Faculteit der Economische Wetenschappen en Econometrie

Serie Research Memoranda

Accessibility of Cities in European Infrastructure Networks;
A comparison of approaches

F. Bruinsma
P. Rietveld

Research-Memorandum 1993-18
april 1993

vrije Universiteit *amsterdam*

ACCESSIBILITY OF CITIES IN EUROPEAN INFRASTRUCTURE NETWORKS; A comparison of approaches

Frank Bruinsma
Piet Rietveld
Faculty of Economics
Vrije Universiteit
Amsterdam, Netherlands

Summary

This paper deals with the importance of accessibility as a factor influencing locational decions of firms at a European level. A comparative analysis will be carried out of studies dealing with this issue. Attention will be paid among others to the importance of international accessibility in comparison with the quality of local transport infrastructure. Also, the importance of non-transport factors (e.g. quality of office space or cost of labour) will be discussed.
In the second part of the paper we will compare the results of three recent studies on the accessibility of about 40 European cities:
-Erlandsson and Törnqvist, who measure the total number of people who can be visited from a certain city on a return trip in one day with a duration of stay of at least four hours
-Healey and Baker, who present subjective estimates of experts on the accessibility of European cities
-Bruinsma and Rietveld who compute accessibility measures based on a gravity type model.

CONTENTS

1. INTRODUCTION

The industrial revolution which took place in Europe about 150 years ago had a strong impact on the spatial distribution of economic activity. The advantages of the economies of scale in production induced the emergence of large industry based cities at favourable locations: sources of raw materials, centres of demand and transshipment points. Adequate transport infrastructure networks (ports, waterways, and railways) were a necessary condition for the successful development of cities.

Later developments in technology and transport led to a certain spatial diffusion of large scale industrial production. The construction of extensive highway networks in the second part of the twentieth century did not only improve the accessibility of large cities, but also strongly improved accessibility of small cities and rural areas. Also telecommunication services greatly improved during this period. It became increasingly possible to separate the locations of production and control in industrial production. An interregional and international division of labour emerged where production takes place at locations with low production costs and adequate transport infrastructure, and where the control functions are located in urban areas with excellent transport and communication infrastructure.

This has led to a change in the character of many large cities in Europe. The share of employment in manufacturing activities has decreased considerably; at the same time the share of the service and distribution sector has increased. This is not only the consequence of the growth of the share of civil servants in employment, but also the consequence of information related activities in cities. It are office quarters rather than industrial areas which determine the profile of most large cities. Information related activities do not only occur in the form of corporate headquarters, but also as research and development laboratories, educational institutions, congress centres and high tech production plants.

Given the economic importance of the above activities (and their perceived attractivity from an environmental viewpoint) European cities have made considerable efforts to improve their competitive position in order to attract activities of this type. The degree of competition has been strengthened by the further reduction of trade barrriers and the harmonization of fiscal and economic policies in the EC context. This makes the question important as to what is the present quality of accessibility of European cities in interregional and international transport networks.

In this contribution we will first discuss the issue of the importance of accessibility in transport networks as a factor determining the development of cities (section 2). In section 3 we will carry out a comparison of approaches to measuring accessibility of cities. About fourty cities will be covered.

Concluding remarks are made in in section 4.

2. THE IMPORTANCE OF ACCESSIBILITY AS A LOCATION FACTOR.

The impact of accessibility on urban development can be analyzed by means of Figure 1. Accessibility itself is related to generalized transport costs, which in its turn is determined by the quality of transport infrastructure. Accessibility is a factor which influences decisions of firms: decisions where to locate or to expand production. As indicated in Fig. 1, there is a two sided relationship between accessibility and the location of economic activity. If some firms decide to locate near a certain city, this will improve the accessibility of the already existing activities and hence of the city as a whole.

Of course, transport infrastructure is not the only factor influencing the attractivity of a city as a location for a firm. Land prices, quality of office space, quality of the labour force, fiscal regimes, attitude of the urban authorities, lengthiness of procedures, quality of life, cultural amnities, etc. also play a role. These factors have to be weighted against the importance of the transport related factors. In addition, it is relevant to know what is the relative importance of the different transport system components: for example accessibility by air versus by car. Another relevant distinction concerns accessibility within an urban area versus interregional and international accessibility.

