Commuting in multinodal urban systems; an empirical comparison of three alternative models

Lambert van der Laan, Jacolien Vogelzang & Richard Schalke1
Erasmus Centre for Labour market Analysis - ECLA;
Erasmus University Rotterdam.
PO-Box 1738; 3000 DR Rotterdam. The Netherlands.
e-mail: vanderlaan@few.eur.nl

Abstract

The article analyses whether the basic monocentric model of urban structure and commuting explains actual commuting in Europe, i.e. the Netherlands. As in the United States much wasteful commuting is established. The basic model has a low degree of explanatory power. In order to get more in line with actual commuting, the article elaborates two alternatives to the basic model. Besides a deconcentrated model, a cross-traffic model is developed. Particularly the latter is quite successful in explaining actual commuting. The article pleads for endogenizing employment and stresses heterogeneity in labour demand and supply.

keywords: multinodality, the Netherlands, urban models, wasteful commuting, density function, heterogeneity.

1. Introduction

Increasing mobility causes the authorities a lot of worry. Commuter traffic is the major culprit here. In line with a number of other European countries the Dutch government wishes to limit commuter traffic through spatial policy (Vinex 1991; Van der Knaap & Van der Laan 1993). Also in the US, similar policies have been proposed (see for a discussion: Cervero & Wu, 1997). On the one hand, policies should be attuned to the supply of labour, the places of residence, and on the other hand, the focus should be on location policies in relation to labour demand. Both aim at the simultaneous concentration of the place of work and residence. Bringing jobs and housing together may lead to a jobs-housing balance and by this to shorter commuter distances and less traffic.

This issue has a theoretical basis. What matters here is the appropriateness of models used in urban analysis. Traditionally the analysis of commuting used the *monocentric urban model* (Alonso 1964; Hamilton 1982; Yinger 1992). Particularly in urban economics this model, even in its simplist form, is still surprisingly dominant as a research paradigm (Bourne, 1995; Gordon & Richardson, 1996a). The monocentric model starts from the individual or the household, assuming that only one of the household members has a job. Households select, within a daily urban system, a place to live, given the location of employment in the city centre. Spending preferences of households are expressed in the indifference curve: the benefit a household derives from different combinations of goods. Households weigh the pros and cons of certain combinations of costs of housing (land price), commuting and other goods. The same utility function applies to all households. The maximum amount a household can spend is determined by the income. In the model this income is given and spent on housing, commuting and other goods and services. The expenses for living concern the cost of a certain location, in which the price of land is the major variable. The longer the distance to the city centre, the higher the cost of commuting. Together with the utility function, the budget equation determines the place where a household wishes to live.

This basic monocentric model is challenged from at least two sides (see Richardson 1988; Waddell 1993; Boarnet 1994). The *first* criticism is the emergence of polynodal employment locations. The monocentric urban model is based on the city as a daily urban system (DUS) with an urban core and a suburban area surrounding it. The DUS became a synonym for a local urban labour market. The boundaries of this labour market are based on the hierarchical-nodal principle: a dispersed labour supply directed at a central location of labour-demand. Increasingly this conceptual framework is no longer valid. The basic model loses its explanatory power because industry deconcentrates resulting in the emergence of subcentres and by this of polynodal urban regions (see Erickson 1983; Goodschild & Munton 1985; Law 1988; Kumar 1990; Berry & Kim 1993; Clark & Kuijpers-Linde, 1994; Gordon & Richardson, 1996a). There are even studies which point at a next stage in the deconcentration process: the dispersed metropolis (Gordon & Richardson, 1996b). The deconcentration is caused by economic and social-cultural reasons and, particularly in Europe, by governmental interference. Because the traditional hierarchic structure changed into a horizontal one, the urban system cannot be described anymore with the help of the hierarchic model. The traditional duality between centre and suburb disappears and a multi-centred urban area develops. In consequence the traditional nodal model becomes less attractive. This is the reason why recent urban research and models start from the proposition of polynodality. But also in these new models the propositions of the basic model in relation to land rent and costs of commuting are kept. Also maintained is quite always the proposition that the ‘residential choice occurs in an exogeneously system of workplace location’ (Berry & Kim 1993, p.3) and that ‘access to fixed (or exogeneuos) employment is an important factor in explaining residential settlement patterns’ (Boarnet 1994, p.80).

A *second* challenge to the basic monocentric model is the study of actual commuting behaviour and particular the existence of the so called ‘wasteful’ or ‘excess’ commuting. This is the difference between the average distance projected by the monocentric model and the actual average commuting distance. Reason for calling this difference ‘wasteful’ is based on the -normative- starting point, that it reflects non-optimal spatial behaviour which should be avoided. However, one could also say that ‘wasteful’ commuting is the commuting distance which can't be explained by the monocentric model. In this perspective ‘wasteful’ indicates the ineffeciency of this model. This relates to the question after the degree in which the basic model explains actual commuting. Although the term ‘wasteful’ is therefore ambiguous, and even can be misleading, we use it here in this -simplistic- form because it is still central in urban economic modelling. For several cities, studies after ‘wasteful’ commuting have been carried out (Hamilton 1982; Cropper & Gordon 1988; White 1991; Small & Song 1992). This established the shortcoming validness of the propositions of the monocentric urban model. Moreover, these studies showed that wasteful commuting existed to a large extent.

The present article adresses two questions. The first is to what degree the basic monocentric model, analysed mainly for the urban systems of the United States, explains actual commuting behaviour in an European country. Is here also a difference between the distance calculated on the propositions of the basic model and the actual commuting distances? This is the question after the extent of wastefulness of commuting. If this is large, actual commuting behaviour does not fit the assumptions of the basic monocentric model.

The second question is whether, in case much excess commuting exists, the basic model can be adapted to actual behaviour. It is indeed surprising that, as Gordon & Richardson (1996a) rightly declare, ‘though much discussed, decentralization trends have not been satisfactorily *modelled* (as opposed to being described and interpreted) except as very partial frameworks’ (p.1730). ‘The strong evidence of progressive decentralization demands more work on a more relevant model’ (p.1740). In relation to this, the present article analyses two alternatives of modelling new urban systems (see also Yinger 1992; Henderson & Slade 1993). The first alternative model starts from a deconcentrated pattern of employment and is based on the suggestion Hamilton (1982) already made. The supposition of complete concentration of employment is dropped, and a more equal distribution of employment over the urban region is supposed. When jobs are decentralized, a reduction of the total of commuter distances may be achieved. This, however, still within the assumption of the maximization of utility given the budget limits. Also, the supposition of an exponential reduction in employment density with increasing distance from the urban centre still holds. According to this decentralized model the place of work is between the home and the ‘old’ centre. So, commuter traffic is assumed in the direction of the city centre. This first alternative to the monocentric model is called the model of ‘*deconcentrated employment*’.

