URBAN TRANSPORT, ENVIRONMENTAL JUSTICE AND HUMAN DAILY ACTIVITY PATTERNS

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ABSTRACT

Emissions from road transport (such as noise, particles and gasses) have been associated with issues of environmental justice in urban areas. The majority of analyses of this issue to date have focussed on identifying potentially or actually affected socio-economic groups by income, education, employment situation and ethnicity. However, in addition to people's residential locations, their daily patterns of time use in conjunction with traffic flows also play a major role in determining their level of exposure to transport emissions. Through analysing time use surveys (TUS) to establish human daily activity patterns (HDAP) in terms of time spent at home, this paper shows that the parameters age and gender are at least as important in identifying groups that are disproportionately affected by road transport emissions in their homes in urban areas as income, education and employment situation.

environmental justice; time use; human daily activity patterns; road traffic patterns; transport; United Kingdom; Germany; Hamburg

INTRODUCTION

Rationale of this study

The development of public awareness of environmental justice concerns originated in the US in the1970s and has since been mirrored by a fairly steady level of scientific activities there (cf. Maschewsky 2005; Kloepfer 2006 & Friedemann 2007 for reviews). The concept is not as well established in Europe, though (cf. Maschewsky 2004; Elvers 2005; Wewer & Pape 2007; Köckler *et al.* 2008), which is true both for its consideration in research activities as well as for its establishment as a paradigm in public debate, guidelines and policies (Maschewsky 2005; Kloepfer 2006). Nevertheless, distributive injustice relating to environmental burdens experienced at home from transport in particular has repeatedly been attested in European settings (McLeod *et al.* 2000; Pennycook *et al.* 2001; Hoffmann, Robra & Swart 2003; Mitchell 2005; Friedemann 2007; Köckler *et al.* 2008).

However, an important analytical and thus empirical gap can be identified in the parameters according to which those population groups are classified, which may or may not be disproportionately negatively affected by environmental effects of transport: Is the common differentiation by income, employment situation and race/ethnicity (US) or education level (Europe) sufficient to identify those, who are most likely to suffer environmental injustice relating to transport? Environmental justice studies generally relate to residential location. Thus exposure to environmental burdens in and around the home relates directly to human daily activity patterns: more time spent at home means higher levels of exposure. Since transport activities (volumes, speeds, vehicle types) as well as their localised environmental effects also vary along daily cycles, the two patterns - human activities and transport - need to be related to each other. It is likely that exposure to environmental burdens from transport relating to residential location varies considerably according to age and gender in addition to the more commonly analysed socio-economic parameters. It is thus also possible, that existing or potential future occurrences of transport related environmental injustice would fail to be identified, because the parameters considered – such as income or education level – do not stratify the population along the most relevant divisions. But neither the daily activity patterns of different population groups nor the temporal variations in transport activities have so far been considered in relation to environmental justice and transport.

The correct identification and solution of environmental *in*justice in relation to transport is directly related to improving social equity and reducing health costs. Additional importance arises from the risk of multiple deprivation: population groups, which are already socio-economically disadvantaged, have limited choice of residential locations. They tend to be more exposed to environmental burdens (cf. Lampert *et al.* 2005; Maschewsky 2008), less able to care for their health (Bolte & Mielck 2004) and less able to reach health care facilities (Gaffron, Hine & Mitchell 2001). Health problems among these groups contribute disproportionately to a society's health costs, which in relation to air pollution from road traffic alone have been calculated at €15.1 billion for Germany in the year 2000 (Schmid 2005). In an ageing society, disproportionate exposure of older people to environmental effects of transport will increase such costs still further in future.

Main objectives

Existing evidence shows, that different population groups distinguished by socio-economic characteristics such as income, ethnicity and employment situation are differently affected by the adverse environmental effects of road transport in and around their homes (such as noise and gaseous and particulate emissions). This study aims to explore the opportunities offered by existing data sets to test the hypotheses resulting from the rationale outlined in the previous section. These are the following:

1. Since noise, as well as most other emissions from road transport, affects people in their homes mostly when both people and vehicles are present simultaneously, human daily activity patterns (HDAP) play a significant role in determining different groups' levels of exposure to these emissions. HDAP, specifically in terms of the time spent at home, are likely to differ between different socio-economic groups due to e.g. life stages and prevailing gender roles.

2. The standard differentiators for grouping the population in environmental justice studies relating to transport do not normally include age or gender. However, these two parameters are likely to also have a strong relationship with activity patterns, time spent at home and thus level of exposure to transport emissions.
3. The correlation between time spent at home and peak traffic times, and thus times of highest risk of exposure to road transport emissions will differ for different socio-economic subgroups of the population.

Firstly, national time use surveys were to be used to compare the average time spent at home by different socio-economic sub-groups of the population. It was decided to look at both the German Time Budget Survey 2001/2002 and the UK Time Use Survey 2000. This would help to establish, whether time use patterns identified for the German population were mirrored in the United Kingdom – where most European environmental justice research has been carried out to date - and if in turn, findings from existing environmental justice research in either context, could equally well be looked at from a time use perspective. It would also ensure some transferability of findings between Germany and the UK. Findings from the analysis of the German time use survey were then to be correlated with data documenting the spatial distribution of different socio-economic groups in the German City of Hamburg as well as their exposure to emissions from road transport, in this case specifically noise. The next step was to formulate the implications of any findings for further research in this field.

INFORMATION ON TIME USE PATTERNS

The main empirical efforts in this study were directed at extracting relevant information from large existing data sets detailing time use and socio-economic variables at national levels. The following data sets were investigated for their usefulness in fulfilling the goals of this study: the German Socio-Economic Panel Study (SOEP, ongoing) and the British Household Panel Survey's (BHPS) Calibrated Time Use Data 1994-2004 as well as the German Time Budget Survey (*Zeitbudgeterhebung* - ZBE 01/02) and the United Kingdom Time Use Survey (UK TUS 2000). The following provides a brief overview over the structure and usefulness of this data.

National Panel Studies

Both the German Socio-Economic Panel Study SOEP and the BHPS provide a rich source of socio-economic data, which in theory could be linked to time use data from other studies using appropriate indicators and weights. In the case of the BHPS, this has already been done once, creating the Calibrated Time Use Data set 1994-2004 by intersecting information from the former with diary information from the Home On-line Study (HoL, 1999 - 2001). For although the BHPS – unlike the SOEP – regularly collects information on time use, the panel survey does not use diaries but asks respondents about how often they engage in particular activities and how much time they usually spend doing paid work and household chores. Information gained in this way usually contains biases, though, not least due to the fact that the perception of time is highly subjective and changes, for example, with the attitude towards the way in which the time is spent (Kan & Gershuny, 2006). Kan & Gershuny (ibid.) therefore used the diary based HoL, which collected information from the same respondents as the BHPS, to calibrate a set of time use variables against the information from the panel study, creating a database, which can be appended to the BHPS response data[1]. However, since the Calibrated Time Use Data only provides sums of minutes per day spent on certain classes of activities (such as 'housework', or 'other unpaid domestic work' which includes voluntary work), it cannot be disaggregated sufficiently to determine with certainty the actual time spent at home by the respondents. Neither does it allow the creation of daily time use curves.

The German SOEP contains no original information on time use and though other parameters are documented in sufficient detail to allow some level of calibration of time use survey responses against this, the ZBE 2001/2002 itself contains so much socio-economic information that for the purpose of this study it was decided to focus the analysis on the German and UK time use data.

Time Use Surveys

National time use surveys (TUS) have become increasingly frequent all over the world over the last decade or so (Fisher *et al.* 2009). They usually survey 'the resident population of [a] country living in private households' (Eurostat 2009, p.7) and provide detailed information on how individuals spend their time, based on standardised time use diaries, as well as a number of variables relating to the person and to the household they live in. Recognising their usefulness not only at a national level but also for cross-country comparisons, the European Commission has issued guidelines for the harmonisation of such surveys (ibid.), which a.o. contain guidance on the survey forms and the coding of answers. TUSs are available from both the United Kingdom and Germany from the beginning of the current millennium. For the purpose of this paper, they have been used to establish, whether certain sub-groups of the population - distinguished for example by income, age, gender and educational status - spend similar or different amounts of time at home and to investigate how this time is distributed over the day.

German Time Use Survey 2001/2002 (ZBE 01/02)

The survey was conducted between April 2001 and March 2002. Survey documentation and scientific use files are available from the German Federal Statistical Office[2]. They contain data on 35,691 diary days documented by 13,798 people above 10 years of age from 5,160 households. The lower age limit is noteworthy, as ideally the time use of younger children and infants – respectively their likelihood of exposure to emission from road traffic – should also be investigated, which with this dataset is not possible. Respondents documented their time use over 3 diary days in ten minute intervals. One of the days was to be a weekend day.

[1] Both datasets can be obtained from the UK Data Archive (http://www.data-archive.ac.uk/findingData/data.asp; last accessed 28.01.2010)
[2] www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Presse/abisz/Zeitbudgeterhebung.psml; last accessed 28.01.2010

The data files contain weighting variables for the structural information relating to both individuals and households. In both cases two weights are available, one for grossing to the entire German population and one for creating a fully representative sample.

UK Time Use Survey 2000 (UK TUS 2000)

The survey was conducted in 2000. The data files provided by the Economic and Social Data Service[3] contain 20,981 diary days[4] from 11,664 individuals above 8 yrs. of age living in 6,414 households. Participants were asked to document two diary days in ten minute intervals, one of these was to be a weekend day. The data files include weighting variables, which allow either a numerical grossing to the entire UK population or a non-grossing weighting to obtain a representative sample of this population. Both weights also automatically exclude those diaries which did not contain sufficient information to make a meaningful contribution to any analysis (resulting, if applied, in a total of 19,898 diary days being available for analysis).

Neither study made a distinction between diaries filled in on a public holiday and those that were not. In both cases, though, respondents were asked to specify, whether the days on which they kept their diaries were normal or unusual compared to average days of the same type. The overall classification of the diary days and their distribution over the seven weekdays is shown in the Appendix (see Table 9). For the purpose of this study it had to be decided, whether or not those days classed as unusual by the survey respondents were going to be included in the analyses. On the one hand it could be argued, that if the goal is to compare the most representative average time use patterns of the different socio-economic groups, days that somehow deviated from the way people normally spend their time should be disregarded. As Table 9 in the Appendix shows, though, such days make up over one fifth (UK TUS 2000) or respectively one quarter (ZBE 01/02) of all the days documented. This suggests that unusual days are actually also a fairly common part of people's lives and excluding them would in fact not result in a good representation of average time use patterns. Secondly, it was found that excluding the non-normal days would, with one exception (age in the UK TUS 2000) for both surveys have resulted in a sub-sample, that was no longer representative of the ungrossed weighted sample represented by the survey results (the main statistics for the non-parametric tests run to establish this are shown in the Appendix in Table 8). It was thus decided to include all valid diary days in the analyses conducted for this study.

