TRANSPORTATION AND URBAN DESIGN:
A SYSTEMS APPROACH TO TORONTO'S FUTURE
TRANSPORTATION NETWORK

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PREFACE

This report was prepared in partial fulfillment of requirements for a Master of Arts degree in geography at the University of Toronto.

The report outlines and exemplifies a relatively recent urban planning methodology. The conceptual approach is developed in the first part of the paper. The second part of the report illustrates this approach within the context of a transportation planning situation in Metropolitan Toronto. The methodology represents an attempt to integrate the elements of urban design and behavioural and technical analysis within a single framework in which subjective as well as objective information can be utilized.
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LIST OF MAPS

Map 1 - 1964 Private Mode Transport System and Isochrones to Nearest Subregional Centre . . . 15
Map 2 - Year 2000 "Trends" Private Mode Transport System and Isochrones to Nearest Subregional Centre . . . 16
Map 3 - Year 2000 "Goals" Transport System and Isochrones to Nearest Subregional Centre . . . 17
Map 4 - 1964 Transport System (Private Mode and GO Train) and Isochrones to Regional Core . . . 18
Map 5 - Year 2000 "Trends" Private Mode Transport System and Isochrones to Regional Core . . . 19
Map 6 - Year 2000 "Goals" Transport System and Isochrones to Regional Core . . . 20
Map 7 - Sampling Areas for MTARTS 1964 Trip Data . . . 26

LIST OF DIAGRAMS

Figure 1 - Comparison of Estimated System Performance Measures of 1964 Design, with MTARTS 1964 Trip Data . . . 29
INTRODUCTION

Transportation facilities are everywhere recognized as having an important influence on widely diverse aspects of urban life, yet the provision of these facilities often shows rather little evidence of such recognition. In this paper, some possibilities of placing the study of transportation in a more comprehensive framework of urban planning are explored.

Some recent planning techniques are considered that use a "systems" approach to the abstracted elements of an interaction problem; it is suggested that such approaches could be modified to enable a clearer assessment of the subjective aspects of the planning process.

The first part of the paper develops this conceptual approach. In the second part, these ideas are applied within the context of the provision of an integrated transportation of the Toronto region for the year 2000. Transportation facilities are included in a regional design constructed from subjective principles; an attempt is then made to test this design objectively, using the abstraction procedure.
PART I

SOME OBSERVATIONS ON A "SYSTEMS" APPROACH

Any successful blending of transportation with the entire urban fabric demands a three-fold perspective: an appreciation of the social requirements of movement, a recognition of the technological potentialities for meeting these demands, and the ability to create a design to resolve ends and means in a particular balance. Expressed in this way - the synthesis, within the limits of a range of technological resources, of a design solution to a set of specifications - this type of problem has been given a rigorous basis by Alexander (1964), within the terms of a "systems" approach.

A system is defined by Hall and Fagin (1956) as "a set of objects together with relationships between the objects and between their attributes". The "objects" comprising a system are grouped (either by a similarity of "attributes", or by interactional "relationships") into subsystems, which are themselves functionally related to form the whole. A system thus has a defined structure. Also, most systems are described as "open": they maintain an internal structure and an organization of energy flows, while at the same time exchanging energy with their environment (the much wider set of objects with which a system has external relationships). An open system is thus a recognizable organization of specific environmental energies.

A system must be defined operationally for the purpose in hand, but the implication is always that the unity is inherent in the situation itself. The view taken here is that relationships between objects, and the structuring of these relationships into subsets, may conveniently be seen as a consequence of the structure of some identifiable mechanism of control common to these relationships: as the Earth "system" is dependent on the control of the sun's energy-flow and gravitational field. It is the existence of control that imparts the
notion of function to the sum of relationships within a system.

But system control structure and system physical structure are not visualized as "cause and effect"; while it may be convenient to regard the essential nature of control to be preordained in any particular case, the actual expression of control in a system is clearly related to the channels physically available for its deployment - that is, to the physical components of system structure. System control structure and system physical structure are thus seen as interdependent, but this interdependence makes sense only in a dynamic framework, in which form and control change and grow with a constant mutual interchange of small influences (a process known as "feedback"), in a physical situation that is expanding to produce a coherent system. It is perhaps a feature of all open systems that they exhibit growth, and that this is accompanied by periodic mutual re-structurings of form and control.¹

If the urban transportation problem can be formulated in such terms, then the implication is that a dynamic organizational situation - such as the relationship of transportation to urban growth - cannot be studied by a simple "trends extended" type of analysis. A specifically systems approach, however, offers a logical framework for studying just those relationships of structure and control through which planning is effective.

