study; this model is contrasted to the Garin interaction submodel and relative strengths discussed. The economic base analysis of the metropolitan economy follows with an investigation into alternative methods. The chapter closes with a brief description of the computer package.

Chapter five presents the results of model trials wherein the best-fit distributions of employment and population possible in this case are discussed and tested for goodness-of-fit. Apparent strengths and weaknesses in both the data and correspondence measures are related to data form, zone system design, and economic base methodology.

Chapter six summarizes the findings and provides a discussion of some of their implications. Finally, some fruitful avenues for possible future research are suggested.

One further aspect of this research should be recognized. This research does not constitute an examination of the model in its fullest capacity; such an undertaking would exceed all practical constraints. Data and other budgets necessitate the adoption of inflexible sets of interaction data for use on the model in this case. In other similar research, it is common for improvements in the allocation of activities to be approached through the interaction data as part of a second-stage calibration procedure. As this option is not available, the final product here represents a comparatively crude form of the model. As such, this research is perhaps best considered as a first exploratory stage in evaluating the model's potential in metropolitan area planning for the case of Winnipeg.

CHAPTER TWO:

INTRODUCTION TO THE MODEL

2.1: The Model Concept

Among the offspring of the quantitative revolution of the 1960's, a period of heightened emphasis on methods of statistical mechanics in social science research, was a substantial body of highly sophisticated mathematical models, new tools for the interpretation of various theories of urban spatial structure.

The central theme of this development was one of 'generalization' or 'idealization' - the reduction of the many inherent complexities of urban form to the more manageable laws of common algebra. This generalization process was considered the 'bridge by which the scientist or theoretician crossed over from induction, or the observation of reality, to deduction, or the testing of theories and their application to new phenomena' (Harris,1966:262). In a different light, this implied a consonant shift from what, until then, were primarily descriptive theories, to operational, analytical, and most noteably predictive tecniques. The challenge of model development, itself a response to a realized need for greater analytical capability in planning and research, is best summarized by Harris:

> ...there are difficulties of identification and classification of concepts, difficulties in detecting regularities, and consequently insurmountable difficulties in devising hypotheses which genuinely produce regularities as deductive consequences. Nevertheless, a scientific approach can be adopted ... It consists of the breakdown of the complex system into manageable components or subsystems to provide an analytical framework. This framework is a tentative first step in the search for

> order and itself represents a degree of explanation. Attention is then directed to the causal relationships (interdependencies or interaction) observed within and between subsystems. (Harris,1966:121)

Since their initiation, models have been attributed multiple definitions yet no attempt would be complete without first clarifying the vital relationship between any model and its parent theory;

> The construction of a model presupposes the use of a theory which explains parts or the whole of the relationships established in the model. Consequently, the predictions and solutions derived from the model are deduced consequences of the theory.
> (Rief,1973:49)

A theory may be considered a well tested hypothesis or more explicitly, a logical (or mathematical) law or set of statements of very high probability characterizing the phenomena or variables to which it refers whereas a model, is an experimental design based on a theory; that is, all laws are models but not all models are laws(Chorley and Haggett,1967:24,Harris,1966:265). There are two possible styles of approach to the development of such models; the hypotheticodeductive approach (building a model and testing the predictions against observations, as the example considered in this research), or the inductive approach (starting with data and attempting to infer general laws) (Wilson,1974:4). Regardless, all models are ultimately low-variety representations of high-variety situations, a view perhaps most cogently described by Chorley and Haggett:

> A model is thus a simplified structuring of reality which presents supposedly significant features or realationships in a generalized form. Models are highly subjective approximations in that they do not include all associated observations or measurements, but as such they are valuable in obscuring incidental detail and in allowing fundamental aspects of reality to appear. This selectivity means that models have varying degrees of probability and a limited range of conditions over which they apply. The most successful models possess a high probability of application and a wide range of conditions in which they seem appropriate.
>
> (Chorley and Haggett, 1967:22)

2.2: The Functions of Models

The predictive function of models has already been commented on; other functions of such models, according to a more universalistic view of such research, include:

a) a psychological or educational function, in enabling some group of phenomena to be visualized and comprehended which could otherwise not be because of its magnitude or complexity,

b) an acquisitive and organizational function, in that the model provides a framework wherein information may be defined, collected, and ordered,

c) a fertility function, in allowing the maximum amount of information to be extracted from the data,

d) a logical or explanatory function, by helping to explain the origin of particular phenomenon,

e) a systematic function, wherein reality is viewed in terms of interlocking systems,

f) a constructional function, in that they form stepping stones to the building of theories and laws,

g) a normative function, by comparing some phenomenon with a more familiar one,

h) a cognative function, by promoting the communication of scientific ideas; "the idea is nothing till it has found expression" (Kaplan, 1964:269) (Chorley and Haggett,1967:24-5).

2.3: The Conventional Lowry Model

The Garin-Lowry framework represents the second generation of a family of urban activity allocation models evolving from Ira Lowry's 'Model of Metropolis' 1962-3. The original model was developed in the U.S.A. as part of a modelling system to generate alternatives and aid decision-making in the Pittsburgh Comprehensive Renewal Programme (CRP), wherein Lowry's intended purpose was "the development of an analytical model capable of assigning urban activities to subareas of a bounded region in accordance with those principles of locational interdependence that could be reduced to quantitative form" (Rief,1973:170). The salient components of urban spatial structure represented in the model comprise three groups of activities; 1.) a Basic sector, including industrial, business, and administrative activities whose locations are assumed to be unconstrained by local circumstances of population distribution, market areas, and so on, (hence the employment level and location in the basic sector must be assumed as 'given', and so determined outside the model); 2.) a Retail or Service sector, including all those activities dependent directly on local resident population and purchasing power; that is, all activities for which a local market or service area can be identified for 'final' products and services, (the employment levels and locations in this sector are treated as endogenous variables whose values are determined inside the model), and 3.) a Household sector, consisting of the resident population on which the retail sector depends and which itself depends on the total employment level (basic and service) available, (it is assumed that the location of households is powerfully influenced by the distribution of employment; thus both population size and distribution are also endogenous)(Reif,1973:171).[1]

Both land use and interactions between land uses are considered. The theory underlying the framework identifies population and service employment as the critical activity variables, and movements between workplace and residential areas, and between residential areas and service centres as the critical interaction variables(Batty,1970:308).

1. Hereafter, the terms 'retail' and 'service' are considered synomonous in reference to this model sector.

Total employment in the study area is partitioned into two sectors, basic and service, implying some foundation in economic base theory. It is assumed that, given the distribution of employment in the basic sector, service employment and population can be derived;[2] that is, the distributions of population and service employment are consistent with the distribution of basic employment. Besides deriving the levels of the dependent variables, the model allocates these activities to different zones of the system (Batty,1970:308), on the basis of a zonal score or value of residential and/or service centre potential in accordance with two sets of activity constraints; one governing maximum population densities and the other, minimum threshold sizes for service functions. Thus the spatial system may consist of four types of zones; 1.) unconstrained, 2.) population constrained, 3.) service constrained, or 4.) both in the same zone (Batty,1976:57).

Once the distribution of basic employment is specified, the model first determines the residential locations of these workers and the associated level and distribution of population by application of a system structural multiplier, an inverse activity-rate.[3] The first increment of service employment is then derived from this basic population using the second structural multiplier, a population-

2. Thus, in the economic base mechanism, basic employment acts as the primary independent variable with population and service employment as the associated dependent variables.
3. The inverse is used since population is derived from employment allocated to residential zones.

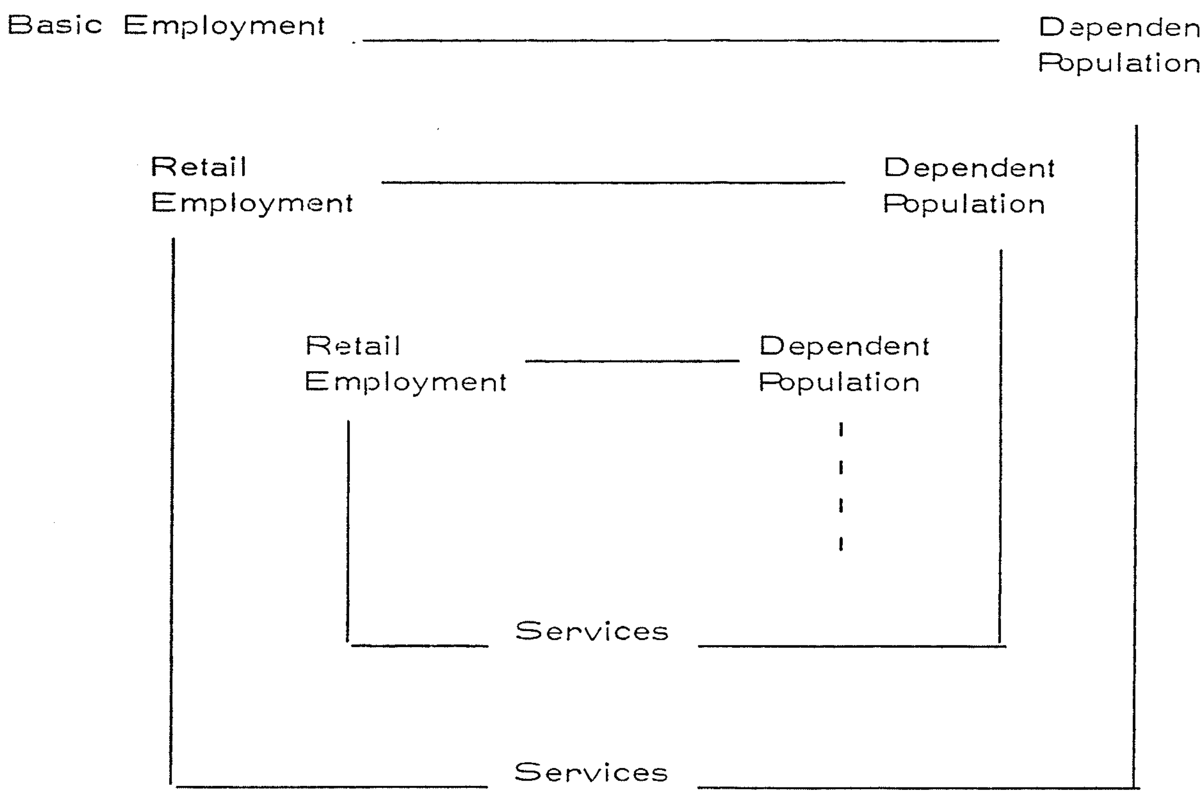
serving ratio (a ratio of service employment to total associated patron population), and this employment is allocated to service centres (Batty,1970:308). These workers require residential locations , thus leading to an additional increment of population and in turn, to a further increment of service employment and so on (Figure One). Continued application of this iterative sequence results in the derivation of successively smaller increments of service employment and associated population to some threshold, below which any added incremental values are negligable. The process is then said to have converged (Batty,1970:308).

Lowry developed a sophisticated structural housing for his functional subsystems which included; 1.) a full land accounting system on a per zonal basis for purposes of monitoring land consumption by land use type at the conclusion of each iteration of the model, 2.) the inclusion of an additional 'potential' submodel describing workplace to service activity interaction, 3.) several options for the disaggregation of households, in varying degrees, according to income group, housing type, and availability by location, 4.) similar options for the disaggregation of the service sector by activity type or employment, 5.) the incorporation of two sets of constraint procedures, one representing maximum population densities in residential zones and the other, minimum threshold sizes for service activities in specific zones, and 6.) a consistency-checking

Figure One:

CAUSAL AND FUNCTIONAL STRUCTURES OF THE LOWRY MODEL

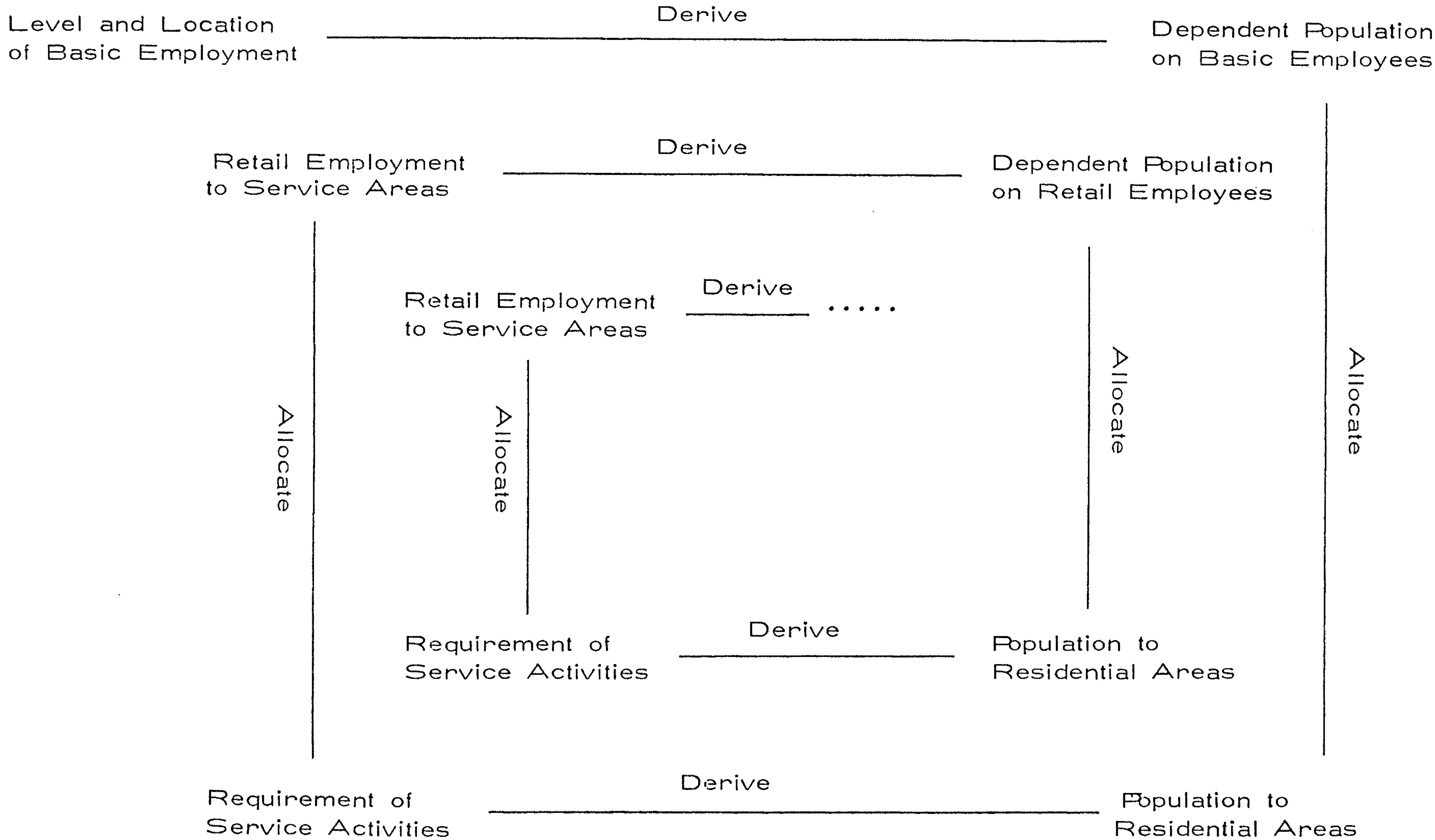
CAUSAL STRUCTURE



Source: (Reif, 1973:176)

Figure One:

FUNCTIONAL STRUCTURE



Source: (Reif,1973:177)

device to assure level similarity in the dependent variables at the input and output stages.[4]

Where the above represent issues of structure and spatial aggregation, a further issue of modelling technique - the treatment of time - must be highlighted in relation to Lowry's model since this is a critical determinant of (and is determined by) both the purpose and potential value of the modelling approach;

> ...the important 'time' question relates to whether the model-builder is attempting to represent the total cross-section of one or more activities at some point(s) in time, or the marginal change between two points in time. This turns out to have a fundamental bearing on technique. The perfect answer to the question would be to seek a fully dynamic model in which 'time' was a continuous variable which had been applied over a very long time period so that both cross-sections and marginal changes were predicted by the model. This is rarely possible in practice...
>
> (Wilson,1974:172)

Time can be treated in three ways; implicitly, explicitly and discretely, or explicitly and continuously (Wilson,1968:260). It must be made clear that there is no dynamic element included in the framework; the model solution defines a static equilibrium of the dependent variables service employment and population, related to and as a direct function of the specified level of basic employment provided as an input. As such, the forecast level and distribution of basic employment serve to implicitly represent the time dimension

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4. Several of these options are retained in more recent derivative forms attributable to other authors.

as the foundations of an 'instant metropolis', thought to characterize the system state in the horizon year. As the distributions of the dependent variables are included in model output and, more importantly, since these distributions are products of a simple 'one-shot' forecast,[5] any attempt at cross-sectional analysis is limited to only two points of reference where, (as is commonly the case), the corresponding time series data are not available. An indication of marginal change in the level of activity is provided at the spatial scale selected by the researcher. The rationale underlying the static equilibrium approach is addressed in the following contention;

> If we believe that the system is an equilibrium system, then (we) can attempt to build a model of the static picture; that is, to relate and explain the variable at one point in time without 'time' appearing as an explicit variable. (Wilson, 1974:25)

It seems clear that the 'time' issue in model design in this case, is conveniently solved by the equilibrium assumption, thereby justifying the use of the basic employment term as proxy. It also seems clear however, that this justification is only one of model design - it has no empirical foundation.

The second primary consideration regarding technique relates to the algebraic notation developed to represent theory in operative form.

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5. This phrase refers to the specification of one time horizon. In updated model forms, a recursive format is used wherein the input requirements for each of a series of runs are computed internally from the output of preceeding iterations. As this was not a feature of the conventional model, it will not be considered here.

