HOW DO PEOPLE GET TO THE RAILWAY STATION; A SPATIAL ANALYSIS OF THE FIRST AND THE LAST PART OF MULTIMODAL TRIPS

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Abstract
The quality of transport networks does not only depend on the quality of the individual links and nodes, but also on the way these nodes and links function in the context of (multimodal) networks. In the present paper we focus on multimodal trips where the railways are the main transport mode. We discuss detour and frequency problems related to multimodal transport chains. Local accessibility of railway stations is an important determinant of railway use in the Netherlands. We find that the propensity to make use of rail services of people living in the ring between 500 to 1000 meter from a railway station is about 20% lower than of people living at most 500 meter away from railway stations. At distances between 1 .O and 3.5 km the distance decay effect is about 30%, and above this distance it may reach values up to 50%. Non-motorized transport modes are dominant at both the home-end and the Activity-end. A rather unique feature of the home-end access mode is the high share of the bicycle. More than one out of every three passengers uses the bike on the trip from home to station. At the activity-end the share of the bike is much smaller, because of the asymmetry in the supply of this transport mode in the home versus the activity-end. This explains the dominant position of walking as the access mode

at the activity-end. Implications are discussed for physical planning and the need for facilities near railway stations.

1. INTRODUCTION

The quality of transport networks does not only depend on the quality of the individual links and nodes, but also on the way these nodes and links function in the context of (multimodal) networks. This means that the success of decisions of owners and operators of network elements concerning investments and services provided will strongly depend on the prevailing conditions in other parts of networks. In principle two cases can be distinguished here: services in a network can function as substitutes or as complements (Roson, 1998). In the first case providers of network services are competing: an improvement of the quality of one of the services (price remaining constant) will lead to a reduction in the demand for other services. In the case of complementarity the reverse holds true: an increase in the quality of a certain service (the price being constant) leads to an increase in the demand for other transport services.

An interesting case of substitution versus complementarity concerns the relationship between rail transport and other transport modes. Within metropolitan areas rail and bus can be both complements and substitutes. When the network structure has been developed in such a way that busses serve as access modes to light rail and metro, the complementarity case would prevail. When on the other hand bus and metro would serve the same origin-destination pairs they would be complements. For inter-regional links in most European countries the complementarity case would prevail: busses serving inter-regional links seldom compete with railways.

In the present paper we will focus on the complementarity between rail and other transport modes. Using the notion of generalized costs it is obvious that a substantial part of the costs of a multimodal public transport trip depends on the non-monetary elements. In addition to the price paid to the operator the traveller has opportunity costs in terms of time lost, costs related to uncertainty (risk of delays), and low levels of comfort. Especially at interchanges the costs related to low comfort levels may be quite high. For example, Van der Waard (1989) finds that the average interchange between modes that is evaluated by public transport travellers to be equal to about 6 minutes travel time in a train. This figure reflects the loss of comfort due to an interchange; in addition it probably includes a valuation of the probability that the traveller will miss his/her connection with the next train or bus. Van der Waard also finds that travel times in the access mode to or from a railway station are weighed more heavily than travel times in the train. For a successful operation of rail services it is therefore of equal importance that the rail services are of sufficient speed and reliability compared with an acceptable level of accessibility of railway stations.

This theme is important for owners of railway infrastructures and operators of railway services from a commercial perspective. It is also relevant for real estate developers and physical planners that consider the feasibility of railway infrastructure as part of urban expansion plans. Accessibility of railway stations is also relevant for metropolitan governments that face problems of congestion on roads and look for multimodal alternatives to reduce demand for car transport. Finally, the theme of multimodality is important from an environmental perspective since when load factors are sufficiently high, a shift from car transport to public transport is beneficial for emissions of various pollutants.

The aim of the present paper is to investigate the spatial aspects of use of railway stations. Based on the Dutch National Travel Survey we will investigate the spatial market areas of railway stations and the relative importance of the various access modes. Special attention will be paid to distance decay in the use of railway services. In section 2 we give a review of some relevant issues in multimodality. In section 3 we discuss modal choice in access modes to and from railway stations. The distributions of distances travelled in the access modes are dealt with in section 4. In section 5 we give a further analysis of the propensity to travel by train as a function of distance of residence from railway stations. Section 6 concludes.

2. REVIEW

Consider a multimodal transport chain linking home H, railway station R_1, railway station R_2 and activity A (see Figure 1). This is obviously a simple example of a multimodal chain. It ignores for example that people may have to walk to the bus stop from where they would go to the railway station. Thus in reality one will often have more than three elements in the chain. The three element case suffices however to demonstrate some basic features of multimodal chains.

H R_1 R_2 A

Figure 1: Multimodal transport chain consisting of three elements

From a competition perspective, travellers usually can choose between various multimodal chains. In addition, on a range of some 1 to 2000 km, for car owners, the car may be an unimodal alternative. Similarly, for bicycle owners unimodal trips by bicycle may be an alternative for trips up to some 10 km. Several potential advantages of multimodal chains can be listed:

- multimodal chains may have better environmental and energy performance than unimodal trips (depends strongly on load factors)
- multimodal chains provide travel opportunities for segments of travellers that do not have a unimodal alternative
- multimodal chains may be cheaper (depends on taxes and subsidies)
- multimodal chains may be faster (especially in congested urban areas and in long distance transport with high speed rail)

Two major disadvantages of multimodal transport have to be mentioned: they may lead to *detours* and to *waiting and rescheduling* (see Rietveld, 1996). Both problems concern discontinuities, i.e. in space (detours) and in time (low frequencies imply waiting and scheduling).

The detour problem is illustrated in Fig. 2a, where the chain between H and A implies a much longer distance travelled compared with the distance as the crow flies. This appears to depend on two critical factors: railway line density and railway station density. The first factor is measured as the ratio of the length of the railway system and the size of an area. It serves as a proxy of the average distance from all points in the area to the nearest railway line. The second factor is measured as the ratio of the number of railway stations on a line and the length of the line. This is the inverse of the average distance between railway stations. In case 2b the detour is smaller because of the higher railway density. In case 2c the higher railway station density is the cause of the smaller detour. It is clear from this picture that the detour problem is most severe in those cases where the total length of the trip is rather small. Hence one may expect that in long distance trips multimodal chains are more attractive than in short distance trips.

