WSG Diskussionspapiere

WSG 23/92

Two Alternative Macro-Based Approaches to Model Telecommunication Traffic

David Batten and Manfred M. Fischer

Institut für Wirtschafts- und Sozialgeographie
Wirtschaftsuniversität Wien

Department of Economic and Social Geography
Vienna University of Economics and Business Administration

WSG Discussion Papers

Institut für Wirtschafts- und Sozialgeographie
Wirtschaftsuniversität Wien

Vorstand: o.Univ.Prof. Dr. Manfred M. Fischer
A - 1090 Wien, Augasse 2-6, Tel. (0222) 313 36 - 4836

WSG 23/92

Two Alternative Macro-Based Approaches to Model Telecommunication Traffic

David Batten and Manfred M. Fischer

WSG-Discussion Paper 23

June 1992

Gedruckt mit Unterstützung
des Bundesministerium
für Wissenschaft und Forschung
in Wien

WSG Discussion Papers are interim reports presenting work in progress and papers which have been submitted for publication elsewhere.

ISBN 3 85037 023 2

1. Introduction

Analyses of interaction patterns across geographical space have always been at the forefront of interest in the spatial sciences. Although a wide variety of contexts have been examined, in this paper we shall restrict our attention to those situations in which patterns of communication are affected by the existence or imposition of barriers. According to Nijkamp, Rietveld and Salomon (1990), obstacles in space or time that impede the smooth transfer or free movement of information-related goods can be regarded as barriers to communication. For our present exploratory purpose, significant discontinuities in the flow intensity of communications may signify the existence of barriers. Their effects on communication patterns are generally nonlinear and often stepwise in character. They may not approximate traditional frictions of distance - which are mostly continuous in character.

The existence and nature of barriers have been discussed elsewhere and will not be explored here.1) Nevertheless it is appropriate 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. We shall begin by considering some methodological approaches which may help to quantify their composite impact. The topic can become complex very quickly because of the diverse nature of various barriers, so our treatment will be introductory and illustrative rather than exhaustive.

Macro, meso and micro-based approaches to the problem may be envisaged (see Table 1). We have stated earlier that there is no reason to believe that the micro-based methods of modelling are inherently more behaviourally valid than the macro-based approaches (see Batten, Fischer and Maggi, 1990). Important distinctions between these different classes of modelling do exist with respect to the quality of the available data and the level of the data analysis. In contrast to aggregate approaches, disaggregate ones require smaller yet detailed data sets for their estimation and make more efficient use of the variation in the data. These and similar arguments indicate that individual choice models should not be viewed as substitutes for aggregate approaches. Rather, they play a distinct and complementary role in analysing barriers to communication.

---

1) The interested reader is referred to other papers in this issue and to a recent special issue of **The Annals of Regional Science,** vol.24, no.4, 1990.

Table 1: Three Analytical Levels of Interactive Behaviour

Level	Scope of Communication Involved	Some Popular Methodological Approaches
Micro	Set of interacting decision makers (e.g. firms, persons)	Behavioural choice models, time-path analysis, or diffusion models
Meso	Set of interacting nodes and links (e.g. traffic grid or telephone network)	Network equilibrium or spatial price equilibrium models
Macro	Set of interacting regions or nations (e.g. trade and communication flows)	Gravity, entropy or potential models

In the following sections, we shall restrict our discussion to two macro-based approaches. These approaches are needed when the available data are aggregate and limited in scope, which is very often the case in the absence of more specialized sample surveys of behavioural preferences. We begin with a brief review of these two candidate approaches to the problem at this level. The data used for the empirical studies refer to the telecommunication traffic on the Austrian public network, as measured by the Austrian PTT in 1991.

2. Two Macro-Based Approaches: Gravity and Intervening Opportunities Models

Spatial interaction in a broad sense involves any movement over space, including journey-to-work, migration, commodity and information flows. Spatial interaction models aim to explain and predict spatial patterns over space. Explanation in this context involves to determine via model calibration the attributes of locations which promote flows of people, commodities or information between them. Used in this mode, the key feature of a spatial interaction model is to identify the effect of each determinant of interaction assessed by means of the associated parameter estimate. Three types of explanatory spatial interaction models may be distinguished (see Fotheringham and O'Kelly 1989):

- **the unconstrained spatial interaction models** which yield insight into spatial interaction patterns by providing information on the attributes of both the origins and the destination of the interactions,
- **the attraction-constrained spatial interaction models** by providing information on the origin characteristics only, and
- **the production-constrained spatial interaction models** by providing information on the destination characteristics.