Algebraic models express relationships between variables using the operations of elementary algebra coupled with the notion of a 'function' (linear, exponential, log, etc.). The relationships may involve notions of causality although this is not necessary (Wilson,1974: 174). The salient options include;

1.) spatial interaction models, the essence of which lay in the concept that the activity to be located has a strong interaction with some other activity ie. an assumed propensity for service activities to locate with respect to resident population and purchasing power (Wilson,1974:174). Such models are typically singly-constrained frameworks (production or attraction) where the allocation process may be regulated by exogenous constraints (hence doubly-constrained) or modified with the incorporation of spatial attraction factors to compliment the travel impedance function;

2.) entropy-maximizing models, wherein methods of statistical averaging are used to derive a measure of uncertainty used in information theory which is concerned with the problems of deriving the maximum useful information from a given signal. If the 'given signal' is considered to be the data which partially describe the urban system, information theory provides a framework for analyzing the data in such a way as to extract from them the least biased description of the state of the urban system as a whole (Rief,1973:70);

3.) matrix operator models, wherein lie the advantages of i.) allowing the accelerated solution of a set of simultaneous linear equations, reflecting both direct and indirect impacts through matrix inversion, and ii.) permitting a more highly resolute representation of spatial structure at the input stage through the use of diagonal matrices for structural multipliers (ie. labour-force activity-rates) of dimension NxN (N= number of zones);

4.) linear programming models, when it is possible to construct an objective function which, when maximized or minimized subject to linear constraints, 'reproduces' behaviour (Wilson, 1974:175);

5.) differential or difference equations, which are concerned with change- the period of change being measured by some independent variable - where the variable is continuous in the first case and discrete in the second. In effect, the body of mathematics associated with these concepts enables the proper handling of 'time' (Wilson, 1974:175);

6.) algorithms or algorithmic models, wherein the model can be specified as a set of rules which enables numbers to be operated on, though the rules and the consequences of applying them cannot be written down as a set of algebraic equations (Wilson, 1974:175). Examples include such procedures as i.) matrix inversion and the corresponding solution of simultaneous linear equations, ii.) the shortest path through a network, iii.) linear programming, iv.) search routines, and v.) multiple regression analysis. As such techniques are often considered methodological 'black-boxes', it is important to know only that the algorithms exist and work, not any detail as to how they work (Wilson, 1974:60);

7.) simulation models, wherein the underlying theory consists of a set of statements involving conditional probabilities. Generally, simulation techniques are used for situations too complicated to be handled by more straight-forward algebraic methods (Wilson,1974:175);

8.) econometric models, usually linear and additive and having some basis in economic theory;

9.) economic, ecological, and game-theoretical techniques, essentially products of some of the previous tecniques and constrained by a set of rules from an adopted viewpoint ie. the economist's view of locational analysis based on the theory of consumer behaviour, suitably aggregated (Wilson,1974:176).

The core of the conventional Lowry model consists of two spatial interaction submodels, one governing each of residential and service centre location. The logical structure of the model can be expressed in nine simultaneous equations and three inequalities (Wilson,1974:222), the latter denoting constraints. Variables are identified by the following according to Wilson;

A = area of land

E = employment

P = population

C = trip cost

Z = constraints

Subscript and superscript definitions are as follows;

U = unuseable land

B = basic sector

R = retail sector

H = household sector

K = class of establishment within the service sector

m = number of classes of service establishments

i, j = zones, usually origin zone i, destination zone j[6]

n = number of zones

(Wilson, 1974: 221-22)

<u>Land Use</u>

$$A_j^H = A_j - A_j^U - A_j^B - A_j^R \qquad (2.1)$$

This land is considered available for residential use.

<u>Household Sector</u>

$$P = @ \sum_{j=1}^{n} E_j \qquad (2.2)$$

or alternatively, the analytical form of the economic base,

$$P = @ \sum_i E_i^b \left(1 - @ \sum_k \&^k\right)^{-1}$$ where

@ = the inverse activity-rate, and

& = the population-serving ratio, from

6. Since the place of work is considered the 'origin' in the model, with respect to work to home interaction, 'j' represents place of residence.

$$P = @E \quad ---- \quad @ = P/E$$

$$E^{R} = \& P \quad ---- \quad \& = E^{R}/P$$

$$E = E^{B} + E^{R}$$

$$P_j = g \sum_{i=1}^{n} E_i f^{1}(C_{ij}) \tag{2.3}$$

represents the residential potential submodel where 'f^1' is some exogenous function (usually a negative exponential),[7] 'C_{ij}' is some measure of trip impedance, and 'g' is a normalizing factor calculated to ensure that

$$P = \sum_{j=1}^{n} P_j \tag{2.4}$$

and the estimates of P_j are modified to ensure that a maximum density constraint is not infringed;

$$P_j \leq Z^{H} A_j^{H} \tag{2.5}$$

The 'potential' concept utilized in this submodel is more effectively highlighted when expressed in the following alternative form;

$$P_j = P \frac{\sum_i E_i f^{1}(C_{ij})}{\sum_i \sum_j E_i f^{1}(C_{ij})}$$

(Batty, 1976:60)

7. The negative exponential, common to trip behaviour modelling, implies the assumption of decreasing interaction potential with increasing trip impedance, the value of the exponent determined from some curve fitting or other exogenous calibration procedure.

Service Sector

Total employment in the K^{th} service sector is assumed to be proportional to population;

$$E^{RK} = a^{K} P \tag{2.6}$$

for a set of constants 'a^K' (exogenous).[8] This employment is then allocated through the second spatial interaction submodel;

$$E_j^{RK} = b^{K} \left(C^{K} \sum_{i=1}^{n} P_i f^{2} (C_{ij}) + d^{K} E_j \right) \tag{2.7}$$

where 'a^K' and 'd^K' give the relative weights of home-based and job-based service utilization,[9] and 'b^K' is calculated to ensure that,

$$E^{K} = \sum_{j=1}^{n} E_j^{K} \tag{2.8}$$

The 'E_j^K' elements are adjusted to ensure that,

$$E_j^{K} > Z^{RK} \tag{2.9}$$

where 'Z^{RK}' is some minimum threshold size for service employment (exogenously specified).

As before, an alternative form of the service centre submodel

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8. The set of 'a^K' signify the disaggregation of the population-serving ratio into K components, thereby necessitating the same number of equations to be solved and summed to derive total service employment at each iteration.
9. As home and job-based service trips are treated, two population serving ratios are utilized, thus expanding the economic base relation from, $P = @\sum_i E_i^{B} (1-@\sum_K \varepsilon^{K})^{-1}$ to $P = @\sum_i E_i^{B} (1-@\sum_K \varepsilon_1^{K} + \varepsilon_2^{K})^{-1}$

appears as;

$$E_i^K = E^K \frac{\sum_j g_j^K P_j f^2(C_{ij}) + q_i^K E_i}{\sum_i \sum_j g_j^K P_j f^2(C_{ij}) + \sum_i q_i^K E_i}$$

(Batty, 1976:60)

where '$f^2(C_{ij})$' is a second function of travel impedance relating to service centre interaction.

At this stage, service land use can be calculated from,

$$A_j^R = \sum_K e^K E_j^{RK} \qquad (2.10)$$

where 'e^K' are exogenous constants relating employment in each of the K service sectors to a quantity of floorspace or land. Equation (2.10) is adjusted through a constraint-checking device to ensure that,

$$A_j^R \leq A_j - A_j^U - A_j^B \qquad (2.11)$$

since the right side is maximum available land. Finally, total employment is determined by,

$$E_j = E_j^B + \sum_K E_j^{RK} \qquad (2.12)$$

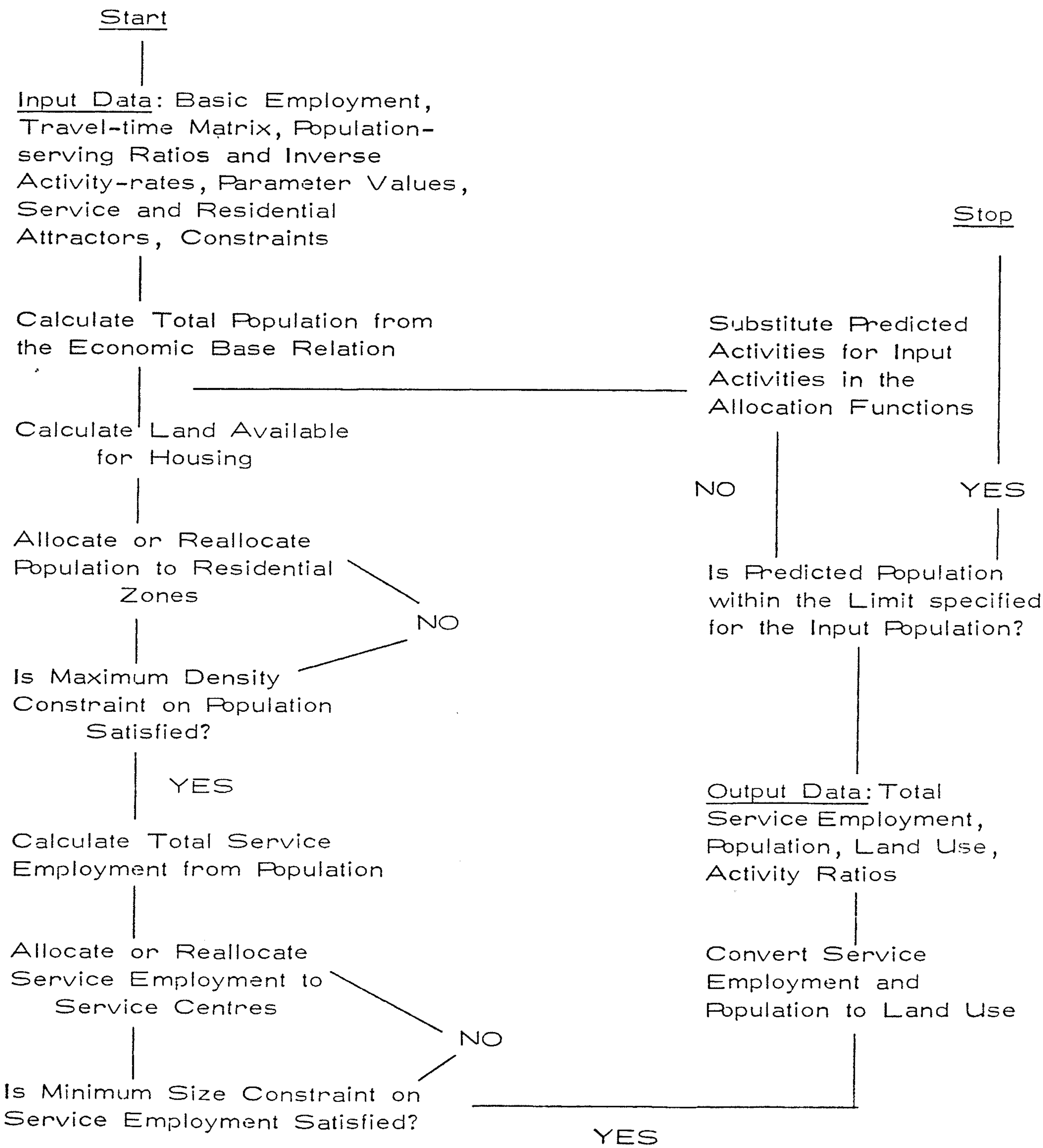
(Wilson, 1974:222-23)

The equation system (2.1) through (2.12) is solved iteratively in the order presented above with A_j^R and E_j initially set equal to zero and E_j^B respectively (Wilson, 1974:223). The iterative sequence

Figure Two:

GENERALIZED FLOW CHART OF

THE LOWRY MODEL



Source: (Batty, 1976:61).

is shown diagrammatically in Figure Two.[10]

2.4: The Garin Derivative

Garin's (1966) modifications of the conventional model are essentially improvements in technique. Generally, the system of simultaneous equations is converted to a matrix operator model; specifically, the potential models are replaced by more explicit production constrained gravity models[11] and the expanded form of the economic base is substituted for the analytical form, hence strengthening the coupling between activity generation and allocation (Batty, 1976:63).

The Economic Base

Given basic employment 'E^B', basic population is first determined from,

$$P^B = E^B @ \qquad (2.13)$$

The amount of service employment 'E_1^S' to serve 'P_1^B' is found,

$$E_1^S = @ \& E_1^B \qquad (2.14)$$

The population 'P_2' related to the service employment 'E_1^S' is found by again, applying the inverse activity-rate,

$$P_2 = @ E^S = @ \& P_1 = @^2 \& E^B \qquad (2.15)$$

---

10. The series of twelve equations above represents the structural relationships comprising the model. For a more comprehensive treatment, see M. Batty, 1976:55-67.
11. The gravity model type evolves from an analogy to Newtonian physics and states that the strength of attraction between two population masses is directly proportional to the product of the masses, and inversely proportional to the intervening distance.

The service employment required by this population is,

$$E^S_2 = \& P_2 = @_2 \&_2 E^B_1 \tag{2.16}$$

E^S_2 also has its associated population, and so on. Thus by recursion,

$$E^S_m = @_m \&_m E^B_1 \tag{2.17}$$

Total employment in the system is found by summing the increments;

$$E = E^B_1 + E^S_1 + E^S_2 + E^S_3 + \ldots + E^S_m \tag{2.18}$$

$$E = E^B_1 + @\&E^B_1 + @_2 \&_2 E^B_1 + \ldots + @_m \&_m E^B_1 \tag{2.19}$$

and factoring,

$$E = E^B_1 \left(1 + @\& + @_2 \&_2 + \ldots + @_m \&_m \right) \tag{2.20}$$

If '@&' is less than one,[12] and the number of iterations 'm' is assumed to approach infinity, it can be shown that equation (2.20) may be expressed as,

$$E = E^B_1 \left(1 - @\& \right)^{-1} \tag{2.21}$$

The functional structure implied in the above sequence is shown diagrammatically in Figure Three: Functional Structure of the Garin Model.

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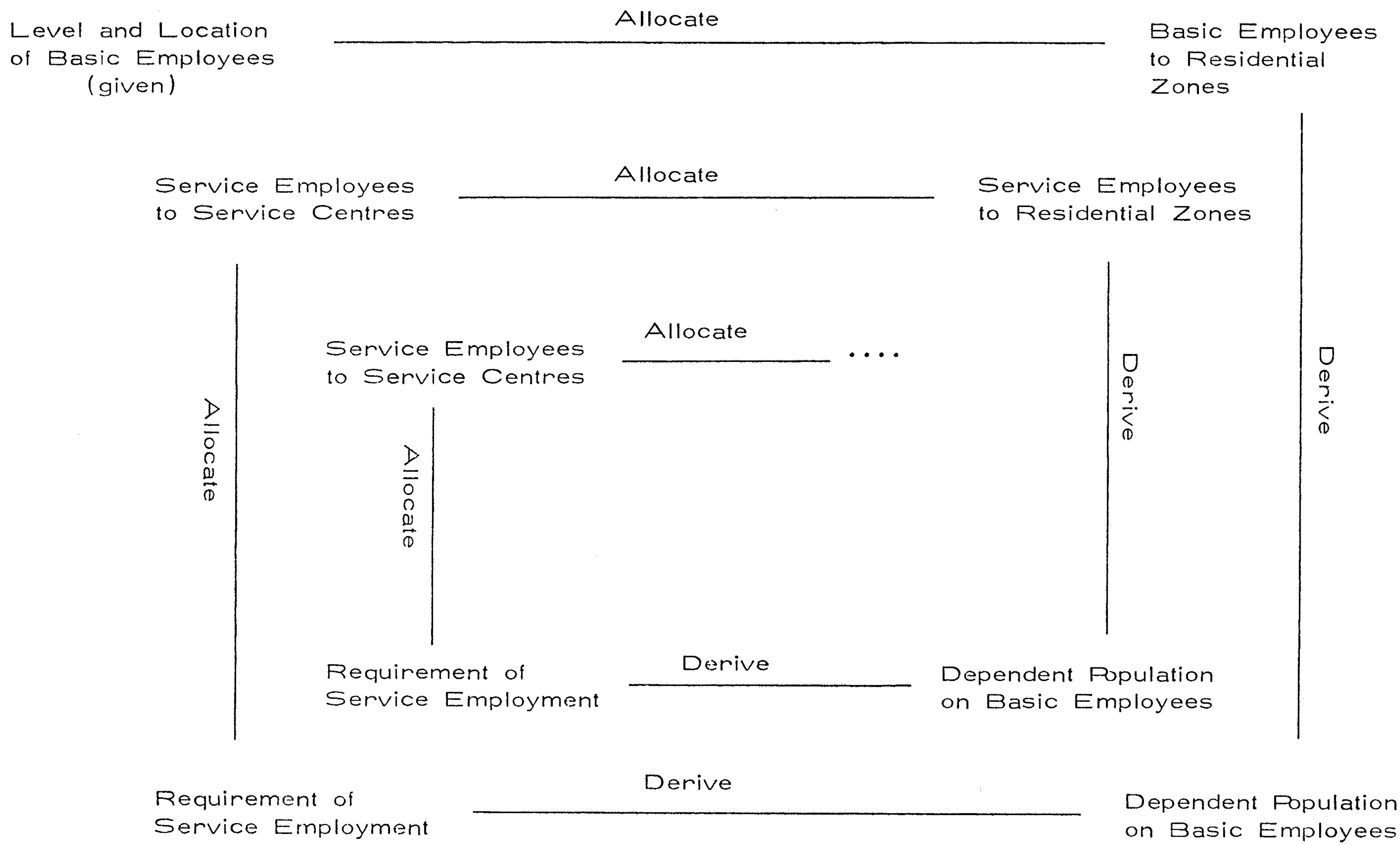
12. This may be safely assumed since '@&' $= \frac{P}{E} \cdot \frac{E^S}{P} = \frac{E^S}{E}$, and E^S greater than E is erroneous.

Figure Three:

FUNCTIONAL STRUCTURE OF THE GARIN DERIVATIVE



Source: Rief (1973).

