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Travel-to-school mode choice modelling and patterns of school choice in urban areas

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Abstract

Because of declining enrollment and school closures in some German regions students have to choose a certain school location from a reduced set of schools. For the analysis of adverse effects of school closures on transport mode choice the patterns of school choice are specified first. It seems that proximity and the profile offered (languages as a core for example) are adequate factors. Second, the travel-to-school mode choice are modelled using a multinomial logit approach, since students might switch from low cost transport modes (cycling for instance) to modes with remarkably higher costs (public transport for instance). Here, the most influencing factors are distance, car availability and weather. Furthermore, these findings are incorporated into a case study to quantify the effects of a modal-shift (switch from one transport mode to another). For this analysis a comprehensive survey was undertaken and a method of data disaggregation and geocoding is presented.

Keywords: Multinomial logit model; Data disaggregation; School choice; Travel-to-school mode choice

1. Introduction

More and more German regions are confronted with declining enrollment numbers caused by decreasing population and negative net migration. This in turn implies the necessity to close some school locations. Students have to choose a certain school location from a reduced set of remaining schools and may face a longer way to school. Since distance strongly influences the travel-to-school mode choice, students switch from modes appropriate for short distances like cycling to modes appropriate for longer distances like public transport (modal-shift). Latest studies on travel-to-school mode choice stress the establishment of neighborhood schools and thus the preponderance of activity-related travel-modes like walking or biking due to short travel-to-school distances (Ewing et al., 2005; de Boer, 2005). Inter alia, these modes are beneficial for students' health (McDonald, 2005; McMillan, 2003). Our focus is on the economic benefit of neighborhood schools and short distances: modes like car or public transport are related to considerably higher costs in contrast to walking and biking. Moreover, neighborhood schools are desirable, because any policy which forces people to use motorized transport modes might not be appropriate within the context of climate change and peaking of global oil production. The closure of schools leads to savings for authorities in infrastructural and personnel costs, but there could be an increase in transport costs, which yields increased total costs. For an estimation of the additional costs within the framework of dynamic school network planning one has to analyze the process and the most influencing factors of school choice and travel-to-school mode choice first. This is a more complex task in urban than in rural areas. Recent studies explain school choice (in Germany) by proximity and tuition fees among others but do not cover the school's profiles – i.e. special courses (Speiser, 1993; Mahr-George, 1999; Hoxby, 2003; Schneider, 2004;

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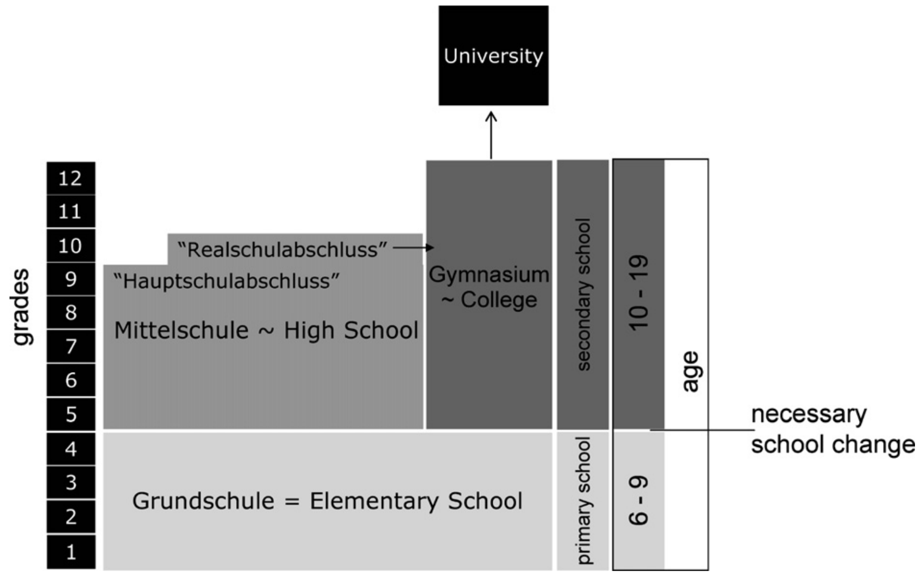

Fig. 1. Main aspects of the educational system of Saxony.

Hastings et al., 2005). We expect that students choose the school closest to their home and those who do not, choose a school with a different profile than the closest one. In this paper we analyze the consequences of a school closure in the City of Dresden, Saxony and present the results of a large empirical study ($n = 4700$).

The remainder of this article is organized as follows. In Section 2 we describe the data used and present a method of data disaggregation. This is followed by the examination of the school choice behavior (Section 3) and the modelling of travel-to-school mode choice (Section 4). In Section 5 we present an example of school closure and modal-shift for the City of Dresden. Some final remarks can be found in Section 6.

2. Data and disaggregation

In this section we depict how the survey was accomplished, what data are available and how these data are disaggregated using a commercial Geographic Information System (GIS). The data are analyzed in detail in Sections 3 and 4.

2.1. Data

This study is focused on secondary schools, particularly colleges (German = "Gymnasium"). College students are aged between 10 and 19 years (see Fig. 1). In Dresden around 45% of all secondary school students are college students (City Council of Dresden (=Landeshauptstadt Dresden, 2003). The possibility to enroll on a college or high school depends on the elementary school report (overall average grade). Our data set includes administrative areas (spatial units), the school locations, the street network, the bus and tram stops and the routes of the public transportation system of Dresden. As administrative areas we consider districts and blocks[1]. A block is bordered by streets (see Fig. 2). Note, each district consists of a unique set of blocks. Using a shortest path algorithm we have determined the street network distances between all blocks within Dresden. These distances have to be interpreted as walking distances in the absence of information about accessibility for cars around one-way street systems for instance. As this paper just considers the commute to school, the car and motorcycle do not play an important role (see also Section 4). Population data cover the age groups 10–19 years at block level for the years 2004 and 2008 (forecast). These data are needed to compute the absolute effects of modal-shift due to a school closure in 2008 compared to the situation in 2004.

In 2004, a survey was carried out covering nearly 4700 of 14000 college students at 12 of the 23 colleges in Dresden lasting from January to November including a pre-test. A short form questionnaire (two pages) was used very similar to that used by the German Federal Ministry of Transport (Federal Ministry of Transport, Building and Urban Affairs, 2002). Information was obtained of each student's home district, the school attended, age, sex, car availability and whether the student owns a driver's license as well as travel-to-school mode choice and total travel-time. The total travel-time is related to the most preferred transport mode from home to school in the summer term. Students were asked to state their preferred transport mode which is usually chosen for the way to school and back home both in winter and summer term. Fair weather was assumed to be synonymous with the summer term and bad weather with the winter term, respectively (see Fig. 3). Furthermore, the students were asked how often they use a certain mode while commuting to school within a representative week.

[1] There are 64 districts and more than 6400 blocks in Dresden.

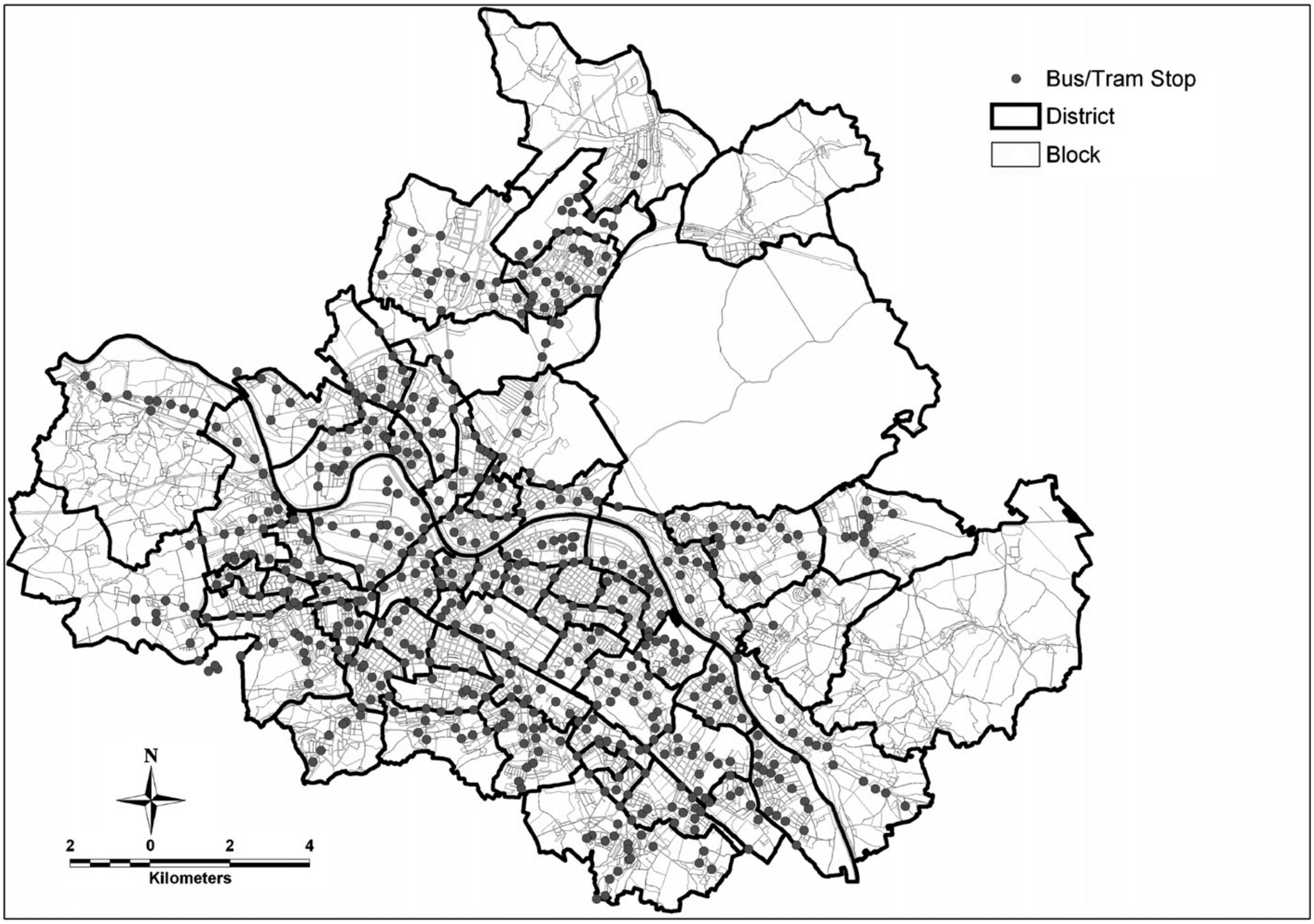

Fig. 2. The City of Dresden – Administrative areas and public transport access.