The major purpose of the fourth type of spatial interaction models, **the double constrained** or **production-attraction-constrained models**, is predictive rather than explanatory in nature in that they take the propulsiveness of origins and the attractiveness of destinations as exogenously given and only attempt to allocate a known volume of out- and inflows to links between the origins and destinations.

Without any loss of generality in the context of this paper, we restrict ourselves to unconstrained spatial interaction models. In these models three basic components are taken into account to model the distribution of telecommunication: a factor A_i representing the intensity of telecommunication generated by region (location) of origin i (i=1,..., n), a factor B_j (j=1,..., n) representing destination-specific pull factors or the degree to which the in situ attributes of a paricular destination attract telecommunication traffic, and a separation factor F_{ij} associated with origin-destination pairs (i, j) representing the inhibiting effect of geographic separation.

In formal terms, the unconstrained spatial interaction models for interregional telephone traffic may be written as follows

$$T_{ij} = K \; A_i^{\alpha_1} \; B_j^{\alpha_2} \; F_{ij} \tag{1}$$

where Tij denotes the volume (intensity) of telecommunication from region i to region j, and A_i and B_j represent suitable variables such as the potential number of callers and receivers (measured, for example, in terms of telephone subscribers) and characterise the telecommunications' potential of regions i and j.

In spatial interaction models of the gravity type (briefly gravity models) the separation factor F_{ij} is assumed to be a function of some measure D_{ij} of geographic separation between i and j. In general, D_{ij} is specified in form of geographical distance from i to j rather than in terms of telephone costs. The functional form is most conveniently specified either as an exponential function

$$F_{ij}\ (D_{ij}) = \exp\ (\beta\ D_{ij}) \tag{2}$$

or as a power funcion

$$F_{ij}\ (D_{ij}) = D_{ij}^{\beta} \tag{3}$$

although more complex functions may be adopted (see Fischer et al. 1992).α_1, α_2 and β are parameters and K is a scaling parameter needed for normalisation.

Various versions of the gravity model have been developed and applied to study barrier effects on flow patterns of various kinds (see e.g. Bröcker and Rohweder, 1990; Rietveld and Janssen, 1990; Rossera, 1990; Fischer et al., 1992). Barrier effects are usually modelled as discrete steps in the decay function F_{ij} $(D_{ij}) = \exp$ $(\beta$ $D_{ij})$ where the decay function has to be reformulated in an appropriate way. Suppose that D_{ij} is measured in cost terms and that there is a barrier with size of β_2 in money terms then the decay function has to be reformulated as F_{ij} $(D_{ij}) = \exp$ $(\beta_1$ $D_{ij} + \beta_2$ $D_{ij})$ where $B_{ij} = 1$ if the barrier under consideration applies to regions i and j, and $B_{ij} = 0$ otherwise. Such an approach enables to detect **link-related barriers**, i.e. barriers affecting the ease or likelihood of communication between various (i, j)-pairs. Well known examples of such barriers are traffic structures of communication, cultural and language barriers, differences in time zones, and congested barriers in form of congested route sections in the telecommunication network.

Barriers can also affect communication patterns via the origin or destination specific variables, A_i or B_j. For example, in some sparsely populated regions, accessibility to handsets may be a barrier which restricts the relative size of the population of candidate callers in region i. Other types of barriers may also determine the composition of the caller population (e.g. budget constraints, seniority of position, exchange conditions, and time-of-year). This latter group of barriers might be termed **nodal barriers**.