The Allocation Functions

A particularily noteable aspect of the allocation submodels in the Garin derivative is the introduction of a zonal attractiveness factor for residential and service activity location - a variation on the potential concept.Garin utilizes these submodels of the following form in such a way as to allow the explicit representation of interactions within the system as flows (Rief,1973:194);

$$I^{wh}_{ij} = K \left(N_j / d^b_{ij} \right) \tag{2.22}$$

where,

I_{ij} = number of trips between working zone 'i' and residential zone 'j'

N_j = population in zone 'j'

d_{ij} = distance or travel time between 'i' and 'j'

b = parameter of home-trip impedance

K = scaling constant

wh = work to home trips

As equation (2.22) gives the number of trips between work zone 'i' and residential zone 'j', the following relation is used to derive the proportion of trips originating in zone 'i' to any zone 'j' ;

$$P^{wh}_{ij} = \frac{\text{number of trips from zone 'i' to zone 'j'}}{\text{number of trips from zone 'i' to all zones}}$$

$$= \frac{KN_j / d^b_{ij}}{\frac{KN_1}{d^b_{i1}} + \frac{KN_2}{d^b_{i2}} + \frac{KN_3}{d^b_{i3}} + \ldots + \frac{KN_n}{d^b_{in}}} \tag{2.23}$$

$$P^{wh}_{ij} = \frac{N_j / d^b_{ij}}{\sum_{j=1}^{n} N_j / d^b_{in}} \quad (2.24)$$ [13]

This proportion (2.24) can be considered the probability that an employee working in zone 'i' lives in zone 'j' (Reif,1973:195). The number of trips from work zone 'i' to residential zone 'j' can then be found by multiplying the number of trips generated in 'i' (equivalent to the number of workers in 'i', E_i) by the proportion of them going to residential zone 'j';

$$I^{wh}_{ij} = E_i \; P^{wh}_{ij} \quad (2.25)$$

(Reif,1973:195)

The allocation mechanism for service activities is developed on the same foundation as the residential submodel above, where the attractiveness factor in this case is service employment in work zone 'i'. That is, the equivalent to equation (2.24) appears as;

$$P^{hs}_{ji} = \frac{E^S_i / d^y_{ij}}{\sum_{i=1}^{n} E^S_i / d^y_{ij}} \quad (2.26)$$ [14]

13. This relation represents a coalition of 'potential' and 'gravity' type models; 'potential' from its proportional nature, and 'gravity' from the division of a mass term by an exponential distance.

14. In other versions of Garin's model, the residential and service allocation equations are expressed in alternative forms as below,

where, E^{S}_{i} = service employment in 'i'

y = parameter of service trip impedance

(Reif,1973:196)

The Operative Sequence

Armed with the two sets of interaction probabilities, for a system of 'n' zones, the model is then formulated in a modified vector-matrix format. Recall that basic employment is given and can be represented as a '1xn' vector;

$$E^{B} = (E^{B}_{1}, E^{B}_{2}, E^{B}_{3}, \ldots, E^{B}_{n}) \qquad (2.27)$$

The remaining model components are prepared as follows;

a.) inverse activity-rate -- an 'nxn' diagonal matrix, $= @_{j}$

---

14. ... which will be of interest in chapter four, when the traffic assignment model used to define the interaction probabilities in this research will be discussed.

Residential Model:

$$T_{ij} = A_{i} . B_{j} . E_{i} . f^{1}(D_{j}, C_{ij}), \quad A_{i} = 1/\sum_{j} B_{j} f^{1}(D_{j}, C_{ij})$$

where, Tij = number of workers employed at 'i' and living at 'j',
Ai = normalizing factor,
Bj = weight on residential attraction,
f^{1}(Dj,Cij) = function relating the attraction 'Dj' of zone 'j' to the generalized cost of travel between 'i' and 'j'.

Service Model:

$$S_{ij} = R_{j} . H_{j} . Q_{i} . f^{2}(D_{j}, C_{ij}), \quad R_{j} = 1/\sum_{i} Q_{i} f^{2}(D_{j}, C_{ij})$$

where, Sij = number of service employees working at 'i' demanded by the population at 'j',
Qi = weight on service centre attraction,
Hj = service employees demanded by Pj,
f^{2}(Dj,Cij) = function relating the attraction of service centres to the generalized cost of travel between 'i' and 'j'.

(Batty,1976:64-5)

b.) population-serving ratio -- an 'n x n' diagonal matrix = $\&_j$

c.) work to home interaction probabilities -- 'n x n' = T_{ij} [15]

d.) home to service interaction probabilities -- 'n x n' = S_{ij}

e.) an Identity matrix -- 'n x n' = I

Basic employment is allocated to residence zones and converted to population by,

$$P^B = E_1^B \cdot T_{ij} \cdot @_j \qquad (2.28)$$

The first increment of service employment is calculated and allocated to service centres by,

$$E_1^S = P^B \cdot \&_j \cdot S_{ij}$$

$$= E_1^B \cdot T_{ij} \cdot @_j \cdot \&_j \cdot S_{ij} \qquad (2.29)$$

Let the product ' $T_{ij} \cdot @_j \cdot \&_j \cdot S_{ij}$ ' equal the matrix 'A' , and let the product ' $T_{ij} \cdot @_j$ ' equal the matrix 'C' for simplicity.

Dependent population on the first increment of service employment E_1^S, is found by,

$$P_2 = E_1^S \cdot C \qquad (2.30)$$

---

15. The square dimensions indicated here for the Tij and Sij matrices are one option; there may be cases where the population or service potential of some zones may not be considered significant. Dimensions for these matrices are then altered accordingly, subject to the requirement, Tij = m x n ; Sij = a x b ; n = a.

$$= E^{B}_{1} . A . C$$

Second increment service employment is,

$$E^{S}_{2} = P_{2} . A = E^{B}_{1} . A . A = E^{B}_{1} . A_{2} \quad (2.31)$$

Dependent population on second increment service employment is then found by,

$$P_{3} = E^{B}_{1} . A_{2} . C \quad (2.32)$$

Third increment service employment derives from,

$$E^{S}_{3} = E^{B}_{1} . A_{2} . A = E^{B}_{1} . A_{3} \quad (2.33)$$

Dependent population on third increment service employment is then,

$$P_{4} = E^{B}_{1} . A . C \quad (2.34)$$

and so on(Batty,1976:71-2). Total employment and population equal the following sums, where 'I' denotes the identity matrix;

$$E = E^{B}_{1} (I + A + A_{2} + A_{3} + A_{4} + \ldots + A_{m}) \quad (2.35)$$

$$P = E^{B}_{1} (I + A + A_{2} + A_{3} + A_{4} + \ldots + A_{m}) C \quad (2.36)$$

Given certain mathematical conditions, it can be shown that the series in equations (2.35) and (2.36) will converge to the inverse of the matrix 'A'. Thus, total employment and population may be directly calculated by,

$$E = E_1^B (I - A)^{-1} \tag{2.37}$$

$$P = E_1^B (I - A)^{-1} C \tag{2.38}$$

Equations (2.37) and (2.38) represent the analytical form of the Garin model. The function and purpose of this model in forecasting are perhaps best summarized as below;

> Planning policy can be used to manipulate the exogenous inputs (basic employment level and distribution, multipliers, work-residence and residence-service interaction probabilities, constraints) and the model can then be used to derive the effects of these manipulations on population and service employment, and their associated trip patterns ... the use of this model is in forecasting a range of possible futures for the system.
> (Batty,1970B:235, 1972:169)

The initial purpose of the approach proposed by Garin was to find a more logical way to deal with the infinite number of iterations needed (Garin,1966:361) to 'solve' the equation system; that is, the computational time and cost incurred in generating activity levels within predetermined error limits. With matrix algebra, it became possible to calculate the system equilibrium state in one step by inverting the matrix which is considered more conceptually satisfying than the original formulation although the model does not include the minimum retail size and maximum population density constraints, nor the land accounting system.[16] In addition, matrix inversion for a large size zone system presents problems of computer storage and time cost (Reif,1973:192).

The merits of the Garin model lie in the improved spatial interaction submodels, added operative ease, and the unique advantage of allowing for the more explicit representation of spatial structure through zone-specific multipliers (activity-rates and population-serving ratios). Apart from these modifications, the general properties of the model are similar to the conventional model in that;

1.) the model attempts to simulate a system whose components adjust themselves immediately to some static equilibrium; that is, the service centres spring up exactly to meet the demand for goods (no time lag between cause and effect is considered), and employees are in equilibrium with the number of jobs and locations of workplaces, all at a single point in time (Reif,1973:190). Lowry suggests that "the service sector probably responds fairly quickly to changes in the demand for service employment; as such, this model provides a reasonable tool in simulating the development of service centres" (Batty,1976:127);

2.) the variable which generates an activity is also considered to be the main factor in that activity's location which explains the dominance of demand factors in the allocation submodels; it is assumed that

16. Modifications which incorporate constraints in the Garin model have been developed and are widely used in British modelling research (Reif,1973:192).

generation and location work together (Barras et. al.,1971:162);
3.) the residential submodel assumes explicitly that the spatial demand for housing by zone is determined by the number and distribution of jobs in neighbouring zones, and assumes implicitly that supply meets demand while ignoring the processes involved in this and the resulting characteristics of house type. This is the case since, on the demand side, it would be necessary to know the preference structures of different types of people and the constraints on their choice; and on the supply side, it would be necessary to be able to express the goals, technology, and managerial capabilities of developers, constructors, and planners. In this light, the traditional supply and demand curve concepts of economists cannot be applied largely because of the complexity of the supply side (Barras et. al.,1971:181);
4.) service centre location-allocation is performed according to a zone potential concept where this potential is considered to be related to its proximity to consumers and to the distribution and attractive power of competing zones (Barras et. al.,1971:186);
5.) the distribution of population generated by employment in various zones is founded upon an assumed propensity of residents to minimize travel impedance (Reif,1973:190) - an highly idealized representation of this factor's contribution to the process of residential site selection;
6.) the stability of the multipliers is assumed relevant over the forecast period;
7.) the atemporal structure of the model naturally suppresses all

questions of land use succession or the internal migration of establishments (Lowry,1973:1);

8.) the model is a self-equilibrating, simulation model capable only of producing the output implications of various inputs according to the rules of behaviour inherent in the design of the spatial interaction submodels (Massey and Cordey-Hayes,1971:38).

Despite its simplifications, the Garin-Lowry model type is considered outstanding for several reasons, among them;

1.) it is probably the most general of all models proposed to date, linking together the major subsystems of the city system, and

2.) it deals explicitly with the interactions between these subsystems (Batty,1972:152), 3.) at any one of several possible levels of spatial exactitude. The reverence attributed the framework by a host of metropolitan area modelling positivists is reflected in the opinion of Goldner (1971);

> ... the conceptual framework of what has come to be known as the 'Lowry model' has stimulated a population explosion of successors, each with meaningful elaborations ...

The model's relative popularity[17] is also considered a function of its 'suggestive' nature, where a successful model contains suggestions for its own extension and generalization (Chorley and Haggett,1976:23).

As there are several alternative urban simulation frameworks

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17. The term 'popularity' is intended to reflect not only the frequency at which continuous theoretical research is documented in planning and geographical journals, but also the intensity of its development and the continued testing of its performance in applied research.

available, some clarification of the Garin model type is warranted, not only to further articulate the model, but also to aid in explaining the endorsement of this model type for more intensive development in the presence of alternatives.

2.5: Model Typology

In the evolution of quantitative modelling, a plethora of types have been guided and generated by a precursory concern for the following design issues;

1. What is the purpose behind the particular modelling exercise?
2. What should be represented as quantified variables within the model?
3. Which of these variables are subject to the planner's control?
4. How aggregated a view can be taken?
5. How should the concept of 'time' be treated?
6. What theories are to be represented in the model?
7. What techniques are available for building the model?
8. What relevant data are available?
9. What methods for calibration and testing can be used?

(Wilson,1974:31)

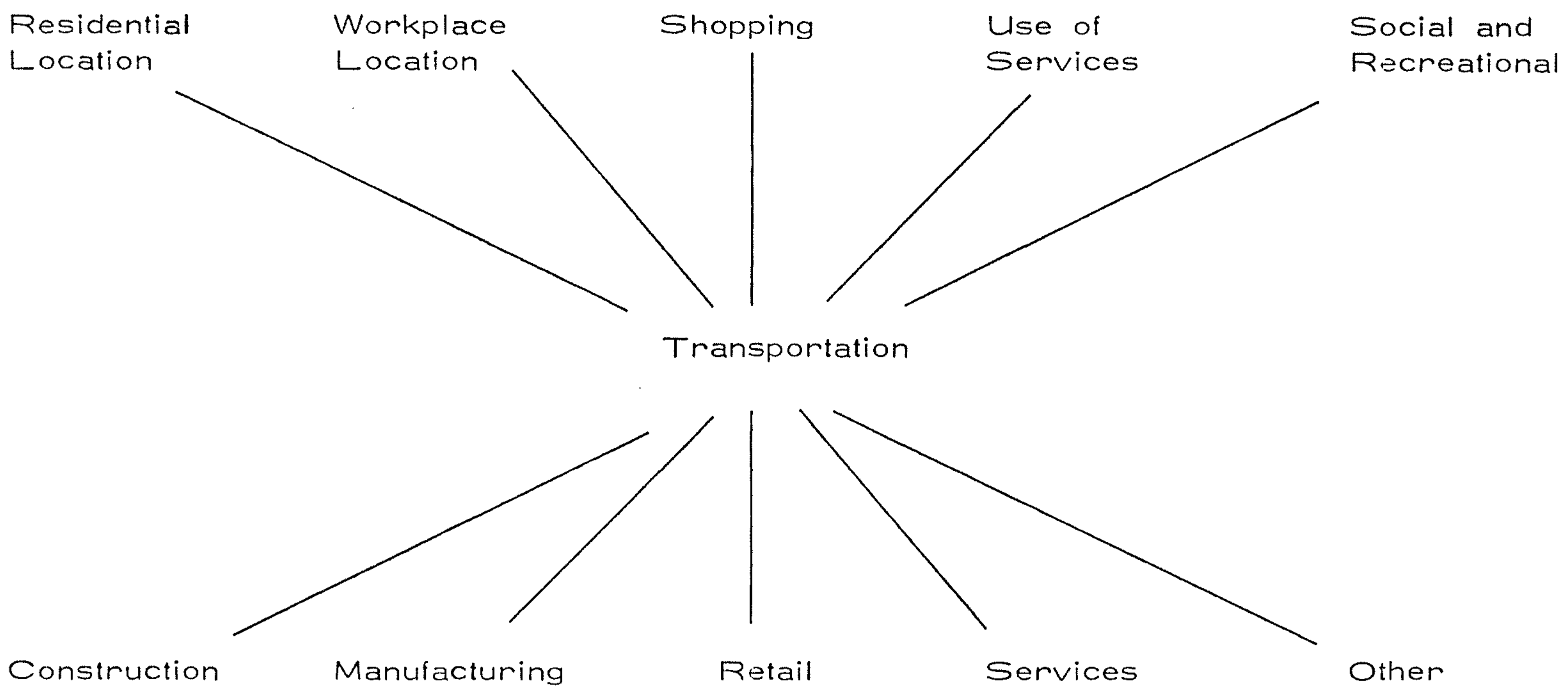
Generally, issues one, two, six, and seven may be considered matters of purpose and issues four, five, seven, eight, and nine matters of model structure and internal methodology. Issue three, regarding variables subject to the planner's or decision-maker's control is arguably the most profound as the answer to this question determines the extent to which any model (or theory) is to be considered a useful planning aid versus a mechanistic forecasting tool only (Massey and Cordey-Hayes, 1971:30). Each of these issues will be addressed in turn in succeeding chapters.

It is important to note at this point that considerable confusion often arises from the various names or labels attached to models of urban spatial structure by different authors. Some are, urban development model, land use model, activity or activities model, location model, allocation model, or model of an ecosystem. They are generally classified according to an emphasis on land use, location, or land use succession or migration patterns, hence one usually finds location or activity-oriented models (Reif, 1973:35). In urban structure and planning-related analyses, model-builders address the above issues while attempting to develop frameworks characterizing the relationships indicated in Figure Four: Model of an Intra-urban System.

The resulting types generally include, a.) spatially aggregated economic and population models, b.) transportation models, (where the 'gravity' and 'potential' concepts are attributed some success), c.) models of residential location and housing supply, d.) models of workplace choice, and e.) models of service usage and supply (Wilson, 1974:20). From the previous introduction, the Garin framework concerns both activities and locations (specifically, the allocation of activities) relating to the general types, a.) population, b.) transportation, c.) residential location, and e.) service usage and supply, from above.

Figure Four:

MODEL OF AN INTRA - URBAN SYSTEM



Source: (Wilson, 1974:26)

As the model deals with more than one land use or activity type, it is referred to as a general framework whereas the residential and service location submodels, dealing with only one activity type, are termed partial models.

The more significant criteria for distinguishing model forms are couched in terms of internal structure and methodology.[18] At the simplest level, the model may be classified as either 'physical' or 'conceptual', and the former type either 'iconic' - wherein the properties of the real world are represented by these same properties with only a change in scale - or 'analogue - having real world properties represented by different properties. The latter type may be one of 'verbal', 'mental', or 'symbolic'; the 'symbolic' class best describes the Garin model as this class concerns 'formal assertions of mathematical nature in logical terms' (Reif,1973:52, Chorley and Haggett,1976:25). The more specific criteria pertain to whether the model is;[19]

1.) descriptive versus analytic

2.) wholistic versus partial

3.) macro versus micro

4.) static versus dynamic

5.) deterministic versus probabilistic

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18. 'Methodology' here alludes to the finer points of technique; that is, not a recapitulation of the modelling techniques previously listed, but the manner in which these techniques are interpreted in operative form.

19. The model types characterizing the Garin framework are underlined for brevity's sake; a more complete discussion and list of definitions follow.

6.) simultaneous versus sequential

7.) optimizing versus non-optimizing

8.) predictive ie. extrapolative versus conditional

9.) explorative versus planning decision model

(Harris,1968:367)

'Description' is logically an essential prerequisite to any model as it would be impossible to explore, predict, or plan any reality without it. This step is usually necessary as the first part of the model-building process to establish the nature of the relationships between variables(Reif,1973:55). Its counterpart, 'analytic' models, are more concerned with what might be expected to occur under certain stated conditions (Chorley and Haggett,1967:25), which in light of the 'forecast' form of exogenous input variables in the Garin model, qualifies its membership in this category. 'Wholistic' models contain implications for a system or reality other and/or greater than the sum of the constituent parts of that system represented in the model, ie. the flows between the various system zones are detailed in the interaction submodels and the sums of these flows over various linkages in the system have implications for such related facets of intra-urban travel demand as peak volumes and route capacities, transit ridership, congestion factors, and so on.