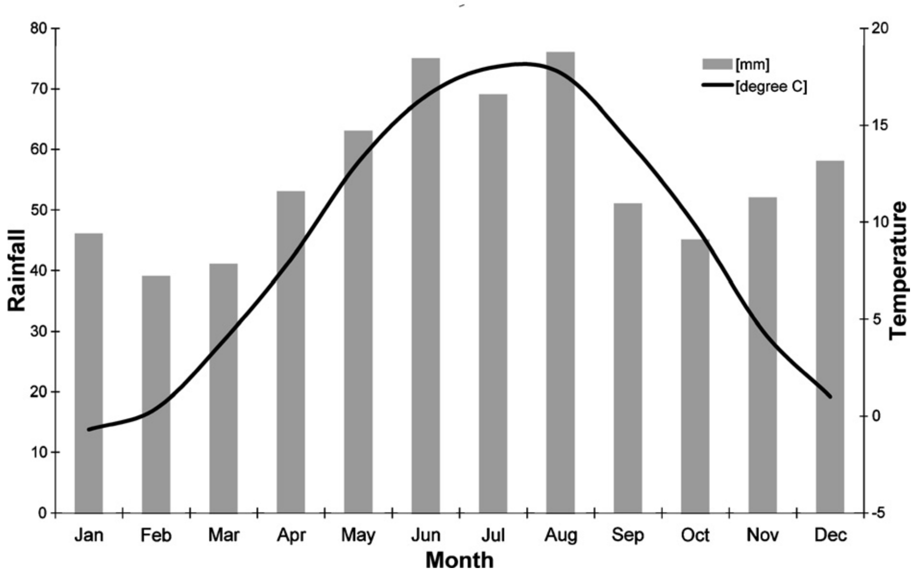

Fig. 3. Climate diagram for Dresden, Saxony.

Again, this information is available for the summer and the winter term. In case of the usage of public transportation, there is information about bus routes and stops (origin, destination and change). Moreover, the students were asked to state their waiting times (departure station, change) and access as well as egress times, which are the walking time from home to the departure station and the walking time from the destination station to school. The questionnaire ends with questions, among others, on the ticket used and the satisfaction with the level of service.

2.2. Disaggregation

Due to administrative restrictions which prohibit inquiring about detailed student addresses, a method was devised for small scale (blocks) geocoding of the survey data using a GIS. The data were collected on the scale of districts. Since distance is an important variable discriminating between most of the transport modes, data as disaggregated as possible are needed in order to obtain a good approximation of exact distances for each student. Several authors stress the use of disaggregated data for distance related analysis (Goodchild, 1979; Bach, 1981; Fotheringham et al., 1995; Longley et al., 2001). There are only a few methods that deal with data disaggregation for transport surveys, but some work has been done in other fields of research (Gimona et al., 2000; Spiekermann and Wegener, 2000; Van der Horst, 2002; Greaves et al., 2004; Oosterhaven, 2005).

Most of the students use public transportation on their way to school (50–60%, see Section 4). Thus, the departure bus or tram stop used and the time needed to get there from home are known. Now, let us assume a student is located in district A (see Fig. 4). Taking into account an average walking speed of 4 km/h, one can determine a student specific isochrone around the stated departure bus or tram stop. So, just a few blocks possibly contain the home of the student. Blocks without population are eliminated. The number of possible blocks could be reduced by considering the bus or tram route chosen by the student. This is based on the assumption that most of the students use the bus stop of the chosen line which is closest to their home. However, the situation arose that more than one possible block has to be taken into account for allocating the specific student although using all information available. Students with comparable properties (travel-time, home district) are allocated to the considered blocks relative to the population of the specific age-group.

Regarding students who never commute to school by public transportation this detailed information is not available. In this case the following procedure has to be used: Imagine another student living in district A and the school attended is located in district B (see Fig. 5). Again, the information of the commuting mode is available from our survey data as well as the total travel-time. We assume a transport mode specific average speed for walking of 4 km/h and for cycling of 12 km/h (Federal Environment Agency Germany, 2007). The speed limit for cars and motorcycles is usually 50 km/h. Due to traffic lights and congestion we suppose an average speed of 30 km/h for cars and motorcycles in (German Aerospace Center, 2007). We expect these average speeds to be sufficient for the geocoding process. Using the average speed and the stated travel-times, we are able to determine a student specific

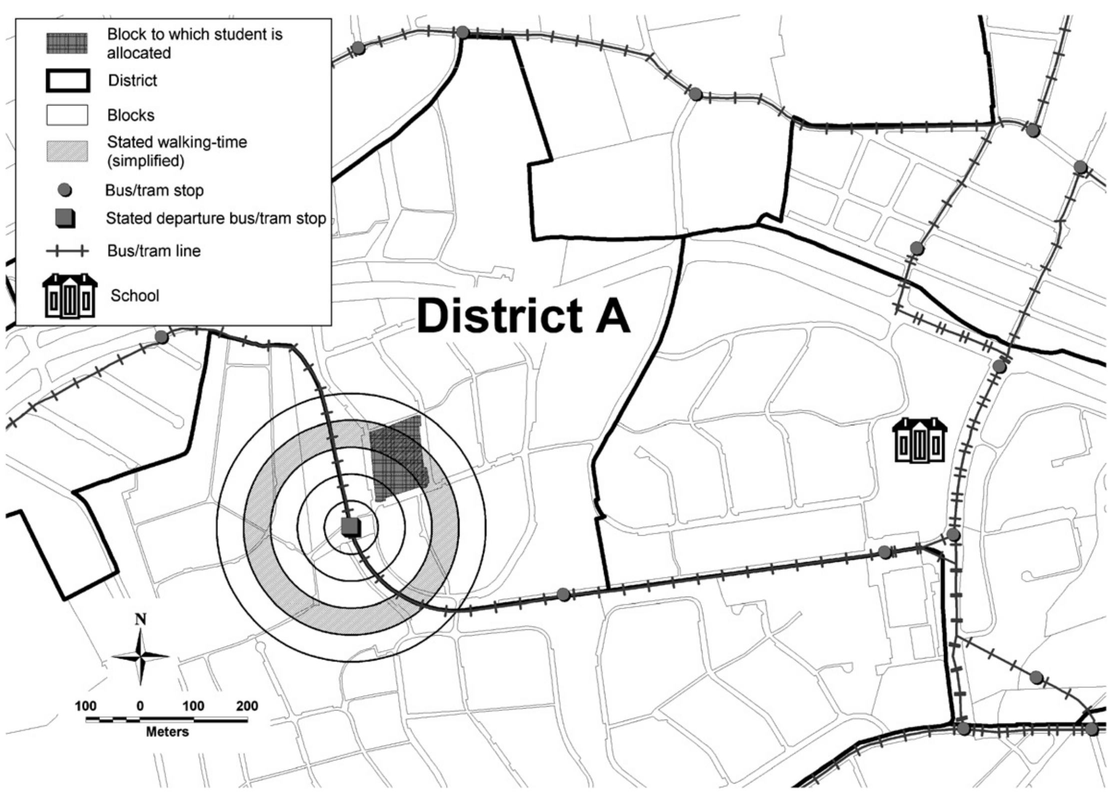

Fig. 4. Allocation of students using public transportation.