Building from these concepts of organizational relationships, the designing of a physical system (which may be anything from a single object to town) has been described by Alexander as the attempt to create a structure which minimizes the "misfit" with its environment; he suggests that "good fit" is best achieved

¹The inevitability of restructuring, or "non-proportional change", with growth has been demonstrated for purely physical systems by Boulding (1953), and this concept could probably be extended to non-physical situations.
by small-scale modifications in the forms designed to meet more or less independent subsets of "misfit variables" - these forms being hierarchically integrated into subsystems compounding to give the whole. The synthesis of total form is thus made consequent upon the breaking-down of its requirements into a goals structure of components and subsystems calculated to minimize interdependence.

Essentially the same structure has been modelled by Ackoff (1967) as that desirable for system control and information-handling. Alexander's algorithm may in fact be thought of as a technique for efficiently organizing system control at the same time as system form.

But in order to be able to deal with possible system restructurings, it is desirable to express Alexander's "misfit variables" in terms as abstracted as possible from their present forms of solution. Interaction and transportation requirements may be fairly easily treated in this way, since in many cases they are not demanded for their own sake, but are often already thought of in abstract misfit-variable terms - time, convenience, cost, comfort, privacy, etc.. These attributes can be regarded as the elements of a language in which the physical-movement characteristics of a subsystem may be expressed; new components can be stated simply as hypothetical attribute sets, and substitution between attributes (eg. between physical movement and physical location) is possible. Some interesting work has been done on this basis.

Reference may be made here to Lancaster's (1966) reformulation of consumer theory in terms of abstracted demands; he expresses the requirements of a commodity as a set of attributes (or misfit variables) each having a range of acceptable values, which when taken together describe the array of all acceptable attribute sets.

See, for instance, Quandt and Baumol's (1966) treatment of modal split, Boulaudon's (1967) isolation of "gaps" in the provision of attribute sets, and Morlok and Bruck's (1967) abstracted comparisons of transportation network potentialities.
Once interaction requirements are abstracted, movement problems can be considered simultaneously with other interdependent and similarly abstracted problems, and thus a comprehensive set of goals structured into a configuration of sub-systems and systems suitable for control. The necessity for treating all physical movement problems arbitrarily as a single and largely isolated phenomenon — "transportation" — is therefore avoided.

Alexander's formulation of the design problem has since been applied to urban planning, where it promises to stimulate the emergence of a more integrated and dynamic planning methodology. It is the contention of this paper, however, that such applications could be brought more into line with existing concepts of both systems analysis and planning theory. An attempt will be made to isolate what are seen as inconsistencies in the approaches to date, and some alternative suggestions will be put forward.

Broadly speaking, Alexander's techniques have been applied in two ways: directly in the unitary planning of a defined system; and, in an adapted form, in the incremental planning over time of an unbounded system. These two may be viewed as different aspects of the same thing: a unitary design really representing the sum of the decisions of a visualized growth process. In both cases, the synthesis of total form is made dependent upon an evaluation of the interdependencies between the smallest elements (goals, or misfit variables) considered.

This type of approach would seem to be lacking in a number of respects. Firstly, the mutual relationship between system control structure and system physical form is but partially accounted for. It will be recognized that the Alexander technique — of directly compounding forms designed to meet the parts of a logical

1eg. Ellis, Wright and Aasen's (1968) planning of a small settlement. Alexander himself included a similar application.

2This kind of temporal process has been advocated in transportation planning by Manheim (1969), and further work is being done in the field of administrative co-ordination.
break-down of system relationships - is something of a simplification, since these newly designed higher forms are likely to alter the pattern of the relationships they resolve. Not only growth, but initial design has to be a complex process of mutual adjustment between changing part and changing whole, such that neither forms nor relationships can be regarded as fixed.

At the same time, it is rather doubtful to what extent an objective system structure can be constructed, and it is objectivity which is the stated aim of the analytic technique. In order to derive a goals structure having some hope of physical solution, it is not unreasonable to assume that the planner must define the elemental interdependencies of the problem with some preconception of what these interdependencies are, and of the potentialities for their physical expression. The approach provides no very clear distinction between objectivity and the predilections of the individual.

Alexander's technique is thus not independent of its physical means of solution, nor of the inevitable knowns and assumptions with which every design problem is attacked. If the terms in which a problem is expressed also contain the shape of their own solutions, then ideally what is required is the synthesis of the theories underlying any particular presentation of the problem. Alexander's technique may be a substitute for such theoretical synthesis, but does not develop the implications of subjective preconceptions, nor encourage their evaluation. It is therefore suggested that in urban planning, Alexander's ideas of system control structure might be used as a guide in the setting up of an initial and frankly subjective system design, in which all preconceptions of interrelationship structures, all favoured technological and social system components, and all perceived environmental potentialities are fused. Once a system control structure has been tentatively defined in this way, it can then be objectively analyzed and evaluated through its performance in terms of selected abstract misfit variables.
Such an approach can only be a characterization, since in practice it is probably impossible to separate analysis and conceptual synthesis in any rigorous manner. Also the relationship is uncertain between any long-term plan and the actual incremental process of its implementation. A subjective system design, once tested may be used as a long-term plan, but it must be flexible enough to survive the modification of both goals and designs as situations change, and as the potentialities and limitations of the design become revealed. Certainly, any initial system structuring would serve several useful purposes. It would give some constancy of direction to the incremental decisions of growth. It would indicate the system potential - the likely future characteristics of the system - giving invaluable information to the organizers of other sectors of activity. And it would allow full scope for the reappearance of a genuine art of large-scale urban design.