The 'macro - micro' distinction embodies interrelated spatial and behavioural elements; that is, the intensity of the desired spatial disaggregation of the study area determines the level at which the behavioural rules of the framework are made operative and visa-versa. The micro approach would ultimately focus on individuals (which is spatially meaningless); hence, this model type commonly considers either small group behaviours or the selective aggregation of individual behaviours. The macro approach on the other hand, utilizes a broader foundation where the resolution of micro structures is unobtainable or unwarranted. The question of scale or disaggregation in the use of the Garin model is primarily a substantive issue of particular applications; it need only be noted here that any number of zones is possible although a finer zone system substantially increases data requirements and computation costs. Thus, most similar research tends toward the macro polar extreme. The same is also true of the statistical foundations of the partial submodels in that the numerators in each (equations 2.24 and 2.26) reflect total quantity terms. A noteable trait of the Garin derivative however, as a matrix operator model, is the more explicit representation of spatial structure through the two diagonal matrices which contrasts sharply with the use of one generalized value for each in the conventional model.[20]

Systems that deterministic models represent are devoid of uncertainty and changes of state can be perfectly predicted. By definition, probabilistic models are those that include stochastic processes (Reif,1973:53). The distinction is made according to the

20. The static versus dynamic issue has been discussed - the model is clearly static. Note however that the dynamic element has more recently been introduced into the Garin model by Rogers (1966).

degree of probability associated with prediction (Chorley and Haggett, 1967:25). Internally, the model seems highly deterministic, particularily the rigidity of the economic base relationship and the fact that only one output pattern may be generated from a single input data set. Yet this is true of any model in that such frameworks are designed to minimize uncertainty and the risk of significant error in prediction. In relation to this issue,

> We must clearly recognize that there will always be a probabilistic element in the simulation of metropolitan phenomena, based on the fact that individual behaviours do indeed contain elements of 'free will' which are inaccessible to us for analysis and prediction. (Reif,1973:53)

Notions of probability were developed as means of minimizing information loss and are intended to most adequately represent the many and varied elements of 'free will'. Recall that the proportions derived from equations (2.24) and (2.26) indicate the probability of interaction from any origin zone to all destination zones; the preparation of exogenous (forecast) inputs is commonly predicated on similar notions. As such, the Garin model is more probabilistic than deterministic, a point further clarified by the stated purpose of the framework - 'the generation of a range of possible futures for the system'(Batty,1972:169). Couple with this definition of model purpose, a second relating the object of probabilistic models;

> ... to discover the range of variation to be

> expected from constrained random decisions
> in the overall pattern of metropolitan development.
> (Reif, 1973:54)

It seems clear that 'random decisions' are interpreted by the interaction submodels, and the 'constraints, in the exogenous input data sets with an optional probability foundation.

The simultaneous versus sequential distinction refers to the exact nature of the solution system, where 'unknowns' are common to all equations. As the Garin model generates one static equilibrium according to one corresponding basic employment distribution, the output represents a solution for only one point in time. That is, the inputs do not alter in value, thus their respective influences can be represented simultaneously. A sequential equation system would be required in a dynamic model where the processes of change are modelled; or where 'time' is an explicit-continuous variable within the model.

The seventh classification, regarding optimization, is one of considerable import. The structure of an optimizing model involves some process in which the model is able to predict 'best' or optimal values of its dependent variables. The criteria upon which optimality is judged have necessarily to be established before the model is operated and the process whereby an optimal solution occurs must be rigorously specified (Batty, 1972:156). Non-optimizing models, as their label suggests, do not use any explicit process involving optimality. The latter are the more common since the difficulties of specifying optimality in 'ill-defined' situations and of measuring same in systems involving human values are fundamental (Wilson, 1974:19). One may initially be tempted to consider the allocation submodels of the Garin framework as optimizing models in light of the travel impedance minimization assumption adopted therein. The distinction applies moreso to the manner in which the impedance exponent is determined. Where this is made on equally theoretical grounds - involving an optimality assumption (ie. where the appropriate empirical sample data are unavailable for calibration), the process could be considered 'optimizing' yet this is unlikely for two reasons; 1.) empirical samples of trip behaviours are common prerequisites to such research as the 'observed' data set in exponent calibration, and 2.) where such samples are unobtainable, researchers tend to assume high degrees of association between their study areas and those of other previous empirical samples drawn from comparable study areas and thus, adopt similar exponent values.

The extrapolative versus conditional distinction refers to the preparation and use of the input data in predicting on the model.[21] Prediction with the former assumes, in some sense, the continuation of current trends which have already been established in the descriptive model. In the 'conditional' case, the mechanisms of cause and effect governing the variables are specified; ie. in an impact analysis where interest lies in the consequences that should be expected to

21. This distinction is often referred to elsewhere as the 'positive' versus 'normative' use of models.

follow a specified exogenous input if the (modelled) environment were otherwise undisturbed (Reif, 1973:55). Assumed stability of the multipliers over the forecast period is clearly an extrapolative notion, which may imply some time-series dependence (although this assumption is not mandatory as in the case of a lengthy forecast period where values may be determined from some other independent forecast). The same is true of the sets of interaction probabilities in that the researcher has the option of forecasting 'anticipated' flows for the horizon year. The nature of the basic employment input, a level and distribution characterizing some preselected alternative plan or updated urban form, is essentially conditional (by definition) although this does not entirely discount their specification on extrapolative grounds. Since however, it is intended that the model be used to demonstrate the likely impacts of specific events or policies, such alternatives can only be conditionally interpreted ie. where a new industrial facility is to be located and its impact examined - its introduction highlighted in an hypothesized distribution of forecast basic employment in accordance with the locational principles accruing in the proposed plan.

The final category, regarding explorative versus planning-decision models, is also one of considerable import. Explorative models are used 'to discover, by speculation, other realities that may be logically possible by systematically varying the basic parameters used in the descriptive model'(Reif,1973:55) whereas in planning or decision frameworks, 'a measure of performance is introduced and the model objective is to determine the optimum solution under certain conditions'(Reif,1973:56). It is clear that the Garin model contains no internal 'evaluation' mechanism - it was never intended to. Rather, the outputs from this model are transformed into indices measuring the relative performance of certain aspects of spatial structure, and such indices have been used to provide a guide in evaluating the relative merits of alternative urban forms (Batty,1976: 80). As such, the model is indirectly a decision framework, although that decision process and the goal criteria governing its direction and emphasis are external, substantive events. As the model is more appropriately a descriptive-analytical aid in generating alternatives for consideration in the decision-making process, it qualifies moreso as an explorative planning tool.

CHAPTER THREE:

THE USE OF THE MODEL IN A PLANNING CONTEXT: A LITERATURE REVIEW AND RESEARCH OBJECTIVE

3.1: Comprehensive Models in Planning and Policy-making

'Planning' is a second concept subject to equally diverse definition; the following are perhaps among the more representative attempts:

> Planning consists in the systematic, continuous forward-looking application of the best intelligence available to programmes of common affairs in the public field ... Planning is a continuous process, and necessitates the constant reexamination of trends, tendencies, and policies in order to adapt and adjust governmental policies with the least possible friction and loss ... Planning is not an end, but a means - a means for better use for what we have, a means for the emancipation of millions of personalities now fettered for the enrichment of human life ...
> (National Resources Planning Board, 1934:83-4)

> Planning is one of the functions of the manager, and as such, involves the selection, from among alternatives, of enterprise objectives, policies, procedures, and programmes. It is thus decision-making affecting the future course of an enterprise... Planning is thus an intellectual process, the conscious determination of courses of action, the basing of decisions on purpose, facts, and considered estimates.
> (Koontz and O'Donnell, 1964:21-2)

Two additional definitions allude more to planning as a rational-adaptive process;

> Planning is an activity by which man in society endeavours to gain mastery over himself and to shape his collective future by power of his reason ... planning is nothing more than a certain manner of arriving at decisions and action, the intention of which is to promote the social good of a society undergoing rapid changes.
> (Friedmann, 1959:327-9)

> Planning is rational, adaptive thought applied to the future and to matters over which the planners or administrative organizations with which they are associated have some degree of control. 22
> (Simon et. al.,1950:423)

A rational decision is one made in the following manner; a.) the decision-maker lists all opportunities open to him in relation to general goals, the existing structure and area problems, the specific regional-metropolitan context, and constraints on financial or other resources, b.) identifies all the consequences which would follow from the adoption of each of the possible actions, c.) further elaborates and tests the alternatives where warranted, and d.) following some evaluation process in relation to goals, selects the action which would be followed by the 'preferred' set of consequences (Faludi,1973:140, Barras et. al.,1971:119). A plan is then a decision with regard to a course of action, where the course of action is a sequence of acts which are mutually related as 'means' and are therefore viewed as a unit; it is the unit which is the plan (Faludi,1973:140). An 'end' or 'goal' is,

> ... an image of a future state of affairs towards which action is oriented. The formulation of the end may be extremely vague and diffuse. If so, it may have to be reduced to specific or 'operational' terms before it can serve as a criterion of choice in the concrete circumstances ... An end may be thought of as having both active and contextual elements. The active elements are those features of the future situation which are actively sought; the contextual are those which, while not actively sought, nevertheless cannot be sacrificed without loss. (Faludi,1973:141)

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22. For a more extensive discussion of planning definitions, see Yehezkel Dror,'The Planning Process: A Facet Design' in Faludi (1973).

Advocates of model-based research and analysis programmes propose to meet the requirements of the goal-reduction process via the representation of alternative structural proposals according to some corresponding manipulation of model input variables, then made operative in highly rationalistic frameworks. This inherent rationality has implications for potential model use with respect to the particular planning environment pertaining - itself, commonly a phenomenon of many facets. Consider first the proposed uses of models in planning and research by those who endorse such methodologies.

The planning function is thought to comprise three primary activities - policy, design, and analysis, and the planner's role to emphasize prediction, design, and evaluation. The designer (planner) needs a good analytical capability so that he can diagnose problems and predict the impacts of his designs. The policy-maker needs good design capability to ensure that he has a good range of alternative plans presented to him, and he needs an additional analytical capability (over and above that of the planner) to help establish evaluation criteria for choosing between alternatives (Wilson,1974:12). As new found tools for the development of such capabilities, simulation models are imputed considerable value at all three stages of the planning-policy function; in analysis, and understanding of the problem, in plan design, and in the evaluation of proposed solutions (Batty,1972:169).

Perhaps the most positive characteristic of these frameworks is their 'flexibility' ;'the whole virtue of simulation is that it explores the influence of the difficult features of real life, ie. having run a simulation and procured a set of results, it is possible to postulate inferences which were not originally considered and run the simulation again (Beer,1966, in Reif,1973:78). In a related though somewhat different light, simulation is considered by some to be a powerful technique for producing conditional forecasts as it allows the planner to work out the behaviour of an urban system under varying conditions (Beer,1966) whereby inferences may be drawn as to the sensitivity of the real world to change, and it is the only method of modelling capable of revealing that the behaviour of social systems may, in many instances, be counter-intuitive (Batty,1976:295). In a similar respect, models are also proposed as operative foundations for continuous monitoring and educational procedures wherein the data are updated to reflect empirical change, and new alternatives generated accordingly, not only for purposes of developing alternatives as a primary planning exercise (Massey and Cordey-Hayes,1971:31), but also as tools for the continuous reexamination of existing policies. As these models are so highly rational, and moreso, consider an urban system as consisting of a number of interdependent subsystems, this combination is thought to increase rigour and order in the thought process as well as aid the provision of systematic statements of the relationships between the different elements comprising the study area and thus improve the planner's and researcher's concepts of the forces associated with community growth and transportation requirements

(Reif,1973:45). Specifically, the planner's goal-related areas include the following;

1.) economic expansion, full employment, and efficient government,

2.) social welfare, crime, delinquency, racial integration,

3.) educational programmes and facilities,

4.) housing construction - redevelopment, and neighbourhood conservation,

5.) public transportation,

6.) sanitation and public health,

7.) cultural and recreational programmes and facilities,

8.) land use control,

9.) urban design values (Faludi,1973:212)

Clearly no singular model would be capable of dealing with such a diversity of issues, in part or in whole; the difficulties of representing the more 'social' concerns (full employment, social welfare, public health and welfare) are currently insurmountable in rationally operative models. This inability is perhaps the most fundamental publicized limitation of such frameworks and yet itself, provides the model-builder's rationale; that is, the model-builder fully realizes his inability to incorporate the 'social' sector and thereby modifies his framework and the purpose(s) for which it is intended to represent only those variables or activities that his level of knowledge and understanding permit. This rationale has a second element, relating to the added selectivity of 'means' used by the model-builder to represent real world phenomena in operative form. It is nowhere possible to claim complete knowledge of any particular phenomenon governing the evolution of metropolitan forms, hence the model-builder is limited on two further fronts; 1.) incomplete knowledge, and 2.) the added difficulties in representing those structural or behavioural determinants he does understand in mathematical forms. On 'abstraction' as criticism, Batty retorts;

> ... many argue that such models are so poor a representation of reality that they are often irrelevant to the problem in hand, whilst others argue in a similar fashion that urban modelling is a worthless task for reality can never be described numerically. Both these views contain an element of truth. Yet the purpose of any model is to simplify reality, thus leading to greater understanding and to means whereby experiments can be made on the model in the quest to explore both the present and the future ... The simplification of reality is a cornerstone in the philosophy of science for all the theories and techniques used by urban planners and researchers involve a degree of abstraction by simplification. (Batty,1976:353)

Emphasis on simplification has created two basic types, or approaches to modelling; 1) partial models, dealing with one behaviour or activity, and 2) general or comprehensive models which are generally comprised of a number of linked partial sub-models. As an example of the latter type, the Garin framework and its many associates are commonly critisized as 'hypercomprehensive', in that they were designed to 1) replicate too complex a system in a single shot, 2) are expected to serve too many purposes, and/or, 3) are proposed as 'means' towards a too diverse multiplicity of ends (Lee,1973:164).

Yet, when policies are implemented, however they were identified, it is usually important to treat the system wide impacts of these policies and this can only be accomplished in a comprehensive framework (Wilson,1974:172). This also points out the advantage of interaction submodel usage in that this approach recognizes that activities undertaken in any one area and in any one sector (type of activity) will have repurcussions in other areas and other sectors, hence interaction models provide not only some representation of the interdependencies, but also a means to simulate the repurcussions (Barras et al.,1971:119).

The debate over simulation model use is active on three additional fronts; 1) the ability of the model - builder to incorporate independent variables which are truly subject to the planner's and/or decision - maker's control, 2) the long - term rational approach implied in model use versus the tendency of political decision - making towards more short-term incremental, (and relatively less rational) policy amendments, and 3) where the planner-analyst becomes involved primarily in the inventing of models of various parts of the processes of urban functioning and development, such techniques may be used, wittingly or unwittingly, to further mystify the public and widen further the gap between planner and planned; that is, the planning profession becomes less capable of meeting its democratic responsibilities in sharing its methodology with other professions and moreso, the public (Harris, in Erber,1970:197, Massey, Cordey - Hayes,1971:42).

The issue of controllable variables is straight forward; indeed this is a governing principle in model design since this trait determines the viability of a simulation framework as a useful planning aid versus a mechanistic forecasting device only. The more common variables include population and employment levels, economic variable describing industrial growth or generated income, and others derived from basic assumptions concerning the linkages between transportation and land use. As the above are typically highly interrelated with both each other and additional smaller scale variables (i.e. the relative contribution of each industrial sector to the total urban economy), significant interdependencies may be postulated and used as 'causative agents' in prediction and impact analyses. The exploitation of these many relationships is considered a major asset of the modelling technique in planning:

> A city ... is an extremely complex, high variety system. Only a planning system with corresponding high variety could control it ... The advantage of using a model - based analysis system ... is that it increases the variety of the control system; the control system adopts, as it were, the variety of the model system, which reflects that of the city itself, and hence provides the information necessary for effective control. (Wilson, 1974: 366)

Wilson's contention seems to make a strong case; the debate however revolves around the suitability of the independent variables selected and moreso, the relationships in which they are framed with respect to the particular problem or function at hand, and the nature of the study area and scale involved.[23]

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23. The Garin framework will be treated in this light in the following section of this chapter.

Probably the least significant of the three issues (for purposes here) is the last; the concern of many practitioners and planning theorists over the heightened technocracy implied by model use in the planning function. The first such concern alludes to the probable development of insular model-builder/planner relationships at the expense of more desirable planner/public interaction. If the planner becomes the model-builder's client, then what of the planner's clients, the public? It is also felt that the added complexity of modelling systems would impede the effective communication of information and opinion concerning goals and means between the planner and his public clientele. Such criticism is perhaps inappropriate for two reasons. First, public participation programmes tend, for the most part, to be encouraged in response to small scale, neighbourhood plans - a spatial scale for which simulation models are rarely (if ever) intended. Furthermore, attempts to encourage public response in the assessment of metropolitan or regional policy are usually met by ill-equipped or insufficient populations for the expression of diverse goals and the extraction of a truly representative public opinion. Yet metropoli continue to grow more complex, hence equally difficult to understand and the planner's need for improved analytical skills towards that greater understanding remains unfulfilled. It is here where model usage is imputed some potential value; as tools among others, to increase the planner's understanding and knowledge of his system so as to improve his capabilities of developing and assessing plans for the effective regulation of that system. The second reason is now apparent; as only tools in plan generation, the technical details of model structure and use need not be considered in planner-public discussions. The planner's responsibilities lie in his communicating the structure, relative merit, and implication of his design, among alternatives, to the public body wherein methods of assessment are embodied for plan endorsement or amendment. That is,

> ... such new tools will not themselves substitute for planning and problem-solving ... the invention of new tools is not the same as the invention of new plans. (Harris, 1970:195)

Hence the role of models in analysis seems clear, but in evaluation, perhaps less so. Clearly different groups will have different goals and therefore, different evaluation functions and the exercise of judgement in the evaluation process is shared (Wilson, 1968A:271). No quantitative model has yet been designed to represent diverse goals (with the possible exception of optimizing methods where the corresponding allocation of resources or capital is the collectively decided goal). Rather, it has recently been emphasized that evaluation should be more generally defined in its initial stages as a learning, probing, testing, and exploring kind of activity for both professional planners and decision-makers (Barras et. al., 1971:119) wherein the objective is not always 'selection', but may also be learning about possible conflicts between objectives, understanding/defining specific problems, identifying trade-offs, or examining the effects of individual policies - especially identifying those policies which emerge as common to all good alternatives (Massey and Cordey-Hayes, 1971:32).