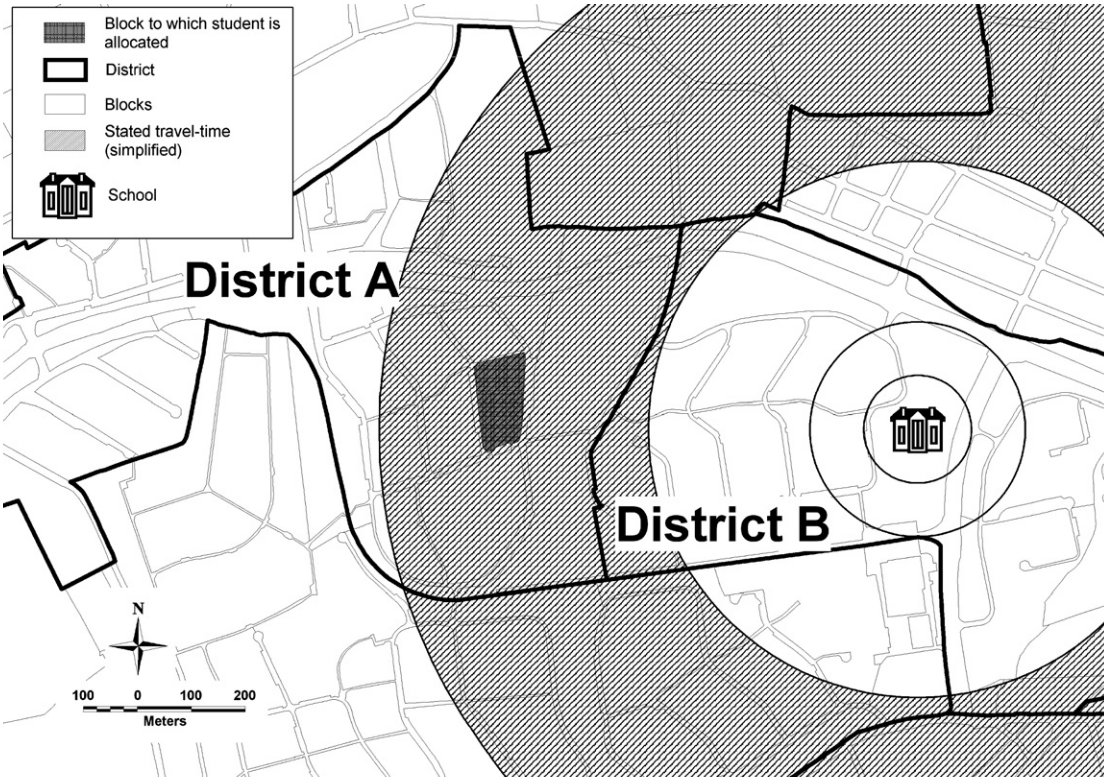

Fig. 5. Allocation of students not using public transportation.

isochrone around the school attended. For the modes biking and in particular car/motorcycling these isochrones are larger than those around bus stops (see above). According to this, there is more uncertainty about the correctness of the allocation of students to blocks in this case. However, there is just a very small percentage (6–10%) of students who commute to school by car or motorcycle (see Section 4). But we expect that possible errors will be limited due to the extent of the sample.

3. Patterns of school choice

In Saxony, no regulations exist restricting the choice of schools. So, there are no intrinsic school-districts and students are free to choose a certain school location. Several surveys yield proximity and the authority responsible (private or public school) as two very important factors of school choice. Others are the reputation of schools and tuition fees, for example Speiser (1993), Mahr-George (1999), Hoxby (2003), Schneider (2004) and Hastings et al. (2005). We expect that the school's profiles could have influence on school choice as well. In this study we will focus on distance, the school profile and the authority responsible to determine the school location choice, since most of the other influencing factors stated in the literature cannot be applied here due to the lack of data or unimportance (i.e. average household income and tuition fees). With regard to profile we differentiate between schools with a common profile and schools with an unique profile. A common profile is offered by several colleges. So these schools are substitutable by others (mathematics/science for example). A unique profile[2] – i.e. advanced-level/core languages – is only offered by one specific school. For an overview of school locations and profiles offered, see Fig. 6.

3.1. School catchment area and proximity

We have to determine the surrounding catchment area of each school first. Therefore, the nearest school location has been verified for each block. Because students will not always realize this strictly drawn border, we have added two zones with virtually reduced distances (zone 2: −1000 m and zone 3: −2000 m). Consequently, the distances of blocks within zones 2 and 3 are minimal to the specific school location (see Fig. 7). Table 1 shows the percentage of students within the corresponding zones for all schools of our sample. In example, 84.8% of all students attending Klotzsche college are located in zone 1 of this college. The surrounding catchment area of each school consists of three zones as defined above. We believe that within this area students recognize the specific school as the closest one. Two main patterns are evident:

- Students attending schools with a common profile mostly are located in the surrounding catchment area. Thus, one could assume that proximity is an important factor for school choice.

[2] Which is comparable to magnet schools.

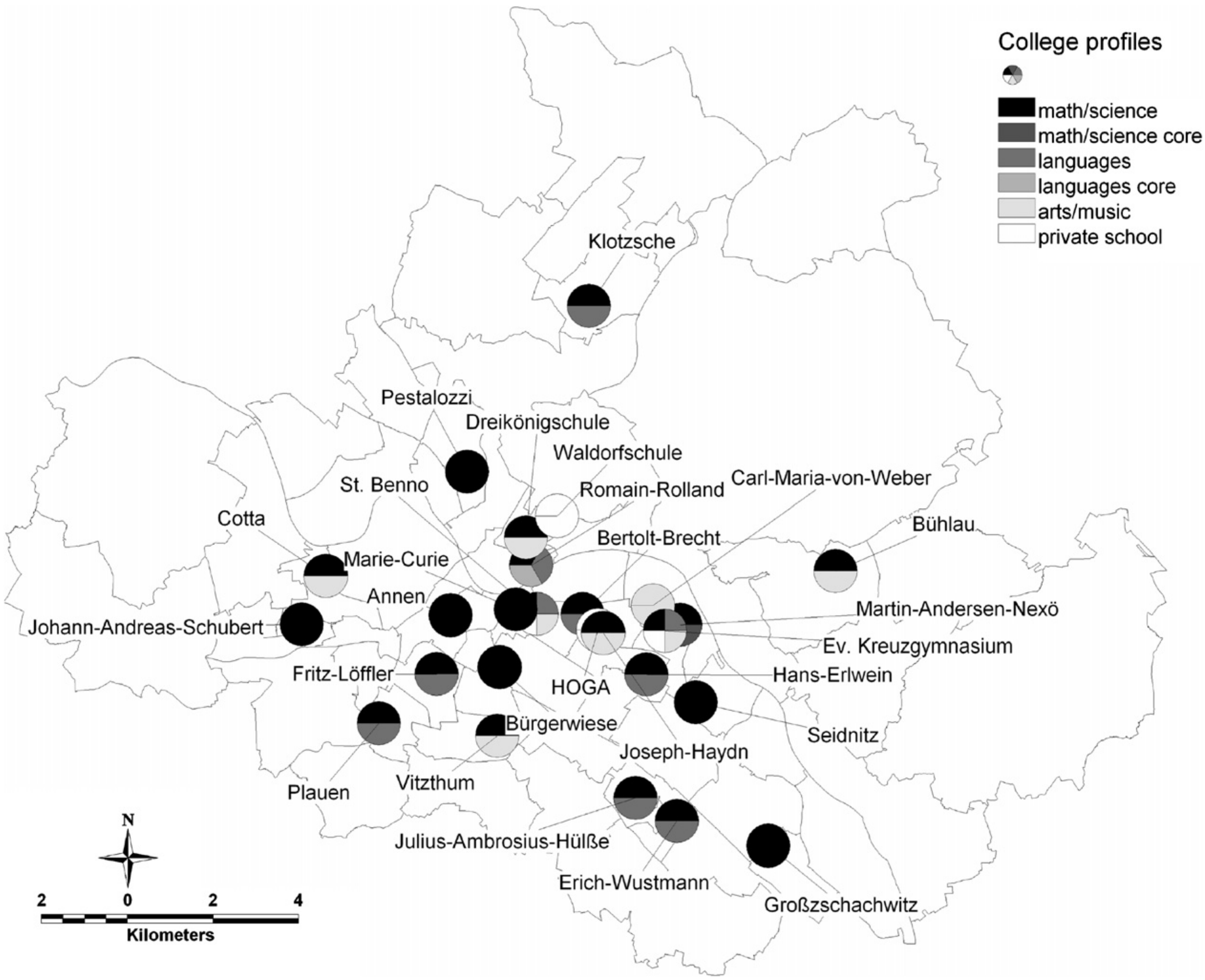

Fig. 6. Colleges in Dresden.

- For schools with a unique profile and for private schools this does not hold true. It seems to be that a unique profile, or a private school, reduces the importance of proximity.

Outliers in both groups – Marie-Curie College and Martin-Andersen-Nexö College, for example – are due to the topology of the school network (see Fig. 6). Schools located in an area with a high density of school locations (spatial cluster) obtain smaller surrounding catchment areas and thus fewer students within them. At the outskirts these catchment areas are larger and possibly contain more students. For students located in blocks close to a spatial cluster it is not always obvious which school location is the closest one. Within a cluster there are many choice alternatives available within remarkable proximity (Bertold-Brecht College for instance, see Fig. 6). It is reasonable to assume that if the closest school location does not match the preferences of students for a combination of profiles, etc., a school within the cluster does so. For students located in a spatial cluster, proximity is less important than for those students located at the outskirts. At the same time other properties like profile, are more important for the decision which school to enroll at.

