Aus dem Institut für Medizinische Psychologie der

Ludwig-Maximilians-Universität München

ehem. Vorstand: Prof. Dr. E. Pöppel

komm. Vorstand: Prof. Dr. T. Roenneberg

Seasonal and geographical distribution of accidents on the way to school in Germany

Dissertation

zum Erwerb des Doktorgrads der Medizin

an der Medizinischen Fakultät der

Ludwig-Maximilians-Universität zu München

vorgelegt von Silke Sondermayer

Freising

2010

Mit Genehmigung der medizinischen Fakultät der Universität

München

Berichterstatter:	Prof. Dr. T. Roenneberg
Mitberichterstatter:	Prof. Dr. W. v. Suchodoletz
	Priv. Doz. Dr. M. Riedel
	Prof. Dr. W. Eisenmenger
Dekan	Prof Dr. med. Dr. h.c. M. Reiser, FACR, FRCR

Tag der mündlichen Prüfung: 04.03.2010

TABLE OF CONTENTS – Inhaltsangabe

1. INTRODUCTION

Thousands of people get hurt in traffic accidents every single day. Many of them are killed or injured severely or remain disabled for the rest of their lives. Like various other organizations the World Health Organisation WHO repeatedly declares that accidents on roads worldwide are then and today an immense public health and development problem. Therefore it should be in the interest of each single country to spare no effort to improve traffic situations for the sake of people's lives. [48] In 2002 the WHO estimated that 1.26 million people were killed in traffic accidents. This was the ninth overall cause of mortality and morbidity and accounted for 2.2% of global deaths. [33] According to the evaluation of a recent health survey the Robert-Koch-Institute claimed that in 2006 in Germany there were more than 19,000 fatal accidents and the number of accidental injuries was more than 8 million [31].

Road traffic accidents – especially when children are involved - are still a big topic in discussions and symposiums all over the world. There is a lot of research aiming at good proposals to improve the safety of road users as well as the circumstances for car drivers in Germany [10, 12, 24, 31] and internationally [12, 48]. In a comparative study injury mortality rates in different countries of the European Union were examined. The results showed that motor vehicle traffic fatalities accounted for 84% of all unintentional injury deaths. Fortunately injury mortality rates in young people aged between 15 and 24 in most European countries were lower than anywhere else in the world. [45]

1.1. General decrease in traffic accidents and participation of children

Looking at data of traffic accidents in Germany during the last 20 years, there was a notable decrease and a persistent downward trend in the yearly amount [45]. But our children on the streets are one of the main subjects who are still at risk. In the year 1995 5.1 of 100,000 children between 5 and 14 years of age were injured fatally [24]. Nearly 50% of them (under 15 years old) were due to traffic accidents [10].

One of the most important risk situations for children getting involved in accidents is the way to school [41]. In the morning in times of rush hour the number of overall injuries is high. The majority of affected children fortunately get hurt mere lightly, but nevertheless there are some, who suffer severe bodily damage or even get killed in an accident.

Based on this background knowledge the present study attempts to examine accidents on the way to school in more detail. A closer look at the circumstances and obvious problems of accidents on the way to school may prevent many young people from exposure to avoidable risk situations.

1.2. Factors influencing traffic accidents

1.2.1. Lighting conditions

As it was shown in several studies light and darkness have big impacts on accident events. Traffic accidents are much more likely to happen in the dark [42]. Regarding these findings the examination should be focused on schoolchildren because they often have to start their way to school in darkness or twilight.

Many children participate in traffic as pedestrians even when only walking from the bus station to school. So far studies concerned pedestrians of all ages, but not children in particular. The highest rates of fatal accidents with pedestrians were found in dark winter months compared to other times of the year [28]. The risk for deaths of pedestrians was estimated to be about four times greater in darkness than in daylight. Compared to other road users they have a generally higher risk in darkness [59, 60].

Furthermore it was found that a change from daylight into twilight could be associated with an increase of fatal crashes with pedestrians of about 300%. As a logically consequence in comparison to twilight the number of crashes with pedestrians decreased in daylight. Light level was regarded to affect fatal crashes rather than clock times. [26]

According these reports it is quite necessary to keep in mind that any change in lighting conditions might mark an influence factor in traffic accidents. Different causes for changing lighting conditions are presented beneath.

1.2.1.1. Time of day

During the day traffic conditions change several times between phases of high and low traffic volume. In times of rush hour the risk for getting involved in an accident is considered to be higher than at any time else.

However there are additional hours where the risk for an accident is higher than at other times of day. The period between 1 to about 8 a.m. is regarded as a critical time span when human and performance catastrophes are far more likely to occur [43].

Driving performance, reaction time, and alertness follows an important diurnal variation. It was found that driving late night and in early morning times was several times more dangerous than during the remaining hours of day. These oberservations especially concerned younger persons [8, 37] and pedestrians [2]. In Berlin 55% of lethal fatalities with children under 15 years of age occurred in the evening or at night [10]. Similar to this in Sweden it was discovered that in the early morning hours driving is about five times more dangerous than in the forenoon [7].