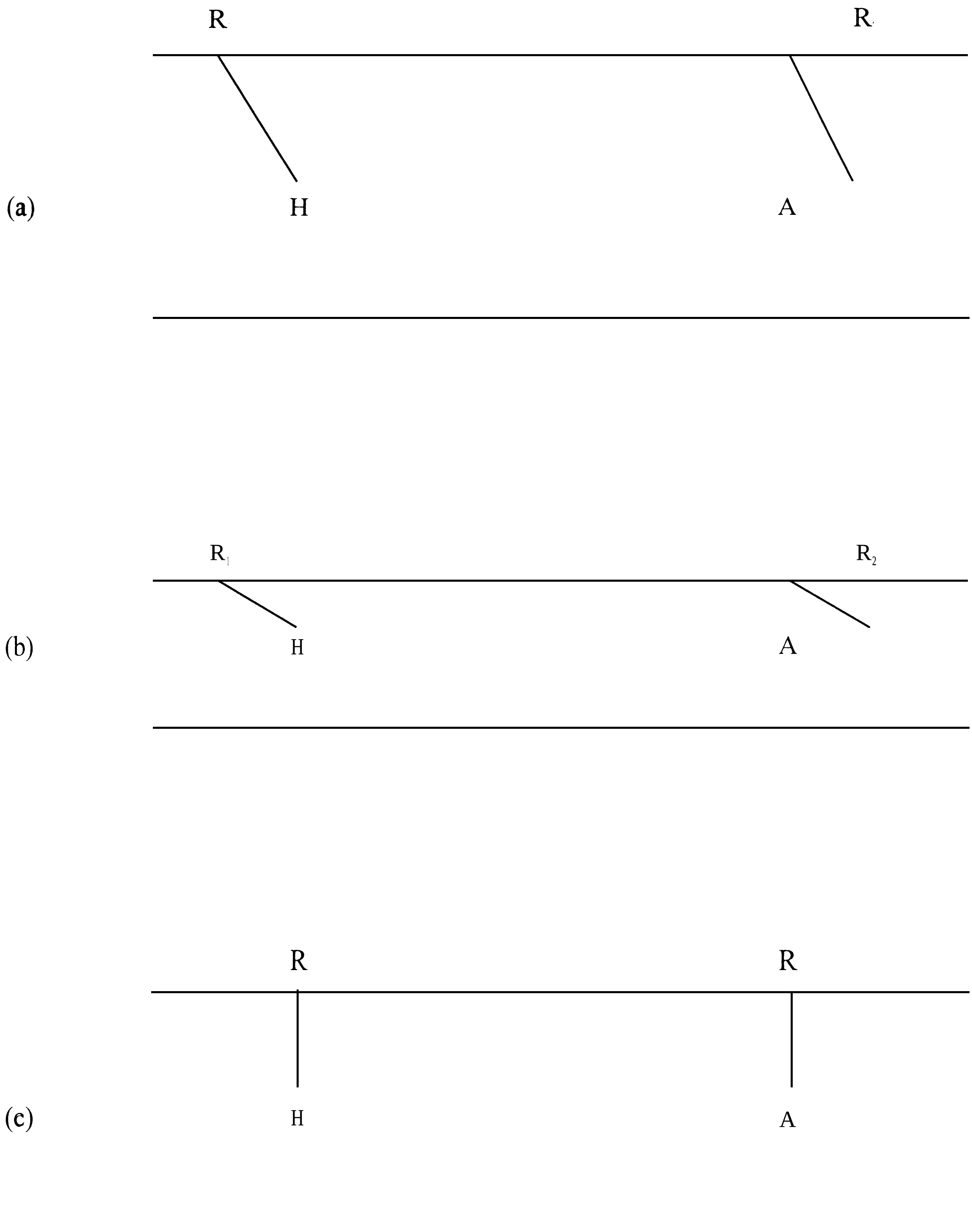


Figure 2: Detours in multimodal trips from H to A as a function ofrailway station density and railway line density

The other disadvantage of multimodal chains is the problem of low frequency. In Table 1 we summarize the various costs related to rescheduling and waiting at the various parts of the trip depending on the frequencies;

Home-end fre-quency	Rail frequen-cy	Activity-end frequen-cy	Home (ab)	Railway station 1 (ab)	Railway station 2 (ab)	Activity location (ab)	Activity location (hb)	Railway station 1 (hb)	Railway station 2 (hb)	Home (hb)
high	high	high	•							
high	high	low	R		W	R	R			R
low	high	high	R			R	R		W	R
low	high	low	R		W	R	R	W	W	R
high	low	high	R			R	R			R
high	low	low	R		W	R	R	W		R
low	low	high	R	W		R	R	W	W	R
low	low	low	R	W	W	R	R	W	W	R

R: rescheduling; W: waiting
ab: activity location bound; hb: home bound

Table 1: Rescheduling and waiting in activity location bound trips (column 4-7) and home bound trips (column 8-l 1) as a function of frequency of transport modes in various parts of multimodal chains

The first alternative shown in the scheme is a seamless public transport: all frequencies are high so that waiting and rescheduling of activities does not occur. As soon as one of the parts of the activity has a low frequency, rescheduling takes place (for the ease of presentation we only distinguish 'high' frequency and 'low' frequency; high frequency means negligible waiting time). Rescheduling may take place both in the activities taking place at home and at the activity location. It means that the length of the activities has to be changed to satisfy the constraints imposed by the public transport operators. For example, it may imply that the times of starting or finishing activities have to be changed, that the travellers have to hurry, and that time may be 'lost' because there may be an interval between the end of an activity and the start of the trip.

The traveller has to trade-off the costs of rescheduling at both sides of the trip. Arriving 15 minutes late at a meeting may be considered as equally unpleasant as arriving 45 minutes early. Such comparisons will have to be linked to the costs at the home side like waking up early. The table clearly shows that as soon as multimodal transport is not seamless it leads to various extra waiting and rescheduling costs. It also leads to the need of planning a trip. Another useful result of table 1 is that it can be employed to investigate the need of facilities for waiting passengers at the transfer points.

In the upper part of the table we show the situation with a high frequency between R_1 and R_2. This is typically the case with a metro or light rail system in metropolitan areas. The lower part of the table deals with low frequency services between R_1 and R,. This usually holds true for intercity railway and aviation services. From the table we can conclude that multimodal chains are especially attractive when high frequency access modes are available. The most obvious high frequency modes are private ones such as car, bike and walking (see Salomon et al., 1993 and Goeverden, 1998). Using these would help to overcome the waiting costs, only the rescheduling costs would remain.

The coordination of schedules of the various operators would be a way to reduce the waiting times in multimodal transport. This may indeed lead to substantial reductions. One should be aware, however, that schedule coordination may lead to problems when services are unreliable, because the probability that one misses a connection may imply a high variance in realized transport times (cf. Rietveld et al, 1998).