HAMBURG DATA

The City of Hamburg is a federal German city state located in the north of the country. It has 1.7 million inhabitants, 14.8% of its population are non-German nationals and it has an

[3] www.esds.ac.uk - Survey Number 4504; last accessed 26.01.2010
[4] Of these, 19,898 are considered of sufficient quality for analysis by the providers. The weighting variables provided – when used – automatically exclude the other cases.

unemployment rate of 8.6% (in September 2009; StaNord - Statistisches Amt für Hamburg und Schleswig-Holstein 2009a; Germany: 8% in the same month; Statistisches Bundesamt 2010). There were 480 private cars per 1000 inhabitants in Hamburg in 2007 (StaNord - Statistisches Amt für Hamburg und Schleswig-Holstein 2009b) compared to 566 in Germany as a whole (Bundesministerium für Verkehr 2008) and the city lies at the intersection of four German motorways, the A1 and A7 going roughly north to south, the A24 leading east towards the Baltic Sea and the A25 going southeast to Berlin. The first two run through the municipal area for some distance while the latter two actually originate in Hamburg and there is no major ring road as an alternative to through traffic (see also Figure 1).

The Hamburg Ministry of Urban Development and the Environment operates continuous traffic counters around the city. These provide information on traffic levels at particular cross sections of main roads sliced into 15 minute intervals, differentiated by, among others, total vehicle numbers and numbers of HGVs above 3.5t. The 2008 traffic count data from the 9 counters *not* located on a motor way was made available for this study. For locations of the counters, see Figure 1.

Two further data sources were used for the Hamburg analyses. The first was a set of georeferenced socio-economic data commercially available from the Infas GEOdaten GmbH. The information that was available for this study is described in Table 1. The parameters are geocoded to either the level of residential quarters[5] or to the level of street sections delimited by street numbers. For maximum comparability, the banded information on age in this dataset determined the recoding of parametric age variables in the TUS. However, it should be noted the Hamburg data age bands start with '0-14yrs', while the ZBE 2001/2002 only documents time use of people aged 10yrs or over and the UK TUS 2000 includes respondents from age 8 upwards.

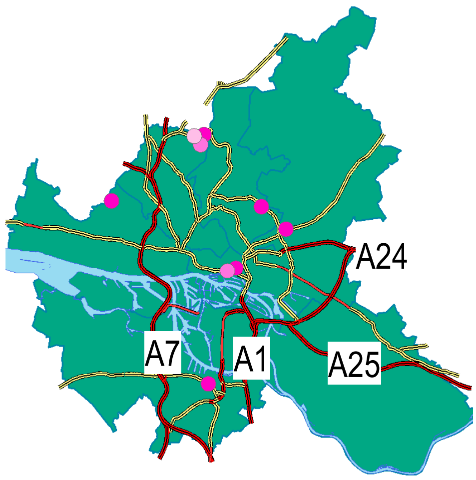

Figure 1: The City of Hamburg area with motorways and national roads; dots indicate location of continuous traffic counters

Parameter	coding level provided	possibility to calculate street section level from data?
no. of residents	residential quarter	yes
no. of households	residential quarter / street section	*n.a.*
average no. of residents / household	street section	*n.a.*
no. and % of residents in 5 age groups	residential quarter	yes
index of average purchasing power per head (relating to 100 = €19,200 net private income)	street sections	*n.a.*

Table 1: Georeferenced socio-economic parameters pertaining to the Hamburg population used

[5] Since the data relates only to people's places of residence, all of Hamburg is subdivided into such quarters, including areas, which predominantly have other uses.

The second data set was the road traffic noise data map constructed in 2007 by the local planning authority – the Hamburg Ministry of Urban Development and the Environment – in accordance with the requirements of German legislation on immission protection (Bundesministerium der Justiz 2006b), which was passed in order to implement the EU Ambient Noise Directive 2002/49/EC[6].

ANALYSIS OF TIME SPENT AT HOME

Germany

The ZBE 2001/2002 data contains information on a.o. household income, age and gender of the respondents, level of education and employment status. Along with the coding of the type of activity respondents were engaged in during each 10 minute interval of their diary days, there are also variables containing information on the location of the respondents during these activities. One of the location codes is defined as '*at home'*. Summing up all time intervals coded in this way thus provides the total time in minutes that each respondent spent at home on each of their diary days. The means of theses sums were compared for gender, different age groups, levels of education, employment situations and income groups. The results of these analyses are presented in Table 2. The last column shows that the average amount of time spent at home differs significantly between males and females and all sub-groups of the parameters age and income. The differences are not quite as clear cut in the case of level of education (highest school based qualification) and employment situation. Nevertheless, for these parameters, too, the means for most sub-groups differ significantly from one another.

TIME SPENT AT HOME PER DAY	sample size **N**	**mean** minutes at home	**SD**	**standard error**	**95% confidence interval for mean**		**significance of difference in *mean minutes spent at home***
					lower limit	upper limit	
GENDER							
female	18,396	1,026	347	2.7	1,021	1,031	T-test for unequal variances: $p < 0.01$
male	17,295	934	349	2.7	929	940	
last column: sub groups NOT significantly different at 95% level (Games Howell) ▼							
AGE	*age groups as for Hamburg data*						
10-14 yrs	2,291	972	309	6.5	960	985	none
15-24 yrs	4,703	830	369	5.4	820	841	none
25-49 yrs	14,011	931	337	2.9	925	936	none
50-64 yrs	8,116	1,020	337	3.7	1,013	1,027	none
65 + yrs	6,569	1,154	323	4.0	1,146	1,162	none
total values for parameter	*35,691*	*982*	*352*	*2*	*978*	*985*	*n.a.*

[6] The noise mapping methodology was based on the relevant German guidelines (Bundesministerium der Justiz 2006a). Noise levels are documented for a 10m x 10m grid, they relate to 4m above ground level and the base year for traffic levels is 2006 – see section on *Road Traffic Noise in Hamburg* for further detail.

TIME SPENT AT HOME PER DAY	sample size **N**	**mean** minutes at home	**SD**	**standard error**	**95% confidence interval for mean** lower limit	upper limit	**significance of difference in *mean minutes spent at home***
EDUCATION	*highest level of school based qualification, nearest UK equivalents to coded German qualifications are used to label sub-groups*						
A-levels	7,285	924	376	4.4	916	933	*vocational qualification*
vocational qualification	2,448	948	349	7.0	934	961	*A-levels; still at school*
O-levels	10,737	984	348	3.4	977	990	*left school without formal qualifications*
formal qualification below O-levels	10,593	1,034	342	3.3	1,028	1,041	*left school without formal qualifications*
left school without formal qualifications	333	1,025	312	17.1	992	1,059	*O-levels; formal qualification below O-levels*
still at school	3,829	947	326	5.3	937	958	*vocational qualification*
total for parameter	*35,691*	*982*	*352*	*1.9*	*978*	*985*	*n.a.*
EMPLOYMENT SITUATION	*respondents under 16 yrs of age and variable category for mandatory military service were excluded*						
full time	13,185	848	329	2.9	842	854	none
part time	1,716	994	287	6.9	980	1,007	*casual / infrequent employment*
in vocational training	752	785	343	12.5	760	809	none
low-level employment	1,376	1,027	319	8.6	1,011	1,044	none
casual / infrequent employment	552	958	390	15.7	925	990	*part-time*
not employed; no paid work	15,161	1,110	333	2.7	1,105	1,115	none
total for parameter	32,297	986	353	2	982	990	*n.a.*
INCOME	*net household income per month*						
0-999 €	2,224	1,060	328	6.9	1,046	1,073	none
1000-2499 €	16,230	1,008	351	2.8	1,002	1,013	none
2500-3749 €	10,573	959	350	3.4	952	965	none
3750-5000 €	3,184	922	353	6.3	910	934	none
5000+ €	1,334	890	352	9.6	871	909	none
total for parameter	*33,546*	*983*	*352*	*1.9*	*979*	*987*	*n.a.*

Table 2: Statistics for the mean sum of minutes spent at home per day by different socio-economic sub groups of the population from ZBE 01/02 (Notes: weighting variable for personal activity variables applied: *gpzv95nn*; mean, SD and confidence intervals rounded to the nearest minute; shaded cells mark sub-groups, for which mean values are *not* significantly different to *any* other group of the same parameter.)

For a more direct comparison, the ranked means only are shown in Table 3. It can be seen that sub-groups of all five parameters analysed are found in the top five ranks. Combining these five ranks, 65+yr old females with formal qualifications below O-levels, who are unemployed or retired and live in a household with a net monthly income of below 1000€ form the socio-economic group, which is likely to spend more time at home than any other. Only 0.8% of the sample population belong in this group. Moving up one income band (1000-

2499 €), though, one already finds 3.6% of the sample in the corresponding group. It is also noteworthy that this is in fact the largest group one can find in the sample, which exhibits a particular combination of expressions of these five socio-economic variables. Conversely, 15-24 yr old males with school based qualifications at A-level, who are in vocational training and live in a household with a net monthly income of 5000+ € would be the group likely to spend least time at home. Though clearly, this combination of the five parameters is highly unlikely (and only found in 0.01% of the sample) individuals with such a combination of gender, qualification and income are found more frequently (1% of the sample).

gender	age	education	employment situation	income
- 5 - ***1,026*** *female*	**- 1 -** ***1,154*** *65 + yrs*	**- 3 -** ***1,034*** *formal qualification below O-levels*	**- 4 -** ***1,110*** *not employed; no paid work*	**- 2 -** ***1,060*** *0-999 €*
- 17 - ***934*** *male*	**- 8 -** ***1,020*** *50-64 yrs*	**- 5 -** ***1,025*** *left school without formal qualifications*	**- 5 -** ***1,027*** *low-level employment*	**- 9 -** ***1,008*** *1,000-2,499 €*
	- 12 - ***972*** *10-14 yrs*	**- 11 -** ***984*** *O-levels*	**- 10 -** ***994*** *part time*	**- 13 -** ***959*** *2,500-3,749 €*
	- 18 - ***931*** *25-49 yrs*	**- 15 -** ***948*** *vocational qualification*	**- 13 -** ***958*** *casual / infrequent employment*	**- 19 -** ***922*** *3,750-5,000 €*
	- 23 - ***830*** *15-24 yrs*	**- 16 -** ***947*** *still at school*	**- 22 -** ***848*** *full time*	**- 21 -** ***890*** *5,000+ €*
		- 19 - ***924*** *A-levels*	**- 24 -** ***785*** *in vocational training*	

Table 3: Time spent at home per day in minutes from ZBE 01/02 **-** ranked means for sub-groups of each parameter in columns with overall rank of each mean value provided in each cell

The variable, which most clearly divides up the sub-groups of all other parameters, is gender. Differentiating time spent at home between males and females shows that girls and women spend more time at home than boys and men in almost all sub-groups of age, education, employment situation and income. The gender specific differences in means are represented in Figure 2[7].