Therefore in addition to light conditions the physical performance and alertness of all traffic participants in the early morning hours may influence the children's accident rate on travel to school.

1.2.1.2. Season

So far there is a lack of studies about a potential relation between traffic accidents and seasonal alterations in Germany, but in many other countries studies were done.

Researchers in Saudi Arabia examined the seasonal variation and weather effects on road traffic accidents in Riyadh City. They found, that the highest percentage of traffic accidents were recorded during the months September, August, and October followed by June, July, and March. The minimum was during January, April, and December followed by February and May due to the extreme differences in temperature [46].

Swedish researchers investigated seasonal characteristics of highway accidents. They excluded alcohol related injuries and came to the result that during winter months (November and December) there was a peak of total accidents at 3 a.m. whereas in summer (May and June) this peak was seen at 4 a.m. [8].

The variant lengths of the days are characteristic for the diversity of the four seasons in Germany. While in summer there is daylight from earliest about 4 a.m. to after 10 p.m. in winter sun rises at the latest after 8 a.m. and sunset is already before 5 p.m. in the afternoon. Contemplating the yearly course of traffic accidents it is quite important to respect seasonal variances in lighting conditions during the year, which are shown above and which influence traffic accidents (see chapter 1.2.1).

1.2.1.3. Daylight saving time

Additional to the natural seasonal changes the Daylight saving time (DST) influences the light conditions over the course of the year. DST means that clock time gets advanced one hour ahead of Greenwich Mean Time (GMT) in the end of March and one hour delayed in the end of October by reason that during the "summer time" daylight could be utilised better. During World War I it has been introduced in several countries for the first time and repealed of most of them later. After the big oil crisis in the year 1973 the European Community concluded this for energy saving reasons. On 6th of April of 1980 Germany DST was reintroduced again. [49]

There is a wide range in researchers' opinions about influences of DST on people's behaviour in daily life, from denying any detrimental effects to confirming big negative impacts of DST. It was found that some human internal clocks needed about 4 weeks to adjust to the change to DST. [32]

In many countries the effects of DST on traffic safety were investigated. Yet the interpretations of the results did not entirely correspond to each other. A couple of researchers were quite undecided about beneficial or detrimental effects of DST on traffic accidents. Swedish investigators came to the conclusion that DST did not have measurable important effects on traffic crash incidence. They examined accidents on Mondays preceding, immediately after and one week after DST in spring and autumn. After them (any) possible negative effects were too small to be reflected in accident incidence in short-term effects. [36] It must be noted that it is quite difficult to give clear evidence only by the examination of the short span within Mondays preceding and after DST transition. Research about long-term effects probably would be more meaningful.

Some studies showed negative effects of DST on traffic accidents. For example Bruehning et al. made evident that in the mornings after DST, when light was turned to darkness, there was an increase of severe accidents with pedestrians. Besides, pedestrians probably suffered most under the new time conditions. [13] By the way after a recent study about the results of the German Telephone Health Survey 2004 of the Robert-Koch-Institute pedestrians account commonly for 41% of all accidents [53]. A different study figured out that on Monday after DST the number of fatal accidents rose [61]. They regarded it as a small effect, though. Other researchers found that after the spring shift to DST there is a measurable increase in the number of traffic accidents with fatal consequences [19].

In contradiction to that various studies denied any detrimental effects of DST on traffic accidents. According to one report in the United States fatal traffic accidents of motor vehicles decreased by 1% after introduction of DST [42]. Others claimed a decline of general fatal crashes during DST [13, 26]. Compared to Bruehning and Ferguson less casualties in traffic accidents were discovered in Great Britain by Whittaker et al. [64]. In addition to this a decrease by at most 11% in automobile crashes including pedestrians could be found in the long-run. It was even a significant crash-saving effect detected. Moreover a decrease of at most 10% was seen in vehicular crashes in the weeks after the spring shift to DST. [56] According to these studies, in the short run DST had no significant negative impact, neither on pedestrians and motor vehicle fatalities nor on automobile crashes.

Many researchers went even further and analysed hypotheses about effects of a fictive year-round DST. Benefit consequences on traffic accident casualties in the morning and evening hours were considered. Besides an anticipated rise in accidents with the change to BST (British Summer Time) was not seen [64]. A study about fatal traffic accidents in North-East England regarded year-round DST having an only small, but tangible effect. It was supposed that absolutely 15 of serious and fatal injuries involving children per year could be avoided. This research was just about the severity but not the incidence of accidents. [5] In a similar study in the United States it was shown that full year-round DST should reduce pedestrian fatalities by 171 per year (13% of all pedestrian fatalities between 5 and 10 p.m. and between 4 and 9 p.m. in the morning) [18]. Others supposed that, when extending DST farther into winter months, additionally lives could be saved. Hundreds of saved lives by decreasing motor vehicle and pedestrian fatalities were estimated [15]. Others similarly supposed that fewer fatal crashes might have occurred in the United States while year-round DST [26].