It is claimed that the provision of transportation facilities would be particularly amenable to this kind of approach. Physical interaction channels may be moulded perhaps quite readily with other components into large-scale tiers of interlocking urban designs, that together form some coherent urban framework perceivable to the multitude of independently acting individuals and urban groups. It may be observed that the organizational powers of past, often accidental, transportation channels show remarkable resilience.

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\(^1\) Vickers (1959) offers an almost technical argument for a "directed" planning process.
PART II

AN ILLUSTRATION: A DESIGN FOR THE TORONTO REGION FOR THE YEAR 2000

The elements of a planning process that attempts to handle transportation simultaneously with the entire range of urban activities have been outlined. The scale of this paper obviously prohibits a fully developed example of such an approach, but some of its major points may be amplified by following the method through in the synthesis of an integrated urban design for the Toronto region for the year 2000, and by the testing of this design by means of abstracted measures of system performance.

A METROPOLITAN SYSTEM AND DESIGN

A general problem is considered: that of how the future provision of transportation facilities may meet efficiently the diverse interaction requirements of Toronto, while at the same time playing a part to encourage the development of an urban setting that is to be both exciting and pleasing to experience. A subjective system design will be set up that purports to embrace, in a way fitting to the Toronto environment, all those relationships thought to be relevant to the functioning of urban transportation. The enormity of the task will be reduced somewhat by considering only the transportation requirements of residents in their capacity as householders (i.e. not as workers, entrepreneurs, or vacationers, etc.), and these requirements only at the neighbourhood or city scale of movement.

As a first step, a system structure of goals will be formulated, derived from personal preconceptions concerning the nature of spatial interactions between residents and each other, and between residents and services, in the urban setting. Preconceptions considered relevant here are: theory concerning the activities of households;\(^1\) theories of service locations;\(^2\) social theories of group

\(^1\)For example, Chapin's (1968) work on the periodicities in the generation of different types of household trip.

\(^2\)Economic theories of the market, locational economies of scale, Central Place Theory, etc..
activity;¹ ideas on the individual's perception of his environment; landscape
design concepts, and so on. A theoretical synthesis will not be attempted, but
a superficial consideration of this body of concepts is able to suggest a small
set of generalized goals which can be synthesized into a system structure.

These goals are completely subjective; they emphasize the efficiency, the
cohesion, and the flexibility of urban relationships, and the individual's per-
ception of these relationships. They may be described as follows:

i) Urban planning should be tied to the level of perception of the in-
dividual and the local group; environmental settings - residential areas, district
communities, and the metropolitan area as a whole should be made more compre-
hensible by giving them a focus.

ii) The locational responses of different types of retailing and service
establishments to the spatial and temporal frequencies of their customers should
be encouraged to coincide and so form coherent and integrated elements of the
environment on suitable focal levels.

iii) Residential access should foster the discrete nature of local areas,
while at the same time allowing easy contact with service locations.

iv) Local areas should have ready access to the wider services offered only
at the metropolitan level; there should thus be a metropolitan system that is
cohesive, but one which is also responsive to change.

Alexander's concept of system structure as an hierarchical arrangement of
semi-independent subsystem relationship may be used to integrate these goals to
form a single prescriptive goals structure. How rigorously this structuring can
be done is unclear. In this illustration, the principal features of a conceptual
system may simply be sketched in the broad terms of subsystem relationships -

¹In this context, Greer (1960) has made an interesting study of the sources of
interdependence, the channels of communication, and the structurings of
behaviour, amongst local suburban groups.
i) local residential circulation and activities are conceived in an architectural context, and referred to a house-and-neighbourhood-subsystem not directly considered here;

ii) intermediate-level service needs (e.g. most shopping and community requirements) are visualized as binding local elements into "community" scale subsystems;

iii) highest-level service needs and establishments (e.g. those retailing, commercial, social, and cultural activities requiring the economies of scale of a metropolis), the cohesion and interactions of community subsystems, and questions of overall urban form, are treated in the context of a single "Toronto region system."

It is to be noticed that a goals structure has been erected in which the transportation problem is split up into various elements that are considered jointly with other social, economic and aesthetic problems of a non-transportation nature. To be effective, each element (i.e. component or subsystem) must be capable of being expressed as some actual or potential entity in social, physical, or environmental design terms. Compatibility with the realities of control structure - group, political or managerial - is obviously basic.¹

But the conceptual structuring of goals (expressed as relationships) is to some degree matched by preconceptions as to their physical fulfillment. In this present illustration, the environment of the Toronto region - its physical configuration, existing physical stock, and spatial trends - defines a problem context whose design potentialities and limitations are already the object of considerable personal preconceptions. This is inevitable and also desirable if an urban design is to be drawn up that is unified in concept and an imaginative development of the existing urban situation.