3.2. School profile and school choice

For a deeper investigation of the influence of profile and the authority responsible we consider Table 2. It shows the distribution of those students who attend schools which are not the closest one. Over all most of the students (80%) choose schools with a different profile and/or a different authority responsible. Let us take Klotzsche College as an example: for 100 students Klotzsche College is the closest one, but they actually choose a different school (sum 1–5). Eighty-eight (0.88, see last column) of them choose colleges with a different profile offered and/ or a different authority responsible (sum 2–5). Twenty of these 88 students choose colleges with an alternative profile (column 3). Over all colleges nearly 70% of the students who choose a different school than the closest one, choose a school with a different profile. Therefore, we assume that profile and the authority responsible are two factors which influence the choice of a certain school. Those 20% of students who attend a

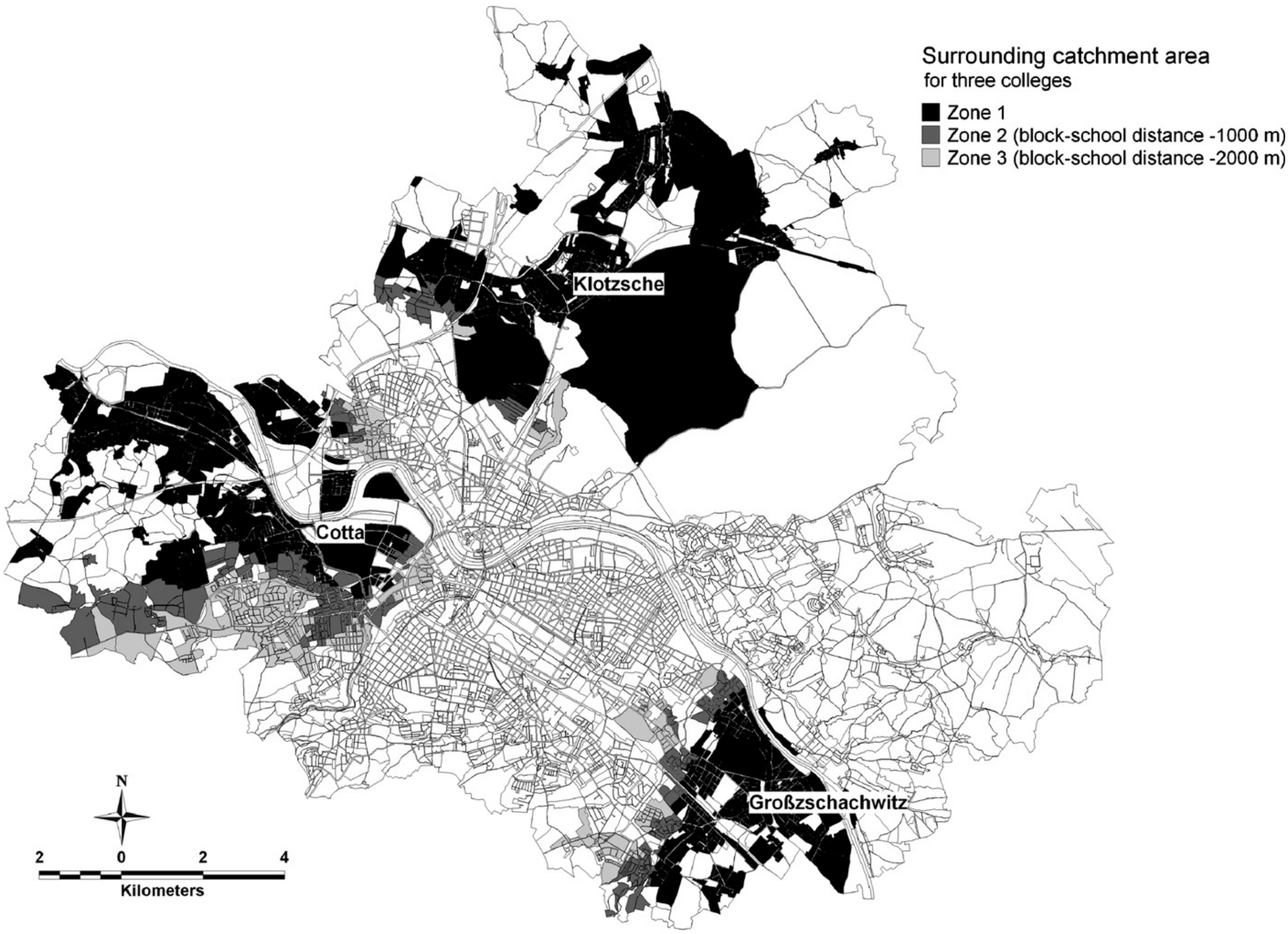

Fig. 7. Surrounding catchment areas: blocks to which the three exemplary colleges are the closest one.

Table 1
School-specific catchment areas

College	Zone 1	Zone 2	Zone 3	Other	Sum zones 1–3
Klotzsche	84.8	0.5	0	14.7	85.3
Großzschachwitz	68	12.9	1.7	17.4	82.6
Cotta	50	23.3	17.5	9.3	90.7
Julius-Ambrosius-Hülße	32.6	28.7	12.4	26.4	73.6
Fritz-Löffler	35.8	11.2	23	30	70
Plauen	46	9.4	8.9	35.7	64.3
Vitzthum	48.6	5.7	17.7	28	72
Romain-Rolland	9.4	18.8	3.6	68.2	31.8
Marie-Curie	8.3	14.8	11.6	65.3	34.7
Martin-Andersen-Nexö	15.1	26.1	17.6	41.2	58.8
Joseph-Haydn	7.3	17	32.1	43.6	56.4
St. Benno[a]	0.4	4.1	10.2	85.3	14.7

Values are given in percentage.
Only schools which are covered in the survey by at least 150 students are considered.
Colleges written bold are magnet schools (unique profile).
[a] Private school.

school with the same properties as their closest one, may be attracted by factors not considered here (extracurricular program for example). Another possible reason may be inner-city student migration.

Table 2
Conditional school choice of students choosing a different school than the closest one

# of students in zone 1 of college	Attending a college with					Sum 2–5	Sum 1–5	Sum 2–5/sum 1–5
	1	2	3	4	5			
Klotzsche	12	29	20	0	39	88	100	.88
Großzschachwitz	49	0	169	0	30	199	248	.80
Cotta	23	0	20	0	17	37	60	.62
Julius-Ambrosius-Hüßle	37	0	31	0	32	63	100	.63
Fritz-Löffler	0	8	81	0	11	100	100	1
Plauen	40	4	67	0	25	96	136	.71
Vitzthum	1	50	97	0	20	167	168	.99
Romain-Rolland	0	3	12	0	13	28	28	1
Marie-Curie	1	0	21	0	6	27	28	.96
Martin-Andersen-Nexö	47	5	19	0	33	57	104	.55
Joseph-Haydn	23	0	20	0	16	36	59	.61
St. Benno[a]	0	0	0	24	0	24	24	1
Average (total numbers)	19.4	8.3	46.4	2	20.2	76.8	96.3	.80
Average (relative numbers, %)	20	9	48	2	21	80		

1: Identical profile and authority responsible; 2: additional feature (additional language i.e.); 3: alternative profile; 4: alternative authority responsible; 5: alternative profile and authority responsible.
Colleges written bold are magnet schools (unique profile).
[a] Private school.

4. Travel-to-school mode choice modelling

Regarding the travel-to-school mode choice, the mode is a categorical variable. We suggest a student chooses the transport mode with the highest utility. So we revert to multinomial logistic regression since this is based on utility theory and appropriate for categorical data analysis. The logit approach has been widely used in fields of transport modelling. The modeler assumes the utility U_{ij} of a transport mode i (walking, cycling, public transport and car/motorcycle) to a student j, and includes a deterministic component V_{ij} and an additive random component ε_{ij}

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad (1)$$

Here, the deterministic component of the utility function is linear in parameters. Assuming that the random component, which represents errors in the modeler's ability to represent all the elements that influence the utility of a transport mode to an individual, is independently and identically Gumbel-distributed across individuals and transport modes, the multinomial logit model (MNL) is as follows:

$$P_{ij} = \frac{\exp V_{ij}}{\sum_{i'=1}^{I} \exp V_{i'j}} \quad (2)$$

where P_{ij} is the probability that transport mode i is chosen by student j and I is the set of different transport modes. The closed form of the MNL makes it straightforward to estimate (maximum likelihood estimation procedure),

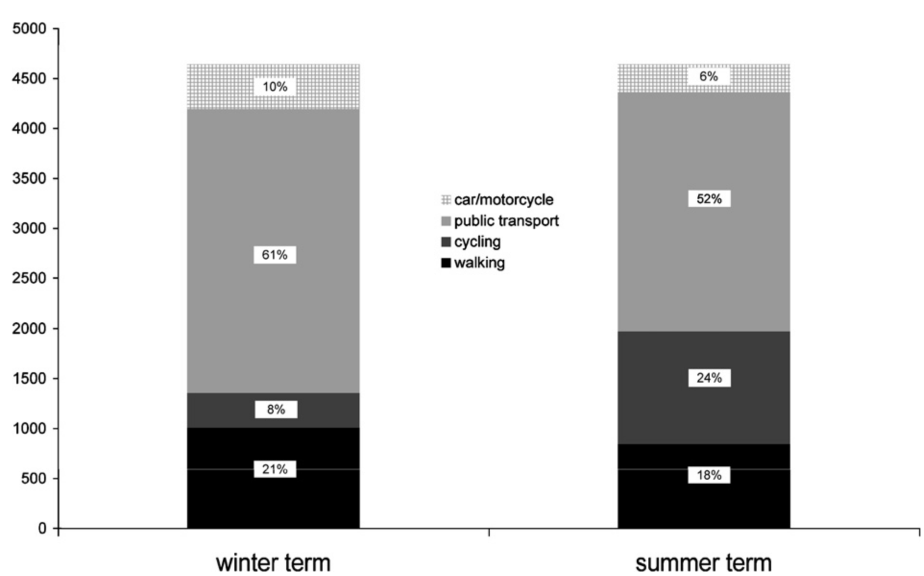

Fig. 8. Modal split.

interpret and use. Detailed work on theory, shortcomings and some applications can be found in the literature (McFadden, 1973; Ben-Akiva and Lerman, 1985; Bhat, 1997; Koppelmann and Sethi, 2000; Greene, 2003). Recent studies concerning travel-to-school mode choice utilizing MNL have been focused on urban form, built environment and distance (McMillan, 2003; Black et al., 2004) as well as travel-time (Woodside et al., 2002; Ewing et al., 2004; McDonald, 2005). Ewing et al. (2005) and de Boer (2005) focused on the relationships between travel-to-school mode choice and school location, safety, and vehicle emission.