It has to be reckoned that the studies mentioned above had not examined homogeneous subjects. Some explored only pedestrians or only highway accidents, others examined only fatal injuries. So their results cannot easily be compared. To sum up these controversial findings there must be a claim for even more meaningful and comparable studies, which are necessary to come to a potentially consistent conclusion.

1.2.2. Weather

Some studies on weather conditions have been pursued in order to try to find out if rain, snow, fog, etc. correlated to the number of accidents.

In Melbourne rainfall was regarded to be the strongest correlated weather parameter, which impact was most distinctive in winter and spring [34]. The risk for a traffic accident in rain was considered to be two or three times greater than in dry weather [11]. It was also found that the number of accidents on very wet days was often twice the number of corresponding dry days [54]. After a Canadian study, collision risk increased from 50 to 100% during precipitation [9]. Children had a 2.3 times higher risk for getting injured in rainy weather than in dry conditions [63]. Besides it was estimated that weather effects were particularly acute at night [9].

A Saudi Arabian study detected exactly the opposite. Accidents on rainy days there showed significantly less road traffic accidents with relative humidity and amount of precipitation of rain, snow, and hail. [46] They also found most accidents happening during noon when sunlight was most intense. It must be mentioned that their findings were connected with heavy traffic and for the region typical quite hot temperatures (in average about 34°C).

It was also noted that in the United States and Canada snow – especially the first snowfall of the season – implicates quite a danger and has a greater effect on collision occurrence than rainfall [9, 22].

1.2.3. Sleep deprivation

By now a lot of studies showed that adolescents and adults differ in their biological sleep needs. While adults in average go to bed before midnight and get awake at about 7 a.m. adolescents naturally have a clearly shifted behaviour. During development they tend to go to bed later and wake up later – if they are not awoken by the alarm clock, of course. About the age of 20 they reach their maximum of "lateness" and then sleeping behaviours change again. [16, 17, 44, 52]

There is a significant association between (too) early school start times and sleep deprivation or daytime sleepiness. Harmful consequences of insufficient sleep in adolescents were described several times. [17, 20, 65] Sleep deprivation increases the risk for crashes [58] because of lower mental alertness. Besides it was assumed that there was a drastic connection between sleep deprivation and transportation [16]. It was found that a small decrease in sleep duration (of about one hour less) significantly can increase accident susceptibility [19]. Moreover, it should be recognized that driving sleepy is comparable more dangerous than driving illegally under alcohol influence [50]. As a possible reason for the morning sleepiness an induction by the circadian system was regarded [7]. Furthermore it was suggested that serious accidents (industrial and engineering disasters), which were caused by human errors had a basis in brain mechanisms that control sleep. Sleep and sleep-related factors were involved in widely disparate types of disaster. [43]

Keeping those findings in mind sleep deprivation might play an important role in the incidence of accidents on the way to school.

1.2.4. Technological advance

In a recent study of 2008 it was ascertained that the travel to school was a relatively safe activity [55]. Such statements surely base on the constant advance during the last years making traffic situations in many aspects safer. A lot of measures were introduced in various dimensions. Safety features on vehicles, such as ABS (anti-lock brake system) and airbags, for example, are a small selection to be mentioned. Improved seatbelts and child safety seats are good measures for reducing the risk of getting severely hurt in an accident. In addition to that intelligent traffic lights, brighter and more street lamps, sleeping policemen, zebra crossings, etc. fortunately help to minimize accidents on the streets. Prevention proposals were made in various directions [35]. The benefits of better illuminations, namely reducing fatal crashes were already described [60]. To prevent accidents on the way to and from school there are many zones with posted speed limits under 30 km/h in front of schools around bus stations. Teachers and the media reach for a better sensibility of the public for children's risk on the streets. Road safety education is an important component in lessons. Clothes with reflectors help children to be better identified by car drivers in fog or twilight. Besides, parents are instructed to practise careful behaviour in traffic situations with their children. Thereto belongs that children are explained to wear a helm when riding the bike. Unfortunately helmet use rates (at least among high school student in the United States) are still low [25]. Moreover in many towns there are now crossing-guards who help children passing the streets at times of pupils' rush hours.

In spite of all improvements making the streets safer for people, especially for children, accidents are still a big problem for public health.

1.3. <u>Accidents with students on the way to school</u>

In Germany like in other countries [62] we have no standard school start time. The beginning of the various schools diversifies about 8 a.m. in the morning - with deviations of about 5 to 15 minutes. Each school has the freedom to adapt their start times depending on the school type, transportation schedules, and on geographical settings.

While a lot of analysis of accidents involving children has already been done worldwide, it is hard to find detailed studies about traffic accidents on the way to school.

The American Academy of Pediatrics concentrated in their current policy statement 2007 repeatedly on school transportation injuries like previous. They wrote that annually 815 students on average died and 152.250 injuries were related to school travel. Most of all injures occurred in passenger vehicles: 75% of the deaths and 84% of other diverse injuries. [6] Even so in New Zealand it was claimed that the absolute risk on the way to and from school was relatively safe and only contributing to a minority of all injuries sustained by young people [55]. In Germany in 1995 transport was the main cause of injury deaths among children between 5 and 14 years [24].