An example of a study on the relative importance of locational factors at the metropolitan level is given by NSS (1991) for the Randstad (consisting of the

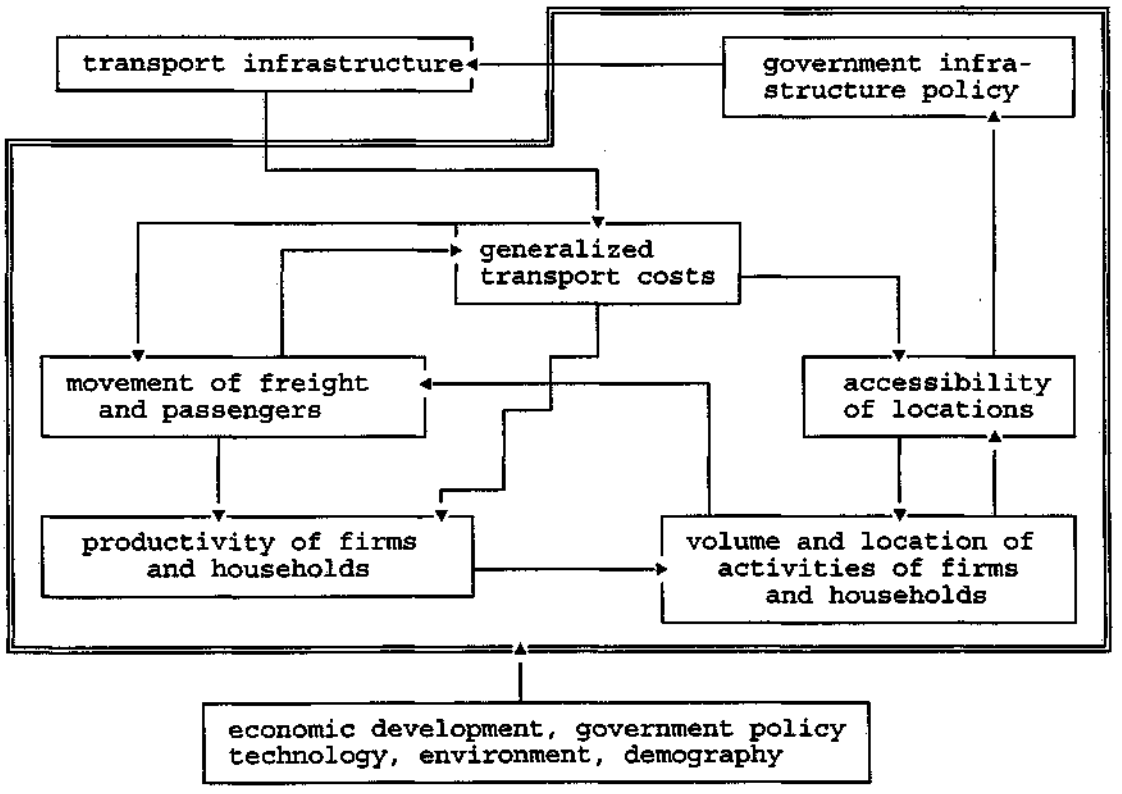

Figure 1. Transport infrastructure and urban development.

urbanized areas around Amsterdam, Rotterdam, The Hague and Utrecht in the Netherlands). A sample of about 1250 entrepreneurs has been asked to indicate the relative importance of 25 locational factors on a scale from 0 to 10. As can be seen from Table 1, there is a group of 11 factors which have clearly higher scores than the rest. Accessibility related variables are strongly present among these: roads, parking, loading/unloading possibilities; telecommunication facilities and services; public transport. The dominant position of road transport is clear. Remarkable are the low ratings for the accessibility of both seaport and airport. It is important to take into account that this result is obtained for firms considering alternative locations within the Randstad. Since all locations in this area are reasonably close to both mainports, it can be understood that they do not play an important role as a location factor within the area. This means that results of this type are not easily transferable from one spatial level to another. If one studies the relative importance of accessibilities at a higher spatial level (interregional, international) one may expect different results.