[7] It should be noted that the numbers used to construct these diagrams are taken from the results of calculations for the general linear model. The software used for all the statistical analyses carried out during this study - SPSS 16® - makes automatic adjustments for the overparameterisation of this test (Brosius 2008). The values obtained for the overall means thus differ slightly from those provided in Table 2. Their comparative 'positions' are, however, not affected.

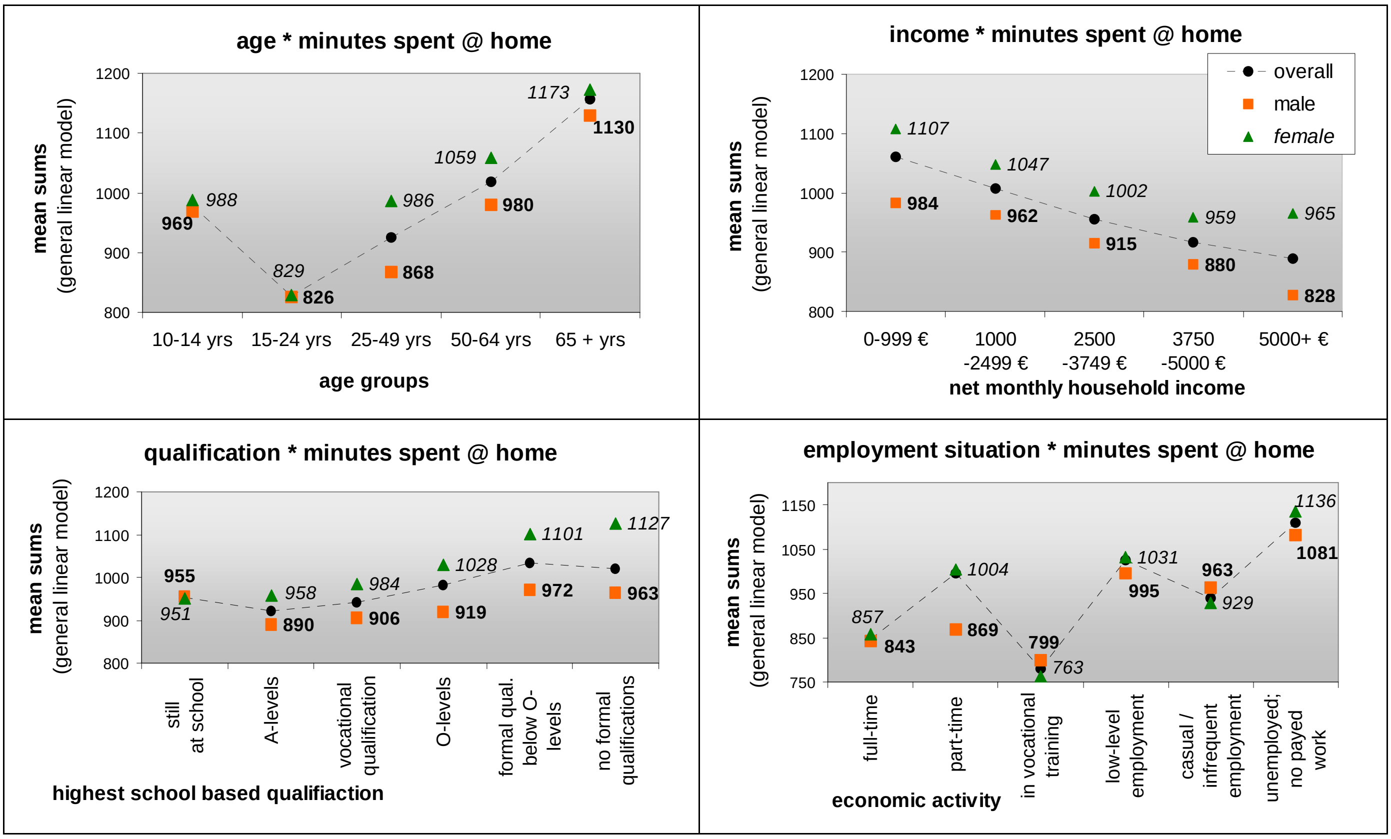

Figure 2: ZBE 01/02, Germany - average amount of minutes spent at home per day by different socio-economic population groups distinguished by gender. Note: The symbol key in the top right corner applies to all diagrams. *(for orientation: 1000 mins = 16hrs 40mins)*

No other parameter separates the others nearly as evidently – partly because the other parameters are also more closely linked, such as e.g. age and education, employment situation and (household) income or (household) income and age.

United Kingdom

The analyses run on the UK TUS 2000 data were to mirror those carried out for the German dataset as closely as possible. However, as the methodologies employed for carrying out and coding the two surveys diverged, some adjustments had to be made. The main difference in the UK time use data from the perspective of this study is the fact, that although location codes are also provided for all 10-minute intervals of the diary days and the location '*at home*' is separately coded[8], these variables also contain a code for '*main activity = sleep/work/study - no code required*'[9]. The data provides no error proof means to precisely correct for the fact, that summing up the 10-minute intervals said to have been spent '*at home*' would miss all the time periods spent at home sleeping – as well as working or studying. In order not to exclude the time people normally spend at home when they are asleep, it was decided to assume for the purpose of the analysis, that all the intervals, for which the main activity was coded as '*sleep*' should be added to those coded as spent '*at*

[8] This code also includes time spent in the yard or in the garden of a one-family or a terraced house as well as work time if the work place is at home.
[9] see variables *wher_001* to *wher_144* in dataset *diary_data_8*

home'. Clearly, this has introduced some level of error, as people do not always sleep at home – just as they do not only work or study away from home. However, it was considered that out of the three activity types, sleeping was the most likely to be done at home. It also made up the greatest amount of time. While this step made any direct statistical comparisons between findings from the two sets of data difficult, it was still considered worth while to ensure as much as possible, that comparable categories were created for the parameters under investigation from both data sets.

To allow any comparisons between time use of households with similar incomes in Germany and the UK would necessitate the use of purchasing power parities (PPP)[10] for an equivalent conversion of incomes measured not only in different currencies but also relating to different price structures making up the costs of living. In the UK TUS 2000, income variables are available at the household as well as the individual level. On the individual level, *net* monthly income is stated for both employees and the self-employed (variables 'empincbd' and 'seincbd', both in 11 income bands). A third variable ('totpinc') states total *net* monthly personal income for/from both categories, grouped into the same income bands. On the household level, the *annual gross* household income is also provided in another 11 income bands[11] ('groshinc'). In the German ZBE 01/02, however, income information is provided only as *monthly net* amounts at the household level. One variable contains the exact monthly *net* household income in Euros ('h14x') stated in multiples of 100. The survey included the option of choosing one of seven *net* income bands rather than stating exact household incomes, a choice made by 30.6% of the respondents. This information is provided in variable 'h15' in Deutschmark (DM) and corresponding Euro amounts. The diverging nature of this information in the two surveys thus does not allow a direct comparison of time use by income groups between Germany and the UK. However, it would theoretically have been possible to calculate *net* monthly household incomes for the UK survey respondents from the respective personal income of all members of one household and then group these corresponding to the *net* monthly household income bands in the German survey having also done the necessary conversions to purchasing power standards.

Thus, tests were run to find out, whether excluding the 30.6% of responses from the German survey, which only provided information on income bands would result in a sub sample that was representative of the full sample in terms of the distribution of gender, age and level of education[12] (note: such tests could not be run regarding income, as the grouping variable used for the non-parametric tests was itself derived from the information provided on income, i.e. whether exact information had been provided or not). Results showed, that such a subsample would not be sufficiently similar to the full sample – and thus not representative -

[10] PPP factors for European countries and beyond are calculated every year by National Statistical Institutes of the participating countries, Eurostat and the OECD. They are intended to help eliminate the effect of price level differences across countries. Dividing individual income values by the corresponding PPP factor (calculated for individual incomes in that country) results in an artificial common currency named purchasing power standard (PPS; European Commission 2009). Such conversions would then allow the direct comparison of for example household incomes in different countries.
[11] They correspond to the rounded amounts of twelve times the monthly *net* personal incomes.
[12] These tests were run using the weighting factor 'hpst95nn' recommended for the analysis of person-related structural data from this survey.

to allow its meaningful use. The actual statistics regarding the probability of both groups - those with and those without exact statements of income - coming from the same population, are as follows: gender (nominal; chi-square) $p<0.005$; educational status (nominal; chi-square) $p<0.005$; age (interval; Kolmogorov-Smirnov) $p<0.005$.

It was not possible, either, to base the comparisons on, for example, quartiles or quintiles of the overall distribution of incomes. The exact incomes from the German sample could not be used for the reasons stated above and the different income bands used in the two studies also did not allow an equivalent conversion into such groups (11 bands in the UK survey with steps between £220 and £2,090; 7 bands in the German survey with steps between €250 and €1,250).

In the UK survey, respondents aged 8 and 9 were included, which was not the case in the German survey. When creating age bands from the UK data, these were therefore coded separately from the 10-14 year olds. The UK TUS 2000 variable relating to employment was coded somewhat differently from that of the ZBE 01/02. Here, distinctions are made between three types of economic activity (full time, part time, unemployed) and five types of economic inactivity (including e.g. being retired or a student). In the German data, though, significant differences in the time spent at home were found not only between those in employment and those respondents, that were not, but also between those active in different types of employment (see Table 2). Those economically inactive or unemployed, though, were all described by one code. It was thus decided to group together all categories of economic inactivity as well as the unemployed to mirror the German group of '*not employed; no paid work*' and to exclude the separately coded group of '*under 16yrs - ineligible for employment questions*'. Together with full time and part time employment, this would leave three groups, that could directly be compared.

An exploratory analysis of the average time spent at home by members of different ethnic groups only showed significant differences between two of seven groups. Since in the German data set the nearest equivalent classification only distinguishes between '*German nationality*' and '*non-German nationality*' and there had been no difference for these groups, this parameter was not explored any further. It is worth noting, though, that studies focussing on the spatial differences in the concentrations of air pollutants and populations with higher proportions of ethnic minorities have found positive correlations between the two parameters in UK contexts (e.g. McLeod *et al.* 2000) as well as in Germany (Köckler *et al.* 2008). The result of the comparison of means of average time spent at home according the UK TUS 2000 are shown in Table 4.