Our ability to mimic barriers errects using the gravity model will partly depend on the proper interpretation and specification of the separation term F_{ij} (D_{ij}). Classical notions of distance deterrence over continuous space may need to give way to notions of directional obstructions over discrete space. Discontinuous functional forms (e.g. step functions) may warrant consideration. From this perspective, a potentially interesting model is Stouffer's hypothesis on intervening opportunities (Stouffer 1940, 1960):

Stouffer's hypothesis, expressed in the context of telecommunication, has the following form: The number of persons calling a given distance is directly proportional to the percentage increase in perceived opportunities (potential contact partners) at that distance. Such a space of opportunities may influence callers in the face of certain barrier effects. If we assume that there exists a continuous function

$$V = f(x) \qquad (4)$$

describing the field of opportunities V surrounding each calling point distant from the origin location of the phone call not more than by distance x, then we can write the following differential equation:

$$dT/dx = (a/V)\ dV/dx \qquad (5)$$

where T is the cumulative number of phone calls originating in a given location and terminating within the ring x around this location, V is the number of intervening opportunities, and a constant. Stouffer substitutes (4) into (5) and integrates to obtain

$$T = a \log f(x) + c \qquad (6)$$

where a and c are constants. Equation (6) captures the essence of a simplified notion of intervening opportunities in the context of telephone traffic; namely that the number of calls T which terminate at any point located within a circle of radius x surrounding the point of origin is directly proportional to the logarithm of opportunities within this circle. This hypothesis has been tested and found to be at least as reliable in the context of intraurban migration analysis as the classical gravity model. Our aim is to explore its potential for the case of telecommunication traffic, since a caller's behaviour may be affected as much by perceived opportunities (or intervening disruptions) as by distance factors.

Intervening opportunities telephone traffic models essentially apply the same basic logic as gravity type models do. There is only one major difference between an intervening opportunities model and a gravity model, namely the way by which the effect of geographic separation is incorporated. Technically considered, the major difference lies in the way in which F_{ij} in (1) is specified. Intervening opportunities models conceptualise geographic separation in terms of the above mentioned intervening opportunities rather than in functional forms of geographic distance leading to spatial interaction models of the following form:

$$T_{ij} = K \; A_i^{\alpha_1} \; B_j^{\alpha_2} \; / \; V_{ij}^{\beta} \; G_{ij}^{\gamma} \tag{7}$$

where V_{ij} denotes the number of intervening opportunities measured as the total number of outgoing calls originating in the circle centered midway between i and j and passing through i and j, G_{ij} the number of competing calls measured as the total number of incoming calls to the circle centred on j and passing through i. The critical factor in (7) is the number of opportunities closer to origin than any particular destination j. K, α_1, α_2, β and γ are parameters to be estimated. It is important to mention that this model approach is a rather crude approach to the measurement of a rather complex phenomenon and should be considered as a forerunner to more sophisticated models.

3. Empirical Study

The empirical study serves to compare the two alternative spatial interaction modelling approaches in practice. The study relies on data measured by the Austrian PTT in 1991, in terms of erlangs, an internationally widely used and reliable measure of telecommunication contact intensity. The data refer to the total telecommunication traffic between the 32 telephone districts (for more details see Fischer et al. 1992).

Specifying the A_i- and B_j-terms in both model types, the gravity model defined by (1) to (2) and the intervening opportunities model (7), in terms of telephone subscribers, and assuming a multiplicative disturbance specification then the two models can be transformed into their log-normal versions:

$$\ln T_{ij} = \ln K + \alpha_1 \ln A_i + \alpha_2 \ln B_j + \beta D_{ij} + \ln u_{ij} \tag{8}$$

and

$$\ln T_{ij} = \ln K + \alpha_1 \ln A_i + \alpha_2 \ln B_j - \beta \ln V_{ij} - \gamma \ln G_{ij} + \ln u_{ij} \qquad (9)$$

respectively, where $\ln u_{ij} \sim N(0, \gamma)$ independently of $\ln A_i$, $\ln B_j$ and D_{ij} ($\ln A_i$, $\ln B_j$, $\ln V_{ij}$ and $\ln G_{ij}$). By adopting the usual OLS-assumptions for $\ln u_{ij}$ both equations are suitable for OLS-estimation of the parameters $\ln K$, α_1, α_2, and β; and $\ln K$, α_1, α_2, β, and γ respectively.