Table 1. Importance attached to locations and their environment by firms in the Randstad.

accessibility via the road	9.0
parking for visitors	8.4
educational level of staff	8.1
presence telecommunication facilities	7.9
representativeness building	7.3
accessibility by public transport	6.7
rental price	6.7
loading/unloading possibilities	6.1
possibility of expansion	5.8
representativeness of direct environment	5.8
presence of telecommunication services	5.3
presence of firms supplying inputs	3.8
presence of logistical services	3.4
landscape quality	3.2
distance to airport	3.1
presence of educational institutions	3.0
presence of international firms	2.9
distance to seaport	2.6
distance to distribution centre	2.4
presence of similar firms	2.4
distance to customs entrepot	2.2
presence of knowledge centre	2.1
possibilities of combined transport	2.0
distance to waterways for freight transport	1.6
possibility of freight transport by rail	1.1

Source: NSS (1991)

A series of studies on the relative importance of location factors at the interregional level have been reviewed in Bruinsma and Rietveld (1992). In this particular study we pay attention to three studies at the international level: Cheshire (1990), Healey and Baker (1992), and NEI (1987).
Cheshire's analysis deals with a set of about 100 European cities where data refer to functional urban regions in 1988. On the basis of expert judgements an index of urban health has been calculated for each city. A multivariate statistical analysis of changes in the index leads to the conclusion that regional economies strongly depending on coal, agriculture and ports experienced an unfavourable development during the seventies and eighties. For accessibility a positive result was found: cities where accessibility improved experienced a more favourable development than other cities. For accessibility Cheshire uses a gravity based concept similar to the formula used by Bruinsma and Rietveld which will be discussed in section 3. Cheshire's accessibility measure relates to road distances. An important reason why accessibilities change in his model is the extension of the EC in the 1980's leading to relatively large increases in cities located near countries which were formerly not included in the EC. The contribution of changes in this road based accessibility measure to changes in the performance of cities is among the highest of the explanatory variables. The study of Cheshire does not include other types of infrastructure.
Another example of a study where the importance of accessibility for large European cities is studied is NEI (1987). Here the relative importance of location factors is directly based on a priori opinions of experts. A differentiation is made between sectors. For example for the distribution sector the two most important factors are assumed to be: the size of the national market, and the distance to the point of gravity of the European market. At the second position several infrastructure related variables can be found such as:
-proximity to international airport
-proximity to seaport
-connection with international road network
-location near waterway
-connection with international railway network
-accessibility by lorry
-availability of new telecommunication facilities
It must be emphasized, however, that also several non-infrastructure related variables (related for example to fiscal laws and customs procedures) achieve high ranks. The NEI study gives a good review of relevant location factors, but the basis of the relative importance of the various location factors is weak.
Healey and Baker (1990-1992) carried out an analysis of the importance of location factors on the basis of interviews with about 500 large European companies. The results can be found in Table 2. It appears that easy access to markets and clients is mentioned by about 60 % of the companies as an absolutely essential location factor. Also other infrastructure related variables such as international (and interregional) transport links and quality of telecommunications are among the most important location factors. Local transport infrastructure quality is considered as much less important than international transport

Table 2. Importance of location factors to large European firms.

	% of firms mentioning location factor as absolutely essential		
	1992	1991	1990
Easy access to markets, customers or clients	62	61	60
Transport links with other cities and internationally	49	--	--
Transport infrastructure	--	48	57
The quality of telecommunications	43	57	59
Cost and availability of staff	39	34	35
The climate government create for business through tax policies and the availability of financial incentives	34	27	30
Value for money of office space	23	18	22
Availability of office space	22	17	27
Ease of travelling around within the city	22	--	--
Languages spoken	17	15	17
Freedom from pollution		11	- --
The quality of life for employees	10	11	14

Source: Healey & Baker (1990, 1992)

infrastructure. Quality of life and freedom from pollution receive relatively low scores.

The studies reviewed here underline that accessibility is an important location factor at the international level. The scientific foundation of some of the results must be considered as soft, however. There is a clear need for rigorous studies on the impact of accessibility according to various infrastructure types on urban development at the international level. Especially studies using data of the revealed preference type would be most welcome as a complement to stated preference approaches.

3. A COMPARISON OF ACCESSIBILITY MEASURES.

Accessibility of cities can be measured in various ways. In the present section we will discuss and compare three approaches: of Erlandsson and Törnqvist (1991), Bruinsma and Rietveld (1993) and Healey and Baker (1992).