The second alternative, called the ‘*cross-traffic model*’, starts from a polynodal urban system in which a multifarious oriented traffic pattern exists. In this case work sites are not only more equally distributed over the urban region but the direction of commuter traffic too, is no longer oriented towards the centre of the urban region or towards work sites in the direction of the centre. Also, the supposition of the exponential reduction of employment density as the distance to urban regional centre increases, is dropped. Instead commuters, because they minimize costs of travel, are supposed to concentrate on jobs in the immediate surroundings of their residential location. Particular this second alternative model attempts to model the recent changes in actual urban commuting patterns, as much as possible, within the framework of the basic urban model. In this way, subsequent steps for modelling new urban polynodal systems, can be formulated.

The structure of this article is as follows: first it concentrates on the data and the territorial division used. Next, the three theoretical models are elaborated: the basic model starting from the concentration of employment, the model of deconcentrated employment and the cross-traffic model. Then the models are compared with the actual commuter behaviour in four large urban regions within the Randstad of the Netherlands: Amsterdam, Rotterdam, The Hague, and Utrecht (see Dieleman & Musterd 1992; Cortie, et al, 1992; Frieling, 1994). Finally, the results are evaluated. Answers are given to the questions whether the basic model is still topical and, if not, if it can be adapted in such a way that it fits actual commuting. Moreover indications about the next step in modelling the new urban structures are proposed

2. Data and Commuting Areas

In commuting employees travel forth and back between their homes and their places of work on a daily basis crossing the municipal border. The analysis uses the 1988, 1989 and 1990 Labour Force Survey (LFS; CBS 1993). This is a continuous monthly inquiry annually reaching about 1.1% of the total population. For obtaining a reliable picture of the structural commuting relationships the averages of the three years were taken. Combining the LFS data over these years shows that more than 220,000 people between 15 and 65 years of age are involved. Because the data were combined, changes within those three years could not be examined. The lowest spatial level used in the analysis is that of 469 areas of with each has at least 10,000 inhabitants (CBS 1993). In the rest of the article these areas are called municipalities. Data on distances commuted were obtained by linking a distances matrix to the LFS-files. For each respondent the distance between municipality of residence and municipality of employment was determined.

The delineation of a daily urban system is of crucial importance for the results of the model calculations. Basically two alternatives for this delineation exist. On the one hand the existing political-administrative division of daily urban systems can be used, on the other hand, the delineation can be based on the actual functional relations of the municipalities involved in commuting. For reasons concerning the availability of data most research uses the first alternative of existing administrative divisions. This, however, implies that relationships with areas outside a certain division will not be part of the analysis, eventually leading to wrong model estimates. Therefore we developed an empirical functional division of urban regions. Starting point for the functional regional division is that the areas created are both living and working areas. It is a major consideration that 'the bulk of residents are employed within the area while the bulk of jobs in the area employ residents' (Campbell & Duffy, 1992, p.7). We start from the assumption that, although individual differences among demand and supply exist, aggregation of individual demand and supply is possible. This assumption is based on a homogeneous view of the labour market. In this labour markets are spatially limited units where supply and demand meet (Hunter & Reid 1968; Van der Laan 1991). The method used here is based on the principle of self-containment which assumes that there will be high rates of commuting within a defined geographical area and low rates of commuting with areas outside (see Smart, 1974; Cervero, 1995). Crucial in this is the criteria for 'high' and 'low'.

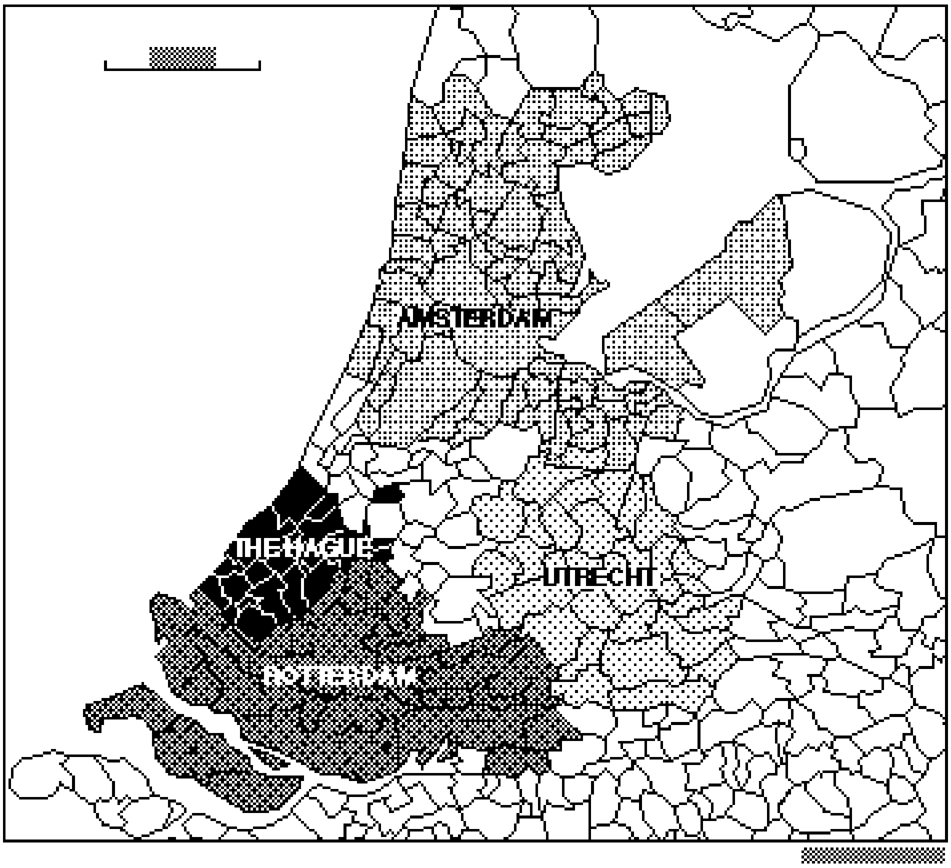
To come to the correct delineation of the four largest urban regions in the Randstad area, we at first made a nation-wide division of commuter areas. The procedure consists of nine steps (Van der Laan & Schalke, 1996). The results of the steps taken are shown in brief in table 1.

