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Barriers to Communication: Reflections on Methodological Approaches

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1. Introduction

Analyses of interaction patterns and communication processes over geographical space have played a pioneering role in the spatial sciences. Although a wide variety of contexts have been examined, in this paper our attention will be restricted to those situations in which patterns of interaction or communication are affected by the existence of various types of barriers. For analytical purposes, barriers to communication can be regarded as those obstacles in space or time that in some way impede the natural flow pattern. They are usually discontinuous (i.e. nonlinear) in character, and should not be confused with the more traditional frictions of distance which are mostly continuous in character.

To study patterns of communication in space, various macrolevel approaches based on gravity and entropy-maximizing formulations were developed in the sixties, and were generally restricted to a set of interacting zones or regions. Because of their apparent lack of behavioural content, subsequent interest developed in the interactive behaviour of individual decision agents such as persons, households or firms. This work resulted in the development of various micro-based approaches which focus on individual choice behaviour. The disaggregate mode of modelling is often regarded as being inherently more behavioural than the aggregate one. This point of view, however, has to be questioned for several reasons. First of all, it is possible to develop aggregate choice and interaction models which are derived from a behavioural representation of choice making at the micro level. Second, disaggregate choice models can be as deficient in their behavioural foundations as any aggregate choice model (see Halperin and Gale 1984, p.9). Thus, it is not reasonable to regard disaggregate choice models as being more behaviourally valid than their aggregate counterparts. The most important distinction between these two modes of modelling lies in the level of data analysis. In contrast to aggregate models, disaggregate ones need smaller data sets for estimation and make more efficient use of the variation in the data. These and similar arguments point to the fact that individual choice models should not be viewed as direct substitutes for aggregate approaches. Rather, they play a distinct and complementary role in analysing barriers to communication.

In some instances it may be necessary to conceive an intermediate level of analysis - the mesolevel - as the most appropriate analytical window through which certain types of communication should be viewed. For example, the mesolevel will usually be superior for the analysis of network systems in which nodes and links prevail, such as traffic grids or telephone networks (see Table 1). In this paper, however, emphasis is laid on micro and macro aproaches to the study of spatial choices and interactions. The primary objective of the paper is to examine some major macro- and micro-approaches as potential methodological framework for analysing barrier effects in communication patterns and processes. Attention is not being paid on the nature of barrier effects, but rather on the difficulties inherent in isolating such effects as well as on the need for a reference state from which the resulting flow attenuations can be monitored. This latter point will be discussed in the beginning of the next section, first.

Table 1: Three Analytical Levels of Interactive Behaviour

Level	**Scope of Interaction**	**Some Possible Methodological Approaches**
Micro	Set of Interacting Decision Agents (e.g. firms, persons)	Behavioural Models, Time-Path Analysis, Diffusion Models
Meso	Set of Interacting Nodes and Links (e.g. traffic grid or telephone network)	Network Equilibrium Models
Macro	Aggregate Interaction Flow Data for a Single Region or Nation	Simple Statistical Methods
	Set of Interacting Regions or Nations (e.g. trade flows)	Spatial Interaction or Intervening Opportunities Models

2. Macrolevel Approaches

2.1. Simple Statistical Methods: An Empirical Illustration

In order to demonstrate the scope and limits of non-interaction analysis, we start by presenting an example of a simple approach to historical macro-data on a national level.

Simple statistical procedures may sometimes provide useful insights in isolating the effect of a specific barrier. They also enable to identify a reference state from which the resulting flow attenuations may be measured. In this section, historical communication data from France and Sweden are analysed to illustrate how basic statistical methodology can provide some thought-provoking insights. We conceive the period of the Second World War as a barrier. This interpretation of the historical interruption refers to the fact that the communication flows drop in a period of war because the closing of borders hinders interactions for which there would still be a demand. A great advantage of this historical perspective is that the reference state without barriers can easily be modelled as a before/after phenomenon.

Table 2 records the volume of mail items and telephone calls in France and Sweden during the period 1925-1965[1] . From these figures, it is apparent that the wartime occupation of Europe caused very little disruption to communication services within Sweden. However, it did have a marked effect on similar services in France. Phone calls almost halved in 1940 as the barriers of war began to grow. Between 1938 and 1944, the French mail system operated under considerable duress.

At least two interesting questions arise. What would the total volume of messages (i.e. mail items and phone calls) have been in the absence of war-time barriers? How much of the unrealized volume of phone traffic could be attributed to the onset of war and how much to other factors? An answer to the first question would serve as a reference state from which the observed deviations could be measured, whereas an answer to the second question would help to isolate the effects of a specific barrier - the onset of war.

Table 2: Mail Items and Telephone Calls in France and Sweden (1925-65)

YEAR	FRANCE MAIL ITEMS (Millions)	FRANCE PHONE CALLS (Millions)	SWEDEN MAIL ITEMS (Millions)	SWEDEN PHONE CALLS (Millions)
Before the Second World War				
1925	5,678	788	420	639
1930	6,281	836	541	790
1935	5,582	903	622	930
1936	5,704	940	626	983
1937	5,707	962	660	1,046
1938	5,664	960	704	1,117
During the Second World War				
1939	5,261	852	713	1,170
1940	4,354	592	731	1,193
1941	4,572	774	753	1,236
1942	3,393	1,008	849	1,377
1943	3,723	1,156	895	1,452
1944	2,342	1,099	967	1,576
1945	3,694	1,358	975	1,694
After the Second World War				
1950	4,050	1,537	1,063	2,099
1955	4,996	2,347	1,149	2,564
1960	6,093	3,849	1,425	N/A
1965	7,432	6,773	1,732	N/A

Source: Mitchell (1975, pages 659 and 662)

Table 3 summarizes the regression results for the total volume of messages and, more specifically, the number of phone calls. Some explanations are in order. The predicted volume of messages is rather straightforward, since the intrusion of the First World War dampened growth in postal services to such an extent that a linear model was as reasonable as any other monotonously increasing function over the period 1870-1920. Although better predictors could be derived **with the benefit of subsequent hindsight,** the historical model is being used as a basis for prediction since this would have seemed the logical choice back in 1925. The model suggests that the total volume of messages would have been almost 50% higher if war had not prevailed during the years 1939-1945.