Clearly the frequency problem is most severe in the case of chains where total travel time is relatively short. Thus, we arrive at a conclusion, similar with the detour problem: the disadvantages of multimodal chains are smallest in long trips (measured in terms of travel time)

We now focus on a specific issue concerning private access modes. A problem with private access modes like car and bicycle is that there is an asymmetry: usually these modes are only available at the home-end side of the chain, whereas at the activity-end their availability is limited.

For the private car as a transport mode at the activity-end the following alternatives exist:
1. taxi
2. rent a car at railway station
3. relative/friend/business relationship picks traveller up from railways station
4. the car is taken with the train.

The last case seldom occurs. An example is that railways may offer long distance services to take the car to holiday destinations.

For the bicycle as an alternative at the activity-end one may encounter the following alternatives;
1. rent a bicycle at railway station
2. traveller owns a second bicycle that is parked at the railway station
3. bicycle is taken with train (see Bracher and Thiemann-Linden, 1998)
4. pedicab (bicycle taxi in developing countries, see Dimitriou, 1995)

These alternatives usually suffer from problems such as limited availability or high costs so that we conclude that from the viewpoint of availability of continuous access modes the activity-end of the chain usually is a bigger problem than the home-end.

A spatial implication of the above is that of the private modes at the activity-end of the trip only walking remains as an alternative. Since walking is typically a short distance mode an implication is that proximity of the location of an activity to a railway station is an important factor determining the potential for multimodal trips where rail is involved. At the home-end, proximity is also important, but less so compared with the activity-end, since here the other private transport modes such as bike and car may be available.

We conclude that distance of the location of activity (and to a less extent of home) to a railway station is an important determinant of the potential of multimodal transport chains with a rail part as an element. It is to this aspect of distance that the present paper is addressed. In the next sections we report some empirical results for the Netherlands.

3. MODAL CHOICE IN MULTIMODAL TRIPS WHERE THE TRAIN IS THE MAIN TRANSPORT MODE

3.1 The Dutch National Travel Survey

In January 1978 the CBS started to conduct the Dutch National Travel Survey (OVG). This survey contains detailed data relating to the observed trips made by the investigated persons, like transport mode(s), location of origin and destination, travel distance and so on. It also contains data concerning individual features like education, income, age, etc.

For this study the data of the Dutch National Travel Survey from 1994 is used. We have selected all trips with the train as the main transport mode while the destination of the trip is *not* the home base; the number of these relevant trips is 5.405 (0.99% of all the trips).

For these trips, it is analyzed which transport mode has been used for the access to the railway-station at the home-end and to leave the railway-station at the he non-home-end of the trips. The non-home-end we call the activity-end.

However, some data-problems emerge, since in the questionnaire of the Dutch National Travel Survey some transport modes are missing. In the survey it is impossible to fill in the same modal choice for the access to the railway-station at the home-end and at the activity-end. For example, it is not possible to register a trip in which first the bus is used, then the train and finally again the bus. It can also be possible that a trip started or ended so close to the railway-station that the respondent didn't fill in the modal choice, but in this case, the modal choice is walking by definition. In the considered data 8% of the respondents didn't fill in the modal choice at the home-end, and even 28% of the respondents at the activity-end. Because of this problem, assumptions have to be made about the relative importance of both problems. We assume that 10% of the trips where the transport mode is missing started or ended very close to the railway-station, so the transport mode is walking. The other 90% of the missing transport modes at the home-end as well at the activity-end are because of the impossibility to fill in the same transport mode two times in one trip. In this case we have used the same mode at the home-end and at the activity-end of the trip.

3.2 Modal choice at the home- and activity-end

Table 2 gives for the 1994 OVG-data an overview of the modal choice at the home-end in multimodal trips where the train is the main transport mode, including the described correction. The category "other" contains transport modes like motor, scooter or lorry. This result has been completed with the figures of surveys from other years, made by the Nederlandse Spoorwegen (NS):

	1975	1978	1988	1992	1994
bicycle	30%	39%	45%	37%	35%

walk	**35%**	**25%**	**25%**	**26%**	**27%**
bus/tram/metro and taxi	**20%**	**21%**	**18%**	**27%**	**27%**
car (driver and passenger)	**15%**	**12%**	11%	9%	11%
other	0%	3%	1%	1%	0%

Table 2: Modal choice in access to the railway-station at the home-end (Source: NS, CBS)

Table 3 gives an overview of the modal choice at the activity-end:

	1975	**1978**	**1988**	**1992**	**1994**
bicycle	5%	**12%**	**14%**	11%	10%
walk	**55%**	**52%**	**52%**	**41%**	**46%**
bus/tram/metro and taxi	**30%**	**29%**	**23%**	**36%**	**36%**
car (driver and passenger)	10%	7%	11%	7%	7%
other	0%	0%	1%	5%	1%

Table 3: Modal choice in access to the railway-station at the activity-end (Source: NS, CBS)

When we compare tables 2 and 3 we observe the asymmetry problem, discussed in section 2. It is clear that most people come to the railway-station by bicycle at the home-end, but few people use the bicycle to leave the station to go to the activity for which they have made the trip. The main explanation for this difference is the availability problem of the bike. Almost everyone in the Netherlands owns a bike that he can use if he starts the trip and goes to the railway-station. But at the activity-end he cannot use this bike, and to hire a bike at the station is often considered too expensive or just impossible. Also the number of people taking their bike into the train is relatively small.

The same reasoning can be given for the difference in proportions for the car as the modal choice. Most of the passengers will use the public transport if they leave the station at the activity-end, or they go by feet.

Tables 2 and 3 also show that the use of the bike has decreased in the past years at the home-end as well at the activity-end. Another important point is that walking as modal choice at the activity-end has considerably decreased in the past years. The main explanation for this phenomenon is the introduction of the Public Transport Card for students (OV-studenten-kaart). All students in the Netherlands received such a card, with which they can make use of the public transport for free. As a result of that many students changed their mode from the bike or walking into public transport.

Shortly summarized, the most important transport mode at the home-end is the bike, followed by walking and public transport and finally the car. This dominant position of the bike in the Netherlands is rather unique in Europe (Gerondeau, 1997). At the activity-end walking is by far the most important mode, followed by the public transport, the bike and again finally the car. So the use of the car as a modal choice is small compared with the other modal choices.