¹Component control structures must be considered as an aspect of initial preconceptions, since there is always a cost associated with replacing an existing control structure with another.
Parallel to these environmental assessments are other preconceptions as to the possible social and technological media (as component forms and control structures) for effecting any particular relationship. This is not to say that a goals structure or a physical design should not stimulate its own demands, but merely that known social and technological potentialities may suggest certain immediate possibilities. An acquaintance with some of the recent developments in transportation technology was important in this illustration— in particular, with the possibilities of an arterial guideway network (NET) capable of distributing at high speed a heavy flow of private vehicles to all parts of a metropolitan area, a very high speed "fast transit link (FTL) to serve outlying urban satellites, and a pedestrian movement system (MAC) to ease circulation in major activity centres.¹

A subjective system design may now be created using the elements mentioned above— the goals structure, and a fragmentary collection of environmental design concepts and hypothetical system components. Again, Alexander's concepts— in this instance, that of the need for isomorphism between the goals structure and its designed physical expression— provide a useful guide.

A system design— a "Goals Plan" for the Toronto region for the year 2000— has been drawn up, and may be found illustrated in Maps 4 and 7, later in the text. The design is simply an example, but since it is to be used below to demonstrate the testing procedure, it will be briefly described.

The design represents what is conceived as a subsystem defining the major spatial relationships of a Toronto metropolitan system (local and interregional

¹These hypothetical modes are taken from the research into possible future urban transportation carried out by the Stanford Research Institute (1968); they have much in common with the recommendations of a number of other workers— eg. Wolf (1967), Bouladon (op. cit.), Canty (1968).
interactions being excluded), and comprises a set of subregional activity centres (visualized as combined service and community foci),¹ a regional core (the focus of higher-level activities), and the links and entry-points of an integrated transportation network of known performance characteristics. Essentially, the design is a tentative structuring of system control: the "centres" representing suggested concentrations of organized development, and the "transportation network" a set of recommendations concerning the controlled investment and operation of transportation facilities.

The centres have been selected as a suitable extension of the structural trends of present-day Toronto.² Within the transportation network, the chief arterial function is provided by a NET system serving the regional core and all subregional centres; the system utilizes existing arterial roads and expressways, and as far as possible avoids the disruption of local neighbourhood areas. Contacts between the core and the more distant centres along the lakeshore are strengthened by means of a very frequent FTL service - an expansion of the concept behind the GO Train commuter service already in operation. The NET and FTL systems between them should reduce the pressure on other facilities, so that existing roads are better able to serve purely local, and the expressways inter-regional, traffic.

An expanded core area receives special attention: only authorized traffic (eg. that of local residents and services) and taxis are allowed on the streets, while exit points of the NET and FTL systems abut directly onto parking facilities

¹Such community centres have been advocated by Carver (1962).

²The Centres have been borrowed from the "Goals Plan I" drawn up by the Community Planning Branch of the Ontario Department of Municipal Affairs. See Metropolitan Toronto and Region Transportation Study (1967), appendix, Map 7.
and onto the arms of an express subway system leading to the heart of the core. In this heart, a MAC system eases circulation by carrying pedestrians at a maximum speed of 15 mph. for distances of up to half a mile or more.

TESTING THE DESIGN

This system design may be analytically tested by means of abstracted performance measures, which can provide a basis for possible modifications of the design, enabling it to be brought closer towards achieving its goals. Such testing is similar to Alexander's misfit-variable analysis, except that it occurs after, rather than during, a subjective design process.

Where system goals can be expressed in manageable misfit-variable terms, the design can be assessed directly with respect to its goals. But rather than attempting to evolve misfit "acceptability margins" and the like, it is often easier to approach goals from a relative standpoint: i.e. simply to make choices of the direction and substitution of goals, by choosing between the performances of alternative system designs. This is the tactic adopted here; the performance of the Goals Plan will be compared with that of two other designs - with an alternative design for the Toronto region for the year 2000, and with the present regional structure (acting as a yardstick). The former - the "Trends Plan" - makes use of the transportation network\(^1\) and "subregional centres" forecast by the Ontario Community Planning Branch as likely features of the region in 2000;\(^2\) the latter borrows from the same source the equivalent features of the Toronto of 1964.\(^3\) The complexities of modal competition are avoided by considering only private-mode facilities (i.e. roads and expressways)\(^4\) in the

\(^1\)Based on the Recommended Transportation Plan of the Metropolitan Toronto Planning Board (1964).
\(^2\)MTARTS (op. cit.), appendix, Map 3.
\(^3\)MTARTS (ibid.), appendix, Map 2.
\(^4\)These constituted the greater part of the Community Planning Branch "Trends Plan".
Trends and 1964 systems.