As proposed exploratory tools within this facet of the planning function, it is here that the implied rationality of modelling enters the debate. This comprehensive-rationalistic philosophy extends back in time to the mid-1940's, the period wherein the 'Master Plan' was conceived. The early 1960's saw the coming of the comprehensive-incremental revision, a different philosophy of planning with less emphasis on the future and heightened concern for more immediate solutions to ever-increasing problems. Where the rationalistic model tends to posit a high degree of control over the decision-making situation on the part of the decision-maker, the incrementalist approach assumes much less command over the environment (and is thus referred to as the art of 'muddling through') (Etzioni, 1970:217). In further contrast to the comprehensive mode, (and as the title suggests), the incrementalist view deals with change over much shorter time periods since, in this view, democracies change their policies almost entirely through incremental adjustments - not in leaps and bounds (Faludi, 1973:161). As such, 'misplaced emphasis on the future frequently produces policy proposals which are not only politically irrelevant, but also highly unpredictable in their consequences (Faludi, 1973:162). Such is common criticism of modelling systems usage but yet itself does not grasp the full intent of model-use advocates.

Rather than using simulation models only for longer-term forecasts in a policy-design process of equal duration, it is felt that models may be made operative within a new coalition of the two philosophies - a structure for which the planner would more likely be responsible. By necessity, the planner must be concerned with both the short and long-term implications of his designs, thus 'foresight' is a mandatory prerequisite to his analytical capabilities. Yet the politician is more concerned with immediate gains or successes (so as to assure his own continued success) and wields the effective power in decision-making (Faludi, 1973:235). Some 'middle-range bridge' must therefore be found between short and long-term concerns whereby suitable short-term solutions may be derived and implemented in response to immediate problems which reflect the guidelines and principles of more generalized long-term goals. It is felt that comprehensive analytical models may be valuable in the provision of data and related information for the continuous monitoring and assessing of these longer-term goals so as to further assure consistency between these and the design of short-term incremental amendments.[24] In addition to long-term use, it would also be possible to test the likely short-term impacts of comprehensive policies on such models where a data base and program have been developed (since they can usually be quickly operationalized) although this then concerns the abilities of such models to simulate marginal change.

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24. This proposal is often couched in different terms in the literature; alluding to whether such models should be 'normative' or 'positive'. It is the most common convention to think of all models as positive models, built for analysis which may then be used within some essentially normative planning process (Wilson, 1974:171).

The more salient issues of the debate regarding model usage in the planning and policy functions have been highlighted above, and it is towards such issues that modelling research must ultimately be directed in a planning context. As one of the more highly regarded comprehensive models, the Garin framework was selected for investigation here; an account of this model's specific assets is then warranted.

3.2: The Garin Model as a Planning-Policy Tool

At its present stage, it would appear that the model has four main attractions to urban and regional planners;

1.) it is relatively comprehensive in its coverage of urban and regional systems in that it is concerned with population and employment, together with the trips between them. These interrelationships are of particular interest to planners, especially those concerned with the formulation of general planning strategies;

2.) it rests largely on assumptions about travel behaviour which are derived from a considerable body of empirical work over the last two decades. As such, it represents a practical model rather than one based on untestable or untested theories about urban systems;

3.) it is conceptually simple to understand;

4.) the submodels can be developed and improved in themselves (Masser et. al.,1971:55).

Added merit is claimed for the following internal structural facets of the model;

1.) the simplicity of the causal structure allows for solution of the framework in more than one way as a function of the way in which the submodels are 'tied-in'; this flexibility is among the model's positive endowments (Batty,1972:157). The matrix format is extremely useful in this respect in that not only can a response (output distributions) be generated from a certain stimulus; the model can also be used to determine a stimulus necessary to produce a certain response (Batty, 1969:428) within a normative procedure;

2.) the use of the model in the generation-evaluation of policy alternatives is aided by the ease and speed of its operation ie. input variables and constraints may be altered for several runs of the model to quickly assess a number of alternative strategies;

3.) the use of a derivative model in recursive forecasting (simulating a series of short-term system states over the entire forecast period where the outputs of each incremental solution become inputs for each successive run) has the advantage of accounting for change in the system between the base and horizon years; hence cause-effect lags may also be built in for impact studies (Batty,1970B:324);

4.) appropriate sectoral disaggregation of the population and service employment variables would allow the examination of other system components such as income, education, social services, recreation, and utility services (Massey and Cordey-Hayes,1971:38);

5.) the possible incorporation of population and service requirement constraints provides a means of enhancing the model's substantive realism.[25]

At the same time, it has two fundamental limitations insofar as planning is concerned. First, it is essentially a descriptive model which does not in itself produce optimal solutions of the type desired by many planners. At best, it can only give some indication whether one possible solution is better, in certain ways, than another solution.

Second, it is essentially a static model which largely ignores the past and gives insight into the future only by way of crude conditional forecasts (Masser et. al.,1971:56). Indeed, in the use of any static model in a predictive and necessarily dynamic context, there is a logical inconsistency in that the model has been calibrated to reflect some average spatial history of the system whereas it is being used predictively to allocate marginal change; this is a problem affecting many models , inevitably reducing their predictive power (Batty,1976: 92). This does not mean that such a model is irrelevant to the problems of spatial planning; it does mean however that the model can only be used for conditional projection which involves interpreting the equilibrium state of the system resulting from given changes in activity (Batty,1970B: 321). In spite of these limitations, some deem the model helpful in planning in four general areas, concerning 1.) <u>impact analyses</u>, wherein the system-wide consequences of changes in population or employment

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25. Items one and two in this list refer to the original unconstrained and non-recursive Garin model. The latter three items refer to modifications of that original model with respect to technique (item three), and structure (items four and five).

distributions could be examined (with the added possibility of constraining the model to prevent development in particular areas)(Masser et. al., 1971:57); 2.)monitoring, where running the model at frequent intervals could allow a close watch on the gradual accumulation of developments within the area through continuous reforecasts with new data, and thereby the evaluation of trends against stated objectives (Massey and Cordey-Hayes,1971:40); 3.) design analysis, wherein model outputs are manipulated to give various measures of the variations in local and overall accessibilities in relation to work and services implied in varying land use and transportation network proposals (Masser et. al.,1971:57), and 4.) education, by further educating the planner toward an heightened awareness of the urban system (Batty,1970B:331).

Recall the exogenous inputs to the model; labour force inverse activity-rate, population-serving ratio, basic employment level and distribution , optional population and service activity constraints, and two sets of interaction probabilities (workplace to residence, and residence to services). As forecasts with the model can only be performed through some appropriate manipulation of these independent variables, the adaptability of each to decision-making control is of considerable import;

a.) Labour Force Inverse Activity-rate; as this variable serves only as a multiplier, it plays a limited role as causative agent in activity distribution (although it shares an indirect link through the population distribution to service and thereby total employment distributions).

Increased employment (or reduced unemployment) is a continuous goal at all levels of government. Furthermore, a more appropriate use of the model would concern analyses of industrial employment growth (reflected in the basic employment input) versus unemployment reduction. Hence, it is more likely for this variable to be expressed at some expected forecast level versus a normative-target level wherein for example, the labour force is disaggregated by sex and an expected increase in the female participation rate reflected as one factor contributing to employment growth over the forecast period. An indirect route to control of the activity-rate might be assumed when the model is used to simulate the impacts of selected investment allocations for purposes of lowering unemployment rates in certain industrial sectors (Massey, 1973:13);

b.) Population-serving Ratio; as this variable functions only as an internal multiplier, and moreso, depends entirely for its values upon the particular method utilized to define the basic and service sectors of study area employment, any discussion of possible control or influence by the planner would be profitless;

c.) Basic Employment Level and Distribution; this input may be manipulated to reflect not only some expected and/or target growth level for the forecast year (a requirement of any forecast in the former case regardless of the analysis objective), but also to reflect various alternative location strategies of growth employment over the forecast period and their impacts on the distributions of total population and employment within the system as a whole. Clearly, the range of options at the input stage is virtually infinite. As such a vital input, the issue of its 'control-ability' by the planner and decision-maker becomes more essential to legitimizing the use of the model in spatial forecasting. Regardless of the method used to specify basic employment,[26] the planning function is afforded some control over basic employment through investment allocations and zoning - the two means by which the real control of planning is directed to the urban landscape.. The level of basic employment is influenced by public investment (ie. toward reduced unemployment) and private investment for industrial growth, and its distribution, to some extent, by zoning regulations intended to spatially impose negative constraints on growth in primarily basic industrial sectors (ie. by disallowing expansion in private enterprises or preventing the negotiation of development applications for basic industries in favour of other more necessary or desirable facilities). Where private investment is encouraged in a plan, zoning plays the immediately operable role in governing the distribution of employment. The corresponding alternative distributions may then be prepared and used as inputs to the model for analysis. Similarily, various employment inputs may be formul ated and run on the model to analyze variations in zoning policy toward some solution which would allow the development while minimizing the costs of the proposal, and maximizing other related

26. One approach defines individual sectors as wholly basic or wholly service whereas a second approach considers each industrial sector as a sum of constituent basic and service proportions.

benefits to be achieved through the plan;

d.) Workplace to Residence and Residence to Service Interaction Probabilities: as these data constitute the foundations of their respective allocation mechanisms, the issue of their succeptability to planner intervention is also of considerable import. The planner is, however, only permitted to 'hypothetically intervene' in the model on the basis of the generalized behavioural assumptions embodied in these data. Assuming (for the moment) that the data do in fact suitably resemble the patterns of residential site selection and consumer shopping behaviour characteristic of his system, the planner is provided two extremely flexible model inputs - ones over which he has a considerable degree of influence. Alterations in the transportation network such as road-widening or surface improvement, bridge construction, or new road and access ramp construction could easily be reflected in the travel impedance factor values in the denominators of both models and their impacts on residential area and shopping centre attraction examined. Similarily, new housing construction or proposed new construction or expansion of service facilities could be represented in 'target' form in the numerator values of the zones within which the development is proposed. This method however, is the most simplistic for the representation of horizon year system states; a more exact operation of same is made available through the use of exogenous constraints;

e.) Optional Constraints on Population Densities and Service Employment Requirements: as these inputs are intended to reflect either empirical states (ie. a zonal population which has reached or surpassed its desired capacity in the base year) or target states outlined in alternative designs by the planner, the issue of their control is superflous or 'after the fact', as it were. These constraints serve as more efficient allocation rules by generating horizon year zonal totals of population and employment which more closely approximate exogenously specified levels.

Although the model provides only general indications of the impacts of developments such as those described above in terms of population and employment distributions and their associated trip patterns, its flexibility and resolution are imputed considerable value in system monitoring, alternative plan generation, and in further educating the planner as analyst of an urban system. Clearly, many housing and transportation-oriented policies cannot be evaluated on the model as the relevant relationships are omitted (Massey and Cordey-Hayes, 1971:41), but this is true of any model, comprehensive or partial.

It is far more pertinent in modelling research to evaluate an individual framework on its own merits; that is, does the model perform acceptably in relation to the goals and purpose(s) for which it was developed?

3.3: Research Objective - The Case of Winnipeg

> The theory of city development underpinning a model is supposed to represent the model-maker's understanding or assumptions of the pattern and order by which the urban system actually works; consequently,

> models are built to test how well the pattern identified by theories fits the real world situation. We can conclude that a model is no better than the theory on which it is based. (Reif,1973:53)

A tenable theory can be substantiated by empirical verification (Yeates,1974:2). In modelling, the underlying theory or theories need be verified and used for prediction only in ways appropriate for that theory (Wilson,1968B:11). A trained capability for making use of these new analytical techniques implies at the same time, a capability for rejecting them when their use is improper or inadequate (Harris,1970: 194) - probably the most valuable product of such research and a goal toward which this research is ultimately directed.

As a comprehensive model intended for large-scale use (ie. regional or metropolitan levels), there are several facets to the operation of the Garin model and hence, to the process of its evaluation. Yet such variation refers primarily to alternative model structures (ie. dependent variable disaggregation or the use of constraints), and to variation of the zone system employed with respect to zone size and internal structure. For any given zone system, model performance is evaluated by measures of the correspondence between empirical and model-generated levels and distributions of the primary dependent variables, population and service employment, for the base year as of allocation submodel calibration. These measures commonly include the chi-square statistic, the Kolmogorov-Smirnov test, and the correlation coefficient or coefficient of determination.

Past research on the model has emphasized a wide range of spatial scale, from explicit metropolitan centre usages in North America (Pittsburgh, Toronto, Santiago, and Chicago, among others), to more characteristically British applications to systems of interdependent cities ie. full economic regions or some proportion thereof (termed 'subregions', containing both urban and rural landscapes)[27] (Batty, 1976: 80). Notably, no significant differences in goodness-of-fit have derived from research on the two types of landscapes when used on the Garin model.

This research, in keeping with the North American emphasis on metropolitan area planning, applies to the Winnipeg metropolis - a study area which may present a significantly unique element into the issues of model performance. Other North American research has concerned metropoli with highly recognizable economic and demographic linkages with other neighbouring centres whereas Winnipeg, although necessarily sharing certain economic linkages with Canadian and American centres as the financial and distribution centre of central Canada, is far more subject to pressures of spatial isolation from other cities of metropolitan rank. As such, there would seem an increased need in Winnipeg for economic and servicing self-sufficiency. This is especially true in service provision and , as service employment is endogenous, may

27. For further details on the more articulate British research, the reader is referred to the following applications of the model from the enclosed bibliography;' Bedfordshire-Cripps and Foot (1969A), 'Cheshire'-Barras et. al. (1971), 'Merseyside'-Masser (1970), 'Milton Keynes'-Echenique et. al. (1972),' Central Lancashire'-Batty (1969), 'Nottinghamshire-Derbyshire'-Batty (1970B), 'Reading'-Echenique et. al. (1964A).

have some notable impact on model performance through the economic base submodel. A second facet of this isolatedness is demographic, as it is common for certain proportions of total employment in centres of high proximity to be shared. Such 'commuting' behaviour complicates the modelling of interaction as it contradicts the travel behaviour assumptions embodied in the model. Yet because of its isolation, this problem is not likely apparent in Winnipeg, thereby simplifying the reality to be modelled and possibly contributing to the more effective behaviour of the model in this case.

The second focus of this research concerns 'internal' methodology; that is, the various techniques available in both gravity modelling, and economic base analyses, and their relative merits and limitations as analytical tools (ie. the amount and type of information gained) and their suitability to operative forecasting of metropolitan systems on the Garin model. Gravity modelling enjoys a rich history with the continued endorsement of traffic engineers and transportation planners. The variation in output or result between alternative gravity model forms however, is often exceeded by that deriving from alternative models of the urban economic base; indeed, the economic base model (ie. product-tangibility versus locational distinctions versus economic distinctions) remains highly contentious and as the more potentially variable, may be the more likely to influence model performance. Thus, it is the one theory underlying the Garin framework to which the concern for suitability seems more appropriately addressed for two immediate reasons; 1.) the method used governs to some extent, the calculation of the population-serving multiplier values and the difficulties encountered therein (as well as in the whole of the base multiplier), and 2.) the economic base is also utilized to specify the distribution of basic employment at the input stage - a critical foundation of the entire allocation process operating within the model.

The third and final issue in this research is in part, a logical extension of the former two and concerns the concept of 'conditional' forecasting with the model. Similarily, it is here where the question of the model's utility in planning enters the discussion. The term 'conditional' typically refers to the operative representation of alternative design proposals for use on the model in prediction; that is, the detailing by the planner of the conditions or structures implied by his intervention in the urban system toward the development over time, of some desired system state. As the model is a static framework however, there is a second and more pertinent aspect of the 'conditional' concept. Recall that the final objective in model preparation is the maximum correspondence between base year empirical and model-generated spatial levels of the dependent variables. The considerable assumptions embodied in calibration of the model are further emphasized by their assumed stability over the forecast period, whereby they clearly serve a dual purpose; 1.) to represent average interzonal interaction at one point in time, and 2.) to continuously represent those behaviours over time. Thus, the analyst's confidence in forecasting on the model is first a direct function of his goodness-of-fit indicators, or the significance of the theoretical description provided for the base year.Indeed, the derivation of satisfactory correspondence measures is a critical precondition to the operation of any forecast. Batty contends,

> ... the use of this model is not in accurate forecasts of the future system, but in forecasting a range of possible futures for the system ... As long as each forecast is based upon a consistent projection system, the different futures predicted by the model can be compared.
> (Batty,1970B:325)

At its best, a model incapable of rendering satisfactory base year correspondence (calibration) will in turn render only incompetent forecasts of no relevance to the planning or analysis of the system under consideration and similarily, would stand little chance of ranking as a worthwhile descriptive tool. This research further constitutes an attempt to observe and test the capabilities of the Garin model to provide such a 'static picture' of the Winnipeg urban system for the base year 1971.[28] From this, it is proposed that some inference may be drawn as to the viability of this model as a structurally descriptive tool of Winnipeg and other comparable urban systems.[29]

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28. It was originally intended to use a 1961 base year as the basis for a ten year forecast attempt to 1971. As the required shopping-trip data are unavailable for 1961, 1971 is necessarily adopted.
29. One qualification of this proposal is warranted; one option in such research regards the systematic variation of the zone system as a means of improving base year correspondence measures or in effect, fitting the zone system to the theory. As data insufficiences disallow the option in this research, only one zone system is considered here (see chapter four, 'Data Base Preparation').

However, the model is proposed as an analyitcal tool - a large step beyond the descriptive level. Where the above test of the model's 'static' capabilities refers to the first facet of the dualistic purpose of the behavioural assumptions, a further test of the model's analytical capabilities alludes to the second - the use of the model where shopping-trip and residential locating behaviours are assumed stable over time (given satisfactory base year correspondence). Yet in practical terms, no true forecast can be tested since no data exist describing the future. Thus for purposes of assuring comparability of horizon year, empirical and model-generated distributions of population and employment in the performance of such a test, it would become necessary to assume that the known structural alterations of the intervening period between the selected base and horizon years were those specified in some hypothetical plan, to be tested on the model relative to that base year. Clearly, any significant error introduced by the stability assumption would preclude any use of the model in forecasting or impact analyses of any design, and similarily, would most unlikely be considered by a planner responsible for recommending programmes concerning the allocation of substantial amounts of municipal capital and other resources.