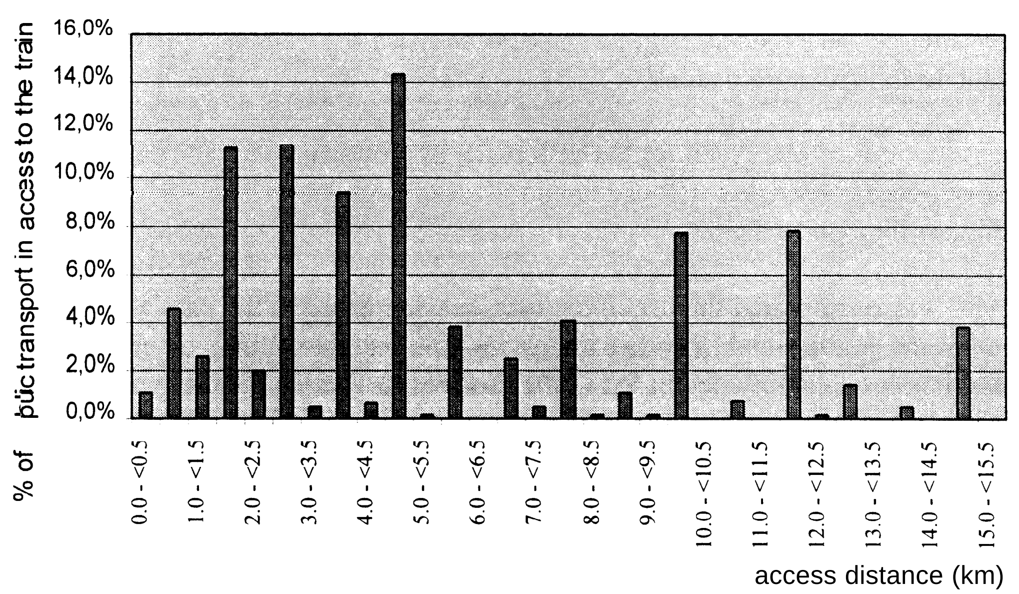
4. DISTANCE TRAVELLED TO RAILWAY-STATIONS

In this section, the travel distance with the transport modes is analyzed. First, in section 4.1 a few corrections in the data from the Dutch National Travel Survey are made. Sections 4.2 and 4.3 describe the relation between travel distance and share of the transport mode at the home-end as well at the activity-end.

The mean travel distance of the train related trips considered equals some 53 km. The mean travel distance from the house to the railway-station (the home-end) is 3.9 km (7.4% of the total trip length) and from the railway-station to the activity (the activity-end), it is 4.1 km (7.7% of the total trip length). The average trip length in the Netherlands is some 10 km. This underlines the finding in section 2 that multimodal trips are most attractive when long distances have to be travelled.

4.1 Corrections in the Dutch National Travel Survey

In the survey, all respondents had to fill out the distance that has been travelled with the various transport modes used in their trip. However, it appears clearly that the respondents have the tendency towards filling in *psychologically easy values* like 5.0, 10.0 or 15.0 kilometers as well as rounded values like 1, 2, 3, . . . kilometers. Graph 1 gives an illustration of this, with the share of public transport as an access mode to the train in relation to access distance.



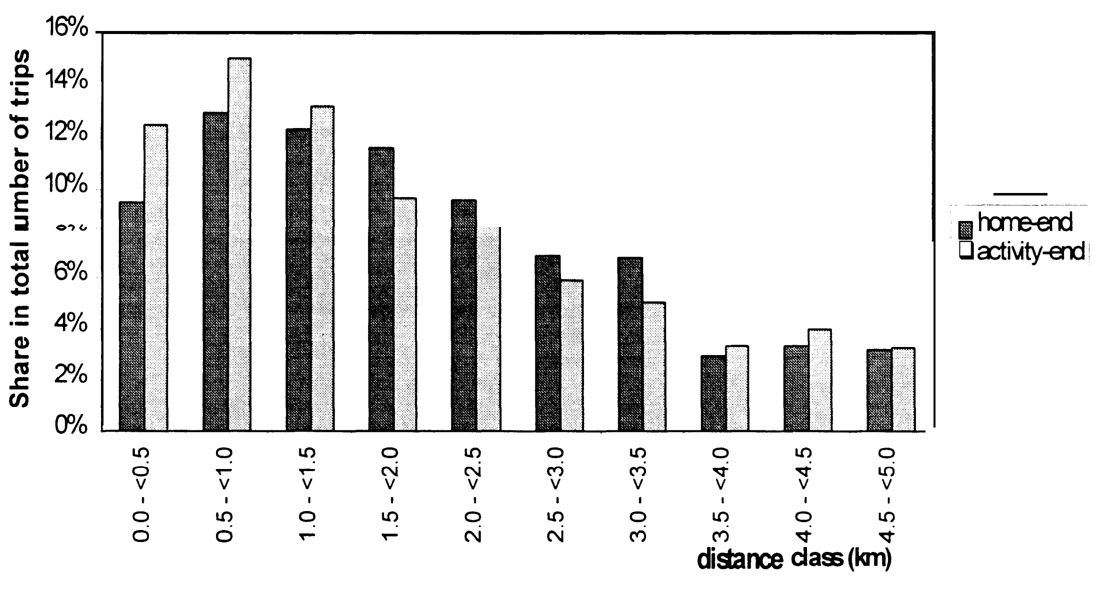
Graph 1: Distribution of travel distances to the railway-station at the home-end of public transport (uncorrected) (Source: CBS)

As graph 1 shows, many respondents have rounded to integer values, so there are large peaks at the distance-classes that contain values like 1 .0, 2.0 or 3.0 km. Also there are extra large peaks at the psychologically easy values like 5.0, 10.0 and 15.0 km.

Of course this distribution is not correct. Therefore, two corrections in the data had to be made:

1. If for example a respondent has filled out an exact value of 1 .0 km, (s)he probably means a value between 0.5 and 1.5 kilometer. So, half of the number of the travelled distances with an exact value of 1 .O km is redistributed to the next distance class (1 .O – <1.5 km). This correction is made for all the travelled distances with an exact value of x.0 km and x.5 km (with x = 0, 1, ..., 15).
2. If a respondent has filled out a psychologically easy value like 10.0 km, (s)he probably means a value between 7.5 and 12.5 km. So, all the psychologically easy values (5.0, 10.0 and 15.0 km) are redistributed to the surrounding distance classes in such a way that the closest classes have the greatest weight. This is done for two transport modes: public transport and car. For walking and the bike this correction was not necessary; persons who are travelling by bike or by feet are probably more aware of the (small) exact value of the travelled distance than those who are travelling by public transport or by car.

In the following of this paper these corrected values are taken for granted. Graph 2 presents the result for the aggregate of all access-modes.