Erlandsson and Törnqvist distinguish inbound and outbound contact potentials. We will use the term 'accessibility' in this context. Inbound accessibility of a city is measured as the total number of people living in urban areas which can travel to that city, stay there for at least four hours, and travel back on the same day. Outbound accessibility of a city is defined in a similar way as the total number of people living in urban areas which can be paid a visit from that city, again with the restriction that the duration of the stay is at least four hours and that the

return trip takes place on the same day. This is indeed a relevant concept for business travel. Generalized costs of communication increase considerably when one has to stay overnight, so that it is really important to know how many people one would be able to visit without the need to stay overnight. A disadvantage of the definition is that 'population' is not always a relevant measure of the economic importance of a city. One would prefer to use the number of workers in particular economic sectors. Especially when international systems of cities are considered with large differences in level of economic development the population size may be a poor proxy. At the European level only population data are available for this purpose. The Erlandsson and Törnqvist measure is based on a joint analysis of all relevant transport modes. Table 3 shows some results for the year 1988. Paris achieves the highest position for both inbound and outbound trips. Remarkable is the second place for Amsterdam for inbound trips. For outbound trips London has the second position. Also Frankfurt achieves high scores. These results underline the dominant importance of the airline system in international accessibility. Very low scores are found for some Eastern European cities. Centrally located cities of small size but with an international airport such as Zürich and Düsseldorf achieve relatively high accessibility scores. In most cases the inbound and outbound accessibility assume similar values. Note that if accessibility would only depend on the road system, inbound and outbound accessibility would be identical.

Bruinsma and Rietveld (1993) define accessibility in the context of a gravity type model (cf. also Keeble et al., 1982). Accessibility of a city is measured as the weighted sum of the population in all cities where weights are equal to the 'travel time decay':

$$Acc_i = \sum_j Pop_j / Travel\ time_{i,j}$$

According to this measure the location of a city at one hour travelling distance contributes more to the accessibility than when that city would be located four hours away. If the travel time parameter is set equal to 1 (this is the parameter value used), the ratio of the weights is 4:1. This measure has been computed by Bruinsma and Rietveld for various transport modes: airlines, railways, road transport, as well as combinations of these. In Table 3 the results of airlines and the combination of all modes is presented for the year 1991. With road transport three different average speeds have been assumed: 30 kilometers per hour within urban areas, 90 kmph on highways and 60 kmph at other connections. For rail and air total travel times also depend on waiting times, which are related to frequencies. The Bruinsma and Rietveld approach shares the disadvantage with the Erlandsson and Törnqvist approach that the importance of cities is measured in terms of population rather than a more relevant economic variable.
If we consider the airline system, Paris and London have clearly higher accessibilities than the other cities. When all modes are taken together, the differences are much smaller and also other cities such as the Ruhr area cities have a high accessibility. The more remote Eastern and Southern European cities receive

Table 3 Accessibility of European cities according to various definitions.

	Bruinsma, fastest travel mode	Rietveld air traffic	Healey & Baker accessibility	Healey & Baker transport infrastructure	Erlandsson, contact potential inbound	Törnqvist contact potential outbound
Düsseldorf	100	69	34	20	83	80
London	98	99	100	97	89	92
Paris	96	100	86	90	100	100
Manchester	91	63	21	8	68	66
Essen	89	60				
Leeds	87	56			58	38
Cologne	87	60			77	65
Liverpool	86	54			46	29
Amsterdam	81	73	29	37	94	88
Brussels	78	74	51	37	87	87
Frankfurt	77	77	79	100	84	91
Birmingham	76	62			65	58
Rotterdam	74	66			86	52
Milan	73	72	33	9	78	79
Berlin	73	75	20	10	76	53
Zürich	73	76	24	24	83	83
Rome	70	73	7	4	65	53
Madrid	70	73	16	6	49	43
Hamburg	70	71	19	8	80	69
Münich	68	70	13	10	64	71
Vienna	68	70	5	5	61	57
Newcastle	67	55			48	36
Lyon	67	65	14	9	61	52
Copenhagen	67	70	6	6	49	57
Istanbul	67	70			14	4
Barcelona	64	67	17	6	40	26
Dublin	63	66			60	51
Turin	62	60	7	3	53	43
Athens	61	64	5		33	5
Boedapest	61	63	5		13	19
Marseille	59	61			45	31
Stockholm	58	60	12	1	54	25
Warsaw	57	58	3		14	14
Prague	57	59	2	1	6	14
Lisbon	57	59	5	1	11	18
Genoa	56	54			17	31
Bucharest	54	56			3	2
Belgrade	53	55			4	6
Naples	53	54			44	12
Zagreb	50	51			4	9
Sofia	49	51			2	1
Lodz	49	49			1	1
Geneva			15	12	76	80
Glasgow			17	6	58	47
Moscow			4		24	29

low scores. Exceptions are large cities such as Athens and Istanbul which owe their relatively high position to their high internal weight.