The most apparent aspect of model performance in this regard is the proposed length of the forecast period. The Garin model has been used in past research over periods ranging from five through twenty years, and averaging about ten years. In this case, data requirements dictate that 1971 be adopted as the base year (footnote 28) and 1976 the horizon year which, although implying a comparatively short interval of five years, should prove an adequate test of the model's ability to allocate marginal change. The performance of this second test is however, contingent upon the goodness-of-fit derived in the first facet of this research for it is at this stage where the decision to attempt a forecast will or will not be justified. Poor correspondence will indicate a low level of description (and hence of explanation) and thereby bar any forward attempts at forecasting on the model. High correspondence on the other hand, will suggest considerable descriptive and explanatory potential of the model and provide a suitable basis upon which to further test the framework's analytical potential wherein the legitimacy of its use in the planning-policy functions may be addressed.

The many varying expressions of the Garin model in the literature may lead to some confusion in reviewing same. The version utilized in this research is characteristic of the original Garin derivative; that is, the matrix format allowing added sophistication to the representation of spatial structure with the population density and minimum service constraints, and the optional workplace to service interaction matrix omitted.[30]

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30. The omission of constraints here refers to the usual manner in which they are introduced into the model ie. as a separate iterative loop succeeding convergence. As the model utilizes a singly (production) constrained gravity submodel, the distinction should be made between this and the model form adopted here from the 1971 Winnipeg Area Transportation Study, a doubly-constrained framework wherein total employment by 'residential' zone is incorporated as a discrete, exogenous variable.

The above discussion highlights the salient aspects of protagonist versus antagonist issues surrounding the proposed use in planning, of simulation models in general, and specifically the Garin model; it is within such an arrangement of knowledge and opinion that the evaluation of any model must be framed.

> ... we clarify ideas by considering their practical consequences. The most important practical consequences of the arguments about method are, presumably, proposals for improvements in specific methods.
> (Wilson, 1969B: 7)

This research might be considered the first step in such a process. However, satisfactory goodness-of-fit is a critical requirement to any justifiable discussion of the analytical capabilities of the Garin model in forecasting or impact analyses and as such, must be the researcher's sole precursory objective to any such analysis of his urban system.[31]

Sufficient consideration is also warranted toward alternatives of internal method, and their likely impact on model performance. Finally, and where base year correspondence is considered adequate, an experimental-hypothetical forecast may be attempted to observe the behaviour of the model over time; not for purposes of extracting definitive answers, rather toward a more wholistic appreciation of the model's capabilities (or lack of same) in relation to its intended function as a structural forecasting tool.

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31. Recall that this research deals with one, inflexible zone system; this imposes a constraint on potential goodness-of-fit to the Winnipeg system in this case. The nature and rationale for this zone system are presented in chapter four, 'Data Base Preparation'.

CHAPTER FOUR:

INTERNAL METHODOLOGY

AND

DATA BASE PREPARATION

4.1: Operational Guidelines

4.2: Modelling Interaction: Zone System Design and Gravity Model Performance

4.3: The Economic Base Submodel: Theoretical and Practical Considerations

4.1: Operational Guidelines

There are four major criteria collectively governing data base preparation with respect to the intended purpose of analysis on the model, the availability of data, and the study area design. Specifically, these are; 1) scale of inquiry, governing not only the study area as a whole but the manner in which the area is partitioned into workable zones, 2) model development whereby the data are organized so that alterations in the zoning system or the model itself may be accomodated with minimal effort, 3) suitability for other analyses, such that data use is not restricted to this model alone, and 4) data base development, where it is possible to refine, add to, or otherwise alter the data base without abandoning the existing organization (Barras et al.,1971:195). There are three further operational guidelines to be heeded; 1) it should be possible to relate data items for the same entity, spatial and/or structural, such as cross-tabulations using new and related variables, 2) in location models is particular and structural planning in general, the location of an entity is an important variable, thus the more precisely location is measured, the greater the flexibility incorporated, and 3) variables should be measured on the smallest practical class interval (Barras et al.,1971:195) to permit subsequent aggregation where warranted. Clearly however, compromises are inevitable as there is no possibility of meeting all the above criteria (Barras et al.,1971:196); the nature and impacts of those necessarily adopted for the variables in this research are introduced as each is discussed.

The primary data sources utilized here are first, the Winnipeg Area Transportation Study (W.A.T.S.) 1962 and 1971 (prepared by local streets and transportation authorities) for the preparation of the zone system and the corresponding interaction data, and second, 1971 and 1976 publications of the Census Bureau of Statistics Canada (Dominion Bureau of Statistics) for the required demographic information. The census 'Confidentiality Rule' comprises the only legal restriction on data availability from the above sources;

> Statistics Canada is subject only to the statuatory prohibition against disclosing information that can be related to identifiable respondents.
> (Social Sciences in Canada, 1978:4)

In effect, this rule prescribes three possible courses of action where violation is apparent; a) the information is totally witheld from public use, b) the data is aggregated, or c) the figures are rounded. Either of the latter two methods introduces some error and information loss into the data although this is a negligable proportion since this research is not concerned with individual activities.[32] The spatial level at which the information is made available is the far more important issue in relation to zone system design, and further, is more a concern

32. It is common for these methods to most distort the data in peripheral areas or those wherein variable totals are relatively small. At the same time, and due to their comparative triviality, they are unimportant to large scale investigation. Conversely, it is rare for one enumeration area to contain only one activity.

with respect to employment versus population as the former is the more 'secretive' in census publications.

Beyond initial data supply considerations are those determining internal method in the three stages of model preparation; zoning system design, gravity model performance, and economic base analysis. Each of these components is subject to certain operational guidelines of considerable import to overall model performance and as such warrant some discussion individually as well as cumulatively. The greatest interdependence exists between the zoning system and gravity model performance, thus these two components are discussed more so in this light.

4.2: Modelling Interaction: Zoning System Design and Gravity Model Performance

Recall the basic hypothesis of the gravity concept;

> ... the gravity concept of human interaction postulates that an attracting force of interaction between two areas of human activity is created by the population masses of the two areas, and a friction against interaction is caused by the intervening space over which the interaction must take place. (Batty,1972:153)

... and the interpretation of this concept operative within the Garin framework (equations 2.22 - 2.25). The gravity concept is used within the model to replicate trip-making behaviours; empirical variation in same seems considerable yet this conceptual model is probably the most successful in quantitative analyses of urban systems (where success is considered a function of a models reapplicability to the real world).

> The patterns of transport flows in cities is extremely complex. Trips are made by a variety of kinds of people, for a variety of purposes, on a maze of routes, and by several modes ... A person trip is made from an 'origin' to a 'destination' by some 'route'.[33] The technological characteristics of the route chosen define the 'mode' of the trip: walk on a footpath or road, car by road or various forms of public transit. The pattern of trips, and the situation faced by a particular traveller also vary with 'time of day'. Inevitably, when (we) build a model there is considerable loss of information which partly helps to resolve some of the definitional difficulties. It is, obviously not possible to work with a level of detail in which trips are recorded from individual address to individual address in the model. The study area is divided into zones and (we) model trips from zone to zone (and to some extent) within a zone. (Wilson,1974:127)

Specifically, zones are defined on variables whose range of variation is within the range of variation of the variables defining the system, and all zones are mutually disjoint and together exactly cover the study area (Barras et al.,1971:140). The operational guidelines of zone system design are primary causative factors in gravity submodel performance and thus warrant introduction.

The first concern regards system closure, or the specifying of

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33. To avoid confusion, the subscript letter 'i' is hereafter used exclusively to denote an <u>origin</u> or trip production i.e. the home end of a home-based trip or the origin end of a non-home-based trip; the letter 'j' denotes a destination or trip attraction i.e. the non-home end of a home-based trip or the destination end of a non-home-based trip. (Wilson,1974:128)

external study area boundaries. There are two complementary concepts of closure implied by the model: the first relates to the idea of spatial closure from the point of view of spatial interaction, whereas the second relates to closure in terms of the economic base mechanism. In terms of spatial closure, it is necessary to define a limit where interaction across the spatial boundary becomes 'insignificant' relative to other interaction in the study area (Batty, 1974:464). Where this limit necessitates consideration of external interaction, the added concept of external 'dummy' zones is incorporated into the model for the representation of these flows. The spatial environs immediately surrounding metropolitan Winnipeg are comprised primarily of agricultural activities, with several small communities of no significant relative size. This is true in all directions except to the north-east towards Beausejour, Lockport, and Selkirk. Although these centres (particularily the latter) are of more considerable size in relation to other surrounding centres, their attraction for employment opportunities and/or commuter residences is not sufficient to warrant consideration.[34] As such, the external zone issue is easily solved in this case (which might also be considered an advantage since past research bears out the difficulties inherent in trying to operationalize this notion in a consistent manner).[35]

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34. The fact that no attempts have been made to measure these interactions serves an adequate justification for this proposal.

35. This problem is usually addressed by the 'fitting' of arbitrary, varying zone size to represent observed levels of interaction. In the past it has been proved a highly uncertain and somewhat lengthy trial and error procedure.

The most immediately obvious alternative then is the use of prescribed municipal boundaries for two major reasons; 1) significant populations and otherwise developed lands have reached these boundaries in several areas, and 2) these legal limits govern the collection of relevant descriptive data required for this research. Although, large parcels of as yet undeveloped land are apparent in other areas within these boundaries, this poses no problem since unit land area is not a variable in the model.

The second and far more critical concern is the partitioning of study area space into 'n' zones for the measurement and representation of intra-system, inter-zonal interaction.

> The design of a zoning system appropriate to a particular model application is perhaps the most important yet the most poorly explored and least understood question in model design. The zoning system determines the level of spatial description and in interaction models, this system also determines the amount of interaction detectable in the system. (Batty, 1976:212)

In short, zones are detectors of trips. As zone size decreases, the strength of interaction increases, where strength of interaction is defined as the fraction of total trips which cross zonal boundaries; this fraction should be as high as possible, or alternatively, the ratio of inter-zonal to intra-zonal interaction should be maximized (Barras et al., 1971:140, Batty, 1976:111). In more precise terms, zone size must be considerably smaller than the average journey to work trip length since, the smaller the zone, the greater the proportion of the population which is allocated to residences outside the zone of employment and thus, the greater is the proportion of interaction modelled (Barras et. al.,1971:140). At the same time, a system of smaller and more numerous zones implies a heightened sensitivity of the model's allocation mechanisms to the interaction data, whereby accuracy in this respect becomes equally more important. Furthermore, while a decrease in zone size produces a corresponding increase in resolution in the measurement of variation, it is also true that the statistical accuracy of the information collected (for goodness-of-fit comparison) will decrease with decreasing zone size - the error depending inversely on population size. This is particularily important if the input numbers are samples (Barras et. al.,1971:140), and as the sample method is most commonly employed (wherein the trip-making behaviours indicated in partial samples of zone populations are extrapolated to their corresponding total populations), a second criterion is active in zone definition. It is desirable that zones be internally homogeneous to the greatest obtainable degree, with respect to residential search and shopping behaviours through income group, housing type, family size, consumption patterns, and so on. Another approach emphasizes the use of 'regular' spatial units, hence the homogeneity of the spatial distribution of activities within zones (particularily where the model's variables are not disaggregated) according to population density, dominant land use, or size similarity (Batty,1976:85,112). A final concern for the total number of zones may also be warranted where certain budget constraints apply in that larger numbers means equally larger matrix dimensions and thus higher data storage and computation costs. Clearly, some compromise of the above design guidelines will, in every case, be necessary.

The most considerable product from zone system design in any case study is the travel time information utilized in the denominators of the interaction submodels. Such data is derived through the application of some form of minimum path algorithm, a tool requiring substantial amounts of data describing the existing transportation network and involving equally substantial man-hour input.[36] There are two available bodies of this data for the Winnipeg system 1971; the first, from the modal-split, route assignment model prepared and calibrated by the Metropolitan Streets and Transit Department as the second (1971) facet of the Winnipeg Area Transportation Study (W.A.T.S.) 1962, and the second, a similar data body utilized in minimum path research by a task force research group of the department of Civil Engineering, University of Manitoba throughout 1969-72. The former model applied to a subdivision of the metropolitan area into nine superzones and a total of 125 zones, and was calibrated according to a twenty percent trip behaviour survey of the city's population for 1971. The nature of

36. The collection of data and the preparation of a minimum path program would itself constitute an ambitious undertaking and, together with the added requirements (costs) in running the model, would prove a task beyond an individual researcher. As such, the availability of similar data for the base year 1971 was a necessary prerequisite to the undertaking of this research on the model as a whole.

the information from the alternative source is however, largely unknown.[37] A further difference applies; the engineering data are provided in the form of travel time in minutes by automobile, whereas the W.A.T.S. information provides absolute numbers of total 'inter-' and intra-zonal work and shopping trips - not the form required for running the gravity submodel, rather the type of data derived from final calibration of the Garin submodel. These latter data were however, necessarily adopted for this research as the required travel time information is not available from the local authorities.[38] This decision raises a further issue of the comparative suitability of the W.A.T.S.

37. None of the persons involved in the task force were available for comment (its director has since left the engineering department). As their research was known to be experimental, no clear indication was available as to the specific nature of the data ie. whether they represent straight-forward travel time or if additional factors such as terminal times or congestion measures (and so on) are built in. Furthermore, these data are presented in a 124 zone design, as the use of 124 zones in the 1962 area transportation study. The time period of this research (1969-72) also precedes the point in time when the 1971 area model was finalized. Finally, some revisions were made to the 1962 zone system for the running of the 1971 W.A.T.S. model and as no listing of zone identities was available for the engineering data, there is some reason to question their adequacy for 1971.

38. The Winnipeg Streets and Transit Department authorities were willing to provide only a limited sample of the 1971 travel time (in minutes by automobile) data for the 125 zone system to allow some evaluation of the civil engineering information through comparison. For the most part, the data contained several similar values although there were also several noteable discrepancies, in some cases more than seven minutes. As the comparison was based on a relatively small sample, and as the nature of the engineering data so highly unknown, it was decided to be highly suspect and as such, unsuited to use in this research.

procedure in relation to the gravity submodels of the Garin framework (since by implication, the W.A.T.S. zone system must also be adopted).[39] In other words, is any significant difference introduced into the analysis using a model which emphasizes a route or trip assignment priority versus one concerned explicitly with the concept of residential location? The two models differ significantly with respect to both structure and requisite data, the W.A.T.S. model the far more sophisticated of the two. Where the Garin submodel operates as a singly (production) constrained framework (through the relation made to the observed origin zone employment term E_i , in equation 2.25), the W.A.T.S. trip assignment priority implies the use of a doubly (production and attraction) constrained model of the following form;

$$I_{ij} = G_i A_j T(F_{ij}) \qquad (4.1)$$

where,

I_{ij} = number of trips from i to j,

G_i = number of work-trips generated at i, (the production constraint)

A_j = number of work-trips absorbed by j, (the attraction constraint)

$T(F_{ij})$ = the travel impedance function (usually a negative exponential)

The formal definition of the doubly-constrained model differs

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39. It is this lack of the complete body of travel time data which dictates the use of a fixed zone system in this research, and as Batty notes, "...there are problems in assessing the change in performance between different zone systems due to the fact that there are difficulties in aggregating the set of travel times" (Batty,1976:226).

slightly from its singly-constrained sequel;

> The trip interchange between zone i and zone j is considered to vary directly with the generating intensity of i, and the absorbing intensity of j, and inversely with the travel impedance between i and j. The travel impedance of 'travel factor' is a quantitative measure of the effect that travel time has on the propensity to travel from i to j. (W.A.T.S.,1966:20)

The advantage of the doubly-constrained model lies in its consideration of both zonal trip generation and attraction as discrete, exogenous variables. The W.A.T.S. technique is perhaps best described as below;

> After establishing a relationship between trip making and land use, for a specific pattern of land use, the model first calculates the number of trips likely to start from and terminate at each zone within the system. It then estimates the interchange of trips between zones with the aid of a quantitative measure of the reluctance of people to travel longer distances to work, and determines their probable choice between available private and public transportation. The estimated trip interchange, or distribution, is then assigned between alternative routes available for each mode of travel in accordance with predetermined route flow characteristics. (W.A.T.S.,1966:4)

From the above summary, two points suggest themselves; 1.) the resolution of modal-split analysis and route assignment are unnecessary to the Garin model, and 2.) such a model as that above is calibrated, and goodness-of-fit is measured not according to the distribution of land uses or activities, rather according to statistical comparisons of simulated and observed traffic volumes on the links included in the analysis. Yet with respect to the former, the use of such sophisticated gravity models is common among transportation planners and engineers in North American centres of metropolitan order and ,as such, provides a valuable data source for the use of Lowry-type models. With respect to the second point, the explicit use of employment versus population by destination zone as the attraction factor,[40] would seem to imply that its distribution, and through it population distribution, (since population is derived from employment in the Garin model), are 'completely' accounted for in the interaction data. In other words, because the distribution of employment is 'known' by both place of work and residence, the W.A.T.S. model is one of interaction via most probable route selection - not one of residential location. Thus the common difficulties in attempting to model the extreme complexity of the residential location process are undermined in the doubly-constrained model.[41] This would further seem to guarantee considerably significant base year goodness-of-fit indicators (assuming satisfactory performance of the remaining model components) since the distributions

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40. In the Garin submodel, place of work is considered the origin whereas place of residence is considered the origin in the W.A.T.S. model. This then necessitates transposing the W.A.T.S. origin-destination trip matrix for purposes on the model in this case. It does not seem likely that such an alteration would render the data unsuitable over the system as a whole.
41. It would also appear that the use of so extensive a framework as the W.A.T.S. design on the more orderly and measurable phenomenon of trip-making behaviour would improve its relative potential in effectively representing such interaction in the Winnipeg system.

of these same variables are utilized in those measures of Lowry-type models. Although this would be true, those correspondence measures would not provide an indication of the degree to which the behaviours simulated by the model were representative of the empirical behaviours determining those activity distributions; hence the need for some other indicator of 'behavioural correspondence'. The common convention in such research of singly-constrained models is the analysis of trip distribution through zone mean trip length statistics whereas in the doubly-constrained W.A.T.S. model, this method is carried one step farther through the extension of trip distribution analysis (governed by the behaviours indicated in the twenty percent sample survey questionnaire, Appendix A) as a method of establishing simulated route flow volumes.[42] A comparatively noteable aspect of the W.A.T.S. model trip distribution function concerns the treatment of the travel impedance concept;

> It seems intuitively clear that there are often several components to what we call 'travel cost' or impedance. If any one of us makes a journey, for example, then we might well take account of the money cost, the different kinds of time expended (ie. travelling and waiting time) and possibly other features like comfort and convenience. It seems reasonable therefore, to try to develop some composite measure of travel cost appropriate to the kind of spatial interaction which is being represented in the model.
> (Wilson, 1974:70)

42. For more detailed information regarding the W.A.T.S. procedure, see 'Travel Analysis', W.A.T.S., Volume Two, 1966.

Where this concept is usually expressed in the Garin submodel as an absolute travel time in minutes modified by a numerical exponent, the W.A.T.S. procedure incorporates additional information into the term by route size or type including, the legal speed limit and average travel speed, and additional data describing route practical capacities and observed vehicle volumes toward more realistic representations of the impact of congestion on inter-zonal travel times (W.A.T.S., 1966:10).