We like to analyze the influence of the variables distance, car availability, season or weather, respectively, on commuting mode choice. Age is considered as an explanatory variable as well, admittedly it turned out to be not significant for public transport. Distance is a continuous variable measured in kilometers. Car availability (all time/not all time) and weather (fair/bad) are dummy variables. Car availability means, whether the student has the possibility of travelling to school by car. This includes the possibility of the student being passenger while the mother for instance drives the car. Car availability equals one, if the student has the possibility of commuting to school by car every day. We just consider a few variables for forecasting purposes and for an easy interpretation of the relationships.

Table 3 displays an aggregated overview of the survey data set. It is remarkable that the average distance of public transport and car/motorcycle increases in summer while the absolute number of students decreases. We suggest that this is because in summer (or fair weather) only those students who are not able to switch to walking or cycling due to too long distances use the bus or car. In winter (or bad weather) there are some students taking the bus/car for reasons of convenience – i.e. avoid walking in the rain – although the distance to school would be acceptable for cycling or walking. With regard to cycling the slight increase in average distance in summer is related to the strong increase in the number of students choosing to cycle. Some of these additional students who are cycling in the summer term show longer distances (using public transportation or car in winter).

We expect that the slight decrease in average distance for walking in winter is conditional on students who switch from cycling in summer (due to distance) to walking in winter due to weather conditions. For example, they avoid taking a risk going by bike in case of snowfall.

Table 3
Mean distances for each transport mode and absolute car availability

Variable	Mean	Standard deviation	*n* cases
Distance, km	3.941	3.566	4644
Distance – walking (summer)	0.710	0.408	845
Distance – walking (winter)	0.859	0.526	1010
Distance – cycling (summer)	2.364	1.307	1130
Distance – cycling (winter)	2.022	0.988	349
Distance – public transportation (summer)	5.390	3.111	2390
Distance – public transportation (winter)	4.943	3.034	2838
Distance – car/motorcycle (summer)	7.693	6.910	279
Distance – car/motorcycle (winter)	6.036	6.104	447
		Winter *n* cases	Summer *n* cases
Car availability – all time		391	502
Car availability – not all time		4253	4142
Season/weather		4644	4644

4.1. Model results and interpretation

The results of the estimation are shown in Table 4. There are 4650 college students within our data set. The sample size for estimation is 9300 because we regard each student as twofold: once for summer and once for winter.

Table 4 shows that on average 81% of all cases are correctly predicted by our model. A logistic analogy to R^2 in ordinary least squares (OLS) regression is the McFadden R^2. In general, the McFadden R^2 greater than 0.4 can be interpreted as a very good goodness of fit (Backhaus et al., 2003). With reference to these aspects, the model appears to have good explanatory qualities.

Table 4
Regression parameters

	Logistic regression		Correctly predicated (per cent)
	Coefficient	Wald	
Walking			88
Absolute term	10.774	2119.891	
Distance	−4.376	1369.57	
Winter season/bad weather	−0.591	13.024	
Car availability (all time)	−5.279	489.696	
Cycling			42
Absolute term	6.57	1196.853	
Distance	−0.904	748.843	
Winter season/bad weather	−2.081	200.51	
Car availability (all time)	−4.772	675.716	
Public transport			89
Absolute term	4.477	686.946	
Distance	−0.052	8.796	
Winter season/bad weather	−0.489	1510.892	
Car availability (all time)	−0.553	13.111	
Car/motorcycle			81
Average			81
Number of observations			9300
2 log likelihood			−9584
McFaddenR^2			0.63

All variables are significant at the 1% level. The Transport mode car/motorcycle is defined as reference category and parameters are set to zero. This means that all the other regression coefficients have to be interpreted in relationship to this category.

Compared to the mode car/motorcycle all other transport modes have a higher utility. If we ignore other influencing factors, walking is the most preferred mode (10.774). Taking into account the other variables, it is obvious that the utility of car/motorcycle will increase in relation to the three other modes. Although some information is provided by the coefficients themselves, the interpretation of the choice probabilities is more revealing. Fig. 9 shows the transport mode choice probabilities. Walking is the most important transport mode for short distances (up to 1 km) regardless of car availability and weather. Concerning cycling, weather and distance have a strong influence on associated probability. Students with car availability switch from bike to car at shorter distances than those with no car available who switch from bike to public transportation. To discriminate between the modes public transport and car/motorcycle the stated car availability is the most important factor. The gap between summer and winter in both motorized transport modes within the range of 1–3 km is related to the reduced probability of travel-to-school by bike in winter. Mostly, distance influences the decision to go by bike or walk on the one hand and to use public transportation or car/motorcycle on the other.

For several reasons it is recommendable to avoid a high proportion of students choosing transport modes other than walking or cycling. Obviously, there are higher costs related to transport modes like car/motorcycle than this is the case for walking and cycling. Moreover, walking and cycling are more activity related and thus better for students' health than motorized transport modes. A large percentage of students using public transport or car/motorcycle yields a negative impact on the environment due to emission (noise/pollution). In the following section these issues will be discussed in more depth.

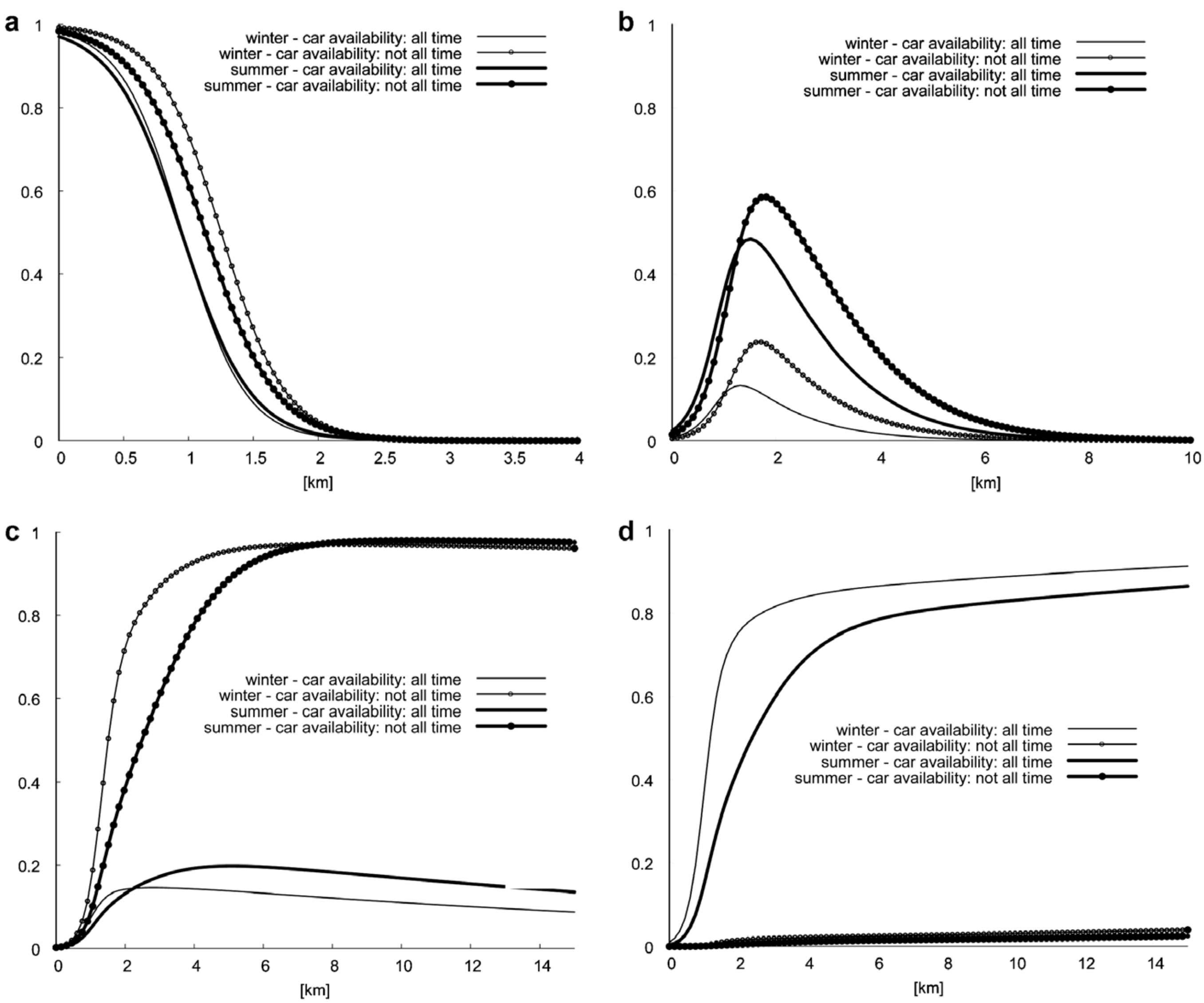

Fig. 9. Mode specific choice probabilities (a: walking, b: cycling, c: public transport, d: car/ motorcycle).