TIME SPENT AT HOME PER DAY	sample size **N**	**mean** minutes at home	**SD**	**standard error**	**95% confidence interval for mean**		**significance of difference in *mean minutes spent at home***
					lower limit	upper limit	
GENDER							
female	10,280	1,048	273	2.8	1,043	1,053	T-test for unequal variances: p < 0.01
male	9,618	959	259	2.6	954	965	

TIME SPENT AT HOME PER DAY	sample size **N**	**mean** minutes at home	**SD**	**standard error**	**95% confidence interval for mean**		**significance of difference in *mean minutes spent at home***
					lower limit	upper limit	
last column: sub groups NOT significantly different at 95% level (Games Howell) ▼							
AGE	*age groups as for Hamburg data*						
8-9 yrs	583	980	188	7.8	965	996	none
10-14 yrs	1,520	953	209	5.4	943	964	*25-49 yrs*
15-24 yrs	2,626	898	251	4.9	888	907	none
25-49 yrs	7,904	944	263	3.0	938	950	*10-14 yrs*
50-64 yrs	3,873	1,033	268	4.3	1,024	1,041	none
65 + yrs	3,392	1,228	199	3.4	1,221	1,234	none
total for parameter	19,898	1,005	270	1.9	1,002	1,009	*n.a.*
EDUCATION	*highest level of qualification*						
degree level or higher	2,338	916	279	5.8	905	927	none
higher education below degree level (e.g. nursing)	1,728	987	272	6.5	974	1,000	O-levels; qualifications below O-levels
A-levels & equivalents	1,746	945	264	6.3	932	957	under 16
O-levels & equivalents	2,482	969	260	5.2	959	979	higher edu. below degree level; under 16
qualifications below O-levels; other qualifications[13]	1,739	1,013	277	6.7	1,000	1,026	higher edu. below degree level
no qualifications	6,734	1,088	265	3.2	1,082	1,095	none
under 16 - ineligible for qualification questions	2,246	955	207	4.4	947	964	A-levels; O-levels
total for parameter	19,012	1,007	270	2.0	1,003	1,010	*n.a.*
EMPLOYMENT SITUATION	*respondents under 16 yrs of age were excluded*						
full time employment	7,220	864	247	2.9	859	870	none
part time employment	2,632	1,009	233	4.5	1,000	1,018	none
economically inactive, unemployed	6,705	1,174	229	2.8	1,168	1,179	none
total for parameter	16,558	1,013	277	2.2	1,008	1,017	*n.a.*
INCOME	*gross household income per year*						
less than £2,160	504	1,108	229	10.2	1,088	1,128	none
£2,160 - 5,210	1,729	1,155	238	5.7	1,144	1,166	none
£5,210 - 10,430	2,537	1,102	253	5.0	1,093	1,112	none
£10,430 - 15,640	2,235	1,008	267	5.6	996	1,019	none
£15,640 - 41,000	6,642	950	258	3.2	944	956	none
£41,000 +	2,422	906	263	5.3	896	917	none
total for parameter	16,070	1003	269	2.1	998	1,007	*n.a.*

Table 4: Statistics for the mean sum of minutes spent at home per day by different socio-economic sub groups of the population from UK TUS 2000 (Notes: non-grossing weighting variable for diary validity applied: *wtdry_ug*; mean, SD and confidence intervals rounded to the nearest minute; shaded cells mark sub-groups, for which mean values are *not* significantly different to *any* other group of the same parameter.)

[13] This category is an aggregate of seven categories in the original data set, all of which code for qualifications without equivalent in the German dataset and with maximum N=608.

As for the ZBE01/02, the means for the different groups are shown in ranked sequence in Table 5. In the UK TUS 2000, the first five ranks are made up from sub-groups of three of the parameters: age, employment situation and income. Using these as a basis for identifying the socio-economic group whose members spend most time in their home identifies people aged 65 or over, who are economically inactive, respectively unemployed, and live in a household with a gross annual income up to £10,430 (€11,944). Such a group makes up 12.2% of the sample. Using all five parameters would add the characteristics '*female*' and '*without qualifications*' and result in a group, which still makes up 6.7% of the sample. If, in parallel to the ZBE 01/02, only the top ranked income bracket is included, the resulting socio-economic group makes up 1.3% of the sample. At the other end of the scale – where people spend least time at home - are 15-24 year old males, who have a degree level or higher qualification, are in full-time employment and live in households with a gross annual income of £41,000 (€46,950) or above. This combination is unsurprisingly rare in actuality and makes up 0.08% of the sample. Moving to the next age bracket in the ranking, those aged 25-49 yrs, one can find 2.3% of the sample in the group. In the German survey, qualifications above A-levels or equivalent were not separately coded. To obtain a more comparable figure, the two qualification categories above A-level should be included. This results in a group making up 3.4% of the sample. Looking at the cross-tabulations combining all five parameters, the single biggest group sharing only one expression of each parameter are males with no qualifications between the age of 25-49, who are in full-time employment and live in households with a gross annual income between £15,640 - 41,000. They make up 3.1% of the sample.

gender	age	education	employment situation	income
- 7 - ***1,048*** *female*	**- 1 -** ***1,228*** *65 + yrs*	**- 6 -** ***1,088*** *no qualifications*	**- 2 -** ***1,174*** *economically inactive, unemployed*	**- 3 -** ***1,155*** *£2,160 - 5,210*
- 15 - ***959*** *male*	**- 8 -** ***1,033*** *50-64 yrs*	**- 9 -** ***1,013*** *qualifications below O-levels & other*	**- 10 -** ***1,009*** *part time employment*	**- 4-** ***1,108*** *< £2,160*
	- 13 - ***980*** *8-9 yrs*	**- 12 -** ***987*** *higher education below degree level*	**- 24 -** ***864*** *full time employment*	**- 5 -** ***1,102*** *£5,210 - 10,430*
	- 16 - ***953*** *10-14 yrs*	**- 14 -** ***969*** *O-levels & equivalents*		**- 10 -** ***1,008*** *£10,430 - 15,640*
	- 19 - ***944*** *25-49 yrs*	**- 16 -** ***955*** *under 16 – not eligible for question*		**- 18 -** ***950*** *£15,640 - 41,000*
	- 22 - ***898*** *15-24 yrs*	**- 19 -** ***945*** *A-levels & equivalents*		**- 22 -** ***906*** *£41,000 +*
		- 21 - ***916*** *degree level or higher*		

Table 5: Time spent at home per day in minutes from UK TUS 2000 **-** ranked means for sub-groups of each parameter in columns with overall rank of each mean value provided in each cell

For the data from the UK TUS 2000, distinguishing analyses by gender were also run for the other four parameters investigated (Figure 3; the same notes apply as for Figure 2). The results show, that female members of the population spend more time at home on average than males in almost all age groups (from 15 yrs onward), in all income bands, all qualification groups safe those under 16 and in all employment situations. These findings are very similar to those from the German data, which showed, too, that girls still at school spend very slightly less time at home than boys and female members of the population are more at home on average than males in all other qualification groups, all age groups and all income bands. The situation in Germany differs only in the sense, that in the groups distinguished by employment situation, women are at home somewhat less than men if they are in vocational training or casual/infrequent employment.

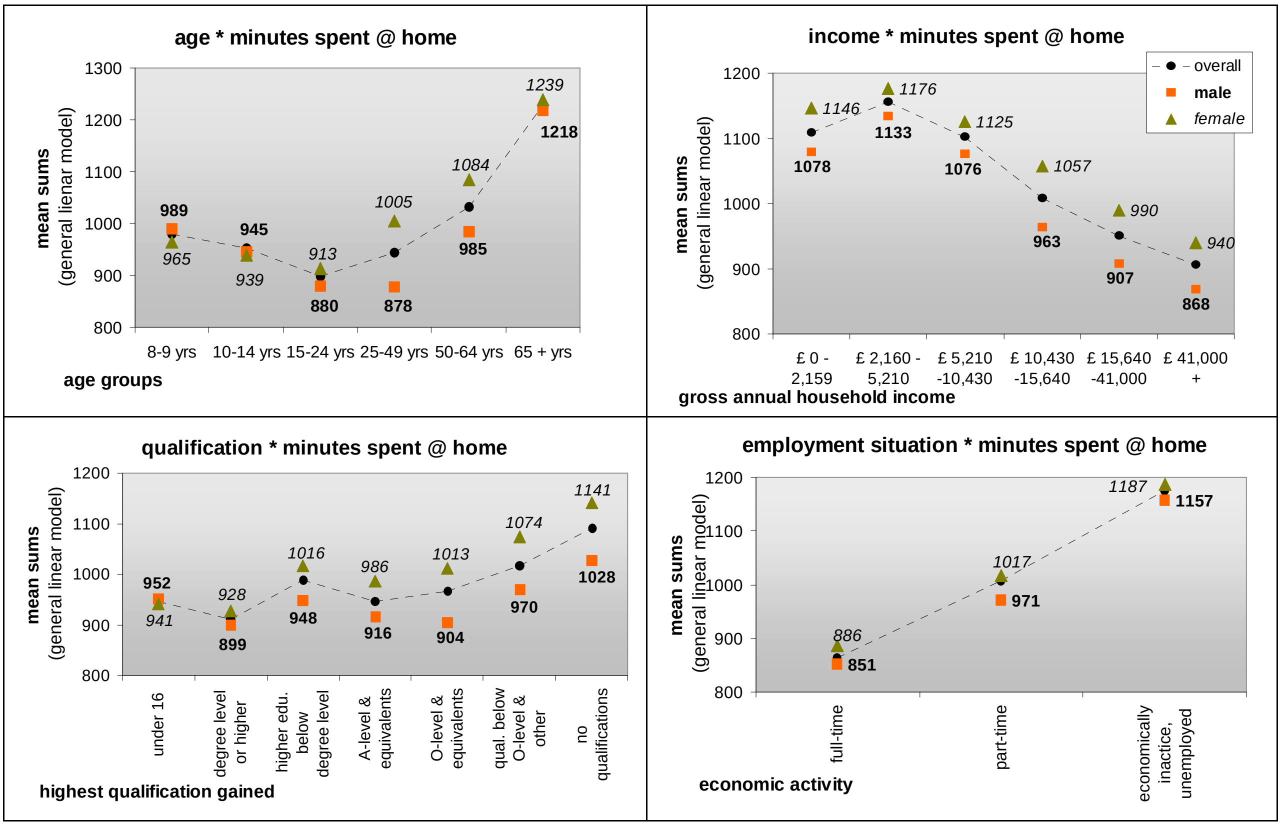

Figure 3: UK TUS 2000 - average amount of minutes spent at home per day by different socio-economic population groups distinguished by gender. Note: The symbol key in the top right corner applies to all diagrams. *(for orientation: 1000 mins = 16hrs 40mins)*

Overall trends in Germany and the UK

As stated earlier, the differences in the methodology of the two time use surveys does not allow for a statistical comparison of the time spent at home by different groups of the population. However, some general comparisons between the results from the two data sets are still possible.