In the above approaches an effort has been made to measure accessibility in objective terms. An alternative approach is followed by Healey and Baker (1990-1992) who measure perceptions of accessibility, rather than accessibility itself. The averages of scores assigned by corporate leaders to the accessibility of about 25 cities are given in Table 3. The two accessibility variables are: 'easy access to markets, customers or clients' and 'transport links with other cities and internationally'. The variation in outcomes is clearly larger than with the other two approaches. London scores somewhat higher than Paris according to both measures, which may be an indication of a British bias in the outcomes. The gap between the top (London, Paris and Frankfurt) and the rest is remarkably large.

The three approaches are different in various respects, so that it is not surprising to find that they yield different results. One source of difference concerns the choice of the set of cities as well as the way cities are delimitated and their total population size is measured. There is no standard data base for this purpose. Erlandsson, and Törnqvist (ET) include cities in the former USSR, which are excluded in Bruinsma and Rietveld (BR). Healey and Baker (HB) confine themselves to a rather small set of major cities and possible new-comers. The delimitation of urban areas is especially difficult in large city regions such as the German Ruhr area, the Dutch Randstad, and the English Midlands.
A difference between the approaches of Bruinsma-Rietveld and Erlandsson-Törnqvist concerns the treatment of travel time decay (see Figure 2). In the BR approach there is a gradual decay: a halving of traveltime leads to a doubling of the weight for the pertaining city pair. Very remote cities do receive a positive weight, although it may be very small. The contribution of a city to its own accessibility may be considerable for large cities. It explains part of the relatively high rankings of cities such as Istanbul, and Athens, but also Paris and London.
In the Erlandsson-Törnqvist approach on the other hand travel time decay does not occur until the travel time exceeds a critical level (about 6 hours) such that it is no longer possible to spend 4 hours at the location of visit. No further diffe-

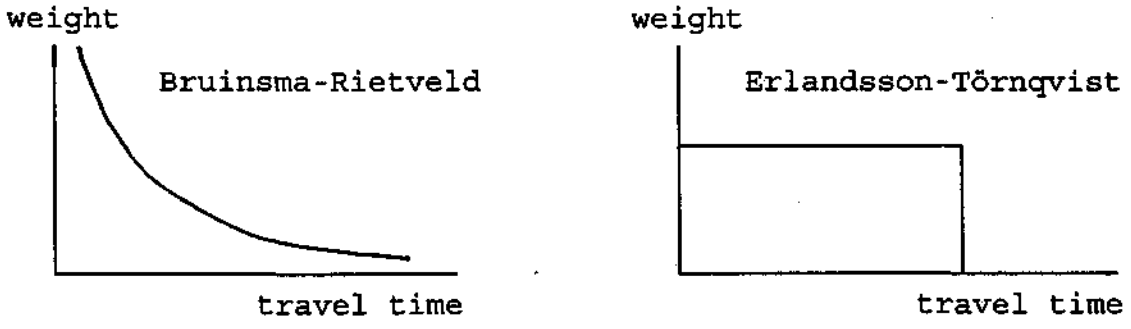

Figure 2. Travel time decay in the Bruinsma-Rietveld and the Erlandsson-Törnqvist model.

rentiation is used within these ranges of travel times. For example, a major improvement of the link between two cities so that travel time is reduced from 5 hours to two hours does not lead to an improvement of the accessibility of these two cities according to the Erlandsson-Törnqvist measure. Another difference between the Erlandsson-Törnqvist and the Bruinsma-Rietveld approach is that in the former attention is paid to a-symmetries in rail and air connections, which is not taken into account in the latter. Indeed it makes a difference when the first flight Copenhagen-Vienna leaves from Copenhagen at 7.30 a.m. or when it only leaves at 10.00 a.m.
Another reason why the measures may differ is that the transport modes considered are different. Erlandsson-Törnqvist consider all transport modes jointly; but in principle it would not be a problem when their approach would be repeated for each travel mode separately, as is done by Bruinsma and Rietveld (BR).