Table 1 Steps taken in the development of commuter areas

step number	0	1	2	3	4/5/6	7	8	9
number of municipalities not yet clustered	469	203	203	151	105	105	18	0
number of clustered municipalities	0	266	266	318	364	364	451	469
% municipalites clustered	0	56.7	56.7	67.8	77.6	77.6	96.2	100
number of clusters	0	71	56	56	56	47	31	31

The procedure led to a national division into 31 commuter areas. Among them are the four we use to analyse commuting patterns in the Randstad. Figure 1 shows the size and location of these four areas.

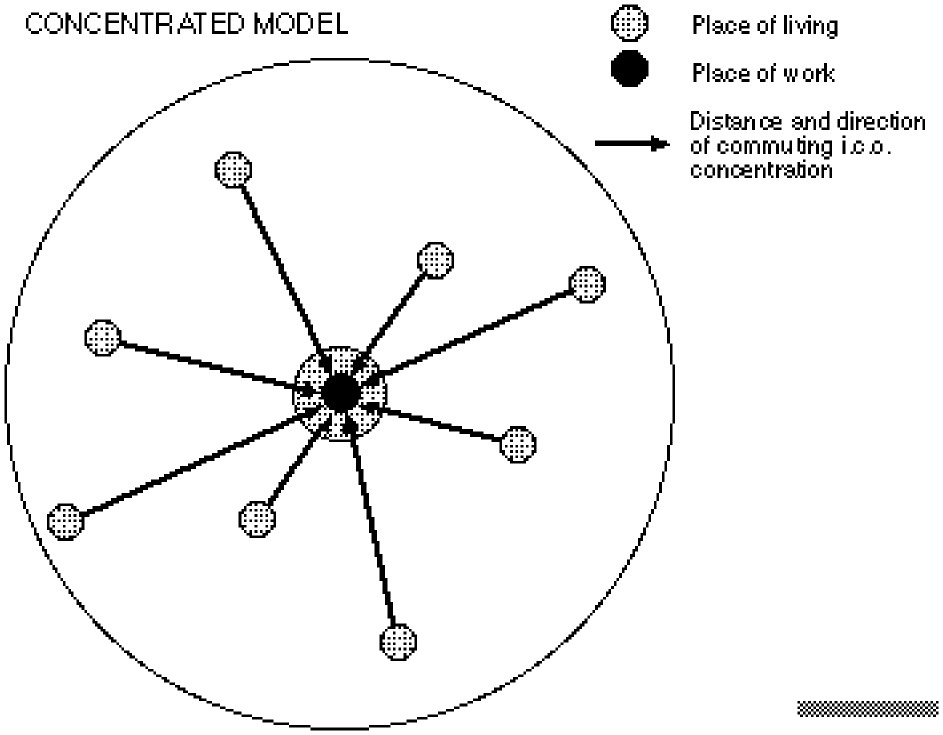
Figure 1 The four large Randstad urban regional commuter areas



3. Model of fully concentrated employment

This section elaborates the basic monocentric model with employment concentrated in one location. Figure 2 shows the direction of commuter flows as presupposed by this model.

Figure 2 Commuter flows in the model of fully concentrated employment



The method for calculating commuter distances on the assumption of fully concentrated employment is a variation on Hamilton (1982). The model predicts the residential location assuming exogeneous employment location. In brief, the method consists of three steps. In the first step the maximum commuter distance of the four urban regions is determined. This is the distance between the edge of the urban region and its centre. Next the potential population density function is determined. By substituting this density function into an integral equation the average commuting distance for each of the urban regions is calculated in a third step. Although to some readers the concepts used in the various steps may be familiar, we elaborate them in some detail because they will be used throughout the rest of the article.

The maximum commuting distance for each of the urban regions

To calculate the commuting distance at full concentration of employment the maximum commuting distance, x_{max}, is determined first. Contrary to Hamilton (1982), who used a limit of 100 people per square mile, we use the edge of the urban region and so, x_{max} is the distance between the city centre and the edge of the urban region. The monocentric model assumes the city centre to be in the middle of a circle shaped area. This implies that, when determining the distance of the city centre to the edge of the urban centre, use can be made of the total surface area of the urban region being the sum of the areas of the different municipalities within the urban region (CBS-view 1989).

The potential population density function

The potential population density function shows the relationship between the distance to the city centre and the place of residence of the potential labour force. Again, in contrast to Hamilton (1982), who starts from the entire population, we use the potential labour force: the population between 15 and 65 years of age. This part of the total population covers the commuters best. Considering the entire population would include also children and old-age pensioners who do not commute. Starting from the presupposition of full employment the potential labour force equals the potential number of commuters. Hamilton used Mill's (1972) ‘population density gradient’, which showed that, the connection between distance and population and between distance and employment, are negative exponential functions. This corresponds to a long tradition of similar findings (see Brueckner 1987; McDonald 1989). The present analysis, too, starts from the assumption that the function for the density of the potential labour force is a negative exponential. By using data on the potential labour force of the municipalities within the four urban regions and the distances of these municipalities to the centre, the density function of the potential labour force is formulated:

$$B(x) = C\,x^{-\tau} \qquad (1)$$

in which:

$B(x)$ = the potential labour force living at a distance x to the city centre; the density function for the potential labour force
C = the constant
x = distance to the centre of the urban region
τ = the distance gradient

The average commuting distance

Given the residential location and full concentration of employment in the city centre, the average commuting distance is similar to the average distance of places of residence to the city centre. The equation enabling us to calculate this average distance is:

$$A = \frac{1}{P} \iint_{x=0}^{x_{max}} x\, B(x)dxdy \qquad (2)$$

in which:

A	=	average commuting distance, given full concentration of employment
x	=	the distance to the centre of the urban region
B(x)	=	the density function for the potential labour force
P	=	the potential labour force in the area
dxdy	=	area within circle at distance x