Table 3: Messages and Telephone Calls in the Absence of War: Predicted Values for France (1935-1950)

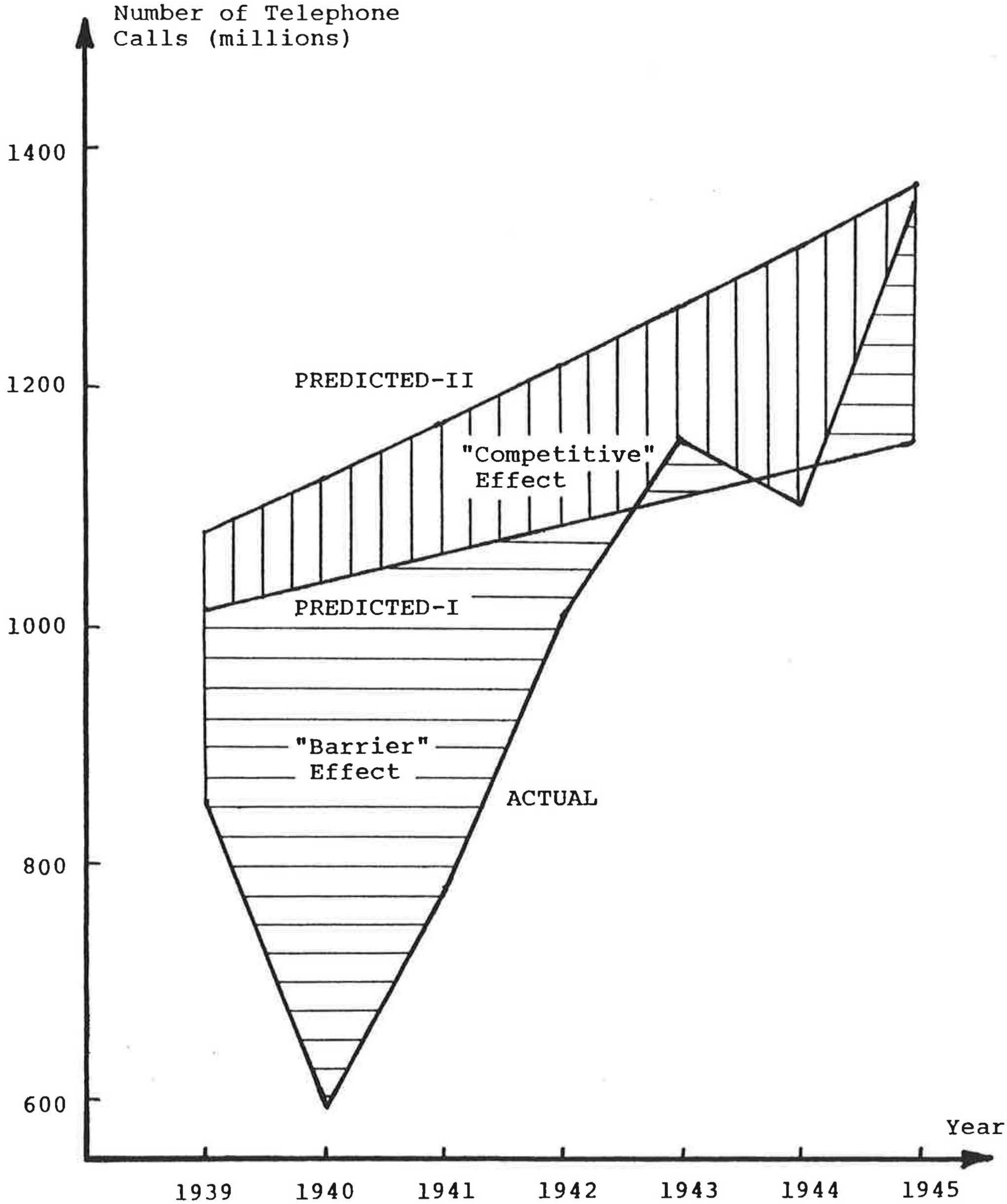
YEAR	MESSAGES (Millions) ACTUAL	PREDICTED	PHONE CALLS (Millions) ACTUAL	PREDICTED-I	PREDICTED-II
1935	6,485	6,663	903	916	913
1936	6,644	6,726	940	940	951
1937	6,669	6,790	962	964	991
1938	6,624	6,853	960	987	1,033
1939	6,113	6,916	852	1,011	1,076
1940	4,946	6,980	592	1,035	1,121
1941	5,346	7,043	774	1,059	1,167
1942	4,501	7,106	1,008	1,083	1,215
1943	4,879	7,169	1,156	1,107	1,264
1944	3,441	7,233	1,099	1,130	1,315
1945	5,052	7,296	1,358	1,154	1,367
1946	5,446	7,359	1,457	1,178	1,421
1950	5,587	7,612	1,537	1,273	1,656