In comparing the efficiency with which these three system designs (1964, Trends, and Goals) meet the goals set up for the Goals design, an abstracted misfit variable suitable for analysis has been chosen as the time required for certain types of trips within each system.¹ "Trip time" could conceivably be used to measure system performance in many ways. The particular measures illustrated here are selected to focus on an aspect of the complementary nature of transportation facilities and other structural features. They are the travel time of a complete trip from a residence to the services associated with the nearest subregional centre, and the equivalent travel time required for a trip to the metropolitan core. Isochrones of these two measures, superimposed on representations of the system designs to which they refer, are shown in Maps 1 to 6; subregional times are shown for Metropolitan Toronto only, but times to the regional core for the whole of the estimated urban region (minus the rival Hamilton focus) of the year 2000. Travel times were calculated on the basis of average values for small tracts of land;² the exact system performance characteristics used in these calculations are set out in the Appendix.

Armed with these attribute maps, some general appraisal of the comparative goals performance of the alternative designs is now possible. The necessity of defining the goals in terms of the misfit variable is avoided by approaching the problem from the other way: the performance measures for each design are simply

¹ Ackoff (1965) offers some support for this independent concern with "time", in his research into the perceived relative importance of transportation attributes.

² The tracts were consolidated from the traffic zones used by MTARTS (1965), based in term on the tracts used by the Census. The set of tracts was designed as the minimum number necessary to distinguish reasonably the variations in timesurface between the three systems.
assessed as to their implications for the spirit of the goals - the efficiency, cohesion, flexibility, and social import of urban residential interactions.

Design performance in terms of the efficiency of movement expresses itself through such measures as the range of service locations accessible from any residential location,¹ the variation (between residential areas) of this range, and (the reverse of these measures) the locational economies of scale and the market areas of service locations. System cohesion may be regarded as an aspect of system efficiency, and may be assessed by overall measures of accessibility, and by the extent to which all parts of the system are integrated with each other.² The likely quality of fit between a system (viewed as a subsystem) and other urban subsystems of different type and level (eg. in this example, an "industrial activity" subsystem, and "housing design" subsystems) is also clearly a facet of system efficiency. Trip time is an important aspect of all these system measures.

System flexibility, and the impacts of the designs on the perceptions of residents, cannot really be assessed from trip time measures. However, some comparison of system performance in these areas is possible by a simple estimation of certain physical properties of the designs - the ease of network expansion, the likely extent of physical disruption, the privacy of local areas, etc..

Although pure urban design considerations were a major influence in the making of the Goals Plan - for instance, in the partly symbolic nature of the community centres, and in the treatment of the core - these would depend for much of their impact on architectural and landscape (and of course chance) qualities falling outside the range of this illustration.

¹ Dodson (1969) has used this criterion in the evaluation of alternative transportation systems.

² The study of large-scale urban relationships, and the possible formulation of desirable structural qualities, would seem a very interesting aspect of "systems" study - and one in which some pioneering work has been done by Miller (1965).
The attribute maps of the 1964, Trends, and Goals systems may be examined in the above terms. Without trying to read too much into the limited source of information, notable differences between the performances of the three systems are indicated.

The Trends system shows an increase in subregional accessibility - and therefore system efficiency - as compared with the 1964 system, and develops some new subregional centres to match the expected urban growth. This increased efficiency is considerably more marked in the Goals system; here, a reach of almost uniform subregional accessibility (reflecting the denser network of arteries, and the more even spread of centres) extends over most of the central metropolitan block - in significant contrast to the more cellular patterns of the other two systems. Such a characteristic would tend to offer greater locational equality of opportunity, which is also effective as a greater freedom of residential location; while not strictly demonstrable, it can likewise be inferred from the maps that the Goals system offers, for any one residential location, a greater choice of accessible centres. Spatial impartiality may further be cited as being conducive to greater flexibility in future physical change.\(^1\)

The Trends Plan best serves in its capacity of increasing regional accessibility to the core. The subregional advantages of the Goals system are accompanied by a regional performance similar to that of the Trends system - except that greater system cohesion is evident in the greatly increased accessibility (both absolute and relative) enjoyed by the distant lakeshore centres, which might be expected to play a fuller role in the life of the metropolis. At the same time, the noticeable high-accessibility pockets would tend to enhance the individuality of the various lakeshore foci. For comparison, the GO Train

\(^1\)Lynch (1958) has considered this question of the role of transportation facilities in the planning of physical adaptability.
service is shown, separately, in the 1964 map; this service appears not to be competitive in terms of time, but may well be in terms of other attributes (eg. convenience).

Another feature of the Goals Plan is the improvement of the local and the internal accessibility of the core, which would increase the likelihood of strong regional cohesion, particularly through social focality. In fact the Goals design is in general a tighter and a more comprehensible urban structure. With regard to the perception of the more local environment, it is probable that the guideways (envisaged as quite small features) of the Goals system would be less disruptive and barrier-like than the webbed expressways of the Trends Plan - though much would depend on the effectiveness of the integration of the NET guideways into street environments.