In school buses 2% of the deaths and 4% of injuries happened [6]. On the one hand bus transportation was considered to be one of the safest ways to commute to school [47]. On the other hand it was suggested that children's activity as pedestrians is highest during the time being on journey to or from school [30]. So at this time there might be an especially high potential risk for accidents.

Most of the studies concerning accidents in the United States or elsewhere might be comparable to accidents on the way to school in Germany. The phase of the time when most of children are commuting only differ slightly, because in some districts of America schools start quite early (earliest at 7.15 a.m.) [62].

Limbourg et al. investigated accidents on the way to school in various aspects. Comparing 1982 and 1989 they found that the number of accidents on the way to school in relation to general accidents with children accounted for about 50% in both years [38].

So far no studies at all could be found about accidents of children on their way to school considering changes during the course of the year, which might include seasonal changes of lighting conditions as well as lighting changes because of DST. In the present study the accident situation in Germany on the way to school was investigated in consideration of the conditions mentioned above.

1.4. Summary of results of various studies

To summarise the findings of the researches mentioned above, traffic accident rates decreased in recent years as a result of many safety improvements, but nevertheless a lot of people get hurt or even suffer fatal damage. There are some important factors, which affect traffic accidents in general. Several studies show that darkness is one of the main negative influence factors on traffic accidents. At night or at early morning times the risk for getting involved in an accident is higher than during daytime. Precipitation (rain, snow, hail, etc.) also affects accident rates negatively. The majority of studies in different countries came to the result that there is no negative influence of DST on traffic accident rates. A fictive year-round DST probably would even reduce them. By the way a lack of sleep and early school start times were considered to bear a greater risk for getting involved in an accident.

Regarding all these results, in this study it should be examined whether there are actually discrepancies in traffic accidents on the way to school and whether they are related to different lighting conditions in Germany.

1.5. Changes in data collection

It must be mentioned that yet 20 years ago people did not bother about accident statistics the way we do now. The data collections in Germany before 1980 give only fragmentary information of pupils involved in accidents. Accidents were either listed as general accidents of pupils or as traffic accidents, but you could draw no conclusions about the time of day of the incidents.

It would have been quite interesting to compare detailed accident data before 1980 with newer statistics, but there was no chance getting such data. Fortunately the introduction of electronic data processing, researchers claiming for better documentation, and the attitude of the people helped very much to improve accident statistics, though. But still the attribute "way to school" in connection with traffic accidents involving children is not established in all federal states of Germany, and if so, there is no nationwide uniform definition [41]. Collecting data for this study accuracy concerning time of day, involvement, and age of children was an important criterion.

1.6. Aim of this study

As it was demonstrated in different studies [26, 42, 59, 60] darkness is one of the most important risk factors influencing traffic accidents negatively. Basing on these investigations we drafted the hypothesis that more accidents happen when during the commute to school there is darkness. This is the case when children already left home and sun has not risen yet.

In Germany we have the situation that between Eastern and Western parts there are differences in sunrise of about half an hour at most (between the ultimate West and East degrees of longitudes: 51N, 6 E and 51N, 15E). Accident data from various federal states and cities in Germany was collected and exploited in order to see if darkness on the way to school increased accident rates. Seasonal effects were analyzed accessorily. It was also taken into account that discrepancies in accident rates with children before school in different federal states may occur, because of different sunrise times in Eastern and Western parts of Germany. If pupils left home one hour later, the phases of darkness on the way to school should be greatly minimized.

It was necessary to collect as much data of traffic accidents with schoolchildren as possible. Detailed information about the exact time of the event was equally required as the age of the involved person.

In the present study accident rates with children in general and on the way to school were compared regarding seasonal courses as well as differences in various geographic regions.

2. METHODS

2.1. Data collection of traffic accidents

The research was restricted to traffic accidents throughout Germany. Cumulative data of the federal statistical office turned out to be quite expensive, so we determined to do investigations on federal states level. As already mentioned by Limbourg [41], in Germany it is not so easy to get data of accidents with the clear declaration "on the way to school", because there is no standard national level of data collection for this attribute. This was one reason, why we decided to collect data of traffic accidents with children in general. The other reason was that sensible comparisons could only be done with the possibility for internal comparison between accidents of different times of day.

Statistical offices of all different states of Germany were contacted, as well as several police departments, federal insurance companies, and the Ministry of the Interior. Finally it could be reverted to data of the Bavarian Research Data Centre of the Federal Statistical Office, the regional authorities of Berlin, Brandenburg, Baden-Württemberg, Lower Saxony, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt and Thuringia. Moreover data was obtained from different police departments of Hamburg, Munich, Lower Bavaria and Upper Palatinate combined, North Rhine-Westphalia, Rhineland-Palatinate, and Saarland. Additional data of Schleswig-Holstein was obtained from the federal statistical office.