Source: Authors' Calculations

The disruption caused by the First World War also suggested that a linear estimator could be used to predict the number of phone calls which would have been made in the absence of the Second World War. Phone traffic grew by an average of 24 million calls per year during the calibration period of 1892 (commencement of records) to 1935. The resulting estimates for the period 1935-1950 are listed under the heading **Predicted-I** in Table 3. Although these estimates suggest that about 34% more calls would have been made in the early years of the war period, this model also suggests that **less calls would have eventuated in later years than were observed.**

The problem with Predicted-I is that it does not recognize any factors other than the removal of the specific barrier of war. In reality, mail items and telephone calls are constantly waging a war of their own as the principal competitors in the message market, with the latter gradually replacing the former. So a model is needed which takes these competitive forces into account. Predicted-II is such a model, being based upon the well-known logistic curve. This loglinear approach takes the market shares of each competitor into account, and usually provides a better fit to these type of data. A short summary of the mathematics involved in this type of curve-fitting exercise is given in the Appendix.

Figure 1: A Graphical Comparison of the Actual and Predicted Volumes of Telephone Traffic in Frame (1939-1945)



What is quite remarkable about the results appearing under the heading of **Predicted-II** is that the whole model has been calibrated using just **ten years of historical data** (from 1926 to 1936). Yet it provides impressively accurate values for the postwar years (particularly in the early fifties). These results might have been even more impressive if a more sophisticated model had been used to predict the size of the whole message market, since the loglinear model deals only with market shares.

The results may be summarised with reference to Figure 1. During the war years of 1939 to 1945, it is possible to distinguish in an aggregate manner between the effects of the onset of war and the effects of competition within the message market. These two components are indicated on the diagramm. From the size of the respective areas, it would appear that the unrealized volume of telephone calls over this six year period was about 25%. Approximately 14% of this could be attributed to the loss of potential gains in market share and 11% purely to the barrier effects of the Second World War.

What can be learnt from this simple aggregate approach to the above mentioned example? First, it has become obvious that the definition of a reference state is basic for the empirical modelling of barriers. Second, non-barrier effects on demand for the medium considered have to be isolated. Third, while the analysis of the aggregate data is quite successfull, barriers cannot be identified in space (or only be located at the border of the nation under consideration), but only in time. Because the intention is to analyse barriers to communication in space we will focus our attention in the sequel on approaches which allow to consider the spatial interaction phenomenon.

2.2. The Gravity Model Approach

Spatial interaction models are used to study and forecast patterns of human and economic interaction over geographic space. Gravity models are the most widely used types of spatial interaction models. There is a wide range of different model specifications (for an overview, see for example Batten and Boyce 1986). Without loss of generality in the context of this paper the discussion is restricted to the classical form of the unconstrained gravity model where the term unconstrained implies that the aggregate flows do not necessarily sum to the total flows in the system.

This model is based upon the hypothesis that the intensity of spatial interaction (for example the volume of telecommunication) from a region i of origin to a region j of destination depends upon the characteristics of regions i and j as well as upon a deterrence function $f(d_{ij})$, assumed to be a decreasing function of the intervening distance d_{ij}. In formal terms the model may be written as:

$$X_{ij} = K\ O_i^{\alpha}\ D_j^{\beta}\ f(d_{ij}) \qquad i,j = 1,\dots, n \qquad (1)$$

where X_{ij} denotes - in our context - the volume of communication (e.g. phone calls) from region i to region j. O_i and D_j represent variables (such as the potential pool of calls in region i and the potential draw of calls in region j, respectively) pertaining to the origin i and to the destination j of communication. $f(d_{ij}) = d_{ij}^{-\gamma}$ is a spatial interaction function in the separation variable d_{ij} (usually specified in form of a distance and/or cost variable). This functional form is most conveniently specified either as an exponential function $f(d_{ij}) = \exp(-\gamma\, d_{ij})$ or as a power function $f(d_{ij}) = d_{ij}^{-\gamma}$. α, β and γ denote parameters of the model and K is a scaling parameter needed for normalisation.

Barriers affecting communication patterns might be introduced into the gravity framework in two ways:

(o) via the origin or destination variables, O_i or D_j, if the barrier is such that it affects the relative size of the population of candidate callers at the origin, or the size of the population of candidate receivers at the destination (e.g. budget constraints, accessibility to handsets, seniority of position, exchange conditions, and time-of-year);

(o) via the difficulty-of-interaction variable, d_{ij}, if the barrier is such that it affects the likelihood of communication between various O-D pairs (e.g. the intervening topography, language differences, other cultural differences, tariffs or line charges, border conditions, and route congestion).

The first group, which might be termed **nodal barriers**, directly affect the determination of the potential number of callers or receivers in any place. The second group, which might be called **link barriers**, directly affect the determination of the traffic volume or intensity between pairs of places. If the gravity model (or one of its derivatives) is to be used for the analysis of communication barriers, then these two categories represent important distinctions from both the conceptual and the analytical viewpoints.

It is prudent to remember that the gravity model is largely a descriptive tool. There is a lack of any theory to explain the values or functions which may be chosen to assign to its variables or exponents. Thus, it is important to specify a reference state (or "no barriers") situation as a yardstick from which the attenuated traffic pattern associated with a set of barriers may be measured. It is also necessary to acknowledge the difficulty of isolating the effect of any one particular barrier, which is generally disguised by the aggregate effects of various barriers which are operating simultaneously.