From the performance measures presented here, it is held that the Goals Plan best meets the system goals as set up. As has been stated above, this evaluation is based simply on an assessment of the general implications - for loosely described goals - one of the performance measures, with choices made between directions and substitutions of the qualities offered by alternative system designs. Problems of the substitution of attributes would have been more in evidence had more than one type of performance measure been taken. In more complex situations, the special value of maps in displaying spatial relations would have to be supported by the further analyses possible with the use of graphs and matrices.

The performance measures thus offer a basis on which a preferred design may be selected, and also on which the chosen design may be refined. In the Goals system, the location of centres in the eastern central area is shown to be rather poor, Brampton (to the N.W.) needs to be better linked to the rest of the region, and so on. Certain failings in the way the designs were formulated also are revealed by the analysis of misfits. The persistence in all three systems
of a zone of poor subregional accessibility in the inner central area is particu-
larly interesting: it is likely that the disequilibrium lies in the choice of
centres rather than in some inherent feature of the Toronto structure, and that
it can be traced to an insensitivity to the differences between the institutions
of the suburbs and the types of community foci and service establishments (those,
presumably, associated with immigrant communities and aging retailing "ribbons")
prevalent in the inner areas. In this instance, social groups, and variations
in service establishments, are indicated to be features that should perhaps have
been included in the initial formulation of goals and system components.

The last observation raises a point that will be considered more directly.
It would be possible to go on to test the system designs through many more per-
formance measures, but such "testing" deals only with a system's internal con-
sistency with its goals structure. In this illustration the goals have been
given, but are assumed normally to arise from an alliance of social research and
political process. But it has yet to be shown how the "goal performance" of the
resulting system design actually relates to the behaviour of its users.

In this last section, therefore, the estimated measures of system perfor-
ance that have been used above, are tested against equivalent observed measures
of the supposed human response to these potentialities. Three things are being
tested:

i) - the validity of the theoretical constructs underlying the structuring
of system goals;

ii) - the appropriateness of the abstraction procedure for expressing
system attributes;

iii) - the relationship of system potential to actual usage.

These three factors may be expected to vary independently, but it is to be hoped
that some insight may be gained into the regularities of these variations.
A comparison is attempted between the estimated travel time potential of the 1964 system, and the data collected by MTARTS (1965) on a sample of weekday trips made within the region in 1964. From the MTARTS data were extracted the travel times of all those trips made from home¹ to any of the 1964 centres for the purpose of "shopping" - the criterion of shopping being used because the 1964 centres probably constitute (at worst) a sample of large retailing centres.

In order to match sets of observed and estimated travel times that could be considered comparable, subsets were identified according to the dictates of the Central Place concepts implicit in the presentation of the 1964 system design.² Trip times were distinguished as to mode (either public or private) and destination, and grouped by areas of origin defined by the 1964 system measures as the areas lying nearest in time to a particular centre or pair of centres.³ The central portions of these origination areas (the portions within which the included centre(s) also served as the nearest local centre(s) - or in the case of the metropolitan core, as the nearest subregional centre), together with the trips originating in these portions, were omitted: so as to avoid an undue bias toward observed trips in the shorter range.

It was hypothesized that the frequency distributions of observed private-mode trip times should, when grouped by destination and by area of origin, be

¹Trips duplicated by the different members of a single household were omitted.

²Specifically, the concepts adopted are:
   i) - all residents require the services associated with subregional centres, and with a metropolitan core;
   ii) - all residents make trips with the same regularity;
   iii) - all residents patronise the centre nearest in time to their home; and therefore,
   iv) - centres draw on a market determined completely by the spatial distribution of residential population, and bounded by indifference-lines with neighbouring centres at equal time-distance.

³See Map 7.
MAP 7

© 1964 centres

- Origination areas for MTARTS trip data.

2 Origination area number

Excluded central portions of area.
of the same form as the equivalent frequency distributions of the tract values of travel times estimated for the 1964 private-mode system, when the tracts are weighted by their populations.\(^1\) This hypothesis would not hold if the estimations of system performance were unreasonable, or if the centres did not serve as subregional foci within the areas delimited (i.e., if the Central Place assumptions are invalid, or the centres and their areas poorly chosen). Also, the predictive accuracy of the hypothesis would vary with the intensity of the use made of system potential.

The comparisons were made, but in view of the shortcomings of the analysis,\(^2\) only some general consistency in the way the system performance measures were matched by the data of observed activity could be expected. This consistency does appear to hold for two groups of subsets—trips to the subregional centres within their areas of origin, and trips from the outer areas to the metropolitan core—which show distinctive distributions. Comparisons for individual subsets\(^3\) tend to be poor; the match is shown perhaps to its best advantage in the summed frequency distributions for the two groups of subsets. These two aggregated pairs

\(^1\)Tract populations were interpolated from the 1961 and 1966 Censuses, and the tracts assigned weights of between one and six, representing multiples of 5,000 population.