The potential labour force in the area (P) is:

$$P = \iint_{x=0}^{x_{max}} B(x)\, dxdy \qquad (3)$$

Substituting (1) in (2) results in:

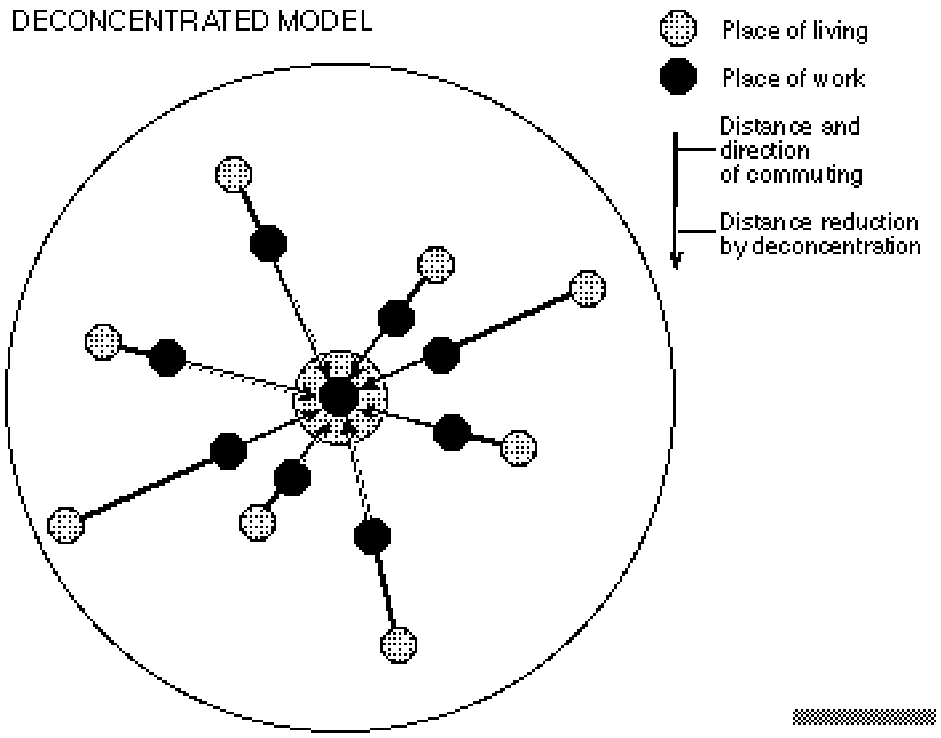
$$A = \frac{2 - \tau}{3 - \tau}\, x_{max} \qquad (4)$$

The integral comprises the entire area between 0 and x_{max} on the horizontal axis, the integration limits and the function B(x). The average optimum commuting distance can be determined with the help of this function and the distance between the city centre and the edge of the urban region. However, there is no potential labour force living at a distance less than one kilometer from the city centre. This area is the location of employment. So the area between 1 kilometer from the centre (x=1) and x_{max} is calculated.

4. The model of deconcentrated employment

The calculation of the distance between place of residence and employment location in the concentrated model is based on a number of assumptions regarding household behaviour and the direction of commuting. On further development of the model, although allowing some degree of deconcentration of employment, these assumptions are maintained. The rational commuter, however, will change either his place of residence or employment in order to minimize the aggregated costs of commuting. Thus, deconcentration of employment may lead to a reduction of the total commuter distance because now employment is nearer to the place of residence. In the deconcentrated model it is assumed that the employment location can be found on the radial between the place of residence and the centre. This is represented in figure 3.

Figure 3 The reduction of commuting distances through deconcentration of employment



For the calculating the reduction in distance in the case of deconcentration of employment, it is once again Hamilton (1982) that we follow. The reduction concerns the distance to the new, deconcentrated employment location. Suppose that, in case of full concentration of employment, a commuter travels 10 kilometers between the place of residence and the employment location, which is the city centre (see figure 3). In case of employment deconcentration the commuter's new employment location is between the city centre and the place of residence, for example at a distance of 7 kilometres of the place of residence. The commuter now no longer needs to cover the distance between the city centre and the new employment location and so the reduction in the commuting distance is 3 kilometres. The equation is, similar to (2), as follows:

$$B = \frac{1}{W} \iint_{x=0}^{x_{max}} x \, W(x) dxdy \qquad (5)$$

in which:

B	=	average distance of deconcentrated employment from the centre of the urban region
x	=	the distance to the centre of the urban region
W(x)	=	the total of employment at a distance x from the centre; the employment density function
W	=	the total of employment within the urban region
dxdy	=	area within circle at distance x

With respect to W(x) the same assumptions hold as in the case of the density function of the potential labour force. The land price is supposed to become lower as the distance to the city centre increases. However, when distances to the city centre increase, the locational advantages go down, too (Alfonso 1964). This implies that the larger the distance to the city centre, the less employment there will be. This connection between employment and distance is again an exponential function (Mills 1972). As this second model also starts from the assumption of full employment, it follows that the number of employed people in a certain municipality equals the number of jobs. So, for calculating the average distance between place of employment and city centre use is made of the number of employed in the different municipalities in the urban regions. W(x) is formulated with the help of the number of employed within the municipalities and the distance between the municipalities and the city centre and is formulated as:

$$W(x) = C x^{-\tau} \qquad (6)$$

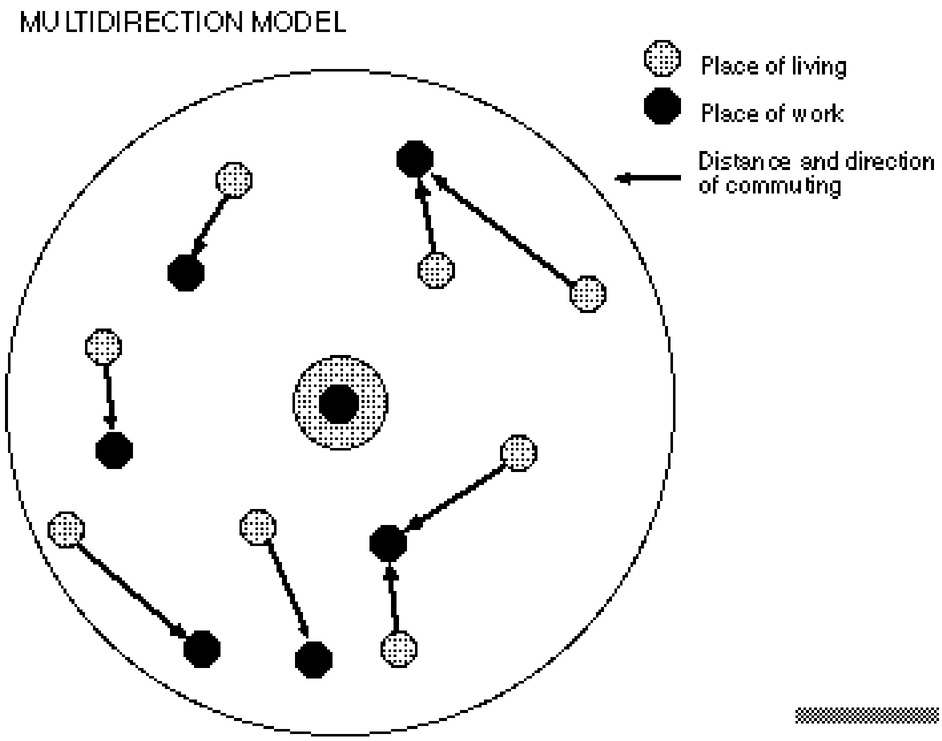
in which :

W(x)	=	the employment density function
C	=	the constant
x	=	distance to the centre of the urban region
τ	=	the distance gradient

By the concentrated and deconcentrated model the minimum commuting distance is determined (Hamilton 1982). This is the difference between the commuting distance at full concentration of employment and the reduction in distance that can be realized in a situation of deconcentrated employment (see also figure 3). We subtract the reduction in distance in the situation of deconcentrated employment (B; see (5)) from the commuting distance in case of full concentrated employment (A; see (2)) (see also figure 3). The supposition that the location of employment in on the radial between the residential location and the urban centre still holds.

5. The Cross-traffic Model

Figure 4 The direction of commuting in the case of cross commuting



The second model of deconcentrated employment still presumes that commuter traffic is directed towards the centre of the urban region: the employment location is found on the radial between the place of residence and the centre of the urban region. It is in this indirect way that the place of residence concentrates on the city centre. As mentioned in the introduction of this article there is, in addition to the radial commuting traffic, increasingly transversal commuting in urban systems. It is possible to compute the average commuting distance starting from this type of transversal cross commuting relations while maintaining the other presuppositions of the monocentric model. In this so-called cross-traffic model the urban region is truly polynodal in character. Commuting is no longer centre-oriented as, in the direct sense, in the concentrated model or, indirect, as in the deconcentrated one. The cross-traffic model assumes that commuters are oriented at the nearest-by municipality. This choice for the nearest-by municipality is based on two assumptions. The first is that, a potential commuter has to commute. This, as such trivial statement, prevents that a potential commuter is oriented at the municipality of living. The second assumption is that commuting is undertaken with a minimization of costs. This assumption prevents that commuters will orientate themselves randomly throughout the daily urban system or at specific job locations. In actual commuting flows, which are described hereafter in section 6, this latter assumption is, of course, removed. Besides these assumptions, the cross-traffic model is also, again, based on the aggregate of the potential labour force and full employment. Figure 4 shows the direction of commuting according to the cross-traffic model.

The model which results from the presuppositions of cross-traffic model is simpler than for the concentrated and deconcentrated models. In the cross-traffic model the average distance of commuting is the weighted average of the number of commuters of each municipality and the distance to the nearest municipality. In this case, population and employment density functions are, of course, not needed. The average distance equation of the cross-traffic model is:

$$C = \frac{\sum_i \sum_j P_i \cdot d_{ij}}{\sum P_i} \qquad (7)$$

in which:

C	=	average distance of the urban region to employment in the nearest municipality
P_i	=	the number of commuters of the residential location $_i$ oriented at the nearest municipality $_j$
d_{ij}	=	the distance between the residential location $_i$ and the nearest municipality $_j$
ΣP_i	=	total number of commuters in the urban region.

6. Actual commuting in the urban regions

Before considering the empirical results of the three different models this section looks briefly at the actual commuter flows. In this, the average actual commuting distances for each of the four urban regions is central. Commuting and distance matrices have been developed for this purpose. The commuting matrix shows the number of commuters travelling back and forth between the municipalities within the urban regions (shown in figure 1). The distance matrix shows the distances by the usual road between the different municipalities. By this matrix and the information on place of residence and employment location each commuter gets a specific distance value (Van der Laan e.a. 1994).

Table 2 Commuting data of the four urban regions

daily urban system	total number of distance km	%	average commuters total	%	average distance pro commuter	distance per km^2
Amsterdam	6878941	54.3	340741	45.4	20.2	2339
Utrecht	1442134	11.4	96290	12.8	15.0	1053
Rotterdam	3174169	25.1	209386	27.9	15.2	1557
The Hague	1168530	9.2	104859	14.0	11.1	2567
Total	12663774	100	751276	100		

Source: Calculations based on CBS (1993)

Table 2 shows that most commuting occurs in the urban region of Amsterdam. The total commuting distance is more than twice as large as in the next urban region, Rotterdam. Utrecht and The Hague are relatively less important. With respect to the number of commuters the differences are smaller, yet quite apparent. There are marked differences in average commuter distance, too. The highest average distance is found in the urban region of Amsterdam: 20.2 km. The average commuter distance in the region of The Hague is only slightly more than half of this: 11.1 km. However, comparing the averages of the actual commuter distance of the four regions is a difficult matter as this strongly depends on the size of the area. Relating the total commuting distance per region to the total area of that same region changes the picture considerably. This becomes clear in the last column of table 2, which shows the number of commuters per square kilometre, representing the commuting intensity for each of the urban regions. It now turns out that The Hague is most commuter intensive. Amsterdam is a good second.

7. Commuting distance in the concentrated model of employment

The following three sections present the results of the theoretical models for each of the urban regions and the comparison with actual commuter flows. First, commuting distance related to the basic model with full employment concentration will be looked at. Next, the outcomes of the deconcentrated model will be considered. The possible reduction in commuting distance will be calculated, assuming the deconcentrated distribution of employment locations. By commuting distances in the case of full concentration, and the reduction realized in the case of deconcentration of employment, the minimal commuting distance is calculated as well as the degree of 'wasteful commuting'. Finally, the cross-traffic model is analysed in a similar way.