2.1.1. Classification of accident data according to recorded age of children and time of incident

Most of the departments had the same kind of data acquisition because of a national standard data recording, but in some cases different focal points of surveyed data, diverse information about circumstances could be found. The time span of collected data was limited by the implementation of electronic data in the different federal states. The database of the present study covers the period between the years 1995 (earliest data) and 2007 (latest data).

Another problem was that not all obtained accident data were registered with the exact time of the event. Police departments were in the majority of cases the ones who ascertained the exact hour and minute of an accident. As it was essential for this study to examine detailed data of the exact time (hour and minute) of the accident, not all of the obtained data was useful. Without the exact time the interval to the sunrise could not be calculated. In the following there is an array of valuable data of different sources.

From the listed regions there was detailed data of children/adolescents involved in traffic accidents with the precise description of the month, day of month, hour and minute as well as the age of the person (between 6 and 14 years). In Table 2.1 the span of years can be seen.

federal states/regions						**years of data**								**sum**
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	sum
Baden-Württemberg						2,992	2,404	2,387	2,497	2,514	2,549	2,338		17,681
Bavaria	3,311	3,037	3,197	2,856	3,214	3,106	3,063	2,918	3,047	2,973	2,955	2,832	2,766	39,275
Berlin	1,533	1,565	1,585	1,375	1,386	1,182	1,028	959	968	865	826	735	757	14,764
Hamburg					776	732	723	819	688	714	706	641	620	6,419
Lower Bavaria and Upper Palatinate							341	332	368	331	334	309		2,015
Lower Saxony								2,357	2,363	2,149	2,378	2,281		11,528
Mecklenburg-Western Pomerania	1,388	1,420	1,345	1,313	1,214	1,023	883	771	743	572	510	511	404	12,097
Munich							465	437	450	426				1,778
North-Rhine-Westphalia						7,200	6,756	6,381	6,454	4,886	6,158	5,665	5,821	49,321
Rhineland-Palatinate									1,316	1,282	1,263	1,159	1,103	6,123
Saarland									261	279	262	261		1,063
Saxony	1,967	2,014	1,929	1,684	1,712	1,510	1,301	1,226	1,057	943	802	782	634	17,561
														179,625

Table 2.1: Amount of registered accidents involving a child between 6 and 14[1] years. The table gives an overview of the federal states/regions and time spans from the data used in this study.

There were two exceptions differing slightly from the precision mentioned above:

Munich, age 6-15 years; no separate specification of age

Rhineland-Palatinate, age 6-15 years; no separate specification of age

Saxony , data listed not every hour but in two hour steps

Furthermore there was data of pupils/adolescents involved in traffic accidents beyond the whole day, but only with the preciseness month and hour. All of them were without separate specification of age. Both were excluded from the study.

Saxony-Anhalt (2002-2003), age under 15 years

Schleswig-Holstein (2000-2003), age 6-14 years

From Brandenburg (1995-2003) and Thuringia (2004-2006) data had to be excluded from the study, because there was a lack of an opportunity to compare the

[1] Data of Munich and Rhineland-Palatinate between 6 and 15 years

way to school with the accident situation at the remaining times of day. Besides, as mentioned right at the beginning, the attribute "way to school" is not defined standardised.

2.1.2. <u>Different definitions of accidents involving children</u>

In all German federal states so far there is no exactly equal definition of traffic accidents with children. The registrations varied somewhat.

Police departments of North Rhine-Westphalia took a note only when a child actively took part in an accident or even was the main causer. So they provided us data, which was registered only when the police was called for an accident. It was restricted to accidents that involved any sort of injury and did *not* cover damage-only accidents, for example when a child was a non-participating passenger in a car, which has for example captured a pedestrian or bicyclist.

The regional statistical authorities of Brandenburg and Saxony collected accidents with bodily injury (hurt lightly, hurt severely, or killed), but no accidents with only material damage.

Contrary to this the regional statistical authorities of Baden-Württemberg, Bavaria, Berlin, Lower Bavaria and Upper Palatinate combined, Lower Saxony, Mecklenburg-Western Pomerania, Munich, Rhineland-Palatinate, Saxony-Anhalt, and Schleswig-Holstein listed up accidents where any child was involved. If there was bodily damage the gravity was recorded with every single accident, but the accident was also noted if the children were involved without being injured. The regional statistical authorities got the raw data material provided by their regional police departments.

Due to the fact that the sources had slightly different accident definitions it was not distinguished between dissimilar kinds of accidents. The onward interest laid just in the actuality that a child was involved in an accident. So in this study an "accident" is defined as a traffic accident in which one child was involved anyhow - notwithstanding to which extent.

2.2. <u>Age of the involved children</u>

Nearly all of accident data collection concerning children is arranged in age groups. Mostly one group ranges from under a year to 5 years and another from 6 to 14 years, with some exceptions. For the school-aged children were of the most interest, the attention was based on children/adolescents from 6 to 14 years of age, who had been participants in traffic accidents.