In addition to an overall consistency across both datasets in the observation, that women and girls spend more time at home than boys and men, the average differences between the genders in the means of each parameter from the German and the UK data sets also point in a similar direction (Table 6). The smallest average difference is found for the parameter employment situation, followed by age. Distinguishing the sample by employment and income leads to larger average differences, though these differ somewhat in magnitude between the two data sets. The figures should not be used for comparisons over and above such general statements, though, due to both the differences between the expressions of the parameters and the possible error in the UK dataset analysis introduced by the assumption, that all time spent sleeping is time spent at home.

	age	**qualification**	**employment situation**	**income**
ZBE 01/02	52	91	28	103
UK TUS 2000	42	69	37	68

Table 6: Average difference in mean sums of minutes spent at home by females and males for each parameter and both data sets; $\Sigma\ (\overline{x}_{\text{female}} - \overline{x}_{\text{male}})\ /\ N_{\text{subgroups}}$

In the ZBE 01/02, the maximum difference between mean time spent at home for females and males is 163 minutes (qualification: *no formal qualifications*), the minimum is |3| (age: *15-24 yrs*; qualification: *still at school*). In the UK dataset, the maximum difference is 127 (age: *25-49 yrs*), the minimum is |6| (age: *10-14 yrs*).

As the diagrams in Figure 4 further show, the general trends which can be observed for all parameters are very similar in both the German and the UK contexts: people with lower qualifications tend to spend more time at home, as do those with a lower degree of economic activity. Young people between 15 and 24 yrs of age are least at home, while those aged 65 or over are at home most often. It can thus be concluded that the overall influence of the socio-economic parameters investigated on the amount of time people spend at home – and on the amount time they are thus likely to be directly exposed to environmental burdens from traffic – is similar in Germany and the UK. From a public health as well as a planning point of view, it is also important to note, that the parameters age and gender are equally important in this respect as the parameters qualification, employment status and income, which are more commonly investigated in conjunction with transport and environmental justice questions.

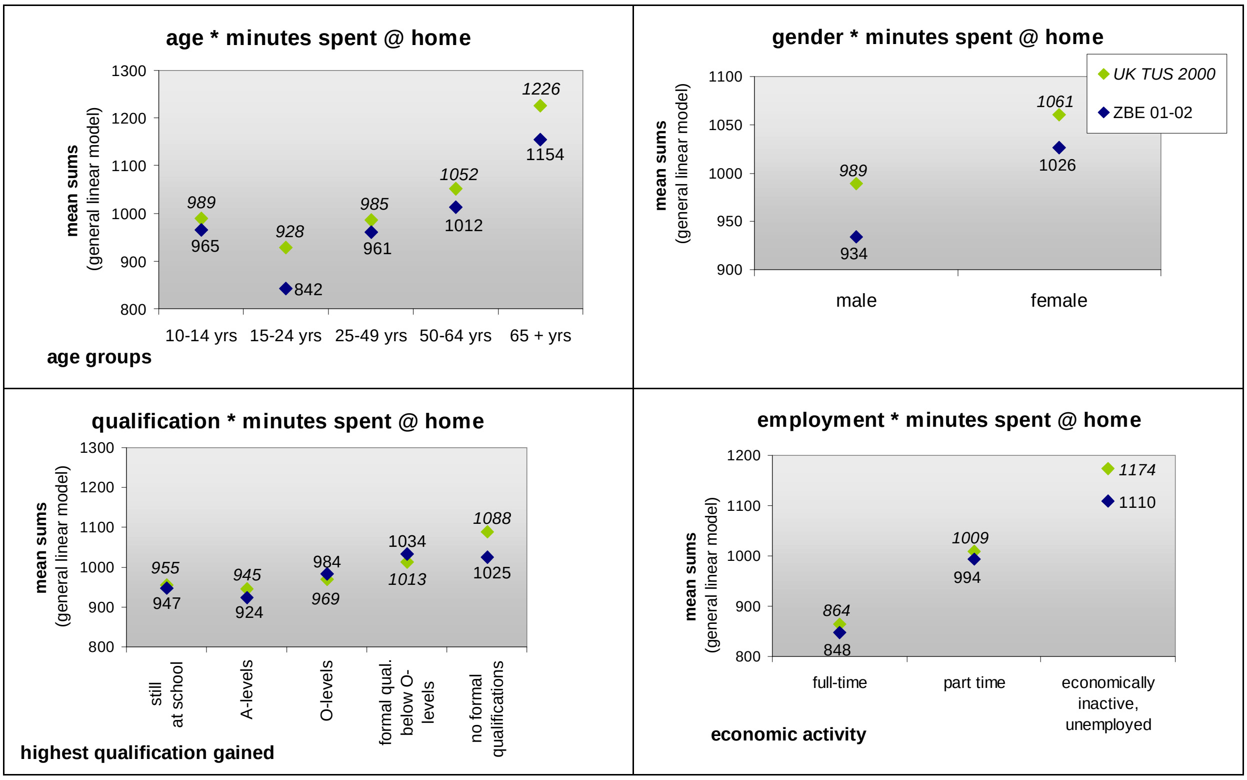

Figure 4: Average amount of minutes spent at home by comparable socio-economic groups in Germany and the UK from the TUS analysed. Notes: The symbol key in the top right corner applies to all diagrams; incomparable sub-groups from either survey are not shown. *(for orientation: 1000 mins = 16hrs 40mins)*

Figure 4 contains no diagram for income bands, as these are too dissimilar between the data sets, but looking at Figure 2 & 3, it can be seen, that people with lower incomes also spend more time at home and those with the highest incomes are home least. In almost all sub-groups, women spend more time at home than men, the overall average difference between genders being 1:32 hrs in Germany and 1:10 hrs in the UK. Most of these observations can relatively easily be explained with reference to life phases and the prevailing – if reducing – prevalence of gender roles. More publications investigating the time use patterns revealed by both surveys, how they differ within each country and also providing some explanation of what these observations reveal about social structures have been published by the bodies responsible and can, among other, be found on their respective websites[14]. The primary purpose of the analyses presented here was to investigate, to what extent different socio-economic parameters can be used to identify sub-groups of the population, which are likely to spend more time at home than others and whose exposure to road traffic emissions in their residential context is thus going to be greater. A comparability between the predictive powers of these parameters in Germany and the UK has also been established. The next step was to investigate more closely the time use patterns of people in Germany, at what times of day different population groups are likely to be at home and how this correlates with patterns of (and thus emissions from) motorised road traffic. For an easier narrative, the

[14] ZBE 01/02: www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Content/Publikationen/Fachveroeffentlichungen/WirtschaftsrechnungenZeitbudget/Zeitbudgeterhebung/ZeitbudgetUeberschrift,templateId=renderPrint.psml (accessed 05.02.2010)
UK TUS 2000: www.statistics.gov.uk/statbase/Product.asp?vlnk=9326 (accessed 05.02.2010)

traffic patterns are discussed first and then integrated into the presentation of the time use patterns.

TRAFFIC PATTERNS

Average daily traffic flows are a common way to represent traffic patterns – either for a particular section of road or more generically for certain types of road in a network for example. These are normally shown as curves along a 24 hr axis, which can be superimposed onto time use diagrams for population groups. Working with time use data, which is representative of all of Germany, the question arose, what level of aggregation in the data used to calculate average daily traffic flows would make most sense. Averages representing traffic flows on main roads in Germany would correspond to the geographic coverage of the time use data set, especially since the data provides no means of distinguishing between the level of urbanisation or settlement density in which the participating households were located. However, such a variable is available in the UK TUS 2000 (banded population density in people per 10 hectare). Running a unifactorial ANOVA test with post hoc Games-Howell comparisons of all bands on the time spent at home by people living in these different density contexts revealed no significant differences between any of the groups. Taking into account the similarities between the time use of people in Germany and the UK revealed in other analyses (see Section *Data Analyses*), it was considered to be a fair assumption, that the situation would be similar in Germany. It was thus decided to utilise the raw data from the continuous traffic counts in the City of Hamburg, which has been described above (see Section *Hamburg Data*). The 9 continuous counters on Hamburg's main roads shown in Figure 1 are in a couple of cases located quite close together. In these cases, they are actually placed at junction points in the network, where flows converge or diverge respectively. Since the data was averaged over all counters, the overall average daily traffic flow figures generated would still be as representative as possible with the data available. Count data for each 15 minute interval in 2008 from all counters was averaged for all days, for weekdays only and for non-week days (weekends and public holidays), showing results for total, bi-directional vehicle flows as well as separately for HGVs above 3.5t. The averages were calculated making allowances for any gaps in the data, which resulted from e.g. temporary malfunctioning of the counting equipment.

Passenger car equivalents (PCE) are often used to allow for the fact, that the effect on e.g. traffic flows, accident risks or infrastructural integrity differs for different types of motor vehicles (e.g. motor bikes, passenger cars and heavy goods vehicles - HGVs). Depending on the context, the adjustment factors vary. Since one of the main concerns when looking at environmental justice and transport is noise, it was decided to use a formula related to German noise abatement planning: $N * (1 + 0.082 * pHGV)$, where N is the total number of motor vehicles per time interval and pHGV the percentage share of HGVs above 3.5t. The values 1 and 0.082 are constants. This formula is based on the German government's guidelines for the interim procedure of calculating ambient noise from road traffic (Bundesministerium der Justiz 2006a). They are part of the legislation, which converts the European Directive on Environmental Noise (2002/49/EC) into national law. The diagrams in

Figure 5 show the traffic flow curves for weekdays and non-weekdays as well as the aggregate curve for all days. The curve for PCEs shows quite clearly, that adjusting for HGV proportions from a noise related perspective, their effect is considerable. It can also be seen, that morning and afternoon traffic peaks on weekdays are actually quite spread out and that average traffic levels on the main road network expressed in noise related PCEs remain above 4000 / hr from about 6:15 till 19:00 (remembering that the values shown in the diagrams relate to 15 minute intervals – see top left diagram of Figure 5).

Figure 5: Average daily traffic flows on Hamburg main roads for total number of vehicles, number of HGVs and passenger car equivalents (PCE). The black arrows in the diagram on the top right mark the two quartiles of total daily flows around the morning and afternoon peak times from 06:30-10:15 and 14:15-18:00 respectively.

TIME USE PATTERNS

The main, if not only, emissions from transport, which are looked at in the context of environmental justice are noise, particulate matter (PM) and nitrous oxides. Being exposed to them in ones residential environment relies to a very large extent – if not exclusively - on actually being at home when traffic in the form of motorised vehicles is present. In the case of noise, this correlation is most direct. Due to dependence on weather conditions as well as road and building structures, the relationship is not as direct for both fine particles and gases, but they settle and/or get dispersed over time, so that their concentrations in the ambient air even around main roads will decrease when traffic is less or absent – while it might increase elsewhere (see e.g. Mitchell 2005). In addition to finding out, how much time different groups of people spend in their homes, one goal of this study was thus also to examine, when people are at home in comparison to when traffic flows are heaviest. Further analyses are restricted to weekday time use patterns and traffic flows since this is when traffic patterns are most extreme and they make up the majority of days in the calendar. It must be remembered, that the time use data comes from people living in all types of residential environments while the observations relating to the traffic flow data will be predominantly relevant to those actually living on or around a main road. The following diagrams show the respective weekday time use curves for groups with different socio-economic characteristics. In each case, the average weekday traffic flow curve for Hamburg is added, plotted against a second y-axis. The pie charts on the right show the share of the subgroups of each parameter in the overall population. The symbol keys are the same as for the line diagrams.