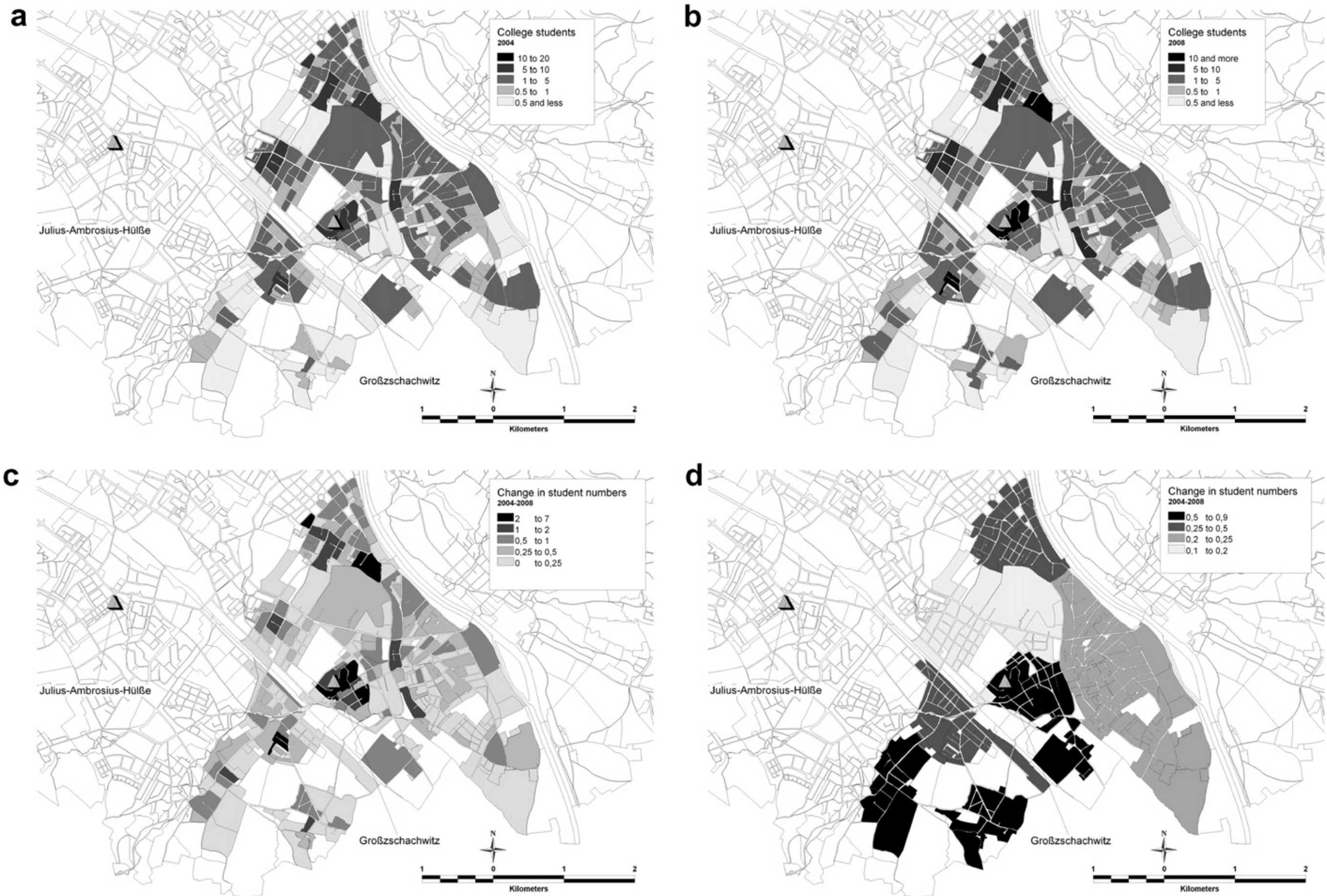

Fig. 10. Zone 1 of Großzschachwitz College: Absolute (c) and relative (d) change in student numbers from 2004 (a) to 2008 (b).

5. Modal-shift and school closure – an example

Under-utilization usually forces authorities to close schools. This is often justified for economic reasons. In this section, we like to analyze whether there is economic or social/ecological evidence emerging from a modal-shift, which could justify keeping open an under-used school.

5.1. Differences in mode choice due to school closure

In the year 2000, the school authorities in Saxony decided to close several school locations in Dresden due to declining enrollment in the 1990s. One of them is Großzschachwitz College which will be closed in summer 2008. According to this, the students affected have to attend different schools which are available. Here, we analyze the shift in transport mode choice and the related consequences. The example is based on the year 2004 and covers a student number forecast for 2008. The forecast shows that student numbers and hence enrollment will increase again (see Fig. 10). This phenomenon is typical for recently prospering cities in Eastern Germany. After years of dramatic decline, the population increases again.

According to Table 1, there are 68% of the students located in zone 1 attending Großzschachwitz College. In 2004, there are overall 467 students enrolled at Großzschachwitz College. Hence, 318 students of Großzschachwitz College are located in zone 1. The total of college students in zone 1 of Großzschachwitz College is 403 in 2004. Thus, 79% of all college students located in a block of zone 1 of Großzschachwitz College attend this college in 2004. Based on this, we assume that 79% of the students located in zone 1 enroll at the closest college available (see Section 3). We apply the MNL specified in Section 4 and yield the number of students[3] choosing a given transport mode for the years 2004 and 2008 (see Figs. 11 and 12). In both cases we just consider those 79% of the students located in zone 1 who attend the closest college, which is Großzschachwitz College in 2004 and Julius-Ambrosius-Hülße College in 2008. Three main patterns are evident:

1. Usually there is no possibility for most of the students to travel-to-school by car (see Fig. 8 and Table 3). So, in both scenarios there is only a small number of students commuting to school by car or motorcycle.

[3] We have computed the average utility due to summer and winter term.

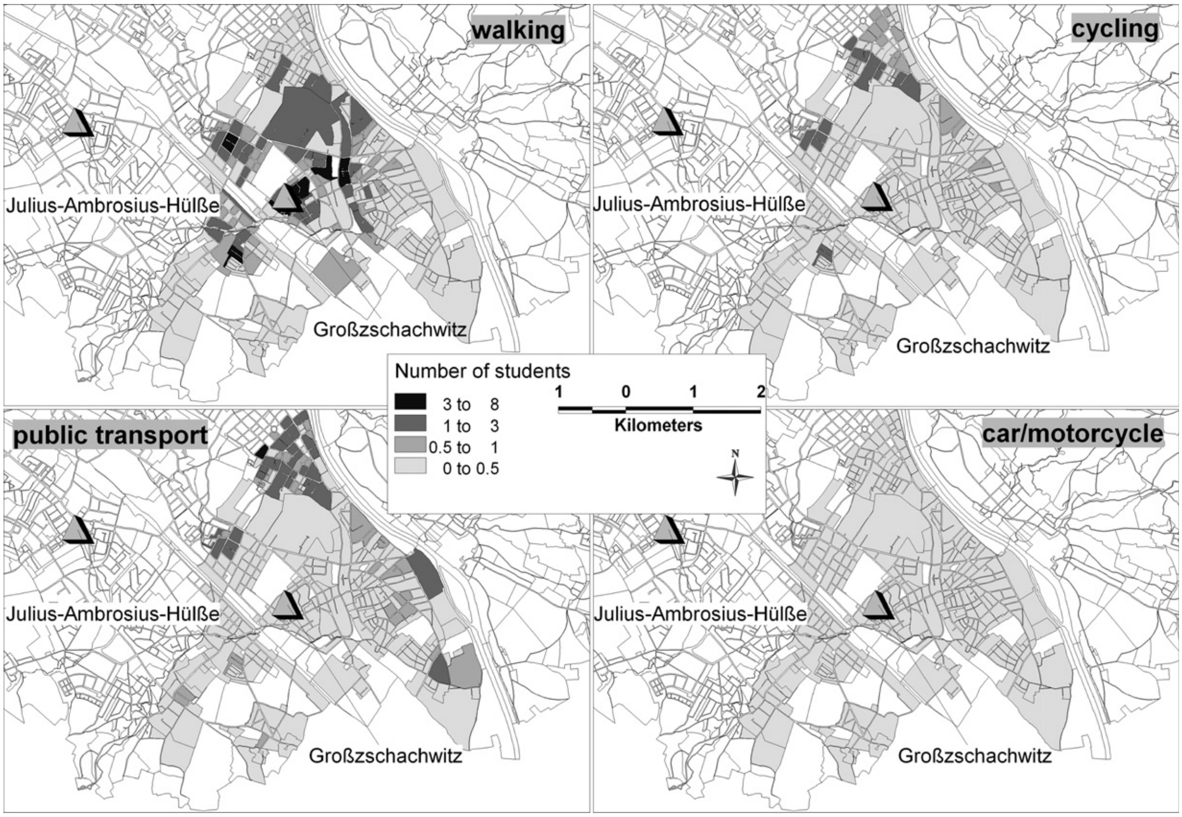

Fig. 11. Number of students walking, cycling, using public transportation or car/ motorcycle in 2004 (before the closure of Großzschachwitz College).