2.3. The Intervening Opportunities Model

The ability to introduce barrier effects into the framework of spatial interaction analysis will partly depend on the proper interpretation and specification of d_{ij}. Classical notions of distance deterrence over continuous space may need to give way to notions of directional deterrence over discrete space. Discontinuous functional forms (e.g. step functions) may need to be tested. One promising approach may be Stouffer's hypothesis on intervening opportunities which postulates in a mobility context that there is no continuous "relationship between mobility and distance ...[rather than]... the number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities" (Stouffer, 1940, pp. 846-847).

If substitute "intervening barriers" are substituted for "intervening opportunities", then an interesting version of Stouffer"s model might be developed. The Stouffer hypothesis has been tested and found to be at least as reliable in certain contexts as the classical gravity model incorporating continuous distance. It may be quite pertinent for the case of telephone traffic, where the caller's behaviour is often affected more by perceived opportunities and intervening disruptions than by distance factors.

2.4. The Minimum Information Principle

To incorporate a reference state from which barrier-associated deviations in communication patterns may be measured, it may be fruitful to adopt the versatile measure of **information gain** introduced by Kullback (1959). Kullback's principle rests on the assumption that information is a relative quantity, thereby allowing us to compare probabilities (e.g. normalized movement patterns) before and after an observation. Such an observation migth be the imposition of a barrier.

Information gain is defined when a **posterior** distribution $\{p_{ij}\}$ is compared with a known **prior** distribution $\{q_{ij}\}$. The gain, I(P;Q), is given by

$$I(P;Q) = \sum_i \sum_j p_{ij} \log (p_{ij} / q_{ij}) \qquad (2)$$

where

$$p_{ij} = X_{ij} / \sum_i \sum_j X_{ij} \qquad (3)$$

and

$$q_{ij} = X^*_{ij} / \sum_i \sum_j X^*_{ij} \qquad (4)$$

X^*_{ij} and X_{ij} define the volume of communication from i to j, respectively, before and after the introduction of a barrier.

The minimum information principle asserts that we should choose that distribution $\{p_{ij}\}$ which minimizes I (P;Q)) subject to related facts about P which are treated as constraints on the set of possible choices. For example, subject to:

$$\sum_j p_{ij} < k_1 O_i \qquad (5)$$

$$\sum_i p_{ij} < k_2 D_j \qquad (6)$$

$$p_{ij} < k_3 \exp(-\gamma \ d_{ij}), \text{ and } \ d_{ij} > d^*_{ij} \qquad (7)$$

where g, k_1, k_2 and k_3 are parameters . In the above **nodal** [see (5) and (6)] and **link-related** [see (7)] constraints may by distinguished.

The advantages of expression (2) - (4) are that it is a relative measure, it is independent of the total traffic volume, it is always positive, it has useful additive properties, and it allows for non-uniform prior probabilities.

3. A Methodological Approach for Analysing Individual Communication Behaviour

3.1 From the Macro to the Micro View

The work on interaction patterns and communication processes over space during the 1960's and the early 1970's was dominated by spatial interaction (gravity) models justified using probability arguments and entropy maximising formulations (see Wilson 1967). This lack of behavioural content, which begun to be criticised in the early 1970's gave rise to the study of individual choice behaviour which, in relation with the parallel development of discrete choice models (see McFadden 1974), made it possible to propose new alternatives. Unlike spatial interaction models, these alternatives could explicitely link individual decisions at the microlevel with population flows and other observables at the macrolevel (Fischer, Nijkamp and Papageorgiou 1990).

Current individual choice analysis, such as discrete choice models (see Hensher and Johnson 1981, Ben-Akiva and Lerman 1985, Fischer and Nijkamp 1985) or decompositional preference models (see Timmermans 1984), are explicitely probabilistic. The former deal with individual choices, the latter with individual preferences. The source of stochasticity in discrete choice models is generated either by the choice rules (see Luce 1959, Tversky 1972) or by stochastic utility (see Thurstone 1972, Manski 1977). Stochastic choice rules have originated with work in psychology. Stochastic utility, on the other hand, can arise either at the level of the individual - a view which is primarily held by psychologists - or because of observer's uncertainty - a view which is primarily held by economists. Similar considerations can be applied to decompositional preference models (Fischer, Nijkamp and Papageorgiou 1990).