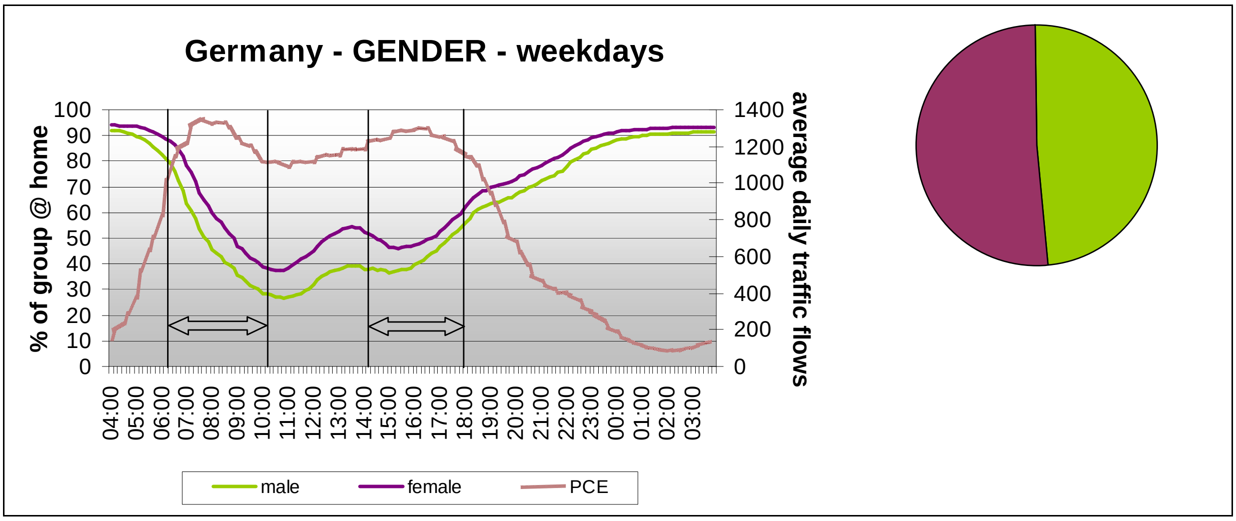

Figure 6: Patterns of time spent at home by female and male members of the population on weekdays (average weekday traffic flow for Hamburg shown in PCEs, flow quartiles around peak hours indicated)

The overall time@home patterns are similar for both genders. Males leave home earlier and do not return home as much in the early afternoon, though. The distance between the curves for both genders is greatest during the day when traffic loads are high. This means, that the exposure of females to traffic related environmental burdens is, relatively speaking, even greater than if the difference in time@home was distributed evenly over the day.

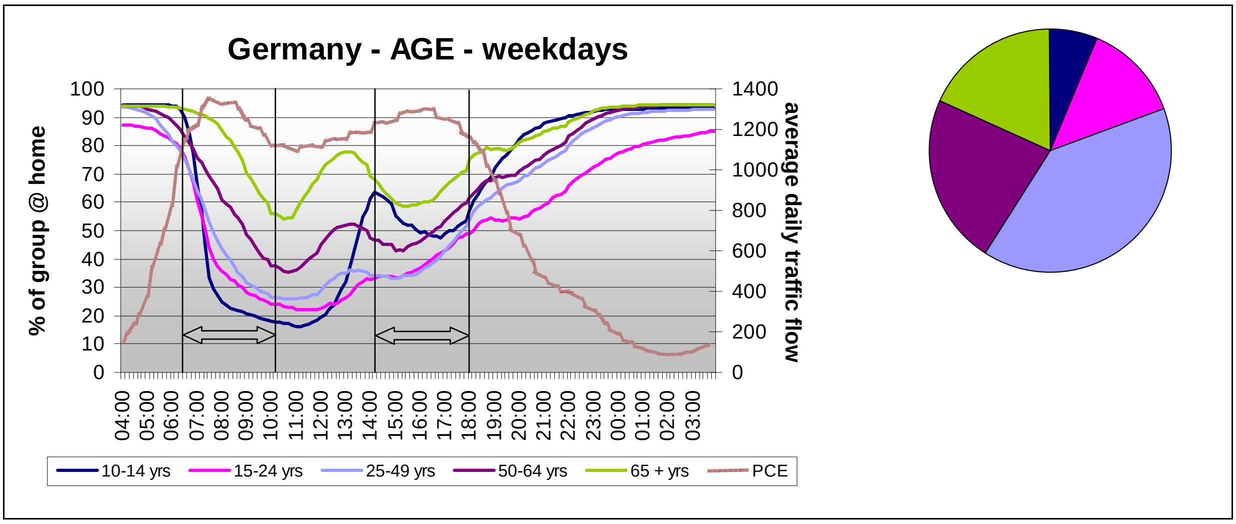

Figure 7: Patterns of time spent at home by different age groups on weekdays (average weekday traffic flow for Hamburg shown in PCEs, flow quartiles around peak hours indicated)

The age related time@home curves in Figure 7 clearly show the average daily rhythms of different life phases. Children in early secondary school leave home somewhat later than the two age groups above them but are away from home more, and more consistently, until early afternoon, when they are actually home more than all other age groups apart from those aged 65+ and when the afternoon traffic peak begins. The age band of 10-14 yr olds has the smallest share of the population but still being at a stage of rapid physiological and psychological development, this age group is also particularly vulnerable to stressors such as noise and pollution. It is likely that younger children – i.e. those in primary school or kindergarten or infants – would be found to be at home still more as they are less self reliant, but no time use data for these age groups was available. People aged 65 or over are at home – and thus potentially exposed to traffic emissions - more than all other age groups at all times except for young teenagers during the evening. This, however, is a time when traffic loads have already dropped quite considerably. Since this group also includes old people, it represents a demographic band, which is not only set to grow in its share of the population (currently the third highest) but is also most likely to suffer from age related ailments (such as respiratory and cardio-vascular diseases; cf. Greiser & Greiser 2010), which would be exacerbated by noise induced stress or exposure to air borne pollutants. The group of 50-64 yr olds comes second in time@home around the morning peak and through till the early afternoon, when the children return home.

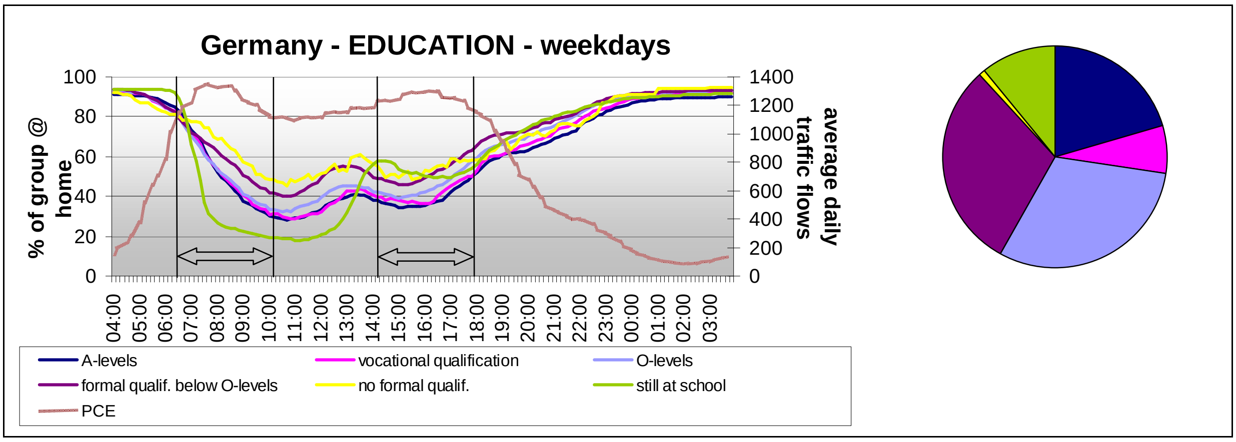

Figure 8: Patterns of time spent at home by groups with different school based qualifications on weekdays (average weekday traffic flow for Hamburg shown in PCEs, flow quartiles around peak hours indicated)

The curve for those ‘still at school’ in Figure 8 is very similar to that for those aged 10-14 yrs in the previous diagram, since school attendance in Germany is compulsory up to the age of 16. Most time is spent at home by those without any formal qualifications, who are, however, a very small portion of the population. The three curves for the top three school-based qualifications (A-levels, vocational qualifications and O-levels) are very close to each other and show, that around 50% of the people in these groups are at home around the morning traffic peak and around 40% during the afternoon peak. Together, they make up just under 60% of the population. The biggest single sub-group of this parameter – those with qualifications below O-levels – are closest to those with no formal qualifications in the time they spend at home and the curve never drops below 40%. Altogether, the curves for the different sub-groups are much closer together than for the age-groups.

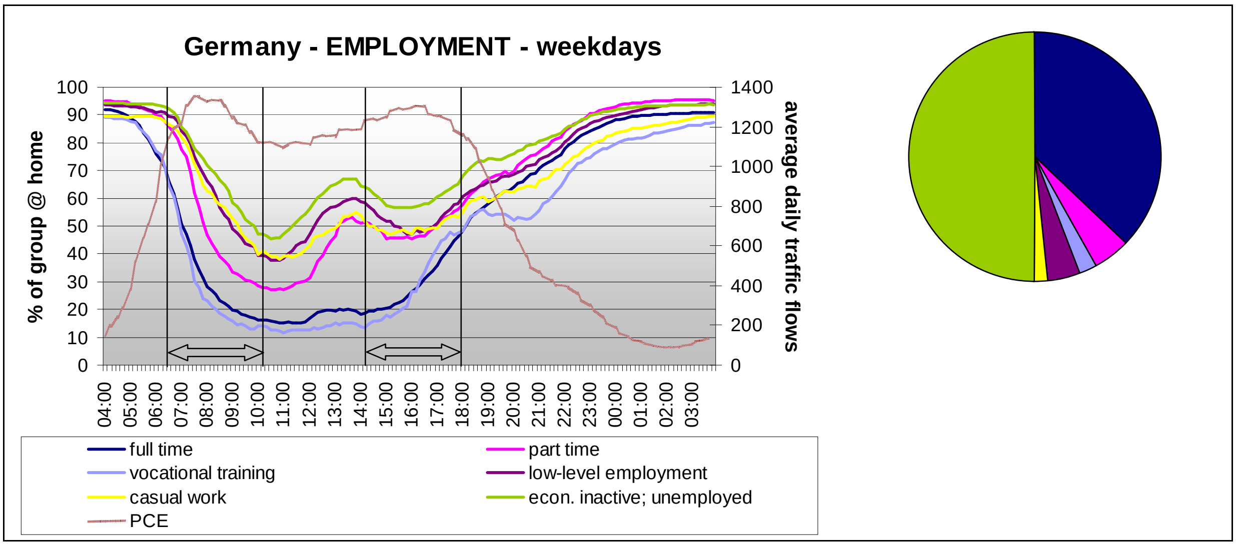

Figure 9: Patterns of time spent at home by groups in different employment situations on weekdays (average weekday traffic flow for Hamburg shown in PCEs, flow quartiles around peak hours indicated)

The overall span between the percentages of different sub-groups of the employment parameter during the day time is almost as large as that between different age groups (see Figure 9). The curve for those in vocational training (a small part of the overall population) drops almost as low as 10% just before noon, while almost 70% of the economically inactive and unemployed can be found at home in the early afternoon. This latter group makes up 50% of the population and is consistently more at home than any other over the entire day (apart from some hours just after midnight, when traffic loads are lowest). The second largest sub-group, those in full time employment, not surprisingly also spend almost as little time at home as those in vocational training. They make up 37% of the population.