Two exceptions regarding the age group were data of Munich and Rhineland-Palatinate. From both regions there was only data of accidents with children between

6 and 15 years without individual declaration of the age of the casualty. Data of Rhineland-Palatinate was included in all calculations, but data of Munich just in selected cases. A comparison of the hourly distribution of accidents with children (from 2003 to 2006) between data of hourly accidents of Rhineland-Palatinate and hourly averages of the other federal states showed no difference in the t-test (p=0.11).

2.3. Definition of the way to school

In Germany most of schools start round about 8 a.m. Each school has the freedom to set school start at anytime between about 7:30 and 8:30 a.m. It can be assumed that the majority of children leave home between 7 and 8 a.m. But mainly in higher grades lessons may start after 8 or occasional not before 9 a.m. It is also important to note that some pupils might have to travel longer distances and might be on their school journey even before 7 a.m.

Considering this the time span between 6 and 9 a.m. was defined as the "way to school", where most of all school-aged children were expected being commuting.

Data of Saxony put an exception here, because of a data collection in two-hour steps, as mentioned before. In this case accidents between 6 and 10 a.m. were included. Figure 2.1 shows two possibilities of working with the data. The monthly average of absolute accidents from 1995 to 2007 between 6 and 10 a.m. (196.33) was about 15% higher than the average of accidents only between 6 and 8 a.m. (167.83). Of all available data of Saxony the *absolute* number of accidents between 8 and 10 a.m. was 342 while the absolute number of all accidents between 6 and 10 a.m. was 2356.

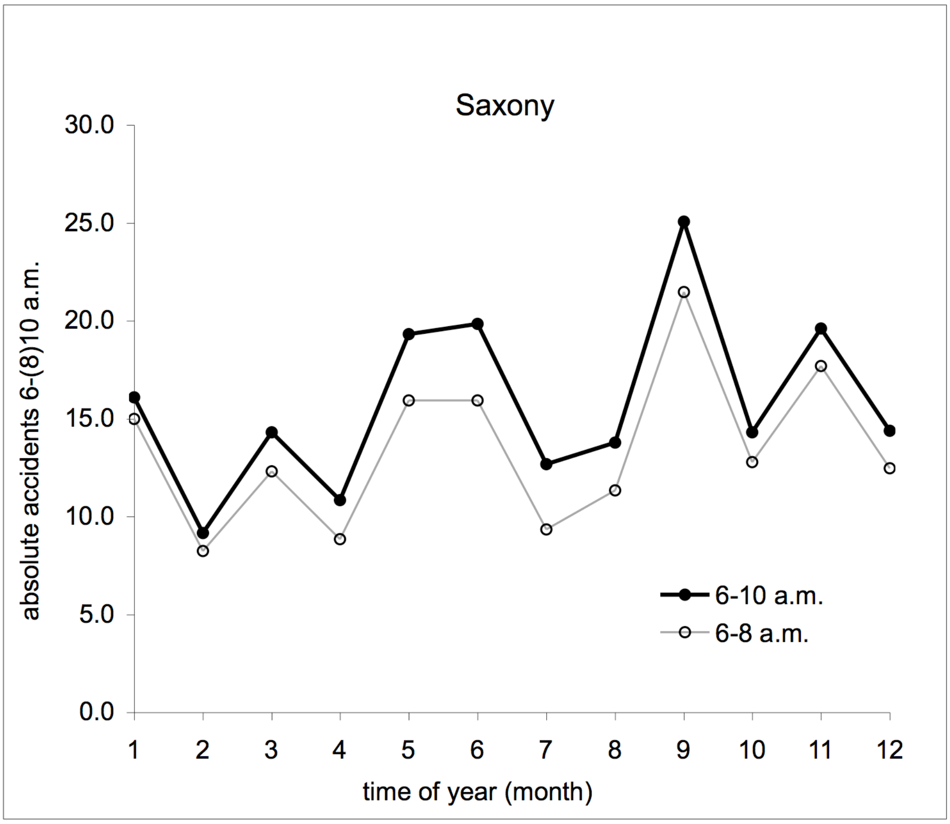


Figure 2.1: Absolute traffic accidents in Saxony between 6 and 8 a.m. (grey line) as well as between 6 and 10 (black line) during the year. Monthly averages of absolute traffic accidents of children between 6 and 14 years are plotted against the time of year.

2.4. Sunrise

In order to get an impression how big the effective time of darkness was on the way to school, it was necessary to look at the exact times of sunrise with regard to different geographical positions.

Data of hours and minutes of sunrise had to be collected to get the accurate phases of darkness on the way to school. Therefore times of sunrise were constructed by means of the webpage[2].

Its times of sunrise are based on official daylight time that is defined as the time when the sun appears above the horizon.