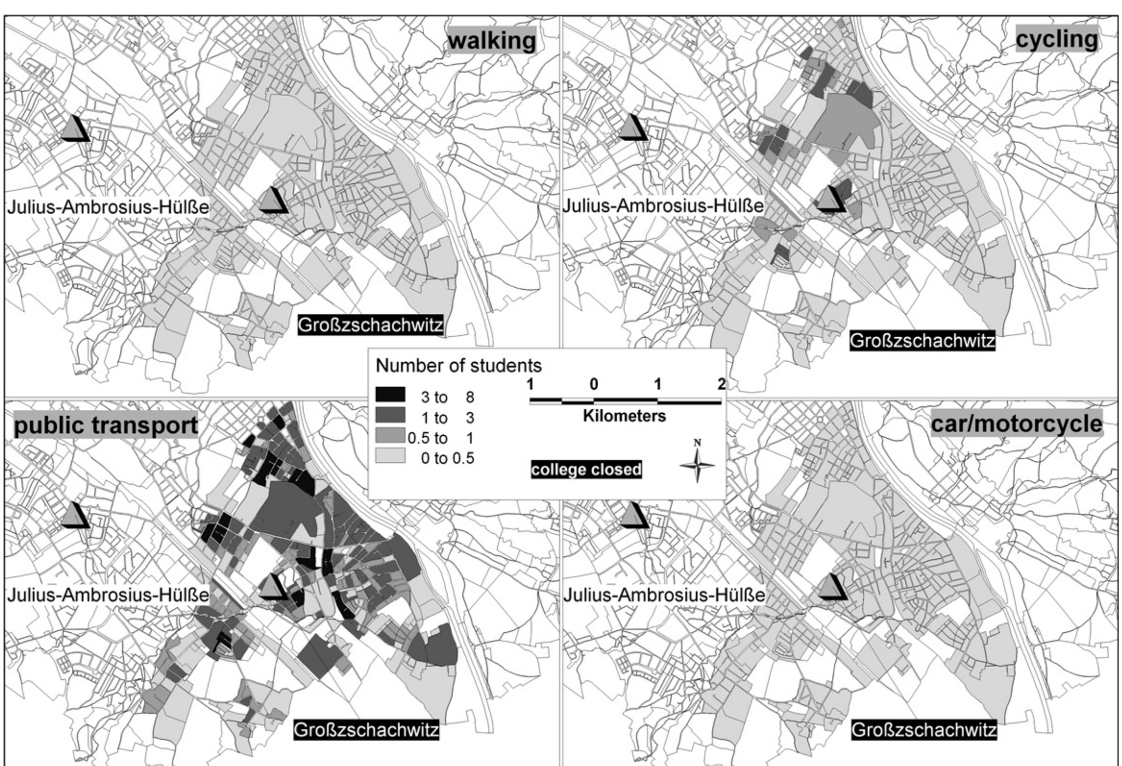

Fig. 12. Number of students walking, cycling, using public transportation or car/motorcycle in 2008 (after the closure of Großzschachwitz College).

2. Although no strong difference in the absolute number of students cycling can be observed, one can identify a difference in the spatial pattern: the spatial center of gravity of students who commute to school by bike shifts toward the location of Großzschachwitz College.
3. Most obviously there is a strong increase in the use of public transport while remarkably fewer students walk to school in 2008.

5.2. Quantification of modal-shift

Here, we try to quantify the consequences of the modal-shift due to a school closure. Since we focus on the transport sector we ignore costs related to the school location like maintenance and rent as well as external location costs like those of the loss of local neighborhood community (i.e. shops and services that depend on local schools are forced to close). We are aware of the difficulties associated with quantifying the modal-shift by costs since these costs are not always easy to determine – particularly external diseconomies. For convenience we do not discuss the different cost figures stated in the literature (see Infras/IWW, 2004; Planco Consulting GmbH, 1993 and Bickel and Friedrich, 1995 for example). Here, we use the cost figures

Table 5
Cost figures

Name	Costs in €	Unit	Source
Plain costs			
Cycling	.005	Student km	Assumed
Bus/tram (fare)	1	Student choosing public transport	Verkehrsverbund Oberelbe (2007)
Car/motorcycle	.165	Student km	FGSV (2002)
Value of travel-time			
Walking	.03	Student min	Baum et al. (1998)
Cycling	.035	Student min	Assumed
Public transport	.04	Student min	Axhausen et al. (2001)
Car/motorcycle	.065	Student min	Axhausen et al. (2001) Baum et al. (1998)
Accident			
Public transport	.28	Student km	
Car/motorcycle	1.64	Student km	
Noise			Baum et al. (1998)
Public transport	.00525	Student km	
Car/motorcycle	.00645	Student km	
Pollution			Baum et al. (1998)
Public transport	.00745	Student km	
Car/motorcycle	.01455	Student km	

Note that all figures are costs per trip.

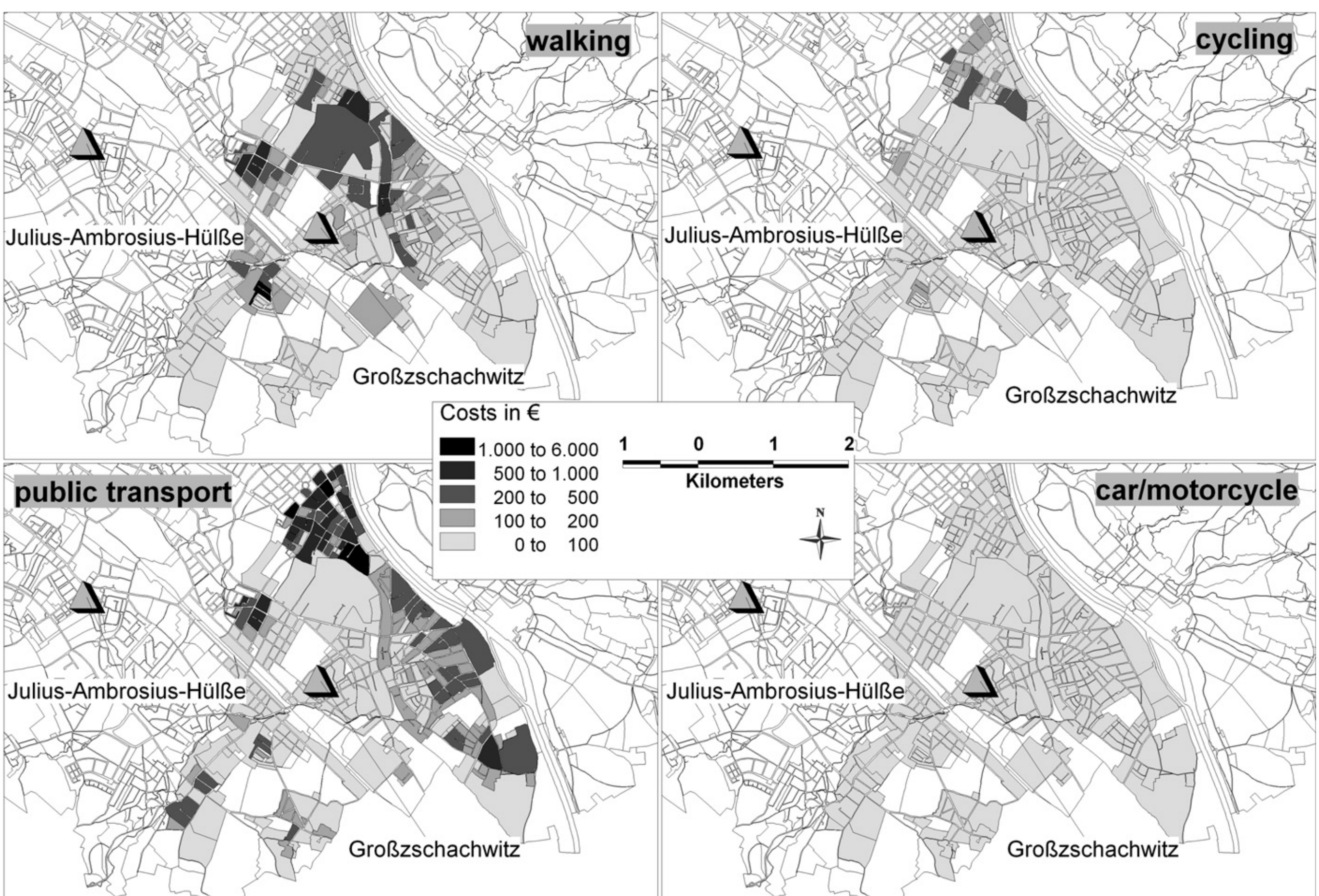

Fig. 13. Transport costs per mode in 2004.