Table 2: Comparison of Spatial Interaction Models of the Gravity Type and the Intervening Opportunities Type to Model Interregional Telephone Traffic in Austria (1991): Parameter Estimates and Goodness-of-Fit Statistics (t-values in parentheses)

	Gravity Model (1) - (2)	**Intervening Opportunities Model (7)**
Constant	- 0.86	-16.06
	(-37.13)	(-21.82)
α_1	0.94	0.95
	(30.37)	(30.20)
α_2	0.92	0.94
	(30.58)	(29.54)
β	- 0.004	0.03
	(-16.94)	(0.81)
γ		- 0.29
		(- 9.98)
R^2 adjusted	0.68	0.74

Table 2 summarizes the coefficient estimates and the goodness of fit statistics of the two models. Both perform reasonably well in terms of R^2 adjusted, the intervening opportunities model slightly better than the standard gravity model not accounting for barrier effects. All the coefficients - except the V_{ij}-term in the intervening opportunities model approach - are significantly different from zero (0.05 level of significance) and have the anticipated sign. It is interesting to note that the parameter estimates of α_1 and α_2 are not affected by the choice of the different notions of separation. In addition it is worthwhile to mention that the V_{ij}-term, i.e. the number of intervening opportunities, has a significant, but comparatively less important influence on telephone communication.

4. Concluding Remarks

Two different models of interregional telephone traffic in Austria have been discussed and compared: the conventional (unconstrained) spatial interaction model of the gravity type and an intervening opportunities based spatial interaction model. There is really only one major difference between the two models, the way by which the effect of geographic separation is conceptualised. Whereas in the gravity model distance per se is supposed to influence the intensity of telephone communication, in the intervening opportunities model the critical factor is the number of opportunities closer to the origin than any particular destination. Clearly, the intervening opportunity model i somewhat similar to the gravity model. In both cases communication intensity from i to j will increase as the number of opportunities at j (here measeured in terms of telephone subscribers) increases and will generally decrease as distance from i to j increases. This is true not only for the intervening opportunities model, since one can generally expect that as distance increases so would the number of intervening opportunities. Thus, it is perhaps not surprising that both models perform about equally well as descriptors of telephone communication patterns.

Acknowledgements:

The work described in this paper has been supported by the Fonds zur Förderung der Wissenschaftlichen Forschung (P 7516) and a twinning grant from the European Science Foundation, for which both authors wish to express their appreciation. We also wish to thank the Director General of the Austrian PTT and Ing. Robert Totz for the tremendous efforts undertaken in 1991 to measure the telephone traffic in Austria for this project, Gerhard Trichtl, Jürgen Essletzbichler and Helmut Gassler for their valuable assistance with data management and model estimations.

References

Batten, D.F. and Boyce, D.E. (1986): Spatial interaction, transportation, and interregional commodity flow models, in Nijkamp, P. (ed.): **Handbook of Regional and Urban Economics. Volume I**, 357-406. Amsterdam et al.: North-Holland.

Batten, D., Fischer, M.M. and Maggi, R. (1990): Barriers to communication: Reflections on methodological approaches, WSG-Discussion Paper 6, Department of Economic and Social Geography, Vienna University of Economics and Business Administration.

Bröcker, J. and Rohweder, M. (1990): Barriers to international trade. Methods of measurement and empirical evidence, **The Annals of Regional Science 24**, 289-305.

Fischer, M.M., Essletzbichler, J., Gassler, H. and Trichtl, G. (1992): Interregional and international telephone communication: Aggregate traffic models and empirical evidence, WSG-Discussion Paper 20, Department of Economic and Social Geography, Vienna University of Economics and Business Administration.

Fotheringham, A.S. and O'Kelly, M.E. (1989): **Spatial Interaction Models: Formulations and Applications**. Dordrecht, Boston and London: Kluwer Academic Publishers.

Nijkamp, P., Rietveld, P. and Salomon, I. (1990): Barriers in spatial interactions and communications, **The Annals of Regional Science 24**, 237-252.

Rietveld, P. and Janssen, L. (1990): Telephone calls and communication barriers. The case of The Netherlands, **The Annals of Regional Science 24**, 307-318.

Rossera, F. (1990): Discontinuities and barriers in communications. The case of Swiss Communities of different language, **The Annals of Regional Science 24**, 319-336.

Schneider, M. (1959): Gravity models and trip distribution theory, **Papers of the Regional Science Association 5**, 137-176.