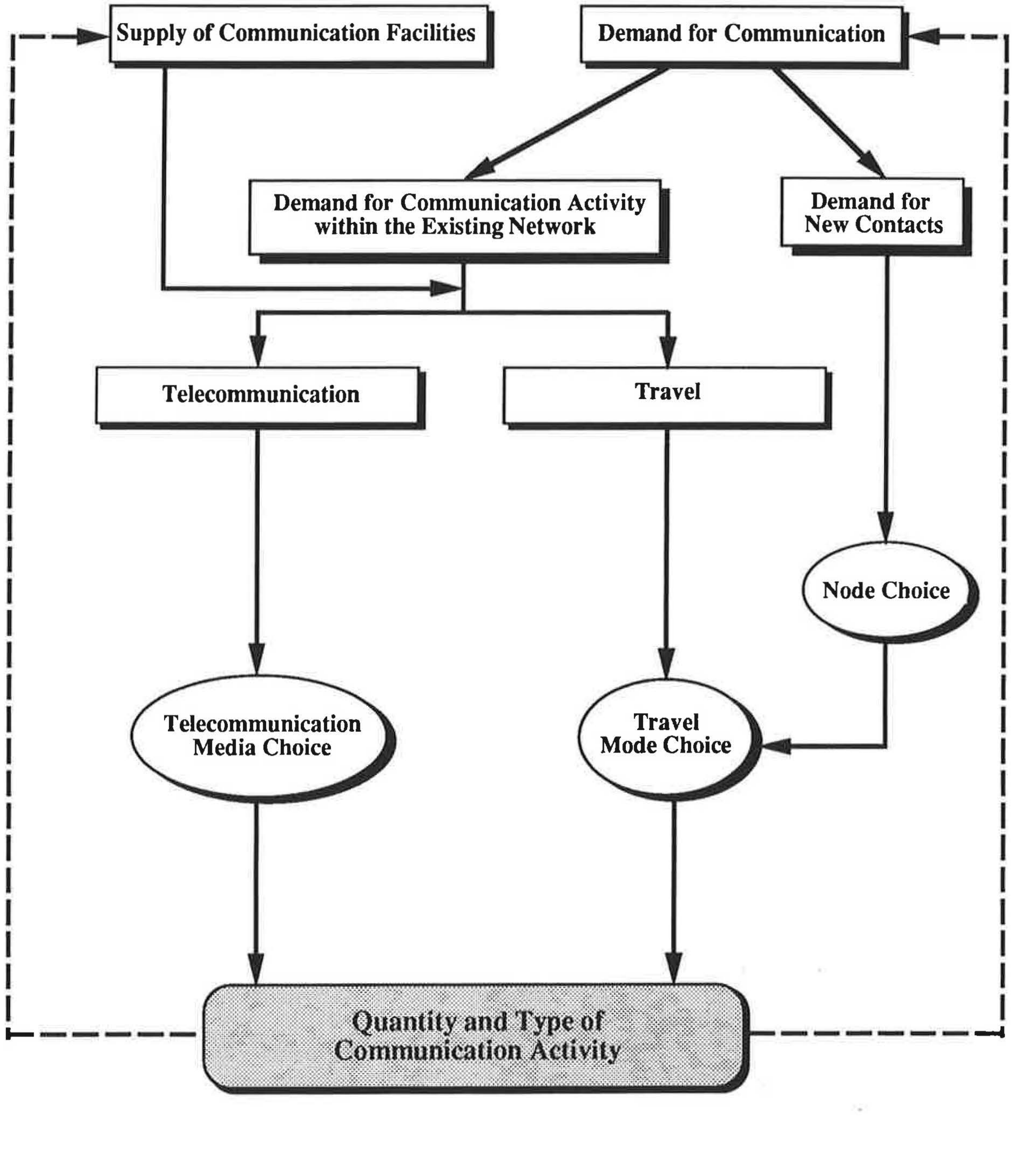
The purpose of this section is to suggest a general conceptual framework within which individual communication behaviour in general and barriers to communication in particular might be studied at the micro level. The conceptual framework and methodology developed is context specific and refers to a university setting.

3.2. A Conceptual Framework for Analysing Individual Communication Behaviour in a University Setting

The conceptual framework which will be outlined in the sequel is refined to a university setting, a particularly information and contact intensive segment of society where it can reasonably be assumed that the individuals take autonomous contact decisions (in the case of node choice). The design of the integrated framework for communication choice behaviour is outlined in Figure 2. It depicts the interaction of a department's supply of communication facilities (media such as telephone, facsimile, electronic mail, courier mail, traditional mail) with the demand for communication in a simplified manner. The demand for communication evolves from the organisational structure of the department including the department's objectives (especially with respect to research) as well as formal or informal rules governing individual behaviour. Supply and demand result in the need for a certain quantity and type of communication activity. Most of the communication needs are met by communication within the existing contact network, either by using communication media or by travel to face-to-face meetings (conferences, workshops, lectures etc.), while others may be satisfied only by establishing new contacts. An important feature of the conceptual model is the feedback from communication outcomes to both the supply of communication facilities and the demand for communication.

Within this conceptual framework the node choice decision may be considered to be derived from the demand for new contacts. The node choice segment of the general framework is expanded in Figure 3. The formation of node preferences is considered to be context specific and may be assumed to depend upon

Figure 2: Integrated Framework for Communication Choice within a University Setting (Source: Fischer, Maggi and Rammer 1990)



(o) characteristics of the academic (such as profession and status, language skills, degree of mobility) who is deciding to establish a new contact (briefly termed: network former), and characteristics of the organisational unit (such as travel rules and budget) to which the network former belongs,

(o) the size and structure of the existing network of the academic (such as the number of contact persons and extension of the network, orientation and direction of the network, intensity of network use), where of course the structure of the network may be strongly influenced by the membership in various professional associations and on

(o) the contact decision context which primarily enters via the characteristics of the potential contact person (profession and status, reputation languages skills, location) and the purpose of the contact.

There are three types of constraints acting on the preferences, namely institutional related constraints (e.g travel reglementations), mobility related constraints (e.g. language skills, fixed service obligations in the home university) and time and cost related constraints (e.g. travel budgets, teaching load). These constraints which normally act negatively on the decision of whether or not to contact a certain person are not necessarily acting as barriers. As will be illustrated in 3.3. the barrier function depends on the specific influence on the decision of one individual and not on the overall cross-sectional impact of a variable.