Starting with the basic model with full concentration of employment (see figure 2), the region of Amsterdam serves as an example for calculating the commuting distances. With its total area of 2941.32 square kilometres Amsterdam is the largest of the four regions. The first step was the calculation of the distance of the city-centre (x=1) towards the edge of the urban region (x_{max}) with means of equation (2). For Amsterdam this showed up to be 30.6 km. The next step was the potential population density function. The potential labour force (P) in the Amsterdam region is 1,701,104 persons. The constant (C) and the coefficient (τ) are calculated by a loglinear regression.

$$C = \ln 10{,}816{,}546 = 49839$$
$$\tau = -0.28$$

Substituting this in the potential population density function results in:

$$P(x) = \underset{(21.76)}{49839} \quad \underset{(1.94)}{x^{-0.28}} \qquad R2 \approx 0.07$$

(t-values in brackets)

R^2 is the expected exponential relationship between the actual and the expected dispersion of the residential locations of the potential labour force. Starting from the potential population density function, together with distance x and the total potential labour force, the average distance of commuting in case of a concentrated pattern of employment is calculated (see equation (2) with limits x=1 and x_{max}).

The results for Amsterdam and the three other regions are presented in table 3, which shows that in The Hague the average distance is the lowest and in Utrecht the highest. The level of explanation of the concentrated model for The Hague reaches a level of 0.65. Amsterdam scores very low and clearly distinct from that of the others. Actual commuting in the region of Amsterdam differs substantially from the suppositions of the concentrated model. Moreover, the table shows that if C is higher, τ becomes higher too: the gradient becomes more negative. Particular τ can be related to the level of suburbanization of the various urban regions. An urban region is more suburbanized as τ lessens with the extreme case of $\tau = 0$, in which density is uniform (see Mills 1992). The table shows that Amsterdam has the most flat overall pattern of the population density. This parallels other studies in which the Amsterdam region, followed by Utrecht, is characterised as more 'advanced' in the deconcentration process than Rotterdam and The Hague (see Van der Laan, 1998).

Table 3 **Average commuting distance for the four urban regions in the case of a concentrated employment pattern**

	Amsterdam		Utrecht		Rotterdam		The Hague	
- constant C	49839		80971		159002		216230	
- τ	-0.28		-0.59		-0.70		-0.95	
- P (x)	49839 $x^{-0.28}$		80971 $x^{-0.59}$		159002 $x^{-.70}$		216230 $x^{-0.95}$	
	(21.76)	(-1.94)	(29.84)	(-4.66)	(28.70)	(-5.21)	(25.45)	(-5.01)
- R^2	0.07		0.47		0.44		0.65	
- A	6.1		7.3		7.2		4.1	

8. Commuting distance in the deconcentrated model of employment

Similar to the concentrated model we illustrate the deconcentrated model again with the Amsterdam region. Also in this case, with means of a loglinear regression, at first, (C) and (τ) are calculated:

$$C = \ln 11{,}188{,}053 = 72262$$
$$\tau = -0.66$$

Substituting this in the employment density function shows the relation between locations of employment and the centre of the urban system:

$$W(x) = \underset{(17.15)}{72262}\ \underset{(-3.42)}{x^{-0.66}} \qquad R2 \approx 0.19$$

The level of explanation by this model is somewhat higher then in case of basic model, but still only 19 percent. The total number of jobs (W) is 942,710. By this information and by using the distance from the centre towards the edge of the system, it is possible to solve equation (5). For Amsterdam, the average distance of the deconcentrated employment locations towards the centre is 5.6 km implying that the average distance of commuting can be reduced to 5.6 km. Table 4 shows, next to Amsterdam, the results for the other urban regions.

Table 4 Average commuting distance for the four urban regions in the case of a deconcentrated employment pattern

	Amsterdam		Utrecht		Rotterdam		The Hague	
- W (x)	$72262\ x^{-0.66}$		$55502\ x^{-0.78}$		$86347\ x^{-0.85}$		$137949\ x^{-1.04}$	
	(17.15)	(-3.42)	(22.91)	(-4.85)	(23.34)	(-5.39)	(20.07)	(-4.53)
- R^2	0.19		0.48		0.46		0.59	
- B	5.6		6.2		6.7		4.0	

(Because C and τ are integrated in W(x) they are, as in table 3, not mentioned separate)

Although the difference with the other regions is less, again, the table shows the lowest level of explanation for the Amsterdam region. In the rank-order of average distance, Rotterdam and Utrecht changed their position. The table shows again the negative relationship between C and τ The distance decay function (τ) is, negatively, steeper if C is higher.

9. Minimal distance of commuting and wasteful commuting

The average distance of the concentrated model minus the reduction in distance made possible in the deconcentrated model leads to the minimal distance (see figure 4). Differences in minimal distance are related to differences in residental and employment locations as reflected by, on the one hand, the potential labour force density functions and, on the other hand, the employment density functions. As table 5 shows, the minimal distance for The Hague is relative small. Utrecht has the largest differences in the location of population and employment.

Table 5 Minimal distance of commuting and wasteful commuting

daily urban system	average distance at concen-tration (km)	reduction in distance at deconcen-tration (km)	minimal commuting distance (km)	Wasteful commuting (km)	(%)
Amsterdam	6.1	5.6	0.5	19.7	97.5
Utrecht	7.3	6.2	0.9	14.1	94.0
Rotterdam	7.2	6.7	0.5	14.7	96.7
The Hague	4.1	4.0	0.1	11.0	99.1

The difference between the actual average distance (see table 2) and the minimal distance is the ‘wasteful’ or ‘excess’ commuting (see table 5). It is the number of kilometers which don't have to be covered when the presuppositions of the concentrated model are satisfied. Or, in other words, it is the commuting distance which can't be explained by the concentration model. This relates to the first main question of this article after the degree the concentration model is able to explain actual commuting distances. Table 5 shows that wasteful commuting is very large. About 96 percent of the actual commuting distance within the four urban regions is wasteful. Although not surprising, the conclusion must be, that the concentrated model dramatically fails to explain actual commuting distances.