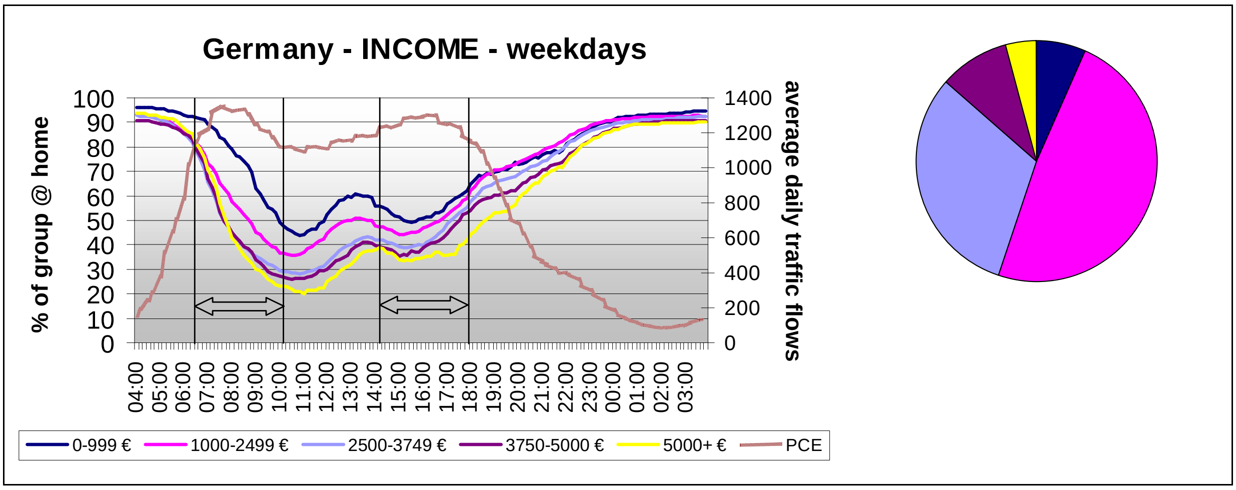

Figure 10: Patterns of time spent at home by groups living in households with different monthly net incomes on weekdays (average weekday traffic flow for Hamburg shown in PCEs, flow quartiles around peak hours indicated)

The time@home curves for people living in households with different incomes cross over almost as little as those for the two genders. So while income is a strong determinant of how much time is spent at home, the average daily rhythms of people in these groups do not differ as much as for the other parameters. Between 40% and 60% of each group leave home around the morning traffic peak, many not till after nine o'clock, though. About half to a third of these return again in the early afternoon. Roughly 5%-10% leave home again for some time later in the afternoon. The ranking of time@home follows the income bands, with those living in the highest income households spending least time at home and those in the lowest income households being at home most. This also reflects the fairly linear relationship between income and time@home seen in Figure 2. Those groups spending most and least time at home are also the smallest two in the population – 4% in the highest income households and 7% in the lowest.

ROAD TRAFFIC NOISE IN HAMBURG

Having established that members of different socio-economic groups spent significantly different amounts of time at home and that these differences are greatest, when traffic loads on main roads are highest – using the example of Hamburg – the next step would be to find out, which socio-economic characteristics are associated with living along busier roads. The Infas geodata set described above (Table 1) contains information on average household incomes by street sections (as a purchasing power index) and the share of different age groups in residential quarters. The purchasing power index was converted into average net monthly household incomes[15], which were banded in accordance with the income bands from the ZBE 01/02. It is worth noting, that this results in income bands for households – not information on households in which individuals represented live, as is the case in the time use surveys. Since the information on age groups was only available at the level of residential quarters, it could merely be inferred, that the average distribution of age groups along the road sections would be the same. No information on the spatial distribution of people with different educational backgrounds or employment situation was available at a sufficiently fine spatial scale to allow for road corridor based analyses. This was not the case for gender, either. This parameter can be expected to display the most homogeneous spatial distribution of all, though.

The only data associated with emissions from road traffic, which is available at a sufficiently fine spatial scale across the entire city, comes from the road traffic noise maps drawn up by the local planning authority (BSU 2007a; BSU 2007b) in accordance with the national guidelines for noise protection planning (Bundesministerium der Justiz 2006a). They show noise immissions from road traffic calculated for 10mx10m squares at 4m above ground level. Only values of 45 dBA and higher are recorded, so that all immission levels below this value are effectively presented as a zero value. Noise level calculations were made for roads with an average traffic load equal to or above 8000 vehicles per day based on 2006 mean annual traffic loads. The mean percentage shares of HGVs were taken into account (on the roads in question, these vary between 2% and 20%, with the highest shares found on the roads and motorways carrying hinterland traffic of the port; BSU 2007c). In Hamburg, almost all main roads are surfaced with bitumen and vary between two and four lane width. Noise

[15] by multiplication of the index - which indicated deviations from net monthly individual incomes of €19,200=100 – with 19,200 and the average number of people per househehold on that street section; Note: according to the documentation of the dataset, the index is calculated per head, irrespective of age or economic activity.

immission levels are provided in dBA as L_{den} (day-evening-night index) and L_{night} (for between 22:00 and 6:00). This information recorded in the noise maps was made available for use in this study by the planning authority in the form of an ESRI ArcGIS® shape file. The dBA levels were firstly coded into bands of 5dB steps, where all values below 45dB were coded as zero (see above) and those above 74dB were taken together (as they are not differentiated in the data). A second set of wider noise level bands was then created in accordance with the guidance issued by the German government's Expert Advisory Committee for Environmental Matters (Sachverständigenrat für Umweltfragen 2008, p.404), which is also used as a basis for the Noise Reduction Plan of the City of Hamburg (ARGUS Stadt- und Verkehrsplanung *et al.* 2008; see Table 7).

Action goal	**time perspective**	L_{den}	L_{night}
Avoiding health damage	short term	65 dB(A)	55 dB(A)
Reducing significant nuisance levels	medium term	60 dB(A)	50 dB(A)
Avoiding significant nuisance levels	long term	55 dB(A)	45 dB(A)

Table 7: Trigger values in dB(A) for noise protection planning in Hamburg for different time perspectives (based on ARGUS Stadt- und Verkehrsplanung *et al.* 2008, p.11)

The noise data was linked with the geocoded socio economic data for Hamburg. The average noise immission levels to which people living in households in the different income bands are exposed are shown in Figure 11. An analysis of variance with a post-hoc Games Howell test revealed, that all average noise immission levels – both L_{den} and L_{night} – differ significantly at the 95% level between all groups except the top two income bands.

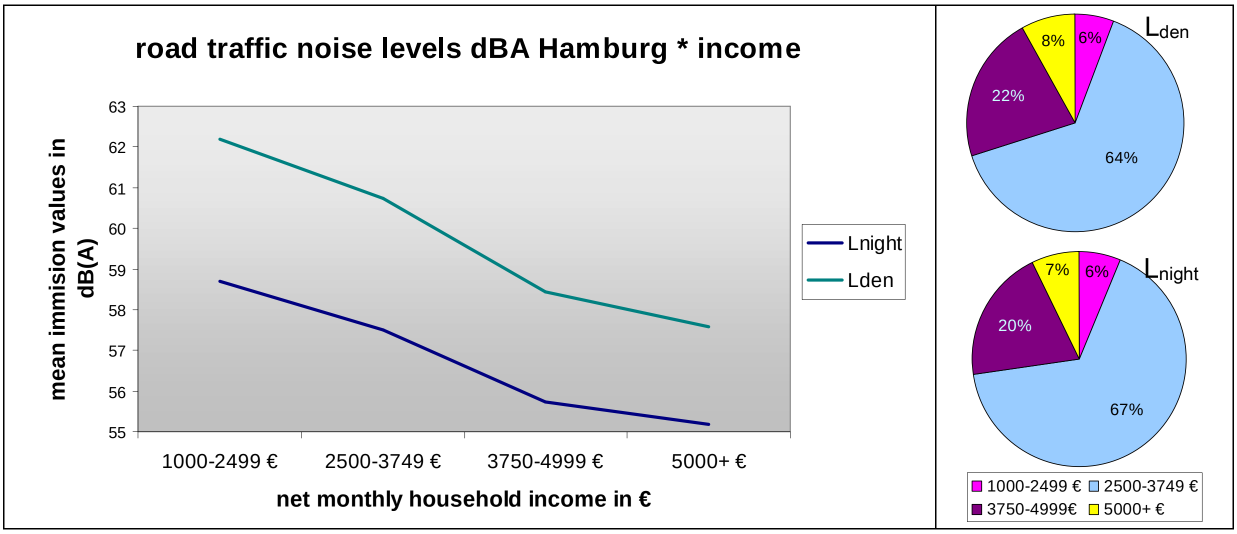

Figure 11: Average noise levels from road traffic to which households from different income bands in Hamburg are exposed (L_{den} and L_{night}); the share of each group in the Hamburg population is shown in the pie charts on the right.

However, the diagram also shows, that according to the data available, there are in fact no street sections in Hamburg, where the average monthly household income is below €1,000. This was the group, which has been found to spend most time at home in the analysis of the ZBE 01/02. The sub-group of this parameter, which comes second in average time spent at home overall - 1000-2499 € net monthly household income - is actually very small in Hamburg, almost as small as the top income group, in which people are home least. The two remaining income bands, which make up over 80% of the households in Hamburg, were shown to be very close in how much time they spend at home and when, although they did still differ significantly for the first aspect (see Table 2). The data indicates, that Hamburg is a comparatively affluent city. Nevertheless, those people, who live in households with net monthly incomes known to spend more time at home are also more likely to be affected by higher noise levels from road traffic in their homes. Figure 12 shows the share of households in each income band, who are affected by noise levels above the trigger values shown in Table 7.