\(^2\)These include certain known biases in the data, as well as more basic theoretical failings.

The recorded trip times were heavily biased towards values of 5, 10, 15, 20, 30, 45, and 60 minutes. They were accordingly plotted at a cell interval of 5 minutes.

The use of average values by tracts in the estimation of system travel times meant that subset samples were very small, and each distribution bunched towards its mode. The same 5 minute cell intervals were used, but the extremities of the frequency distributions are unreliable.

More importantly, an assumption has been made that trips meeting certain criteria constitute samples of previously designated theoretical subsets. The analysis as it stands is too dependent on the arbitrary choice of centres and area boundaries, which should be more directly related to empirical observations of trip flows. A better approach might have been to analyze the system measures for a sample of specific individual trips, or for the outflow of trips from each tract.

\(^3\)Only trip samples of greater than 25 were considered.
of distributions are illustrated in Figure I, but it was not thought that the
fit merited other than a purely visual analysis.

Frequency distributions of observed trips to the nearest subregional centre(s) show a concentration in the lower time range, with an upper limit of 15 to 20 minutes. The fact that very few trips were recorded to subregional centres outside the area of origin tends to support the notion of distinct "subregional areas" (at least at the spatial scale considered) - although there is no check on the
distribution of trip origins within these areas, or on the competition between
other centres in each area. Trips within the core's "subregional area" are anomalous - as might be expected from the congestion, modal competition, and social and physical characteristics peculiar to the area, and from the dual "subregional" and "regional" nature of its focus. Trips from the outer areas to the core have a range of from 15 to 60 minutes, clustering about the 30 minute mark.

The equivalent system performance measures do react with some perceptible consistency to these rather distinctive trip subsets. On these grounds, it may be claimed that it was not disproven that residential interaction varies significantly by areal and modal subsets in ways consistent with the concepts used in the structuring of the system designed.

With the comparison of "observed" and "expected" patterns of activity within a system, the realm of behavioural analysis has been entered. Consideration, for instance, of the variation in Figure I in the match between the observed and expected trip frequencies possibly due to variations in intensity of use of

1 Calculated for areas 1, 2 and 3; area 4 has no included centres.
2 Areas 1, 2, 3 and 4 were conformable, but area 3 alone afforded a reasonable sample; area 1 (a trip sample of 13) was however also included in the summed distribution.
3 The travel behaviour of individuals, that is, may be examined in the context of groups established by a common choice of residential location and type, choice of mode, etc.
FIGURE 1
Comparison of Estimated System Performance Measures of 1964 Design, with MTARTS 1964 Trip Data

- Observed frequency distribution of trip times to nearest subregional centre (summed for areas 1, 2, and 3).
- Estimated frequency distribution of weighted tract times to nearest subregional centre (summed for areas 1, 2, and 3).
- Observed frequency distribution of trip times to regional core (summed for areas 1 and 3).
- Estimated frequency distribution of weighted tract times to regional core (summed for areas 1 and 3).
system potential, immediately calls to attention a theoretical relationship not mentioned until now – that between the "level" of trip purpose (here, "subregional" as opposed to "regional") and the frequency with which the trip is made. Similarly hinted at are the complexes of spatial competition.

Clearly, if this illustration were to be followed through, the simplistic theoretical constructs would soon become replaced, in the balancing process of observation against assumption. But given the partial vindication of the abstraction procedure and of the concepts supporting the system design, it would be logical to go on to derive a more precise probabilistic goal structure and a further refinement of design concepts, and so test the Trends and Goals designs more rigorously.\(^1\) It should however be noted that while there is some evidence to suppose that the time people are prepared to spend in travelling for a given purpose remains fairly constant over a short period\(^2\), any projection of existing behaviour to be incorporated into a goals structure for future subsystems must take into account something of the system/subsystem interdependencies involved: the expected changes in other related systems, possible "latent" demands that may respond to new potentials, the possibility of the rise of entirely new social (and therefore behavioural) groups, etc.

Such an extension was not attempted for the example presented here\(^3\), but there appears no reason why a fuller exploration – using a similar abstraction of variables, and again integrating concepts of social science and design – could not do so.

\(^1\) Diamant (1967) has done this in a simple form – as has Bouladon (op. cit.) – constructing curves representing "acceptable" and "unacceptable" zones in time/distance functions.

\(^2\) The 1964 MTARTS trip data affords a frequency distribution of travel times for purposes of "shopping, school, and personal business" that is very similar to the equivalent distribution derives from a survey made in 1956, despite the extensive urban changes in the intervening period. See MTARTS (1965), page 22.

\(^3\) The results would in fact be largely dependent on estimations of the locational distribution of the considerable population expansion expected for Toronto, and of the likely redevelopment of areas of existing urban stock.
CONCLUSION

The study of transportation is a fascinating one, holding a key place in urban research. But transportation also provides the planner with one of his most powerful tools, and between these two realms is something of a dualism. Urban design - the creative manipulation of the physical and emotive environment - is to some extent independent of behavioural and technical analysis - that is, of the logical study of interactions, and of the means of catering for them. Yet both analysis and design are fundamental to all planning.