Slawski, J. (1990): Model of intervening opportunities as related to the phenomenon of spatial behaviours - its derivations and interpretations, **Prace Naukowe Instytutu Historii Architektury, Szluki i Techniki Politechniki Wroclawskiej 21**, 13-25.

Stouffer, S.A. (1940): Intervening opportunities: A theory relating mobility and distance, **American Sociological Review 5**, 845-867.

Stouffer, S.A. (1960): Intervening opportunities and competing migrants, **Journal of Regional Science 1**, 1-20.

1. Introduction

Analyses of interaction patterns across geographical space have always been at the forefront of interest in the spatial sciences. Although a wide variety of contexts have been examined, in this paper we shall restrict our attention to those situations in which patterns of communication are affected by the existence or imposition of barriers. According to Nijkamp, Rietveld and Salomon (1990), obstacles in space or time that impede the smooth transfer or free movement of information-related goods can be regarded as barriers to communication. For our present exploratory purpose, significant discontinuities in the flow intensity of communications may signify the existence of barriers. Their effects on communication patterns are generally nonlinear and often stepwise in character. They may not approximate traditional frictions of distance - which are mostly continuous in character.

The existence and nature of barriers have been discussed elsewhere and will not be explored here.1) Nevertheless it is appropriate 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. We shall begin by considering some methodological approaches which may help to quantify their composite impact. The topic can become complex very quickly because of the diverse nature of various barriers, so our treatment will be introductory and illustrative rather than exhaustive.

Macro, meso and micro-based approaches to the problem may be envisaged (see Table 1). We have stated earlier that there is no reason to believe that the micro-based methods of modelling are inherently more behaviourally valid than the macro-based approaches (see Batten, Fischer and Maggi, 1990). Important distinctions between these different classes of modelling do exist with respect to the quality of the available data and the level of the data analysis. In contrast to aggregate approaches, disaggregate ones require smaller yet detailed data sets for their estimation and make more efficient use of the variation in the data. These and similar arguments indicate that individual choice models should not be viewed as substitutes for aggregate approaches. Rather, they play a distinct and complementary role in analysing barriers to communication.

---

1) The interested reader is referred to other papers in this issue and to a recent special issue of **The Annals of Regional Science,** vol.24, no.4, 1990.

Table 1: Three Analytical Levels of Interactive Behaviour

Level	Scope of Communication Involved	Some Popular Methodological Approaches
Micro	Set of interacting decision makers (e.g. firms, persons)	Behavioural choice models, time-path analysis, or diffusion models
Meso	Set of interacting nodes and links (e.g. traffic grid or telephone network)	Network equilibrium or spatial price equilibrium models
Macro	Set of interacting regions or nations (e.g. trade and communication flows)	Gravity, entropy or potential models

In the following sections, we shall restrict our discussion to two macro-based approaches. These approaches are needed when the available data are aggregate and limited in scope, which is very often the case in the absence of more specialized sample surveys of behavioural preferences. We begin with a brief review of these two candidate approaches to the problem at this level. The data used for the empirical studies refer to the telecommunication traffic on the Austrian public network, as measured by the Austrian PTT in 1991.

2. Two Macro-Based Approaches: Gravity and Intervening Opportunities Models

Spatial interaction in a broad sense involves any movement over space, including journey-to-work, migration, commodity and information flows. Spatial interaction models aim to explain and predict spatial patterns over space. Explanation in this context involves to determine via model calibration the attributes of locations which promote flows of people, commodities or information between them. Used in this mode, the key feature of a spatial interaction model is to identify the effect of each determinant of interaction assessed by means of the associated parameter estimate. Three types of explanatory spatial interaction models may be distinguished (see Fotheringham and O'Kelly 1989):

- **the unconstrained spatial interaction models** which yield insight into spatial interaction patterns by providing information on the attributes of both the origins and the destination of the interactions,

- **the attraction-constrained spatial interaction models** by providing information on the origin characteristics only, and

- **the production-constrained spatial interaction models** by providing information on the destination characteristics.

The major purpose of the fourth type of spatial interaction models, **the double constrained** or **production-attraction-constrained models**, is predictive rather than explanatory in nature in that they take the propulsiveness of origins and the attractiveness of destinations as exogenously given and only attempt to allocate a known volume of out- and inflows to links between the origins and destinations.