The media choice segment of the conceptual framework is elaborated in Figure 4. The media choice process is conceptualised as including the following stages. First, the communication initiator becomes aware of the need to communicate in a specific context. The initiator has individual characteristics (e.g. profession and status, age, keybord and typing skills, attitude towards computer technology) and works in a department with specific characteristics (e.g. cost control norms, media access and usage rules). Second, given the initiator's awareness of the communication context it is assumed that the characteristics of the communication activity itself (such as the complexity of the communication, volume of communication, urgency and confidentiality of the message) and characteristics of the initiator-recipient relationship (such as status effects, location of the recipient, familiarity with the

Figure 3: A Conceptual Framework for Media Choice Behaviour
(source: Fischer, Maggi and Rammer 1990)

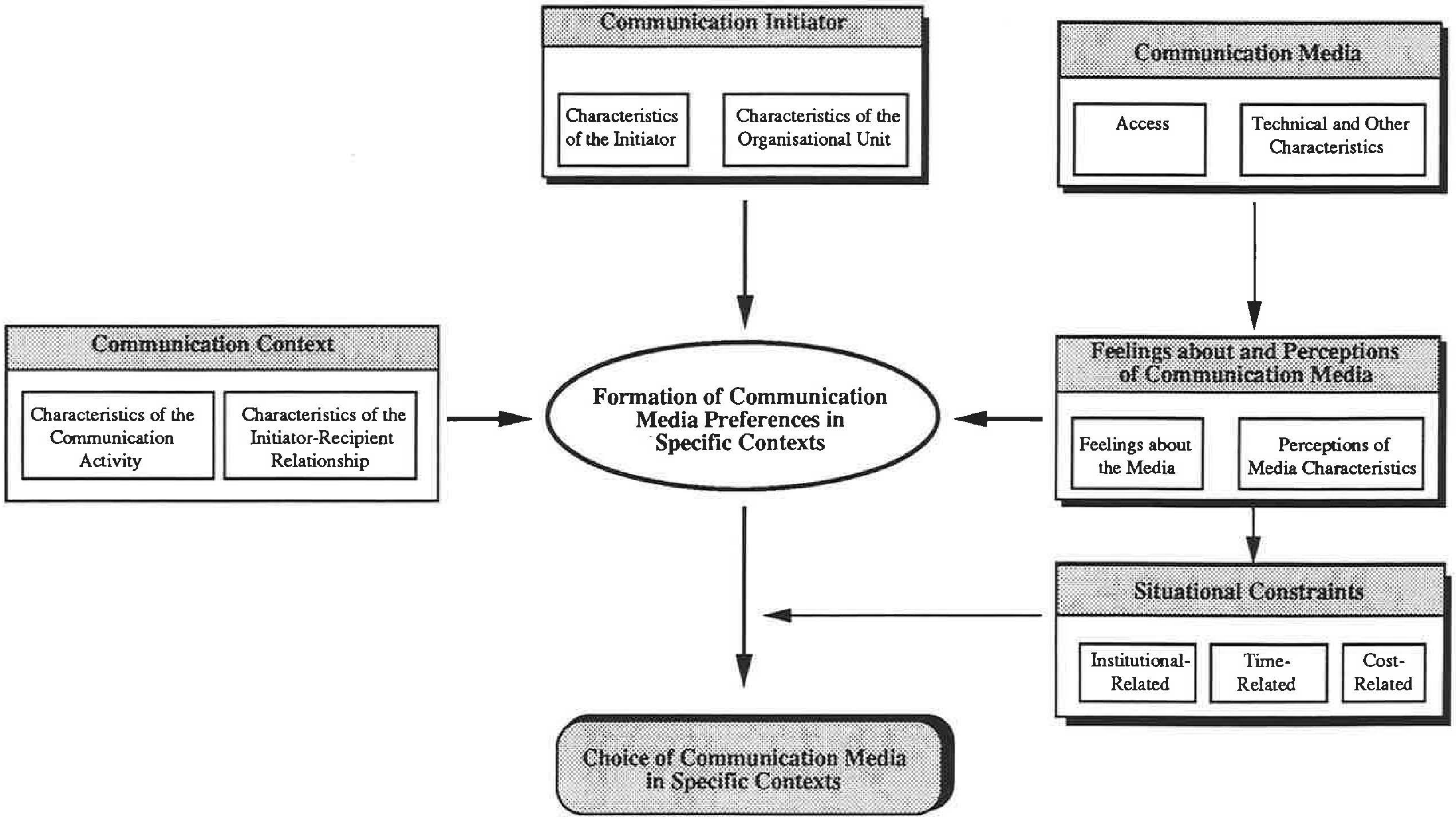
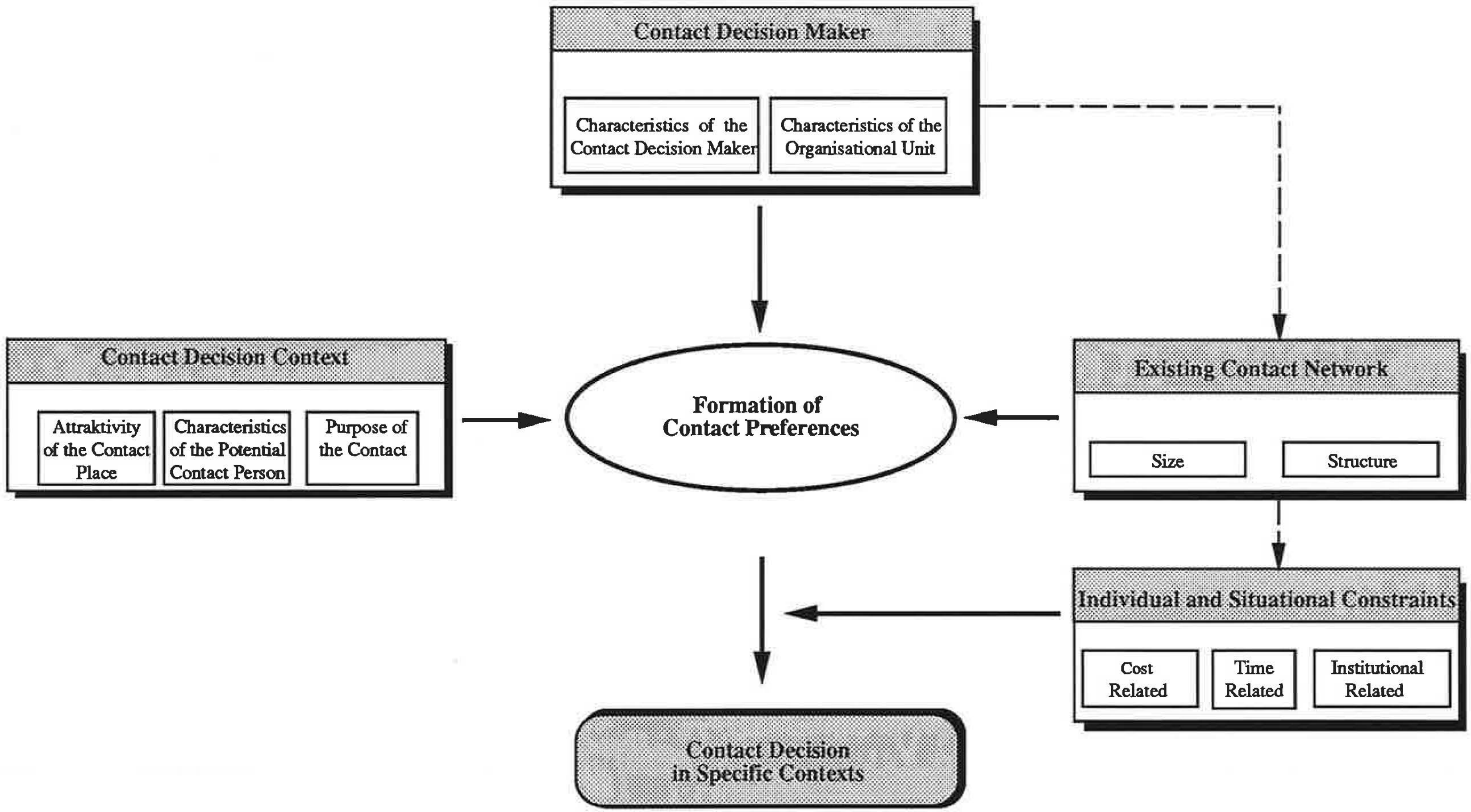