2

http://galupki.de/kalender/monatsblatt.php?jahr=2001&monat=1&txtat=Arbeitstage&txtkw=KW&txtnm=Neumond&txtvm=Vollmond&pxbreite=750&pxhoehe=500&css=kalender.css&csvdatei=feiertage.csv&layout=blatt&spalten=1&sonne=1&zenith=90.8333&lon=11.5&lat=48.16666667&diff=1&szb=2454556&sze=2454766&ueber=

In the command line the adequate numbers of latitude (lat=) and longitude (lon=) were inserted and thus exact times of sunrise for each federal state were gained. The year 2001 was chosen as the reference year because the accident data ranged round about it, and the times of sunrise varied in a negligible manner between earlier or later years. There were minimal changes of about at most one or two minutes per day. Leap years could be ignored for the same reason. Of the calendar of the webpage the time of sunrise of the 15th of the month was taken. In February exceptionally the term of the 14th was used, because of a month length of only 28 (29) days. Each sunrise time was charged monthly for each federal state.

After the "least-square" procedure of Stineman [57] monthly courses of times of sunrise could be adapted to the collected values.

$$y = t + a * \cos(x * Pi()) + -b * \sin(x * Pi()) + c * \cos(x * Pi()) + d * \sin(x * Pi()) + AM$$

X= middle of the month/12*2

AM= annual mean= average of the year

Now times of sunrise of the middle of months were interpolated in order to get several terms per month. It was done as much as to 0.05 month. This is equivalent to 1.5 days. The calculated times were corrected for the daylight saving time shift of one additional hour in the end of March and one hour less in the end of October.

2.5. Data normalisation

As mentioned above not all of the collected data was suitable for the analysis; only data of Baden-Württemberg, Bavaria, Berlin, Hamburg, Lower Saxony, Lower Bavaria and Upper Palatinate combined, Mecklenburg-Western Pomerania, Munich, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, and Saxony could be used for an accurate examination. The others had to be excluded.

For data processing Microsoft Excel for Macintosh, version 11.1.1. was used, and for statistical analysis Prism 4 for Macintosh, version 4.0c. All data was scaled in charts for adequate comparison. Columns were made for the following topics of each available year separately for each of the chosen territories.

Every time a child was involved in an accident the data therefore was arranged in different columns. As an example on Table 2.2 an extract of data of Berlin of 2001 can be seen. After the following formula, for each accident at a certain time a "1" was written in the correspondent column on the right side. That means that "1" stands for one accident where one child was involved in a certain hour.

$$1 = if(h = h;1,"")$$

h= hour (0-23)

So averages of accidents on school days could be calculated for each month hourly by dividing the monthly sum of accidents by the actual school (or free) days of this month.

Weekends, holidays and public holidays were marked (grey). Moveable holidays were neglected, because they are quite rare (at the most two days per year) and defined independently by each school.

Information on school holidays and public holidays were gathered from two web pages[3].

2001	month	day	day of the week	hour	minute	age (6-14)	hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	...	23	0
	1	2	Tue	17	25	12																		1				
	1	2	Tue	18	55	12																			1			
	1	3	Wed	18	20	7																			1			
	1	3	Wed	14	45	9															1							
	1	3	Wed	7	30	9								1														
	1	3	Wed	16	50	12																	1					
	1	4	Thu	16	20	8																	1					
	1	4	Thu	13	40	10														1								
	1	4	Thu	14	30	10															1							
	1	4	Thu	7	50	14								1														
	1	5	Fri	15	45	9																1						
	1	5	Fri	7	30	9								1														
	1	5	Fri	7	45	10								1														
	1	5	Fri	17	40	11																		1				
	1	5	Fri	18	15	11																			1			
	...	...	...	...	...	...																						
						actual days		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**...**	**23**	**0**
						21 January	(school)	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.05	0.10	0.05	0.10	...	0.00	0.00
						10 January	(free)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	...	0.00	0.00

Table 2.2: Example of the arrangement of modified raw accident data; hour "10" corresponds to the time between 10.00 and 10.59 a.m. for example.

2.6. State of data base and calculations

For the consequent analysis data of the following ten federal states was included: Baden-Württemberg, Bavaria, Berlin, Hamburg, Lower Saxony, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, and Saxony. Data from Munich and Lower Bavaria and Upper Palatinate combined were at first excluded in the following data analysis, because of an overlap with those from Bavaria, but could be used again later. They were then used to have a closer look on

[3] www.schulferien.org and www.feiertage-newsletter.de

different regions of Bavaria. The numbers of all available data are presented in Table 2.1.

For this research there was an amount of more than 150 thousands (n=179,625) single accident data available, in which at least *one* child/adolescent between 6 and 14 (15) years has been involved – regardless the severity of the injury.

As shown above, the data of the different regions regrettably did not extend over the same number of years. If not mentioned elsewise calculations refer to averages of all (ten) available years for each federal state to include as much information as possible.

Relative accident numbers, for example monthly or hourly traffic accidents per school or free day, were calculated separately for each year and afterwards averaged for all available years. An example of the raw form is shown in Table 2.2. Calculations for hourly distributions of accidents per school or free days were done after the formula beneath on the left side. With the formula on the right relative accidents per month (for school or free days) were produced.

$$\%(rel)_h = \frac{sum(accidents)_h}{sum(days)_m} \qquad sum_{24h}\left[\%(rel) = \frac{sum(accidents)_h}{sum(days)_m}\right]_m$$

$(rel)_h$ = relative hourly accidents on school or free days
h= in the hour
sum_{24h}= sum of values of all hours
m= in the month
(days)= number of school days or free days

Because in some fractions the denominator was 0.00 and further calculations became impossible, it was substituted by 1+(0.00), if necessary.