Without any loss of generality in the context of this paper, we restrict ourselves to unconstrained spatial interaction models. In these models three basic components are taken into account to model the distribution of telecommunication: a factor A_i representing the intensity of telecommunication generated by region (location) of origin i (i=1,..., n), a factor B_j (j=1,..., n) representing destination-specific pull factors or the degree to which the in situ attributes of a paricular destination attract telecommunication traffic, and a separation factor F_{ij} associated with origin-destination pairs (i, j) representing the inhibiting effect of geographic separation.

In formal terms, the unconstrained spatial interaction models for interregional telephone traffic may be written as follows

$$T_{ij} = K \; A_i^{\alpha_1} \; B_j^{\alpha_2} \; F_{ij} \qquad (1)$$

where Tij denotes the volume (intensity) of telecommunication from region i to region j, and A_i and B_j represent suitable variables such as the potential number of callers and receivers (measured, for example, in terms of telephone subscribers) and characterise the telecommunications' potential of regions i and j.

In spatial interaction models of the gravity type (briefly gravity models) the separation factor F_{ij} is assumed to be a function of some measure D_{ij} of geographic separation between i and j. In general, D_{ij} is specified in form of geographical distance from i to j rather than in terms of telephone costs. The functional form is most conveniently specified either as an exponential function

$$F_{ij}\ (D_{ij}) = \exp\ (\beta\ D_{ij}) \tag{2}$$

or as a power funcion

$$F_{ij}\ (D_{ij}) = D_{ij}^{\beta} \tag{3}$$

although more complex functions may be adopted (see Fischer et al. 1992).α_1, α_2 and β are parameters and K is a scaling parameter needed for normalisation.

Various versions of the gravity model have been developed and applied to study barrier effects on flow patterns of various kinds (see e.g. Bröcker and Rohweder, 1990; Rietveld and Janssen, 1990; Rossera, 1990; Fischer et al., 1992). Barrier effects are usually modelled as discrete steps in the decay function $F_{ij}\ (D_{ij}) = \exp\ (\beta\ D_{ij})$ where the decay function has to be reformulated in an appropriate way. Suppose that D_{ij} is measured in cost terms and that there is a barrier with size of β_2 in money terms then the decay function has to be reformulated as $F_{ij}\ (D_{ij}) = \exp\ (\beta_1\ D_{ij} + \beta_2\ D_{ij})$ where $B_{ij} = 1$ if the barrier under consideration applies to regions i and j, and $B_{ij} = 0$ otherwise. Such an approach enables to detect **link-related barriers**, i.e. barriers affecting the ease or likelihood of communication between various (i, j)-pairs. Well known examples of such barriers are traffic structures of communication, cultural and language barriers, differences in time zones, and congested barriers in form of congested route sections in the telecommunication network.

Barriers can also affect communication patterns via the origin or destination specific variables, A_i or B_j. For example, in some sparsely populated regions, accessibility to handsets may be a barrier which restricts the relative size of the population of candidate callers in region i. Other types of barriers may also determine the composition of the caller population (e.g. budget constraints, seniority of position, exchange conditions, and time-of-year). This latter group of barriers might be termed **nodal barriers**.

Our ability to mimic barriers errects using the gravity model will partly depend on the proper interpretation and specification of the separation term F_{ij} (D_{ij}). Classical notions of distance deterrence over continuous space may need to give way to notions of directional obstructions over discrete space. Discontinuous functional forms (e.g. step functions) may warrant consideration. From this perspective, a potentially interesting model is Stouffer's hypothesis on intervening opportunities (Stouffer 1940, 1960):