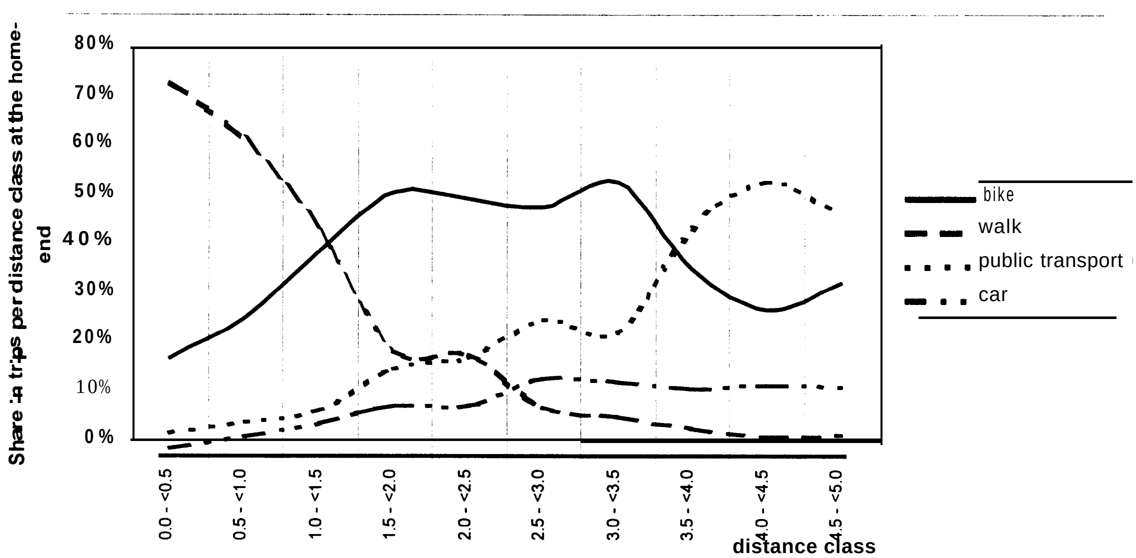
Graph 2: Distribution of travel distance to and from railway-station, all access modes corrected (Source: CBS, processed)

As graph 2 shows, relatively many of the trips have their *destination* in the first three distance classes, whereas the *origin* of the trips is more evenly distributed in the first seven classes. It appears that **79%** of all trips start at the home-end within a distance of 5.0 km from the railway-station, and 80% of all the trips have their destination within a distance of 5.0 km from the railway-station.

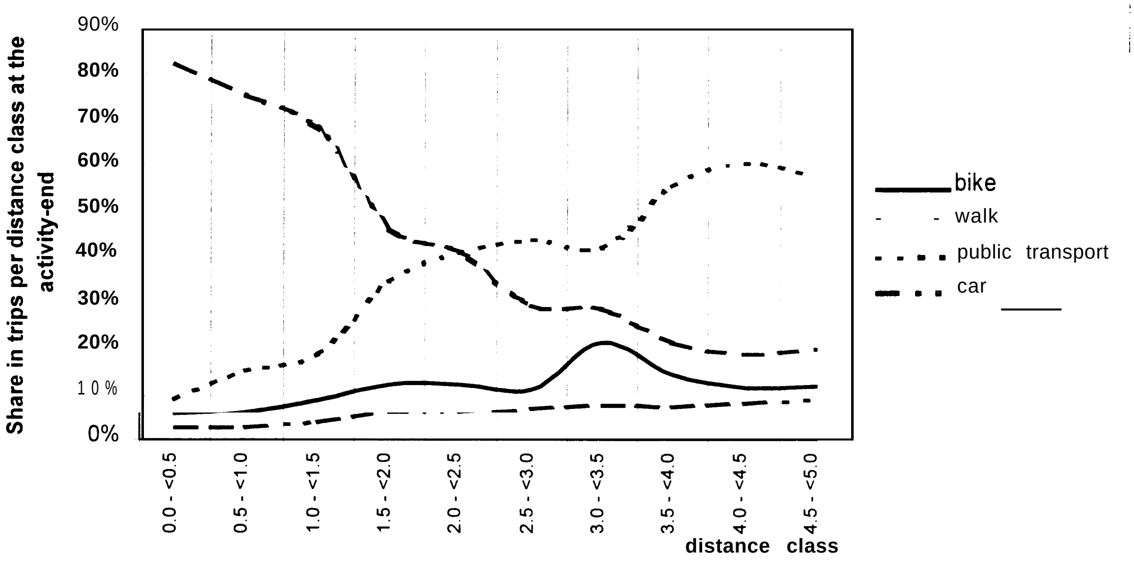
4.2 Choice of access mode

The shares of the access modes chosen depend strongly on distance. For the short distance most people prefer to walk or they take the bike, whereas they take public transport or the car for the long distance access trips.

Graphs 3 and 4 show the share of the four main transport modes in the total number of trips in every distance class. From graph 3 it appears that most of the people who are living close to the railway station come to this station by feet. Is the station further situated than 1.5 km but within a distance of 3.5 km, most people take the bike. For a distance longer than 3.5 km, the majority of the travellers chose public transport.
Graph 4 illustrates again, that the bike plays a much smaller role at the activity-end than at the home-end. The most important explanation for this difference is the availability-problem (see also section 2.2). Now most of the people prefer to walk if the destination of the trip is situated within a distance of 2.0 km from the railway-station. If the destination is more distant, people prefer to take public transport.