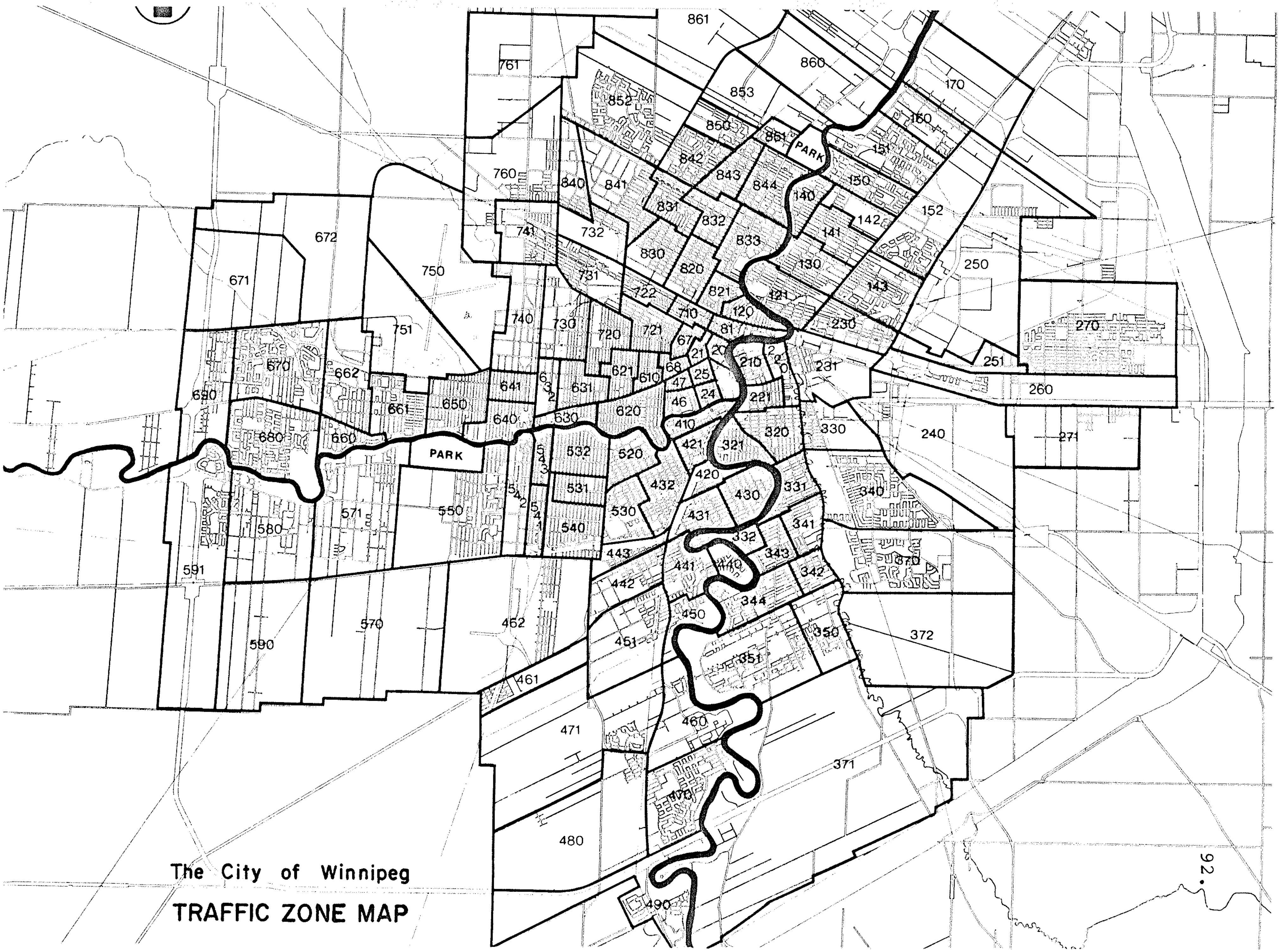
No explicit analysis of correspondence was performed for the 1971 area model in terms of trip distribution or route flows since local authorities assumed that 1971 indicators would differ little from those derived from a previous 1966 analysis. Thus for purposes here, the 1966 indicators must be utilized as measures of behavioural correspondence. The measure derived for work-trip generation over the system was a correlation coefficient (r) equal to 0.9750, and for work-trip attraction, a value of 0.9950 (W.A.T.S.,1966:19). In light of these extremely significant values, it does not seem unreasonable to conclude that the W.A.T.S. information is adequately suited to this research.

As the W.A.T.S. interaction data are adopted, the second issue at this stage of data base preparation concerns the nature and suitability of their corresponding zone system in light of the design guidelines discussed above.[43] These may be summarized as, 1.) the

43. This discussion is intended to point out any possible negative impacts of the zone system on model preparation and performance.

structural homogeneity of zones, 2.) closure with respect to intra-zonal trips, 3.) compatibility with other required data formats, and 4.) use on the Garin model. The nature of the zone system is illustrated in Map 4.1, indicating the 125 zones and nine superzones into which the metropolitan area is partitioned. Essential statistics describing trip behaviours from the 1971 model are then provided in Table 4.1.

Zone size is of greater concern than the total number of zones since the model is proposed as a tool for the simulation of given developments or structural alterations. It follows that the finer the zone system, the greater the spatial exactitude represented. Clearly, this model is not intended to represent the level of individual activities or sites, although a system approaching that level is more desirable than one tending toward larger spatial units since all metropolitan area development ultimately concerns absolute site amenity and cost. Relative to past research on this model in metropolitan systems, the W.A.T.S. design compares favourably in this respect; that is, the zones tend to be small and more numerous spatial entities. It seems likely that such exactitude will prove a rigorous test of the model's capabilities. A further aspect of the tests regards the possible over-emphasis or over-attraction in the model of large-scale service facilities (see column E, Table 4.1) such as particular land uses in the centre core (Eatons-025, the Hudsons Bay Company and Art Gallery-047), or other sites at Polo Park-632, the Unicity Mall-670, and the Garden City Mall-842, and their corresponding impacts upon the allocation of service employment.


The City of Winnipeg
TRAFFIC ZONE MAP
PARK
PARK
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842
843
844
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840
841
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Table 4.1

Selected Trip Descriptive Statistics for 125 System Zones, Winnipeg, 1971

A = Zone Area in Acres
B = Total Person Work-trips Generated as Origin by Place of Residence
C = Total Person Shopping-trips Generated as Origin by Place of Residence
D = Total Person Work-trips Absorbed as Destination by Place of Residence
E = Total Person Shopping-trips Absorbed as Destination by Place of Work
F = Percentage Generated Intra-zonal Person Work-trips as Origin by Place of Work

Zone	A	B	C	D	E	F
020	83.7	8303			211	
021	85.8	9870	13	163	885	1.1
024	174.6	6426	1092	3054	430	9.2
025	124.2	14,273	489	818	10,029	1.7
046	150.5	3358	980	2202	94	5.6
047	69.5	6577	226	602	3643	1.2
067	125.8	2225	414	3405	73	8.6
068	88.6	6932*	326	1998	398	3.4
081	183.5	3388	146	400	217	2.2
SUM		61,352	3686	12,642	15,980	
120	161.9	1188	140	786	58	2.1
121	552.7	1533	1016	4349	234	27.5

Table 4.1

Zone	A	B	C	D	E	F
130	414.7	1228	551	2125	87	21.7
140	246.8	320	603	1850	545	18.4
141	425.5	466	514	2651	133	25.9
142	305.4	349	461	1443	905	10.1
143	670.2	253	786	3309	235	48.2
150	434.0	613	865	3484	316	35.0
151	816.6	416	392	1787	30	37.8
152	1302.5	334	28	93	0	1.5
160	545.3	92	91	423	15	5.4
170	1401.9	211	214	742	0	45.0
SUM		7003	5661	23,042	2558	
210	222.2	1234	108	621	46	7.5
220	177.5	509	87	553	81	6.1
221	180.0	1075	363	1895	77	40.3
230	484.9	706	491	3033	223	14.9
231	846.8	1215	35	409	21	6.1
240	2576.9	3293	15	156	36	0.80
250	2825.1	352	35	159	28	2.9
251	334.7	213	30	68	10	0.0
260	1453.6	3764	40	177	1988	0.70
270	2360.9	932	1443	6198	645	50.2
271	1362.1	48	41	108	0	0.0

Table 4.1

Zone	A	B	C	D	E	F
SUM		13,344	2688	13,377	3155	
320	432.1	1303	942	3360	1041	19.9
321	289.8	152	460	1453	41	27.6
330	530.3	2572	85	783	32	3.3
331	351.9	543	550	1945	329	25.0
332	191.2	212	126	474	0	17.9
340	1565.0	690	1629	5135	507	27.6
341	281.6	244	330	1339	426	8.2
342	224.3	158	395	1474	103	55.0
343	241.8	222	270	1150	52	19.4
344	545.4	257	512	1973	120	44.7
350	577.4	79	108	913	36	37.9
351	1477.2	735	348	1596	334	18.4
370	4483.9	449	280	662	1093	2.3
371	7548.9	146	71	359	6	0.0
SUM		7762	6106	22,616	4120	
410	227.9	1090	1064	5325	518	17.3
420	198.8	1097	132	899	46	2.9
421	160.8	973	227	1822	194	4.7
430	364.5	736	632	1460	80	6.4
431	336.8	225	591	1502	439	24.4

Table 4.1

Zone	A	B	C	D	E	F
432	477.7	2565	1334	3700	321	7.3
440	185.1	46	131	468	5	32.6
441	411.0	490	594	1481	203	10.8
442	515.7	1651	345	1119	404	3.3
443	165.4	70	84	342	10	40.0
450	270.4	166	246	678	39	3.0
451	933.5	2380	220	1457	425	4.2
460	894.8	17,375*	313	2007	29	8.8
461	478.7	188	0	64	0	10.6
462	2793.4	248	0	31	0	0.0
470	1026.5	198	712	2285	225	17.2
471	3147.5	93	101	445	26	9.7
480	2514.9	101	6	76	0	2.0
490	1686.3	179	140	662	60	42.4
SUM		29,871	7054	25,823	3024	
520	346.6	570	748	2066	246	15.3
530	421.7	1393	1109	3357	3221	16.6
531	258.9	172	628	1549	65	15.7
532	447.8	227	954	2078	155	28.6
540	554.7	232	759	2216	133	24.1
541	205.7	114	423	1116	271	4.4

Table 4.1

Zone	A	B	C	D	E	F
542	549.1	1190	218	887	28	11.4
543	174.5	196	357	1021	275	10.7
550	2173.2	490	365	1029	376	1.2
570	2709.0	23	0	47	0	42.0
571	1759.8	408	517	1864	227	20.6
580	1432.8	209	255	1036	25	26.3
590	1628.0	32	0	1	0	0.0
591	2155.0	75	157	406	5	6.7
SUM		5331	6490	18,673	5027	
610	153.5	1056	708	2583	279	8.2
620	457.4	3262	1395	5913	589	12.2
621	247.6	1174	939	3026	390	16.1
630	160.4	408	248	1134	67	7.1
631	342.1	2983	605	2262	437	7.2
632	200.3	4859	0	0	6257	0.0
640	343.6	1018	692	2092	220	7.9
641	230.8	811	331	1403	91	7.2
650	549.3	1520	599	2860	325	11.6
660	238.8	175	319	828	245	2.9
661	527.1	506	1190	3611	385	28.0
662	802.5	1702	1007	3007	792	13.0

Table 4.1

Zone	A	B	C	D	E	F
670	1248.4	643	1291	4329	120	30.0
671	3821.7	6	0	0	0	0.0
672		0	0	0	0	0.0
680	1129.1	912	1418	4208	1509	24.1
690	972.4	542	263	1214	1097	15.5
SUM		21,577	11,005	38,470	12,803	
710	150.0	1158	135	850	35	7.8
720	382.7	1796	1020	2709	260	7.9
721	375.5	7981	1295	4301	583	12.4
722	227.0	1459	163	778	33	3.7
730	635.6	3382	360	1222	64	1.7
731	558.4	2009	750	2935	313	10.4
732	436.9	2373	278	1034	57	3.7
740	759.7	7844	15	15	196	0.0
741	625.3	5215*	362	1442	35	4.5
750	3922.8	4521	0	3	18	0.0
760	3667.8	291	40	144	0	3.8
SUM		38,029	4418	15,433	1594	
820	382.5	1537	534	3215	658	20.2
821	187.6	1150	307	1586	174	3.9
830	437.2	944	513	2381	195	15.1

Table 4.1

Zone	A	B	C	D	E	F
831	350.4	274	677	2492	254	22.6
832	313.5	286	588	2570	151	21.7
833	483.9	1811	1456	4287	1269	18.8
840	404.6	105	147	804	23	11.4
841	946.3	2309	563	2144	78	6.8
842	421.3	594	1117	2522	899	20.5
843	326.5	212	533	2286	32	30.6
844	491.1	921	588	2901	522	31.0
850	370.1	492	81	277	1646	2.3
851	384.6	220	40	329	15	6.8
852	1723.1	31	35	133	5	0.0
853	884.7	237	34	108	0	7.2
860	1290.7	119	63	298	5	11.8
861	2130.7	37	0	61	5	40.5
870	2557.3	84	120	729	10	78.6
SUM		11,363	7396	29,123	5941	
GRAND TOTAL	108,788.5	195,632	54,504	199,184	54,202	

* In the W.A.T.S. analysis, Student trips were incorporated in the data as work trips because of their demand on the transportation network. This accounts for the large values for origin generated work trips in zones 068-the University of Winnipeg, 460-the University of Manitoba, and 741-the Red River Community College.

As the zones tend to be small, any resulting error should be readily apparent.

The spatial closure issue is equally satisfied in the W.A.T.S. design. A generally recommended maximum percentage of intra-zonal work-trips[44] in spatial interaction modelling is twenty percent. As indicated in the zonal percentages in the final column of Table 4.1, this criterion is met for the most part, ie. 94 of the 125 cases equal (within one percent) or fall below that limit. In the cases where the twenty percent limit is exceeded, total employment levels tend to be comparatively small and thus of lesser relative significance.

The third guideline regarding the internal homogeneity of zones is perhaps the most difficult of the four to meet or maintain. Yet, it was necessarily an active criterion in the W.A.T.S. design since the simulated trip distribution analysis was fitted to the twenty percent sample survey of zonal work and shopping-trip behaviours. The variables emphasized indlude income or socio-economic group, housing type and cost, and family size. For non-residential areas, the homogeneity of activities was emphasized, for example, the inclusion of the Polo Park shopping centre and the stadium--arena complex in a single zone, and exclusively in another, the Grant Park plaza and Pan-American sports complex. The same is also true of industrial activity throughout the city, for example, the Fort Garry, St. James, and Inkster industrial areas

44. Work-trips are utilized as this total commonly far out-strips corresponding zonal totals of person shopping-trips.

and lands associated with the CN and CP railways and yards. As there is no explicit means of measuring the degree to which this criterion is satisfied, its suitability in the W.A.T.S. design must be assumed.

The final consideration lies in the compatibility of the zone system with other required sources of published demographic data; in this case, population and employment information provided according to census tracts and enumeration areas. The superimposition of traffic zone boundaries on the Winnipeg census tract system (1971) illustrates a poor correspondence and thus necessitates the aligning of enumeration areas to traffic zones. The required data include, 1.) population by zone of residence, 2.) employment by zone of residence, and 3.) employment by industry group by place of work.[45] The former two are used in the calculation of the zone activity-rate multipliers, and the third, in the economic base analysis and the distribution of input basic employment.[46]

The zone demographic statistics are presented in Table 4.2. As enumeration areas are small, they can easily be fitted to the zone system and thus improve on potential information loss, not only in describing activity distributions, but also in the representation of spatial structure in the multiplier matrices.

The singly significant problem of the zone system is the partial coverage provided of the peripheral population in north-east Winnipeg at

45. As the Canadian census does not publish information at the enumeration area level, it must be acquired from the Ottawa head-quarters. Where the information must be tabulated, there is some cost incurred.
46. Economic base methodology is discussed in the following section of this chapter.