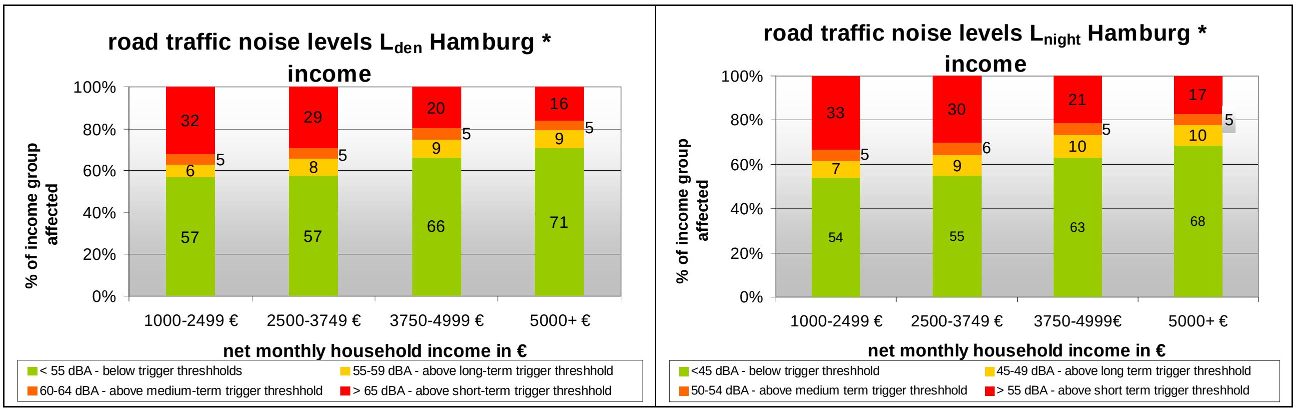

Figure 12: Share of households in different income bands affected by road traffic noise levels above – and below – various trigger thresholds for L_{den} and L_{night} in dB(A) in Hamburg

The diagrams show, that overall, slightly more people live in households exposed to road traffic noise levels above certain trigger thresholds for L_{night} than for L_{den}. The situation is similar in both cases for households in Hamburg's lower two income bands, of which around a third are situated along roads, where noise levels exceed the short term thresholds for noise reduction measures – those set to avoid damage to health. Just under three quarters of households in Hamburg are found in these income bands. About a fifth of households belong in the income band 3750-4999 € and about a fifth of these are also affected by noise levels, which are above the short-term trigger values. A slightly smaller proportion of households in the top income band (which holds around 8% of those in Hamburg) are similarly affected. This shows that, there are clear differences in the level of affectedness of households in different income bands and these are inversely related to the average time the people living in these households spend at home.

The data on the affectedness of different age groups by different noise levels showed no clear trends. The age groups were found to be distributed almost homogeneously across the L_{den} and L_{night} bands. Even this being the case, the findings relating to the time spent at home and the patterns of time use still mean, that people in different age groups experience different levels of exposure to road traffic emissions in their homes.

DISCUSSION

The findings presented in this paper have confirmed the research hypotheses outlined at its beginning:

1. It has been shown, that most parameters commonly used in environmental justice analysis – *level of education, employment situation* and *income* – do indeed separate the population into sub groups, which spend significantly different amounts of time at home. This was true for both Germany and the UK (though – contrary to expectations - in the UK, for which such data was available, no differences were found between different ethnic groups). The average daily patterns of *when* people in these sub-groups are at home also differed (this point was investigated only for the German TUS). The differences in the daily patterns are more pronounced in groups distinguished by their education and employment situation than those distinguished by income. Generally speaking – and this is again true for Germany and the UK - people are likely to spend more time at home the lower their level of education and/or the income of the household they live in are. Different types of economic activity are more difficult to arrange along a linear scale, but it became clear, that those in some kind of employment are home less, than those, who are economically inactive or unemployed. Unsurprisingly, people in full-time employment spend least time at home.
2. Both age and gender – parameters not previously considered - have also been shown to have a significant correlation with the time people spend at home. For the German data, the relationship with *age* was found to be more pronounced than that with *income* and *level of education*. In the UK data set, the association was stronger than with all three – *level of education, employment situation* and *income* – though for *income* it was smallest. In both the UK and Germany, *gender* clearly divided all other parameters in the sense, that female members of the population spend more time at home than males in almost all the sub-groups of the socio-economic parameters analysed.
3. For the parameters *age* and *employment situation*, it has been shown that some groups are not only likely to spend more time at home than others but on weekdays also particularly so, when traffic levels are high – measured against average weekday flows on main roads in Hamburg. This is true for anyone not in full time employment or vocational training as well as the age groups 10-14 yrs, 50-54 yrs and 65 yrs+. This analysis was restricted to weekday activity as well as traffic patterns.

In themselves, these findings do not say anything about actual exposure of different population groups to transport emissions. They only become relevant when superimposed onto data, which shows, where those groups identified as being at risk from higher exposure due to their time use patterns actually live. One such analysis was carried out with household income data geocoded at the level of street sections for the City of Hamburg combined with data from road traffic noise maps. This showed, that lower income households – in which people also spend more time at home - are more likely to experience higher levels of road traffic noise than higher income households. This indicates a dual effect of income on exposure levels: not only are lower income households more likely to be exposed to higher noise levels from road traffic, the people living in these households are also likely to spend more time there, particularly, when traffic levels are high. However, the analysis also showed, that even some of the highest income households suffer exposure to high levels of road traffic noise, even at levels detrimental to human health. Unfortunately, no local information was available for the other parameters at a sufficiently fine spatial scale to allow similar analyses and compare the strengths of the association with road traffic noise between them.

In the EU, the stratification of society according to income, education status and employment is less strongly related to race and ethnicity (Alsnih & Stopher 2003) than in the USA. The same is true for socio-spatial population patterns (Kloepfer 2006). Nevertheless, distributive injustice relating to environmental burdens and benefits has repeatedly been attested in European settings (cf Bolte & Mielck 2004; Elvers 2005; Lampert *et al.* 2005), also in relation to environmental burdens from transport. It is thus important to examine, which parameters are the strongest determinants of an unequal distribution of exposure to transport emissions in the home. Since it has been shown, that age and gender are at least as strongly associated with differences in time use patterns as income or employment, the risk of exposure resulting from these is certainly similar for groups defined by the different parameters. More spatially disaggregated data on the residential location of these groups along with information on emissions from transport is needed to test, what this means for actual exposure levels. This is particularly important for a city like Hamburg, where – comparatively speaking - economic stratification for example is relatively weak.

The situation can then also become more complex, since the residential spatial distribution of people belonging to different age groups or sexes is more even than for example of those with different household incomes or employment situations, as financial capacities are more closely linked to residential location through housing prices. This level of complexity is additional to the fact, that firstly, transport emissions do not just come from roads but also airports and railroads, that secondly in their homes, people are not only exposed to transport emissions but also e.g. to emissions from industry and that thirdly, people also experience exposure to pollutants more directly associated with their living space e.g. from paint, household chemicals or cigarette smoke (Umweltbundesamt (UBA) 2006).

Further empirical work needs to be carried out regarding the association with age and gender and actual exposure to transport emissions. It will also be important to establish more clearly, how closely connected road traffic noise levels are with the concentration of other transport related pollutants like particulate matter or nitrous oxides and to what extent they could thus be used as a predictor for overall transport related burdens. This will differ according to local weather patterns and urban structure, therefore more specific case studies are needed, particularly in a German context. Since emissions from transport more persistent than noise actually get dispersed in space, it is possible, that specific areas away from roads with high traffic loads become affected, even if their subjective perception of transport as a disturbance – which is mostly associated with noise and barrier effects – is quite low. Such studies would allow stating with more certainty, to what extent the relationship between environmental justice and transport in different situations is comparable and how directly analytical and planning tools or strategies can be transferred from one context to another. What has been shown in this study is that differences in time use patterns of different socio economic groups display similar trends in Germany and the UK and the implication of these differences thus need to be taken into account in both contexts.

A broader conceptual discussion on strategies for dealing with transport related environmental injustice and how these interact with other measures aiming at e.g. the reduction of CO_2 emissions from transport or mitigating congestion problems is also required. It should not be forgotten, that even leaving finer distinctions of environmental inequality associated with transport aside, an overall reduction of levels of motorised transport is an important and much stated goal (e.g. Die Bundesregierung 2008). What environmental justice studies can add, is help in prioritising and targeting measures more clearly for overall gains in not just environmental but also social sustainability.

APPENDIX

	parameter	level of coding	test used	probability of null hypothesis being correct
ZBE 01/02	gender	nominal	Chi-square	p ≤ 0.001
	age	ordinal	Mann-Whitney U	p ≤ 0.000
	income	ordinal	Mann-Whitney U	p ≤ 0.000
	highest educational qualification	nominal	Chi-square	p ≤ 0.000
UK TUS 2000	gender	nominal	Chi-square	p ≤ 0.000
	age	ordinal	Mann-Whitney U	p ≤ 0.340
	income	ordinal	Mann-Whitney U	p ≤ 0.000
	highest educational qualification	nominal	Chi-square	p ≤ 0.000

Table 8: Results of testing for differences in the sub-samples defined by ‘normal’ vs. ‘unusual’ diary days in both time use surveys (null hypothesis: Both sub samples come from the same population.)

N of diary days in the survey sequence					
		1st	**2nd**	**3rd**	**totals**
ZBE 01/02	no. of days	11,908	11,895	11,888	35,691
	% of total	*33.4*	*33.3*	*33.3*	*100*
	classed as ‘normal’	8,820	8,761	8,171	25,752
	% of diary day	*74.1*	*73.7*	*68.7*	*72.1*
UK TUS 2000	no. of days	10,526	10,455	*n.a.*	20,981
	% of total	*50.2*	*49.8*	*n.a.*	*100*
	classed as ‘normal’	8,410	8,153	*n.a.*	16,563
% of day(s)		*79.9*	*78*	*n.a.*	*78.9*

N of diary days per weekday									
		Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**	**totals**
ZBE 01/02	no. of days	4,516	4,690	4,600	4,869	4,480	6,025	6,511	35,691
	% of total	*12.7*	*13.1*	*12.9*	*13.6*	*12.6*	*16.9*	*18.2*	*100*
	classed as ‘normal’	3,481	3,575	3,573	3,713	3,155	3,914	4,341	25,752
	% of day(s)	*77.1*	*76.2*	*77.7*	*76.2*	*70.4*	*65*	*66.7*	*72.1*

N of diary days per weekday									
UK TUS 2000	no. of days	2,055	2,037	2,081	2,153	2,160	5,313	5,182	20,981
	% of total	*9.8*	*9.7*	*9.9*	*10.3*	*10.3*	*25.3*	*24.7*	*100*
	classed as 'normal'	1,619	1,616	1,715	1,771	1,754	4,072	4,016	16,563
	% of day(s)	*78.8*	*79.3*	*82.4*	*82.2*	*81.2*	*76.6*	*77.5*	*78.9*

Table 9: Overview over the diary days, their distribution over the week and their classification as 'normal' (as opposed to 'unusual') from the ZBE 01/02 and the UK TUS 2000

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