Figure 4: A Conceptual Framework for Contact Decision Making
(source: Fischer, Maggi and Rammer 1990)



recipient, awareness of recipients media dislikes) influence the formation of communication media preferences. Third, the initiator is assumed to have knowledge of the characteristics of the communication media. The conceptualisation focuses on perceptions and feelings related to media characteristics rather than objective charateristics (such as cost of use, accessibility, ease of use, reliability of time delivery, reliability of success delivery). The link between objective and perceived characteristics is very difficult to analyse and outside the scope of the study.

Finally there are situational constraints and barriers (such as institutional-related, time-related and cost-related ones) which may influence the choice outcome. Again, these constraints do not necessarily act as barriers. They can either represent normal cost factors having a negative impact on the choice via the indirect utility function or they may act as a barrier in the way which will be described in the following subsection.

3.3. Random Utility Based Choice Models of Node Choice and Communication Choice Behaviour

Testing the node and the media choice segments of the conceptual framework may be based upon the discrete choice modelling approach, with economic random utility theory as the underlying theoretical rationale, using stated rather than revealed preference data. Revealed preference data concerns the observation of choice behaviour in real world choice contexts, while stated preference data are typically based on behavioural responses to hypothetical choice experiments. The stated preference data approach provides an attractive empirical setting in which individual communication behaviour can be analysed within the context of discrete choice modelling. The approach enables to analyse different communication situations while allowing to determine the influence of contextual variables and barriers. A key characteristic of this approach is that the individuals are exposed to a set of choice experiments generated by some controlled experimental design procedure (for more details see Fischer, Maggi and Rammer 1990).

In order to arrive at operational models representing the node and the media choice segments discussed in 3.2., it is assumed that an individual's preferences among a set A of discrete choice options (various communication media in the media choice context, the options to establish a contact or not in the node choice context) can be conceptually described by a utility function. The utility of an alternative a ε A is represented as the sum of a deterministic and a random component of utility:

$$u_{ia} = V(x_{ia}, \theta) + \varepsilon_{ia} = v_{ia} + \varepsilon_{ia} \qquad a \varepsilon A \qquad (8)$$

where V is the deterministic component of utility, x_{ia} is a vector of observed characteristics of the individual i and the alternative a, θ is a vector of parameters and ε_{ia} is the random component relating to faulty perception of the choice options, idiosyncratic preferences, neglected choice-relevant attributes etc.

Let us assume that communication decisions are made on the basis of the utility-maximising principle or in other words that an individual i chooses the alternative a that yields greatest utility, then the probability p_{ia} that an individual i selects choice option a is given by

$$p_{ia} = \text{Prob } [u_{ia} > u_{ib} \text{ for all } b \neq a] \qquad (9)$$

$$= \text{Prob } [v_{ia} + \varepsilon_{ia} > v_{ib} + \varepsilon_{ib} \text{ for all } b \neq a]$$

Given equation (8), the functional specification of a probabilistic media choice model (i.e. the definition of a specific functional form for p_{ia}) involves three major steps:

* first, the specification of the probability distribution of ε_{ia},
* second, the specification of the functional form of the deterministic compoent of utility, and
* third, the set A of alternatives among which individual i may choose.

Then the values of the parameters q and of any unknown parameters of the distribution of e_{ia} may be statistically estimated by fitting (9) to the stated preference observations.