The 6 measures presented in Table 3 can be compared by using correlation coefficients. The results are shown in Table 4, where in the SE part the ordinary Pearson correlations are shown. Spearman correlations based on the ranks are shown in the NW part. The level of the correlations is never lower than .60. The mutual correlations within the ET and the HB clusters are very high. This means for example that inbound and outbound accessibility are very similar in the ET case. In BR a much lower correlation is found between accessibility according to the fastest travel mode and according to air traffic only. The reason of this difference is that the fastest travel mode includes trips to nearby cities which receive a large weight in the gravity formula. It is for the same reason that we find a fairly high correlation between the accessibility with the fastest travel mode in BR and the ET accessibility measures. One might have expected that the HB data have low correlations with each of the other accessibility measures, because the underlying data are so different (travel time data versus perceptions). In reality this does not appear to be the case. Especially the rankcorrelati-

Table 4. Correlations between accessibility measures.

--- Rank Index ---	Bruinsma, Rietveld		Healey & Baker		Erlandsson, Törnqvist	
	fastest	air	access.	infrastr.	inbound	outbound
Bruinsma, Rietveld						
- fastest travel mode	---	.60	.91	.83	.86	.83
- air traffic	.60	---	.77	.77	.77	.78
Healey & Baker						
- accessibility markets	.76	.86	---	.87	.89	.85
- transport infrastructure	.65	.82	.96	---	.88	.91
Erlandsson, Törnqvist						
- contact potential, inbound	.79	.71	.67	.60	---	.94
- contact potential, outbound	.78	.76	.72	.69	.92	---

ons are considerable for the HB data.
The most striking difference between the various approaches to studying accessibility concerns the range of the outcomes. In the Bruinsma-Rietveld approach the scores range from about 50 to 100. In the other two approaches the range is much bigger: from 1 to 100. For example, the outbound accessibility of Lodz is only 1% of that of Paris according to Erlandsson-Törnqvist. These low accessibilities occur in cities in Southern and Eastern Europe. In the remaining cities the scores range from about 50 to 100 with cities like Paris, London, Frankfurt and Amsterdam at the top. The gap between these cities and several other Western European cities such as Brussels, Zürich, Milan and Dusseldorf is very small, however. In this respect the ET result are similar to those of BR.
In the Healey and Baker study the gap between the top three: London, Paris and Frankfurt and the rest is very big. A possible explanation is that in the HB survey respondents only had the opportunity to rank the three most accessible destinations. In a second stage the accessibility scores were computed on the basis of a weighted summation of ranknumbers. A probable consequence is that the differences between the accessibility scores of the cities are overestimated. A city with a reasonable degree of perceiced accessibility will not easily enter the top three of respondents, so that it will receive a very low score in the computational procedure.

4. CONCLUSION.

Various studies based on direct interviews with entrepreneurs indicate that accessibility is an important location factor at the international level. The scientific foundation of some of the results is soft, however. It is desirable that studies based on stated preferences of entrepreneurs are complemented by studies on revealed preferences. This would entail the analysis of real location decisions of firms in the context of accessibility indicators and other location factors.

A comparison of three conceptually different approaches to measuring accessibility of European cities yields that (Pearson and Spearman) correlations are rather high. This suggests that for several analytical purposes the choice for one of the three approaches will not seriously influence the results. It is interesting to note that the perception based accessibility indicators of Healey and Baker have rather high correlations with accessibility indicators based on actual travel times.

Bigger differences are found between the three studies when the relative differences in accessibility are considered.
The range of outcomes in the Bruinsma-Rietveld study is clearly smaller than in the Erlandsson-Törnqvist study and even more so than in the Healey-Baker study. These differences in the range of outcomes can be explained by the differences in the operationalization of the accessibility concept and the measurement procedures. The differences reported by Healey and Baker are most probably overestimated. Nevertheless the rather different results obtained in the

various studies on the range of accessibility scores implies that one has to be cautious with statements about relative differences in accessibility of European cities.

The measurement of accessibility in European networks deserves attention in future studies. One possible direction is to investigate accessibility for specific modes. This would enable one for example to study the impact of the introduction of rapid trains on the European accessibility landscape (see Bruinsma and Rietveld, 1993). Another direction is that accessibility measures are constructed in a sector specific way since each economic sector has its own pattern of relevant communication partners, transport modes and travel time decay.

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