Two causes are responsible for this. The first is the failure of the supposition of an exponential decrease of the population and employment densities. Only a small proportion of the actual distances is explained by the respective density functions. Table 6 shows the correlation coefficients of the population and employment density functions with actual distances (see also table 3 and 4). The coefficients are particular low in the Amsterdam region. For this region the population density function only amounts to 7 percent, but also for other regions the relationship is not clear. The highest is the Hague with 65 per cent. The employment function shows a similar picture. Causes for the deviation between actual distances and the supposed ones are, for example, that the centre of the region is actually not exactly in the middle and that the region itself is not circular.

Table 6 **The relationship between the potential population and employment density functions and actual distances (correlation coefficients - R2)**

daily urban system	Potential population	Employment
Amsterdam	0.07	0.19
Utrecht	0.47	0.48
Rotterdam	0.44	0.46
The Hague	0.65	0.59

Another reason for the failing of the basic concentrated model is, of course, that actual behaviour of commuters does not satisfy the presuppositions of the model. Because the monocentric model starts from rather rigid presuppositions, the removal of these, lowers the degree of wastefulness and by this increases the level of explanation by the adapted model. That all commuting is towards the centre is one of these presuppositions. Wastefulness should be seen in a broader framework of ‘other factors’ which co-determine the locational choice (Waddell 1993). If these are incorporated in a model which determines the minimal distance, it is possible to increase its explanatory power. One such effort is the cross-traffic model. This model makes room for traffic not - direct or indirect - oriented at the centre of the urban region and is connected to the second main question of this article: is it possible to adapt the basic model in such a way that it becomes more in accordance with the actual behaviour of commuters?

10. The cross-traffic model

In the present situation, with more and more polynodality, it is increasingly plausible that wasteful commuting results from cross-commuting. That is, commuter traffic is going in other directions than towards the centre of the urban region. As discussed, the commuting distance in the case of cross-traffic is calculated from the potential labour force per municipality and the distance towards the nearest-by municipality. The neighbouring municipality with the shortest distance by the usual road is selected. The figures for the distances of each municipality were added up for each of the urban regions and, related to the entire potential labour force of those regions. All other presuppositions still hold. This also includes that employment location is still exogeneous to population location.

Table 7 Commuting distances and wasteful commuting by the cross-traffic model

daily urban system	Actual distance (km)	The cross-traffic model (km)	Wasteful commuting (km)	(%)
Amsterdam	20.19	8.00	12.19	60.4
Utrecht	14.98	7.63	7.35	49.1
Rotterdam	15.16	7.92	7.24	47.8
The Hague	11.14	6.06	5.08	45.6

Table 7 shows that including cross-commuting leads to a considerable reduction of wasteful commuting. The percentage of excess kilometres is reduced to about half of the actual commuting distance. Wasteful commuting was clearly higher in the other models. Particularly The Hague, with a percentage of slightly over 45%, now shows a considerable reduction in wasteful commuting. The value of Amsterdam is still relatively high: 60.4% but considerably lower. Starting from a polynodal urban region with cross-traffic results inevitably in a considerable improvement of the explanatory power of the basic model. This is the affirmative answer to the second main question of this article. The adapted model is more in accordance with actual commuting behaviour.

11. Conclusions

This article examined two questions. The first was to what extent the basic monocentric urban model explains commuting distances within European urban areas. Is there a difference between the commuting distance calculated on the basis of this model and the actual commuting distance? The analysis shows that less than 4 % of the actual commuting distances is explained by the concentrated urban model. So the answer to the first question is negative.

As the basic model starts from restricted assumptions regarding the direction of commuting and commuter behaviour, a large part of the failure of the model, can probably traced back to these assumptions. Therefore, the second question concerns the possibility of adjusting the basic model in such a way, that it is more similar to the population's actual behaviour. This would lead to a reduction in wasteful commuting and by this in a higher level of explanation of the adapted urban model. Two alternatives were analysed for that purpose. The first starts from the deconcentration of employment at locations on the radial of the residential locations towards the centre of the city region. In this case only a slight improvement in the explanation was achieved. Leaving aside the presuppositions regarding the direction of commuting, and considering polynodality and cross commuter traffic instead, lead to a second alternative. The results of this cross-traffic model show, that this is the case, indeed, the share of wasteful commuting or, in other words, that part the other models could not explain, decreased considerably. Adjustment of the model made the explanatory degree go up from 4% to 40 to 55%. Thus the answer to the second question is affirmative.

Although the cross-model results in a considerable increase in the explanation of the commuting distance, a large part still cannot be explained. This is partly due to misspecifications of the density functions for employment and population. With respect to the latter it would be desirable to use data on the actually working population. For, a part of the potential labour force is, for reasons of for example further studies, unemployment or incapacity, not actively working and by this not commuting. A further restriction to the actively employed will also present a clearer picture regarding the decision to commute.

Another potential improvement of the explanatory level is the specification of distance. In the models presented here distance was defined as the shortest road distance. However, commuters possibly do not act in relation to this distance, but more likely to the time spent on commuting. Unfortunately, we did not (yet) dispose of data on actual (or perceived) travel time, but it is our impression that the inclusion of this in modelling would indeed increase the explanatory power. Moreover, commuter behaviour is not just affected by the costs of housing and commuting as included in the models discussed. Other aspects are important too, like age, education, household stage, living environment, availability of housing, the presence of certain kinds of transport and governmental policies. As these aspects affect different groups of commuters in different ways, analyses of urban commuting behaviour need to consider this heterogeneity of labour supply (see Cervero & Wu, 1997).

Related to this is also the misspecification of employment location. Two aspects are crucial in this. Firstly, there is the assumption of exogeneity of employment to population location. Several studies suggest, however, that present urban employment location increasingly becomes endogeneous to population (Simpson, 1987; Giuliano & Small 1991; Boarnet 1994). Not only do people follow jobs but also do jobs follow people. Secondly, in addition it is suggested that, as with population, heterogeneity of employment is important (Thurston & Yezer 1994). This implies that estimates of employment location decisions, and whether the latter should be modelled exogeneous or endogeneous, differ by type of industry. It is this heterogeneity in both employment and residential location and its spatial separation which causes widening jobs-housing imbalances and counteract governmental urban policies aimed at reducing spatial demand-supply mismatches. Therefore further research has to concentrate on the topic of heterogeneity.