In both, the node and the media choice context it may be assumed that e_{ia} is independently and identically Gumbel distributed across individuals and alternatives with the following cumulative distribution function:

$$F(\varepsilon) = \exp(-\exp(-\varepsilon)) \qquad (10)$$

which leads to a logit model of communication behaviour where p_{ia} is given as

$$p_{ia} = \exp v_{ia} \Big/ \sum_{b \varepsilon A} \exp v_{ib} \qquad (11)$$

The most simple model of communication choice may be obtained by embodying a compensatory decision rule where it is assumed that individuals trade off attributes of the choice options in the decision process. This assumption implies a linear-in-parameter specification of the deterministic component of utility:

$$v_{ia} = \sum_{k} \theta_k x_{iak} \qquad (12)$$

where θ_k is the k-th component of θ and x_{iak} the k-th component of x_{ia}.

Finally, it is worthwhile to mention that the node choice decision is a binary and the media choice decision typically a multinominal decision. Thus, the choice set in the node choice context is made up of two choice options, namely to establish a contact or not, while the choice set in the media choice context typically consists of several choice options, such as, for example, traditional mail, courier, telephone, facsimile, electronic mail, teleconferencing.

Barriers affecting communication behaviour might be introduced into the discrete choice modelling framework in three ways:

(o) Via the **specification of the functional form of the deterministic component of utility:** If the barrier is such that the response to attribute changes is discontinuous or that the communication behavioural attributes are not compensatory, then the linear additive utility formulation of the above mentioned compensatory model has to be replaced by a non-compensatory decision rule, such as a dominance,conjunctive, disjunctive, lexicographic,satislex, minimax regret, elimination by aspect or a similar decision rule. Non-compensatory choice models are considerably more complicated than compensatory ones.

(o) Via the **definition of choice-relevant variables** (alternative specific attributes, e.g. characteristics of the contact partners or their organisations), if foselected individuals the influence of a discrete barrier indicator for variable is such that it turns a positive contact decision into a negative one.

(o) Via the **definition of individual specific choice sets** (in the context of media choice behaviour only) if the barrier is such that an alternative is not feasible to an individual (e.g. due to institutional restrictions) (for more details see Fischer and Aufhauser 1987).

4. Concluding Remarks

In this paper some major approaches to the analysis of interaction patterns and communication processes have been reviewed. Complementary methodologies exist at the micro, the meso and the macro levels of analysis. To a certain extent, each of these levels offers scope for consideration of barrier effects and their influence on communication behaviour. The choice of a suitable methodology will depend rather crucially on the precise nature of the barrier effect under examination.

Some preliminary suggestions may be summarized:

(o) Simple statistical methods may be helpful when the need is to identify a reference state from which the resulting flow attenuations can be measured or to isolate the effect of a specific barrier.

(o) Traditional macrolevel approaches, such as modified forms of the gravity model, offer some potential for the analysis of information flows (such as telephone traffic). However, the less common intervening-opportunities model approach might be superior in situations where a caller's behaviour is affected more by perceived opportunities and intervening disruptions than by distance factors.

(o) Network equilibrium models - not discussed in this issue - are particularly important if focus is laid on the study of the type of barrier effect associated with scale diseconomies - namely traffic congestion. This may be an important issue in the study of telephone traffic between nations or regions with vastly different "propensities to phone or fax". Recent formulations of network equilibrium models for the analysis of knowledge exchange processes (Batten, Kobayashi and Andersson 1989) offer further tools for the study of university contact patterns.

(o) The conceptual framework and methodology outlined for individual communication behaviour provides a great potential for analysing communication behaviour at the microlevel. The methodology allows for the influence of context at two levels: first, a range of contexts may be chosen at the data collection stage, with contexts created by the use of experimential design procedures, and second, the experimental design allows for choice models to be estimated on context-specific segments of the data by dividing the data set across some context variables of interest (for more details see Fischer, Maggi and Rammer 1990).

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Appendix: **The Mathematics of Multimodal Substitution**

Let x_i denote the demand for transport mode i. Define a market for transport services as a group I in which the various modes $i\varepsilon I$ compete to provide a similar type of transport service. Then, at any time t, mode i's share of this market is given by

$$f_i = x_i / \sum_{i \in I} x_i \qquad \text{(A1)}$$

so that

$$\sum_{i \varepsilon I} f_i = 1 \qquad \text{(A2)}$$

If the marginal propensity to invest in each mode does not differ appreciably, then we can write down the following system of differential equations:

$$\frac{d}{dt} \{ \ln (f_i / f_j) \} = \alpha_{ij} \qquad \text{(A3)}$$

where the paramter α_{ij} represents of qualitative differences (including relative price differences) between modes i and j, and therefore measures the spread over time of the substitution between these two modes. The following symmetric form of the system defined by (A2) and (A3) may be obtained:

$$f_i + f_i \sum_{k \varepsilon I} \alpha_{kj} \, f_j = 0 \qquad \text{(A4)}$$

If the coefficients a_{ij} are seen to be reasonably time-invariant, then the solution to (A4) takes the following logistic form:

$$f_i(t) / f_j(t) = \exp \{\alpha_{ij} (t - t_0) + \beta_{ij}\}$$

or (A5)

$$\ln \{f_i(t) / f_j(t)\} = \alpha_{ij} (t - t_0) + \beta_{ij}$$

where t_0 is the time when mode i has captured half of the transport market and a_{ij} is a time positioning paramter.

The above equation means that the logarithm of the ratio of market shares between any pair of modes, i and j, when plotted as a function of time, should follow a straight line.