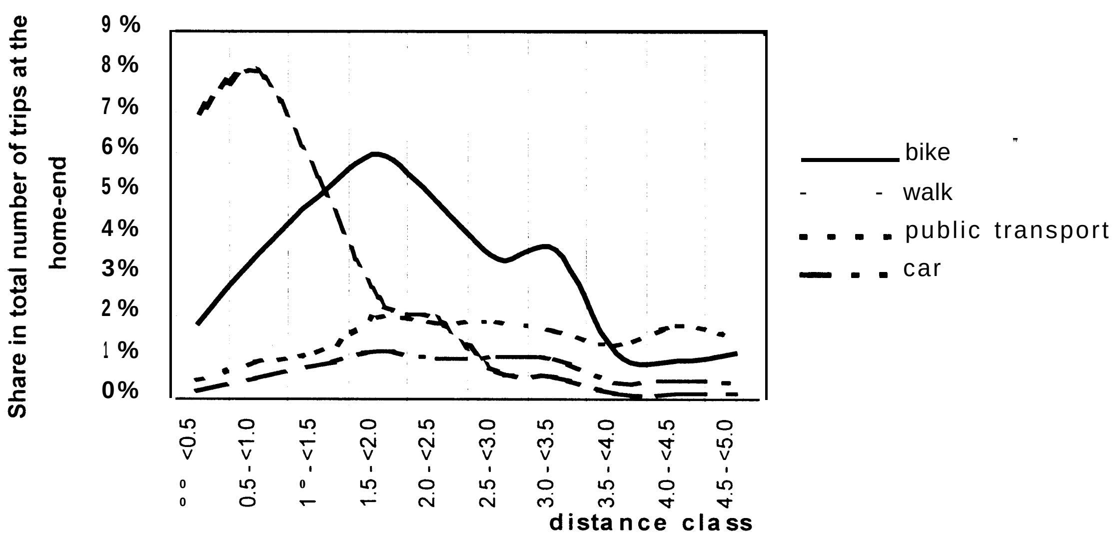


Graph 3: Share of transport modes per distance class at the home-end



Graph 4: Share of transport modes per distance class at the activity-end

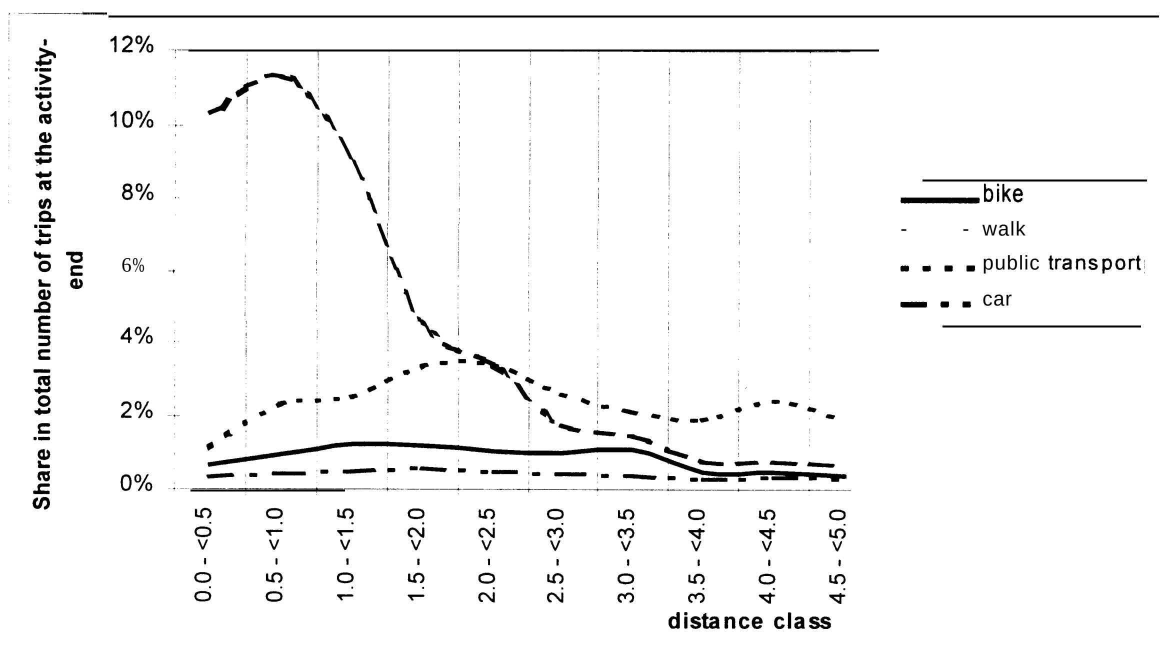
Now we know for every distance class which transport mode is most important, but as has been described in graph 2, not every distance class is of the same importance. For a really good understanding of the role of every transport mode in relation to the travel distance, we have to combine graph 2 with graphs 3 and 4. Then we can see the share of every transport mode in the total number of trips (made by all the transport modes). This is done in graphs 5 and 6.



Graph 5: Importance of transport modes in relation to the distance at the home-end

Because the first five distance-classes play a considerable role in the trip at the home-end and at the activity-end (especially the second and the third class), also the transport modes that are most frequently chosen in these classes tend to dominate the result.

Graph 5 shows that it is above all the bike and walking that travellers prefer to take when they want to reach the railway-station. Though public transport and car play a big role at the longer distances, their meaning in the total access to the railway-station is relatively limited. At the activity-end (graph 6) walking is by far the most important modal choice, but now also public transport plays a considerable role (see also tables 1 and 2)

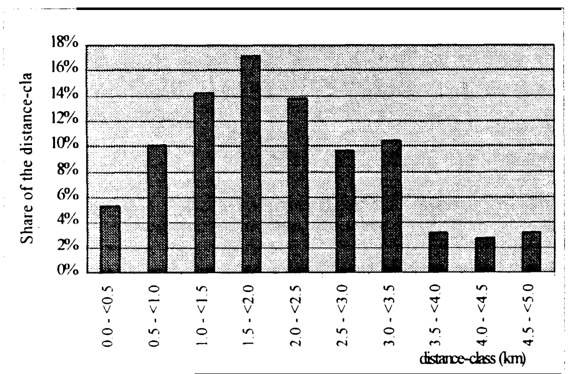


Graph 6: Importance of transport modes in relation to the distance at the activity-end

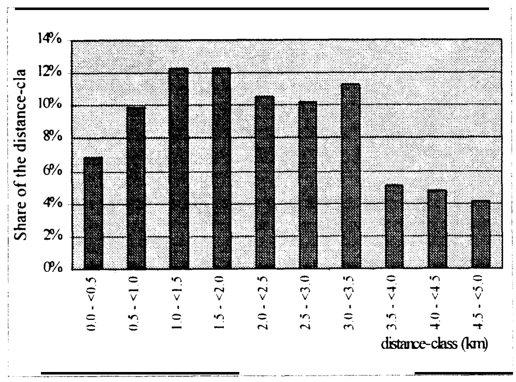
4.3 Analysis per transport mode

In this section, each of the four transport modes (bicycle, walking, public transport and car) is analyzed for the home-end as well as the activity-end.