Table 4.2

Demographic Statistics for 125 System Zones 1971

Zone	Population	Employment (by residence)	Activity Rate %*	Activity Rate Inverse
020	276	96	34%	2.936
021	573	237	41	2.438
024	3065	1826	61	1.634
025	728	323	47	2.141
046	3386	1803	53	1.878
047	1013	608	59	1.688
067	4076	1806	44	2.264
068	3130	1516	48	2.110
081	754	286	39	2.664
120	2225	745	33	3.007
121	10,725	4590	43	2.336
130	6192	2825	46	2.192
140	3720	1695	45	2.220
141	9464	3584	38	2.667
142	1851	1502	80	1.243
143	8910	3615	41	2.438

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
150	10,440	4685	49	2.228
151	4650	2015	43	2.307
152	397	145	36	2.737
160	1550	610	39	2.541
170	2590**	1070**	41	2.438
210	1883	937	49	2.009
220	1473	717	50	2.083
221	5545	2390	43	2.311
230	9724	3345	34	2.916
231	1045	439	42	2.380
240	500	200	40	2.500
250	678	245	36	2.767
251	263	113	43	2.327
260	263	113	43	2.327
270	21,475	8115	38	2.659
271	485	210	43	2.309
320	8690	3740	43	2.324
321	3640	1730	48	2.104

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
330	2645	1140	43	2.320
331	3179	1998	63	1.591
332	995	432	43	2.319
340	17,465	7015	40	2.502
341	3948	2263	57	1.741
342	3278	1688	51	1.941
343	4069	1755	43	2.318
344	8238	3343	41	2.464
350	818	336	40	2.493
351	5403	2328	43	2.321
370	2130	875	41	2.434
371	1475	550	37	2.682
410	9018	5132	57	1.744
420	1925	649	33	3.007
421	3263	1778	54	1.835
430	4930	2260	46	2.181
431	5690	2269	40	2.507
432	9583	4325	45	2.215

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
440	1060	349	33	3.037
441	3570	1594	44	2.258
442	3230	1275	39	2.533
443	360	165	44	2.250
450	3523	1565	45	2.215
451	3195	1365	43	2.341
460	2248	1090	48	2.062
461	155	74	48	2.094
462	470	205	40	2.473
470	5675	2185	39	2.597
471	155	73	48	2.094
480	1145	502	44	2.281
490	2165	823	38	2.649
520	6628	2970	45	2.231
530	7895	3828	48	2.062
531	3975	1645	41	2.416
532	5885	2425	41	2.426
540	5000	2070	41	2.415
541	3310	1460	44	2.267

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
542	2965	1265	43	2.344
543	2515	1125	45	2.235
550	2790	1085	39	2.571
570	363	106	29	3.424
571	5434	2329	43	2.333
580	2836	1106	39	2.564
590	83	35	42	2.371
591	3134	912	29	3.436
610	7275	3245	45	2.242
620	14,925	7290	49	2.047
621	7429	3295	44	2.254
630	2870	1335	46	2.149
631	5424	2557	47	2.121
632	610	345	56	1.768
640	5790	2490	43	2.325
641	2988	1207	40	2.475
650	8105	3667	45	2.210
660	1640	750	46	2.186
661	11,175	5020	45	2.226

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
662	5985	2445	41	2.447
670	12,321	4650	38	2.649
671	0	0	0	0
672	40	10	25	4.000
680	11,235	4295	38	2.649
690	6305	2325	37	2.712
710	3330	972	29	3.426
720	7545	3270	43	2.307
721	11,845	5420	46	2.185
722	1795	705	39	2.546
730	2755	1325	48	2.079
731	7625	3130	41	2.436
732	2590	1120	43	2.313
740	618	247	40	2.502
741	3945	1420	36	2.778
750	340	165	49	2.061
760	320	145	45	2.207
820	9904	3340	34	2.965

Table 4.2

Zone	Population	Employment	Activity Rate	Activity Rate Inverse
821	4732	1412	30	3.352
830	7999	3130	39	2.556
831	6550	2983	46	2.196
832	7695	3299	43	2.333
833	12,380	4745	38	2.609
840	2580	830	32	3.109
841	6428	2663	41	2.414
842	6845	2835	41	2.414
843	4922	2411	49	2.041
844	8323	3597	43	2.314
850	1300	525	40	2.476
851	1930	750	39	2.573
852	413	179	43	2.307
853	336	154	46	2.182
860	926	388	42	2.387
861	375	65	17	5.769
870	2455**	970**	40	2.531
SUM	534,504	188,753		

* Activity-rate percentage values are rounded.
** As the municipality of St. Paul is bisected by zones 170 and 870, the above totals reflect census totals for that municipality, according to the areas subdivided by the respective zones.

St. Paul. Zones 170 and 870 in effect, spatially bisect the municipality, thereby omitting significant levels of population immediately adjacent to their outer boundaries. Yet because the interactions indicated by the gravity model for these zones were also of some significance, the total population and employment levels were utilized here.

The W.A.T.S. (1971) information is adopted then for six major reasons. 1) no reliable data describing inter-zonal travel time in Winnipeg are available, (and) 2) the preparation of a minimum path programme as only one facet of research on the model, would be beyond the limitations of this research, 3) the W.A.T.S. information is the best available source in that the data reflect, 4) work-trip distributions provided in a twenty percent empirical survey of such behavious in the Winnipeg system, according to, 5) a doubly-constrained versus singly-constrained model of interaction within which is incorporated, 6) substantial amounts of additional data describing the Winnipeg transportation network which heighten the realism of the travel impedance function considered in the model relative to that characteristic of the conventional Garin submodel. Furthermore, the corresponding zone system is of sufficient scale for use on the Garin model and adequately satisfies the operational guidelines of zoning system design implied in the use of the gravity formulation for the modelling of spatial interaction; that is, activities of high trip-generating and attracting intensity are isolated by the system and a satisfactory proportion of total inter-zonal interaction is represented in the model.

The absolute numbers of inter-zonal trips indicated by the model are taken as proportions of total generated trips by zone of origin and compiled in two, square 125 x 125 dimension matrices, one describing each of workplace to residence, and residence to service interaction. As such, all rows in both matrices sum to a value of one.

4.3: The Economic Base Submodel: Theoretical and Practical Considerations

The term 'economic base' is a familiar one to the urban economist and city planner. There is a fairly general concensus that the economic base, as presently conceived, refers to those activities of an urban community which export goods and services outside the economic confines of the community, or which market their goods and services to persons who come from outside the community's economic boundaries; in other words, these base activities are the wage earners of the community family (Andrews, 1953:161). Thus, the 'base' or 'basic' sector of an urban economy consists of income-generating enterprises, those providing the impetus for economic growth and considered necessary and primarily responsible for overall community development. That remaining economic section of the community which the base directly supports is referred to as service activity;

> ... including those enterprises whose principal function is that of providing for the needs of the persons within the community's economic limits. They are also distinguished from the base in that they are principally importers or, if they do not import, do not export their finished goods or services. In a sense, they can be considered the spenders of the community wages earned by the basic activities.
> (Andrews, 1953:161)

The fundamental aspects of the base concept or economic base theory are little changed from their original expression according to Aurouseau (1921) and Olmstead (1927), the latter providing the first explicitly dualistic definition of the urban economy in the 1927 - "Regional Survey of New York and Its Environs";

> The multiplicity of (their) productive occupations may be roughly divided into those which can be considered primary, such as carrying on the marine shipping business of the port and manufacturing goods for general use (ie. not confined to use within the community itself), and those occupations which may be called ancillary, such as those devoted directly or indirectly to the service and convenience of the people engaged in primary occupations.
> (Olmstead,1927:42-3)

Probably the most significant development of the base concept is attributable to the pioneering work of Homer Hoyt, an economist who in 1936, suggested a variable mathematical relationship between basic employment and service employment in cities, and hence a ratio relationship between the former and total population (Andrews,1953:163). Hoyt considered the economic base concept to be a tool that might be employed in analyzing the economic background of cities with the objective of forecasting the future of the entire city (Andrews,1953:163). His interpretation was to mark the formal beginnings of the concept as an analytical technique for direct application to the planning process, by way of a four-stage process which is commonly apparent in current studies of regional and metropolitan industrial growth. The logic of his outline is also readily apparent within the base submodel of the Gavin framework:

1. calculation of total basic employment in the community and particularly the amount of basic employment in each basic activity,

2. estimation of the proportion of basic employment to service employment. Hoyt assumed this ratio to be 1:1 but later determined that actual calculations and estimates had to be made for individual cities,

3. estimation of the future trend in each segment of the base as indicated by analysis of the demand for its product or service, locational factors, productive efficiency, and so on,

4. calculation of total employment and total future population on the basis of future trends in basic employment (Andrews,1953:163).

The essence of Hoyt's technique is the calculation of an economic base multiplier characterizing a given study area wherein basic employment plays the causative role in the generation of forecast employment and population levels. This priority on basic activity for planners was first proposed by Jones (1944);

> Those industries are the foundation upon which the town has been built...Their size will determine the size of the industrial structure and population of the town; no town can grow merely by adding to an already adequate supply of local industries and services...
>
> Every area, large and small, must contain some industries that export their products to the world outside the area...the inhabitants of the towns could not be expected to live by taking in each others' washing. (Jones,1944:126-27)

This priority is further apparent in alternative usages of the economic base concept in functional classifications of centres within their economic regions, according to variations in industrial employment structure.

The rationale of this usage of the concept as a comparative indicator is that the relationships revealed by data on basic employment constitute a more meaningful basis for analyzing a city's economy than do those comprised by total employment, since the structure of non-basic activities is substantially the same for every city (Alexander,1959:92). Hence the segregation of basic and non-basic components would reveal an entirely different structure for each example and provide a more satisfactory means of distinguishing comparative and contrasting traits, and further provide a meaningful expression of the fundamental space-relations between cities and their supporting areas[45] (Alexander,1959:90). A substantial body of empirical work since 1944 attests the strong sensitivity of the service sector to alterations in the basic sector (rising and declining with it) and thus, seems to justify the 'basic' priority adopted in economic base research. Yet this assumption, among others, has become a target of considerable scrutiny since the late 1950's to present, a period wherein the whole of economic base theory and its corresponding operative methods have become highly suspect as viable analytical tools.

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45. In this respect the technique has significant roots in central place theory.

Thus the previous confidence placed in this theory is displaced by an aura of caution (perhaps moreso in the academic than the applied planning sphere), itself a determinant of the limited forward development and revision of the theory, its associated methods, and their implications.

4.3.2: The Economic Base Controversy

The controversy centres on both theoretical and methodological issues and stems largely from attempts to reconcile varying definitions of the concept from economic and location theory;

1) one kind of definition takes as its main criterion the fact that the service sector does not produce anything tangible. The distinction is thus based on the character of the product - goods or services. In this case, the service sector is being distinguished from the manufacturing sector;

2) economic base considerations necessitate a definition of basic and service employment in terms of their function in relation to the study area economy. On these criteria, service industries compose that sector of the economy which exists to maintain the population of the area; they do not generate income, and their level is itself determined by the level of the area's economic growth. The basic sector is then defined as the income and growth generating sector (exports), the level of which is dependent on forces external to the study area considered. This then, is a distinction in terms of 'economic function';

3) the term 'service sector' has also been applied to those activities

which are locationally oriented to the local population. The basic sector is then that which is site oriented. This provides a split in terms of locational characteristics (Barras et. al., 1971:161).

Within the Garin model, the economic base mechanism is operative in the processes of both employment generation and allocation. With respect to the above criteria,

> ... the problem of determining levels of employment must be dealt with on the basis of a functional distinction for here, the question is one of employment generation. On the other hand, the problem of distributing employment among zones ... is more appropriately tackled using a distinction based on criteria of location factors.
>
> (Barras et. al., 1971:162)

This distinction is however, not so easily realized for throughout the model, the economic base submodel also dominates the allocation procedure (through the initial basic employment distribution and the population-serving multipliers) and not just the generation of levels of activity for which it was designed (Barras et. al., 1971:162). That is,

> In the model, the variable which generates an activity is also considered as the main factor in that activity's location. Thus, basic employment is both generative and site oriented. Conversely, service industries are both generated by final demand (population), and locationally tied to that final demand; hence, functional and locational criteria are assumed compatible.
>
> (Massey, 1973:8)

This is not considered a theoretically sound proposal by several critics. Clearly, both basic and service activities will locate within reach of their markets, however, once the area has been specified within which access to the market is possible, the location decision within that area may be influenced by market or non-market variables (Barras et. al.,1971:162). The latter will more likely hold where the study area is comparatively small. In other words, an activity classification depends heavily on the nature and proposed level of spatial disaggregation of the study area - the level at which the location decision is operating. Consider, for example, the case of water treatment plants which would likely be functionally defined as service since they are generated by the demands of a local market or intra-urban population. On a national level with large zones, their distribution would correlate highly with the distribution of population, hence they would be classified as locationally service. At the intra-urban level however, their distribution would no longer be population, but site-oriented, hence locationally basic. Recall from a previous section that the most suitable outer spatial limits for the interaction submodels in this case are the Winnipeg census metropolitan area (CMA) boundaries; ie. the activities and areas comprising the centre's economic hinterland are excluded from consideration. It seems clear that the entirely intra-urban nature of the landscape will prove the singly most significant factor governing the managability of the base concept here. Ultimately, every location decision at the intra-urban level concerns absolute site suitability, ie. level of service, zoning requirements, and cost, which according to the conventional definitions, would render all activities locationally characteristic of the basic sector - this is meaningless in distinguishing activities. The problem is one of isolating the primary locational variable of an economic activity and for the service sector, identifying those activities for which this variable is accessibility to the local population (Massey, 1973:3). The operative utility of this criterion is however, complicated by the fact that basic activities are also oriented to population as a source of labour and where applicable, existing scale economies maintained by that labour force.[46] This fact highlights a general weakness of the locational criteria in that,

> ... not only does basic employment influence the location of population and service employment, but these latter are also likely to influence the location of basic employment in return. Hence, the assumed locational independence of basic employment (activities) from other activities seems highly unrealistic. (Batty, 1972:172)

In the case of an intra-urban study area, it might initially seem plausible to make the distinction according to the relevance of such factors as transfer, production, and distribution costs to the location decision but this would, in effect, constitute a simple recapitulation of the product tangibility criteria.[47] That is, the functional export of

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46. The nature of the product, location of raw and/or intermediate materials, and the nature of transfer, production, and distribution costs are other determinants for 'basic' industries producing tangible exports.
47. Such factors are conventionally applied to the primary and secondary industries ie. mining, forestry, fisheries, manufacturing, and construction. The remaining industries then include transportation, wholesale and retail trade, finance, community-business-personal service, and public administration.

intangible commodities such as government administration and banking or other financial services would not be considered. On functional criteria, the use of CMA boundaries would imply that basic activities include those located within those boundaries that market all or some proportion of their total production to points outside those limits. Conversely, the service sector would be comprised of those activities whose market areas are coincident with, or smaller than the census metropolitan area. Yet Winnipeg is the sole urban centre of metropolitan order in the provincial-regional system and serves to some extent, as the administrative, transportation, distribution, and financial node of that system. For example, the city contains the head-offices of several of the larger finance, insurance, and trust companies for the western provinces and the same is true of several large-scale trade enterprises (ie. Hudsons Bay Company). Winnipeg is also the primary distribution centre for prairie grains and the raw materials and intermediate products of extraction activities in northern Manitoba, as well as the major transportation (CN and CP railways, and air transport) and administrative hub for the province and the prairie region.[48] Significant regional forces will likely affect the basic-nonbasic multiplier operating within the centre and thus, it may hold that the use of CMA boundaries proposes too strict a spatial limitation on the nature of the economic base in Winnipeg. In other words, although those boundaries are the

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48. An in-depth analysis of the role of Winnipeg in the economy of western Canada is provided in 'Winnipeg 1874-1974, Progress and Prospects', Manitoba Dept. of Industry and Commerce, edited by T. J. Kuz, 1974.

most suitable for the interaction submodels, 1.) is any considerable growth impetus being generated by basic activities beyond the CMA, and 2.) to what extent, if at all, do external demands for services influence the growth (level) of corresponding service functions within the CMA?

4.3.3: The Role of Winnipeg in the Provincial Economy

Table 4.3 shows the labour force levels for Manitoba and CMA Winnipeg by census standard industrial groups (S.I.C.) for 1971.[49] It is clear that the city plays an unimportant role in all of the primary industries with a corresponding labour force accounting for only 3% of the provincial total. For secondary industries however, Winnipeg accounts for a half or more of the total labour force and for manufacturing the city is dominant; ie. in 1971, it accounted for 78.1% of the total manufacturing labour force (Barber et. al.,1977:28). This is clearly due to the dominance of primary activities - agriculture, mining, and forestry, in non-metropolitan Manitoba. The table also indicates significantly large proportions of provincial totals in several of the 'service' industries in Winnipeg; ie. transportation - 70.8% and 67.9%, business and personal service - 83.6% and 66.8%, and local administration at 68.4%. An alternative investigation into the role of Winnipeg as an

49. It is a common convention in generalized inquiries to consider the basic sector as comprised by all primary activities in addition to manufacturing, construction, and utilities; hence, the service sector consists of transportation, trade, finance, administration, and all community, personal, and business services. These are also the groups utilized in Canadian census publications.

Table 4.3

Labour Force, Manitoba and Metropolitan Winnipeg 1971

	Manitoba	Winnipeg	Winnipeg as % of Manitoba
TOTAL	413,920	243,800	58.9%
Agriculture	47,070	1,205	2.6
Forestry	705	75	10.6
Fishing and Trapping	325	25	7.7
Mining	7,800	560	7.2
Manufacturing	56,945	44,480	78.1
Construction	22,320	12,485	55.9
Transportation	24,785	17,545	70.8
Storage	2,035	1,270	62.4
Communications	8,440	5,630	66.7
Utilities	4,750	3,080	64.8
Trade;	65,215	45,705	70.0
i.) Wholesale	20,070	15,065	75.1
ii.) Retail	45,145	30,640	67.9
Finance, Insurance, Real Estate	15,815	12,895	81.5
Services:	94,520	62,620	66.3
i.) Education	25,405	15,930	62.7
ii.) Health and Welfare	26,785	17,090	63.8
iii.) Recreation	3,395	2,545	75.0
iv.) Business	7,240	6,055	83.6

Table 4.3

	Manitoba	Winnipeg	Winnipeg as % of Manitoba
Services:			
v.) Personal	7,450	4,980	66.8%
vi.) Accomodation	16,745	10,565	63.1
Administration:	34,010	20,000	58.8
i.) Federal Defence	8,265	4,120	49.8
ii.) Federal Other	9,655	5,115	53.0
iii.) Provincial	8,160	5,345	65.5
iv.) Local	7,890	5,395	68.4

Source: Statistics Canada, 1971 Census of Canada, Industries, Vol. III, Pt. 5, Cat. No. 94-752 and 94-756.