Stouffer's hypothesis, expressed in the context of telecommunication, has the following form: The number of persons calling a given distance is directly proportional to the percentage increase in perceived opportunities (potential contact partners) at that distance. Such a space of opportunities may influence callers in the face of certain barrier effects. If we assume that there exists a continuous function

$$V = f(x) \tag{4}$$

describing the field of opportunities V surrounding each calling point distant from the origin location of the phone call not more than by distance x, then we can write the following differential equation:

$$dT/dx = (a/V)\ dV/dx \tag{5}$$

where T is the cumulative number of phone calls originating in a given location and terminating within the ring x around this location, V is the number of intervening opportunities, and a constant. Stouffer substitutes (4) into (5) and integrates to obtain

$$T = a \log f(x) + c \tag{6}$$

where a and c are constants. Equation (6) captures the essence of a simplified notion of intervening opportunities in the context of telephone traffic; namely that the number of calls T which terminate at any point located within a circle of radius x surrounding the point of origin is directly proportional to the logarithm of opportunities within this circle. This hypothesis has been tested and found to be at least as reliable in the context of intraurban migration analysis as the classical gravity model. Our aim is to explore its potential for the case of telecommunication traffic, since a caller's behaviour may be affected as much by perceived opportunities (or intervening disruptions) as by distance factors.

Intervening opportunities telephone traffic models essentially apply the same basic logic as gravity type models do. There is only one major difference between an intervening opportunities model and a gravity model, namely the way by which the effect of geographic separation is incorporated. Technically considered, the major difference lies in the way in which F_{ij} in (1) is specified. Intervening opportunities models conceptualise geographic separation in terms of the above mentioned intervening opportunities rather than in functional forms of geographic distance leading to spatial interaction models of the following form:

$$T_{ij} = K \; A_i^{\alpha_1} \; B_j^{\alpha_2} \; / \; V_{ij}^{\beta} \; G_{ij}^{\gamma} \tag{7}$$

where V_{ij} denotes the number of intervening opportunities measured as the total number of outgoing calls originating in the circle centered midway between i and j and passing through i and j, G_{ij} the number of competing calls measured as the total number of incoming calls to the circle centred on j and passing through i. The critical factor in (7) is the number of opportunities closer to origin than any particular destination j. K, α_1, α_2, β and γ are parameters to be estimated. It is important to mention that this model approach is a rather crude approach to the measurement of a rather complex phenomenon and should be considered as a forerunner to more sophisticated models.

3. Empirical Study

The empirical study serves to compare the two alternative spatial interaction modelling approaches in practice. The study relies on data measured by the Austrian PTT in 1991, in terms of erlangs, an internationally widely used and reliable measure of telecommunication contact intensity. The data refer to the total telecommunication traffic between the 32 telephone districts (for more details see Fischer et al. 1992).

Specifying the A_i- and B_j-terms in both model types, the gravity model defined by (1) to (2) and the intervening opportunities model (7), in terms of telephone subscribers, and assuming a multiplicative disturbance specification then the two models can be transformed into their log-normal versions:

$$\ln T_{ij} = \ln K + \alpha_1 \ln A_i + \alpha_2 \ln B_j + \beta D_{ij} + \ln u_{ij} \tag{8}$$

and

$$\ln T_{ij} = \ln K + \alpha_1 \ln A_i + \alpha_2 \ln B_j - \beta \ln V_{ij} - \gamma \ln G_{ij} + \ln u_{ij} \qquad (9)$$

respectively, where $\ln u_{ij} \sim N(0, \gamma)$ independently of $\ln A_i$, $\ln B_j$ and D_{ij} ($\ln A_i$, $\ln B_j$, $\ln V_{ij}$ and $\ln G_{ij}$). By adopting the usual OLS-assumptions for $\ln u_{ij}$ both equations are suitable for OLS-estimation of the parameters $\ln K$, α_1, α_2, and β; and $\ln K$, α_1, α_2, β, and γ respectively.

Table 2: Comparison of Spatial Interaction Models of the Gravity Type and the Intervening Opportunities Type to Model Interregional Telephone Traffic in Austria (1991): Parameter Estimates and Goodness-of-Fit Statistics (t-values in parentheses)

	Gravity Model (1) - (2)	**Intervening Opportunities Model (7)**
Constant	- 0.86 (-37.13)	-16.06 (-21.82)
α_1	0.94 (30.37)	0.95 (30.20)
α_2	0.92 (30.58)	0.94 (29.54)
β	- 0.004 (-16.94)	0.03 (0.81)
γ		- 0.29 (- 9.98)
R^2 adjusted	0.68	0.74

Table 2 summarizes the coefficient estimates and the goodness of fit statistics of the two models. Both perform reasonably well in terms of R^2 adjusted, the intervening opportunities model slightly better than the standard gravity model not accounting for barrier effects. All the coefficients - except the V_{ij}-term in the intervening opportunities model approach - are significantly different from zero (0.05 level of significance) and have the anticipated sign. It is interesting to note that the parameter estimates of α_1 and α_2 are not affected by the choice of the different notions of separation. In addition it is worthwhile to mention that the V_{ij}-term, i.e. the number of intervening opportunities, has a significant, but comparatively less important influence on telephone communication.