Note

1 The authors wish to thank Hans Kuiper, Jean Pealinck and Wilfred Sleegers for their remarks on a earlier version of this paper.

References

Alonso, W. (1964), Location and Land Use: Toward a General Theory of Land Rent. Cambridge, Mass: Harvard University Press.

Berry, B.J.L. & H-M. Kim (1993), Challenges to the monocentric model. Geographical Analysis, 25-1, pp.1-4.

Boarnet, M.G. (1994), The monocentric model and employment location. Journal of Urban Economics, 36, pp.79-97.

Bourne, L.S. (1995), Reinventing the suburbs: old myths and new realities. Presentation to the Presidential Panel of the IBG. Newcastle-upon-Tyne. January.

Brueckner, J. (1987), The structure of urban equilibria: a unified treatment of the Muth-Mills model. In: E. Mills (ed.) Handbook of Regional and Urban Economics. New York: North-Holland.

Campbell, M. & K. Duffy (1992), Local Labour Markets: Problems and Policies. London: Longman.

CBS-view (1989) Voorburg/Heerlen: Centraal Bureau voor de Statistiek.

CBS (1993), Enquête Beroepsbevolking Woon-werk verkeer 1987-1990. Voorburg/Heerlen: Centraal Bureau voor de Statistiek.

Cervero, R. (1995), Planned communities, self-containment and commuting: a cross-national perspective. Urban Studies, 82-7, pp.1135-1161.

Cervero, R. & K-L. Wu (1997), Polycentrism, commuting, and residential location in San Francisco Bay area. Environment & Planning A, 29-5, pp.865-886.

Clark, W.A.V. & M. Kuijpers-Linde (1994), Commuting in restructuring urban regions. Urban Studies, 31-3, pp.465-483.

Cortie, C.; M. Dijst & W. Ostendorf (1992), The Randstad a metropolis? Tijdschrift voor Economische en Sociale Geografie, 83-4, pp.278-288.

Cropper, M.L. & P.L. Gordon (1991), Wasteful commuting: A Re-examination. Journal of Urban Economics, 29, pp.2-13.

Dieleman, F.M. & S. Musterd (1992), The Randstad: a research and policy laboratory. London: Kluwer Academic Publishers.

Erickson, R.A. (1983), The evolution of the suburban space economy. Urban Geography, 4-2, pp.95-121.

Frieling, D.H. (1994), Development of a multi-centred metropolis: from physical planning to investment strategy. Tijdschrift voor Economische en Sociale Geografie, 85-2, pp.171-175.

Giuliano, G. & K.A. Small (1991), Subcenters in the Los Angeles region. Regional Science and Urban Economics, 21, pp.163-182.

Goodschild, R.N. & R. Munton (1985), Development and the Landowner: an analysis of the British Experience. London: Allen & Unwin.

Gordon, P. & H.W. Richardson (1996a), Employment decentralization in US metropolitan areas: is Los Angeles an outlier or the norm? Environment & Planning A, 28-10, pp.1727-1743.

Gordon, P. & H.W. Richardson (1996b), Beyond polycentricity; the dispersed metropolis, Los Angeles 1970-1990. Journal of the American Planning Association, 62-3, pp.289-295.

Hamilton, B.W. (1982), Wasteful Commuting. Journal of Political Economy, 90-5, pp.1035-1051.

Henderson, V. & E. Slade (1993), Development games in non-monocentric cities. Journal of Urban Economics, 34, pp.207-229.

Hunter, L.C. & G.J. Reid (1968), Urban worker mobility. Paris: OECD.

Knaap, G.A. van der & L. van der Laan (1993), Urban revitalization in the Netherlands: current trends versus actual policies. European Planning Studies, 1-4, pp.484-497.

Kumar, A. (1990), Impact of technological developments on urban form and travel behaviour. Regional Studies, 24-2, p..137-148.

Laan, L. van der (1991), Spatial Labour Markets in the Netherlands. Delft: Eburon.

Laan, L. van der (1998), Changing urban systems; an empirical analysis at two spatial levels. Regional Studies 32-3, pp. 235-247.

Laan, L. van der, S.C. de Groot, J.W.A. Arissen, R. Schalke (1994). Beroepsbevolking, Forensisme en Mobiliteit. Projectrapport 1, de regionale structuur van het forensisme. Rotterdam: Economisch-Geografisch Instituut Erasmus Universiteit Rotterdam.

Laan, L. van der & R. Schalke (1998), Regionale arbeidsmarktgebieden in Nederland. Planning, 98- , (forthcoming).

Law, C.M. (1988), The uncertain future of the urban core. London: Routledge.

McDonald, J.F. (1989), Econometric studies of urban population density: a survey. Journal of Urban Economics, 26, pp.361-385.

Mills, E.S. (1972), Studies in the Structure of the Urban Economy. Published for Resources for the Future, Inc. The Johns Hopkins Press: Baltimore.

Mills, E.S. (1992), The measurement and determinants of suburbanization. Journal of Urban Economics, 32, pp.377-387.

Richardson, H.W. (1988), Monocentric vs. policentric models: the future of urban economics in regional science. Annals of Regional Science, 32, pp.1-12.

Simpson, W. (1987), Workplace location, residential location, and urban commuting. Urban Studies, 24, pp.119-128.

Small, K.A. & S. Song (1992), Wasteful commuting: A resolution. Journal of Political Economy, 100-4, pp.888-898.

Smart, M.W. (1974), Labour market areas: uses and definition. Progress in Planning, 2-4, pp.239-353.

Thurston, L. & A.M.J. Yezer (1994), Causality in the suburbanization of population and employment. Journal of Urban Economics, 35, pp.105-118.

VINEX (1991), Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Vierde Nota over de Ruimtelijke Ordening Extra: Op weg naar 2015: deel 3. kabinetsstandpunt. Tweede Kamer, vergaderjaar 1990-1991, 21879, nrs.5-6. The Hague: SDU.

Waddell, P. (1993), Exogenous workplace choice in residential location models: is the assumption valid? Geographical Analysis, 25-1, pp.65-82.

White, M.J. (1988), Urban Commuting Journeys Are Not ‘Wasteful’. Journal of Political Economy, 96-5, pp.1097-1110.

Yinger, J. (1992), City and suburb: urban models with more than one employment center. Journal of Urban Economics, 31, pp.181-205.