4.3. I The bicycle



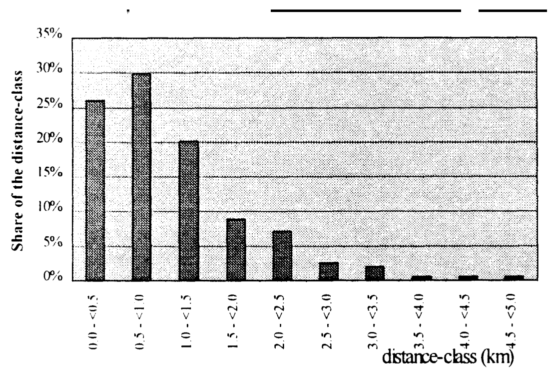
Graph 7: The bike at the home-end



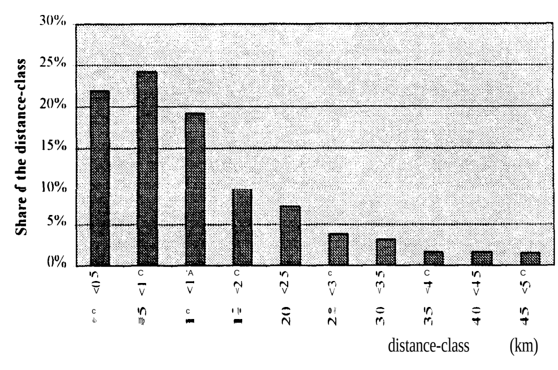
Graph **8:** *The bike at the activity-end*

If the bike is used at the home-end, it is mainly for the shorter distances. When the distance is longer than 3.5 kilometers, the use of the bike decreases strongly. At the activity-end, there is no clear peak. The most travelled distances varv between 1 .O and 3.5 kilometers.

4.3.2 Walking



Graph 9: Walking at the home-end

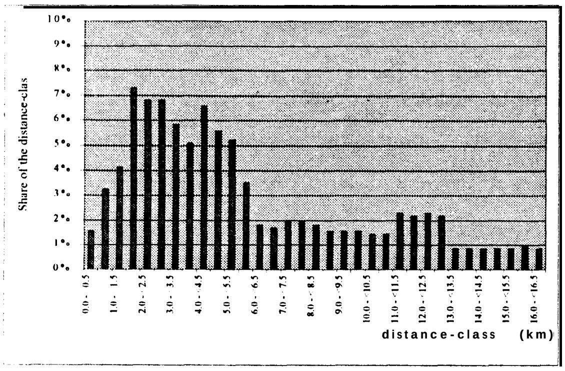


G 'raph 10: Walking at the activity-end

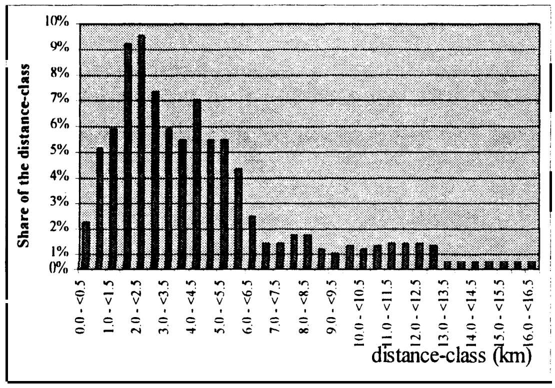
For walking as transport mode at the home-end as well as at the activity-end the same picture emerges as for the bicycle: most of the trips are very short. When the distance is longer than 1.5 kilometers, the share of the distance-class decreases quickly. When the distance is longer than 2.5 kilometers, hardly anybody chooses to walk.

4.3.3 Public transport

In contradiction to the bicycle and walking, the public transport is a more important transport mode at the intermedium distance between 2 and 6 kilometers. This is true for the home-end as well as for the activity-end. But also for distances longer than 6 kilometers public transport remains very important (see graphs 11 and 12).



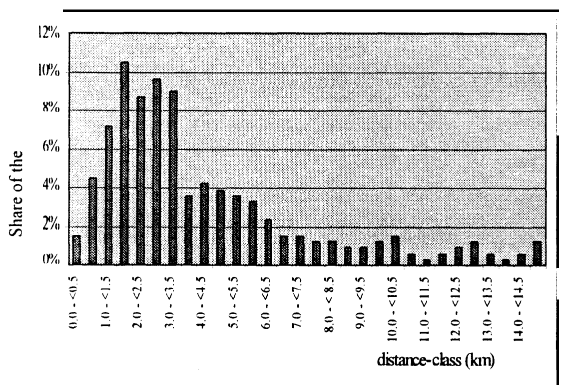
Graph 11: Public transport at the home-end



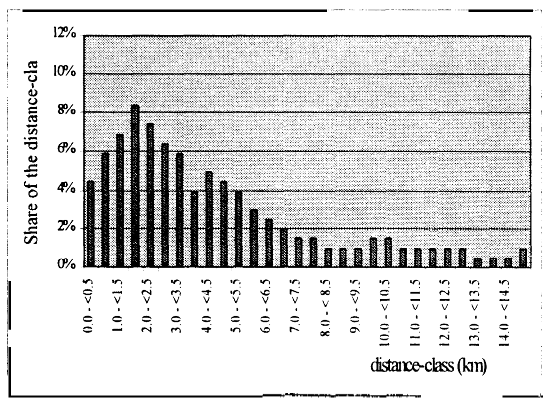
Graph 12: Public transport at the activity-end

4.3.4 The car

Just as with public transport, the car is used for the long distance between 1 and 7 kilometers, for the home-end as well as for the activity-end. Most of the car trips have their origin at about 2 kilometers from the station and their destination at about the same distance. It is noteworthy that especially at the home-end, the car-users are passengers (9 1 %) and not drivers. This means that kiss and ride is a much more common phenomenon than park and ride. An implication is that the demand for parking facilities near railway-stations is smaller than one might otherwise expect.



Graph 13: The car at the home-end



Graph 14: The car at the activity-end

Table 4 gives a survey of the mode and the mean distance of the various transport modes. The mode tells us, what distance most people have to travel.

	Home-end		Activity-end	
	mode	mean	mode	mean
bicycle	18 ,	26 ,	18 ,	31 ,
walk	0,8	1,1	0,8	1,3
public transport	18 ,	72 ,	23 ,	5,8
car	18 ,	6,6	1,8	13,7

Table 4: Mode and mean of the several transport modes

The table shows that people take the bike and they walk at the short distance, while they use the public transport and the car at the long distance. In all cases the modes are smaller than the means. Especially for public transport and the car the means are much larger than the modes This underlines that the distribution for these transport modes are skewed.

5. PROPENSITY TO TRAVEL BY TRAIN AS A FUNCTION OF DISTANCE TO THE RAILWAY STATION

The results presented thus far provide various types of useful information on the access modes of railway passengers as a function of distance. However, if one wants to know to what extent distance to railway-stations matters on the decision to chose rail as the transport mode for a trip, the above results are not sufficient to provide the answer. Additional data are needed, i.e. data on the spatial distribution of people's residences before such a question can be answered. We start therefore with a method to generate the spatial distribution of people's residences in terms of distance to railway stations.