This paper represents no more than a first attempt to resolve these two elements within a single framework. A general approach has been suggested in which an initial subjective design is erected, and then amplified and tested analytically. In the background is the notion that relationships are best studied through their interdependencies, and that organization (and therefore planning) should be couched in these terms.

The approach has been illustrated in the context of transportation planning for Toronto. The illustration was necessarily only a partial and a cursory one, and leaves several questions unanswered - the relationships between plans and actions and between "objective" testing and "subjective" synthesis are by no means clear-cut, especially in their temporal aspects. But these qualifications should not be allowed to cloud the points that are made. Firstly, that artistic values (in this case, of urban design) and scientific analysis are not incompatible, and can and should be consciously integrated. Secondly, it is hoped that the illustration has revealed something of the valuable flexibility that may be attained in the testing of designs by means of abstracted variables of analysis.
APPENDIX

THE CALCULATION OF TRAVEL TIMES FOR THE "1964", "TRENDS", AND "GOALS" SYSTEM DESIGNS

INDIVIDUAL MODAL PERFORMANCE CHARACTERISTICS

Private mode - roads

Performance was expressed as average speeds of off-peak travel on different types of road. Such "averages" no doubt obscure significant spatial variation, but arbitrary values were chosen from those speeds possible at the present time under favourable road conditions - ie.:

- local feeder roads 20 mph.
- arterial roads 30 mph.
- expressways 60 mph.

The same values were used for all three systems, on the assumption that future road improvements would keep pace with the increase in traffic.

GO Train (1964 only)

The service has an effective speed of about 35 mph.; travel times, however, were taken directly from the April 1969 time-table.

Hypothetical Modes (Goals system)

All performance characteristics were adapted from the research of the Stanford Research Institute (1968), who have developed fairly specific performance requirements for a set of feasible future modes.

NET Similar to a number of contemporary prototypes (eg. the Alden Starrcar and M.I.T. Commucar electric systems), it is thought to be capable of development within 15 years, and was estimated to be an economic proposition in a system simulated for the Minneapolis metropolitan region.

The network is able to act as both a 'public' and a 'private' mode system: cars may be hired at any entry-point for a single ride, but the system is chiefly designed for private dual-mode cars that can transfer directly onto normal roads for local circulation.
An average speed of 60 mph. was adopted, and a link and entry-point spacing of the order of \(\frac{1}{3}\) to 3 miles. Use of the system was restricted to trips of 2\(\frac{1}{2}\) miles or longer - shorter trips not being thought to justify the inconvenience of widely spaced entry- and exit-points.

**FTL** High-speed tracked systems (eg. the tracked hovercraft) could be operational within a decade.

Maximum speed may be plotted against station spacing to give curves of effective trip speed. An effective speed of 120 mph. was thought reasonable for longer distance intra-metropolitan travel, and would require station spacings of not less than 8 miles, given a maximum speed set at a feasible 160 mph.; these dimensions fit the physical layout of the Toronto region rather well.

For an individual trip, very short "headways" (the intervals between trains" are required in order to maintain the speed advantages; 90 seconds was chosen.

**Subway** An express service at 40 mph. was taken to serve NET and FTL terminals and one or two central points within the core, at a headway of 2 minutes. This headway was halved for local services at a speed of 20 mph. (Toronto's existing system operates at an effective speed of 20 mph., with a headway of 2 minutes.)

**THE CALCULATION OF COMPLETE TRIP TIME**

Travel times were calculated to represent complete trips, and therefore included estimations of the excess time spent on waiting, transferring between modes, parking, etc..

Waiting times for public modes were set at one half of vehicle headway. All excess times at trip origin (ie. the home), and vehicle transfer time from roads to NET system, were ignored.

Excess time at destination was for private mode trips set at 3 minutes (6 minutes, for the core and the close-by Yonge/St. Clair centre), for parking.\(^1\)

\(^1\)These were the figures used by MTARTS (1965) in their simulation of trip times.
In the Goals system, this was reduced to 2 minutes at NET and FTL terminals, to represent the integration of parking facilities.

For the core area in the Goals system: local taxi service was set at $\frac{1}{4}$ minute call time and $\frac{1}{2}$ minute destination excess time; walking time from NET and FTL terminals to the subway at 1 minute, and subway destination excess time also at 1 minute; walking time from the NET and FTL terminal, with a destination trip on the MAC system ($\frac{1}{4}$ mile at 10 mph.), at a standard total of $3\frac{1}{2}$ minutes.

For the GO Train service, patrons were assumed to drive by car to the nearest station (to maximize convenience) and to have to wait for a standard 5 minutes. A further 5 minutes was allowed at the core for walking.

Total excess times could then be assigned for each destination and combination of modes, per system design.
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