4. Concluding Remarks

Two different models of interregional telephone traffic in Austria have been discussed and compared: the conventional (unconstrained) spatial interaction model of the gravity type and an intervening opportunities based spatial interaction model. There is really only one major difference between the two models, the way by which the effect of geographic separation is conceptualised. Whereas in the gravity model distance per se is supposed to influence the intensity of telephone communication, in the intervening opportunities model the critical factor is the number of opportunities closer to the origin than any particular destination. Clearly, the intervening opportunity model i somewhat similar to the gravity model. In both cases communication intensity from i to j will increase as the number of opportunities at j (here measeured in terms of telephone subscribers) increases and will generally decrease as distance from i to j increases. This is true not only for the intervening opportunities model, since one can generally expect that as distance increases so would the number of intervening opportunities. Thus, it is perhaps not surprising that both models perform about equally well as descriptors of telephone communication patterns.

Acknowledgements:

The work described in this paper has been supported by the Fonds zur Förderung der Wissenschaftlichen Forschung (P 7516) and a twinning grant from the European Science Foundation, for which both authors wish to express their appreciation. We also wish to thank the Director General of the Austrian PTT and Ing. Robert Totz for the tremendous efforts undertaken in 1991 to measure the telephone traffic in Austria for this project, Gerhard Trichtl, Jürgen Essletzbichler and Helmut Gassler for their valuable assistance with data management and model estimations.

References

Batten, D.F. and Boyce, D.E. (1986): Spatial interaction, transportation, and interregional commodity flow models, in Nijkamp, P. (ed.): **Handbook of Regional and Urban Economics. Volume I**, 357-406. Amsterdam et al.: North-Holland.

Batten, D., Fischer, M.M. and Maggi, R. (1990): Barriers to communication: Reflections on methodological approaches, WSG-Discussion Paper 6, Department of Economic and Social Geography, Vienna University of Economics and Business Administration.

Bröcker, J. and Rohweder, M. (1990): Barriers to international trade. Methods of measurement and empirical evidence, **The Annals of Regional Science 24**, 289-305.

Fischer, M.M., Essletzbichler, J., Gassler, H. and Trichtl, G. (1992): Interregional and international telephone communication: Aggregate traffic models and empirical evidence, WSG-Discussion Paper 20, Department of Economic and Social Geography, Vienna University of Economics and Business Administration.

Fotheringham, A.S. and O'Kelly, M.E. (1989): **Spatial Interaction Models: Formulations and Applications**. Dordrecht, Boston and London: Kluwer Academic Publishers.

Nijkamp, P., Rietveld, P. and Salomon, I. (1990): Barriers in spatial interactions and communications, **The Annals of Regional Science 24**, 237-252.

Rietveld, P. and Janssen, L. (1990): Telephone calls and communication barriers. The case of The Netherlands, **The Annals of Regional Science 24**, 307-318.

Rossera, F. (1990): Discontinuities and barriers in communications. The case of Swiss Communities of different language, **The Annals of Regional Science 24**, 319-336.

Schneider, M. (1959): Gravity models and trip distribution theory, **Papers of the Regional Science Association 5**, 137-176.

Slawski, J. (1990): Model of intervening opportunities as related to the phenomenon of spatial behaviours - its derivations and interpretations, **Prace Naukowe Instytutu Historii Architektury, Szluki i Techniki Politechniki Wroclawskiej 21**, 13-25.

Stouffer, S.A. (1940): Intervening opportunities: A theory relating mobility and distance, **American Sociological Review 5**, 845-867.

Stouffer, S.A. (1960): Intervening opportunities and competing migrants, **Journal of Regional Science 1**, 1-20.