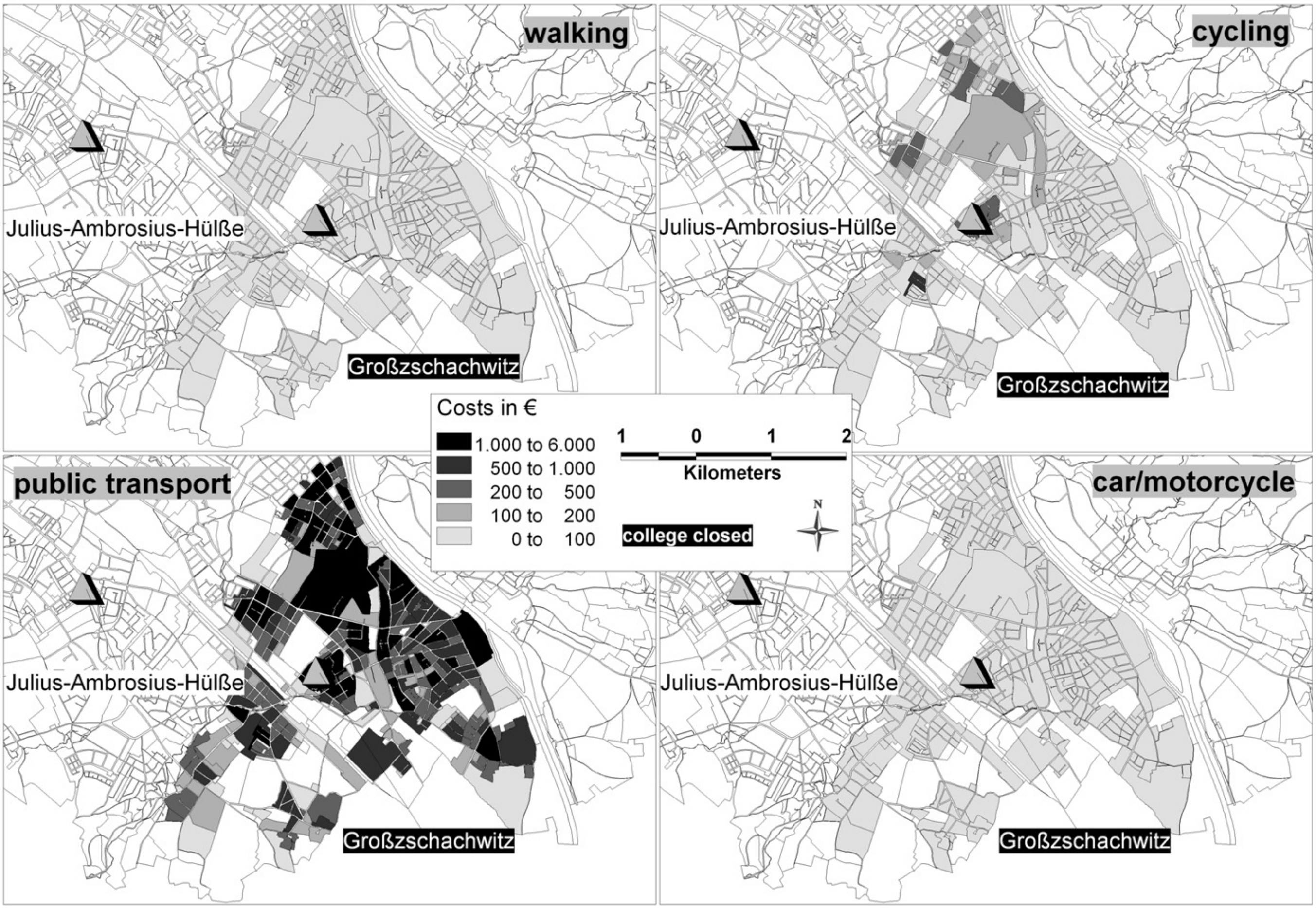

Fig. 14. Transport costs per mode in 2008.

given in Table 5. As plain costs we consider the average usage and consumption costs for cars and bicycles covering fuel usage, insurance as well as purchase and maintenance costs. The bus or tram fare reflects the costs of one trip using a standard seasonal ticket. We carefully assume that a student makes 2.2 trips to school per day.[4] There are usually 200 days of school per year in Saxony. The travel-times are derived from the distance matrix and the assumed average speeds (see Section 2). For public transport travel-times we use a travel-time matrix based on the bus and tram line network. We do not explicitly consider congestion costs because we assume these are included in the value of travel-time, pollution and noise costs. Furthermore, there arise costs due to decreased physical activity which is related to the transport modes public transport and car. An increase in the number of students commuting to school by car or bus yields increased levels of obesity, type 2 diabetes, heart disease etc. Unfortunately, we cannot obtain information about the relationship between student illness and students choosing motorized transport modes, nor do we have costs figures available based on diseases. Figs. 13 and 14 present the mode specific transport costs allocated to the location of the originator (student) for 2004 and 2008. In 2004 the walking costs are due to the value of travel-time of a lot of students walking to school with distances up to 1.5 km. Due to longer distances the number of students walking is very low in 2008 – and so are the walking costs. There is an increase in cycling costs observable, particularly within proximity of Großzschachwitz College. This is reasonable since there is a strong increase in student numbers in this area. Moreover, more students go by bike due to longer commuting distances. The increased number of students is a cogent reason for the increase in public transport costs as well. But most of all of this is because of the modal-shift due to longer commuting distances caused by the closure of Großzschachwitz College. There is a remarkable increase in students commuting by public transport, in particular within proximity to Großzschachwitz College. Because of the low level of car availability this transport mode and its costs are neglectable. In absolute numbers the transport costs rise from nearly 80,000€ in 2004 to more than 200,000€ in 2008 (increase by 150%). This increase is

[4] One trip to school in the morning and one trip back home at midday per school day. On some days there are additional trips necessary in the afternoon, for example sports.

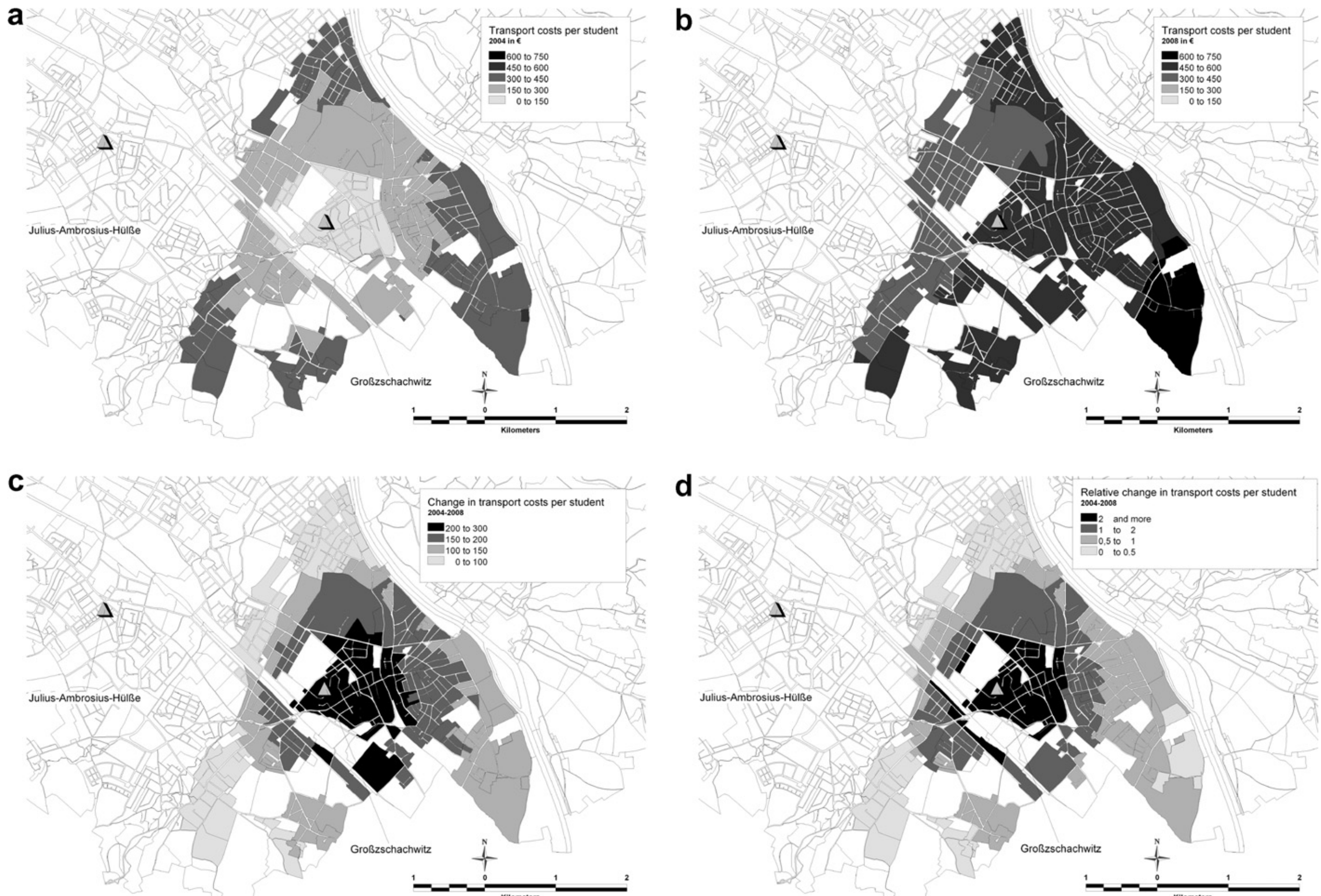

Fig. 15. Zone 1 of Großzschachwitz college: Absolute (c) and relative (d) change in transport costs from 2004 (a) to 2008 (b).

mainly due to public transport costs and focuses spatially on the proximate area (radius of 1 km) of Großzschachwitz College (see Fig. 15).

Assuming realistic location costs of a college of more than 1 million euros per year, the increase in transport costs does not justify the decision to keep an underused college running. This will probably hold true even if one considers additional external diseconomies (health, loss of community). From an economic point of view it is therefore not advisable to maintain a dense school network which is not appropriate for a smaller number of students. But if we consider other interests like ecological and social benefits, the example gives some evidence that local neighborhood schools are desirable.

6. Conclusion

We have presented a method utilizing GIS to disaggregate travel survey data. Particularly for travel-to-school analysis this could be a useful procedure to gain better and even more realistic modelling results. Mostly, students choose public transportation and thus detailed spatial information is available. In our analysis we have shown that besides the well-known factors like distance and authority responsible, the school's profile is affecting the school choice as well. The results of the multivariate analysis illustrate that weather or season, respectively, have a strong influence on transport mode choice for students' travel-to-school. Furthermore, we show that distance is the most important factor for discrimination between modes of transport linked with costs (public transport and car/motorcycle) and those with lower costs (walking and cycling). Our findings are consistent with the literature in the field. Moreover, the findings generate robust empirical evidence due to the extent of the sample.

By using an example we have made the attempt to quantify the costs of a modal-shift due to school closure. Although the increase in transport costs is remarkable this is not a substantial reason – from an economic point of view – against a school closure within an urbanized area. If we mostly consider other factors like the health of the students or ecological aspects, the costs of a modal-shift become apparent. Note, these findings are only valuable for an urban area. The closure of a school location in rural areas will have much more dramatic effects on travel-times and modal-shift as well as other socio-economic consequences.

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