The attraction of a railway-station depends of many factors, like the frequency of the serving trains at the station, the surrounding area, the local infrastructure, local bus services, etc. If we take these factors as given for a certain station, the following can describe the number of travellers:

(1) $T_i = I_i * r_i * C$

where T_i = travellers per time unit, originating from distance-class i
I_i = inhabitants of distance-class i
r_i = distance decay factor for distance-class i
C = constant, depending on features of railway station

The distance-classes are the same as described in the above sections, so distance-class 1 is 0 - <500 meter from the station, distance-class 2 is 500 - <1000 meter from the station, etc. The distance decay factor tells us, which influence the distance to the station has on the number of travellers. If we assume that $r_1 = 1$, formula 1 implies that as when T_i and I_i are known for all distance classes, the distance decay factor can be computed as:

(2) $r_i = (T_i/I_i) * (I_1/T_1)$

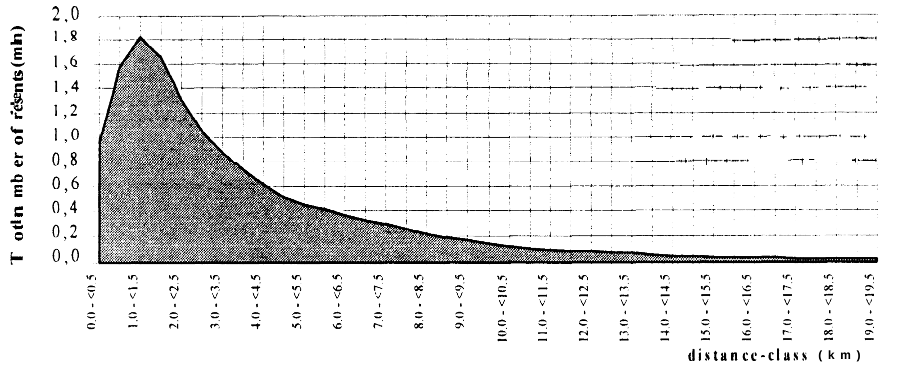
So if we know the number of inhabitants and travellers of distance-class 1 as well as distance-class i, we can calculate the various distance decay factors. This will be done for an average station in the Netherlands, which means that we have to *know* the *total* number of people that live in each distance-class, and the *total* number of travellers originating from each distance-class.

The total number of travellers in each distance-class follows from the Dutch National Travel Survey from 1994. 82.835 respondents filled in this survey, which is 0,54% of the total Dutch population. So if we multiply the results of the Dutch National Travel Survey with a factor (l/0,0054..) = 183,71, we know the total number of travellers in each distance class.

To determine the total number of inhabitants in each distance-class around the railway-station, three kind of data are used:

1. The number of inhabitants in each postal-area in the Netherlands.
2. The distance of the centre of gravity of each postal-area to the closest railway-station.
3. The surface of each postal-area.

Assuming that each postal-area in the Netherlands is circular, the radius of each area can be calculated. Comparing this radius with the distance of the centre of gravity to the closest railway-station, the number of inhabitants in each postal-area can be distributed in a proportional way (for details refer to Keijer, 1998). This leads to graph 15:



Graph 1.5: Distribution of residents according to distance to nearest railway station

It is clear from graph 15 that the Netherlands have a dense railway network. The average distance of residents to the nearest railway station is about 4.0 km. The mode is only about 1.3 km (middle of distance-class 3). Only some 8.4% of the populations lives further away from the nearest railway station than 10.0 km. Thus, from the access viewpoint the railway system seems to have a good prospective to attract passengers.

The question remains of course, how sensitive people are to distance to the railway station in their decision. Table 5 gives an overview of the collected data (number of inhabitants and travellers of each distance class) and the calculated distance decay factor for each distance-class. This factor is calculated with formula 2 ($r_i = (T_i/I_i) * (I_1/T_1)$):

distance-class	distance (m)	travellers per day	residents	distance decay factor
1	0 - < 500	52.724	954.932	1,oo
2	500 - <1000	71.646	1.579.637	0,82
3	1000 - <1500	68.156	1.817.965	0,68
4	1500 - <2000	64.114	1.657.785	0,70
5	2000 - <2500	53.092	1.316.459	0,73
6	2500 - <3000	38.579	1.053.103	0,66
7	3000 <3500	37.844	878.081	0,78

8	3500 – <4000	16.534	726.695	0,41
9	4000 – <4500	18.555	616.806	0,54
10	4500 – <5000	17.820	506.237	0,64

Table 5: Distance decay factors for railway use

From table 5 it follows, that the calculated distance decay factor is pretty stable in distance-classes 3 to 7, what means that the influence of the travelled distance (between 1 .O and 3.5 km) to the railway-station on the propensity to travel by train is not too big. When the travelled distance is longer than 3.5 km, the propensity to travel by train decreases.

6 CONCLUSIONS

Multimodal chains are most attractive in the case of long distance trips. Local accessibility of railway stations is an important determinant of railway use. We find for the Netherlands that the propensity to make use of rail services of people living in the ring between 500 to 1000 meter from a railway station is about 20% lower than of people living at most 500 meter away from railway stations. At distances between 1 .O and 3.5 km the distance decay effect is about 30%, and above this distance it may reach values up to 50%. With a mean distance for all households of some 4 km and a median of about 2.5 km to the nearest railway station, the density of the Dutch railway network can be judged as quite high. Non-motorized transport modes are dominant at both the home-end and the activity-end. A rather unique feature of the home-end access mode is the high share of the bicycle. More than one of every three passengers uses the bike on the trip from home to station. At the activity-end the share of the bike is much smaller because of the asymmetry problem discussed in section 2. This explains the dominant position of walking as the access mode at the activity-end.

An implication for the construction of facilities near railway stations is that parking facilities for bikes deserve more attention than they usually receive. An inspection of parking facilities near railway stations in the Netherlands indeed reveals rather chaotic situations.

A policy implication for physical planning is that when one wants to stimulate the use of multimodal transport it is important to coordinate the policies with respect to the location of new residential and working areas on the one hand and policies concerning rail infrastructure. Given the asymmetry in the opportunities to use private transport modes at the activity side of the multimodal chain walking is a very important mode at the access side. This would imply priority for the construction of travel intensive activities (offices, shopping areas) near railway stations. For residential areas the orientation towards railway stations remains relatively stable as long as the distance does not exceed some 3.5 km.

Among the many subjects for further research in the area of multimodal transport we mention the issue of choice of a particular railway station as part of a transport chain. In the present paper we ignored the trade-off between going to a near railway station with a low frequency of service and a railway station further away with a higher frequency. Another subject that deserves more attention is the distance decay at the activity-end of the chain. In the present paper we only focused on distance decay at the home-end, but a similar analysis for the activity-end would be welcome.

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