For the level of significance it counted in all tests the probability value $p<0.05$ as significant, $p<0.01$ as very significant and $p<0.001$ as most significant.

2.7. Analysis

2.7.1. General survey

Right at the beginning the average hourly number of accidents for each month was figured out separately for school days and free days. For example, the average number of accidents in one federal state in a certain year was calculated for a certain time. The time was defined by the following example: "7" corresponds to the time between 7.00 and 7.59 a.m. Analogous "24" relates to the time between 0.00 and 0.59 a.m.

Those *relative* numbers became the basic data form, which was used for several subsequent calculations.

Furthermore a general overview was created to see the monthly average distribution of traffic accidents involving children for each territory. These average values of the different federal states were subsumed in order to get a nearly national average. All data was separated into school days and free days.

2.7.2. Analyzing the period on the way to school

The way to school was expected to be high-risk situation for children in comparison with the time, when they were participants in traffic at other times of day. In order to quantify the risk for an accident between 6 and 9 a.m.[4] it was necessary to put this phase in relation to accidents at the remaining hours of day. For these analyses relative numbers of accidents on school days were used in monthly arrays. With the following three methods this proportion was examined.

2.7.2.1. 1st method:

The monthly average numbers of accidents on school days between 6 and 9 a.m. (way to school=WTS) were taken. These numbers were divided by the average numbers of accidents of the remaining 21 hours of day.

$$\%(WTS) = \frac{6-9a.m.(_{school})}{10\text{-}5a.m.(_{school})}$$

This showed the casualties on school journey as percentage of those at all times of the rest of the day to show if any tendency existed throughout the year.

[4] data of Saxony between 6 and 10 a.m.

2.7.2.2. 2nd method:

Because there were not only the numbers of accidents on school days but also on free days available, another relation could be draught.
Comparing the accidents, which happen between 6 and 9 a.m. with all accidents that happen on free days, could illustrate another distribution throughout the year.

$$\%(WTS) = \frac{6 - 9a.m.(school)}{0a.m.\text{-}12p.m.(\text{free})}$$

For the second method the average values between 6 and 9 a.m. on school days were taken and divided by the average numbers of cumulative accidents on all free days of the month. This enabled us to compare the amount of accidents happening before school start to the number of those happening on free days.

2.7.2.3. 3rd method:

Combining method one and two the average values of accidents between 6 to 9 a.m. on school days were needed. Those were divided by values, which were composed of the 21 remaining hours of all school days multiplied with all accidents of free days of this month.

$$\%(WTS) = \frac{6 - 9a.m.(school)}{10\text{ - }5a.m.(\text{school}) * 0a.m.\text{ - }12p.m.(\text{free})}$$

Again data of Saxony posed an exception. According data records in the numerator the average value of accidents between 6 to 10 a.m. monthly was used. The denominator analogical was composed of the 20 remaining hours of school days per month multiplied with all accidents of free days of this month.

(school)= relative accidents on school days
(free) = relative accidents on free days

2.7.3. Geographic differences

As data of ten different federal states was available there was the possibility to prove if the geographical position connected with certain consequences like different sunrise times might play a role in traffic accident manners. Therefore various possibilities for correlations were examined. In the following several implications of geographic differences are presented.

2.7.3.1. Geographical position

Geographical data of each of the data sources were taken. Every position is geographically defined by degrees of longitudes and latitudes. It would have been excellent having longitudes and latitudes written down with every accident location, but this unfortunately was not practised. For getting a feasible geographical characterization, though, a simplification was neccessary. Approximate grades of the North-South and East-West dimensions of each region were taken. The averages of them were arranged as decimals (Table 2.3). So respectively middles points of longitudes and latitudes for each federal state were received.

federal states/regions	**longitude (E)**	**latitude (N)**
Baden-Württemberg	8.75	48.25
Bavaria	11.88	49.00
Berlin	13.42	52.52
Hamburg	9.98	53.58
Lower Bavaria and Upper Palatinate	12.62	49.04
Lower Saxony	9.00	52.63
Mecklenburg-Western Pomerania	12.38	53.88
Munich	11.56	48.16
North-Rhine-Westphalia	7.65	51.37
Rhineland-Palatinate	7.25	50.00
Saarland	6.92	49.42
Saxony	14.13	50.50

Table 2.3: All available data sources including average numbers of longitudes (E=East) and latitudes (N=North) for raw characterizations of each geographical position.

2.7.3.2. Deviation of the annual mean

To detect a possible effect of the earlier sunrise in Western parts of Germany compared to Eastern ones the different degrees of longitudes and latitudes were incorporated. Therefore the average geographical value of each region as listed in Table 2.3 was used. For a comparison inter months the deviation of the annual mean (AM) was generated.

$$dev.AM = average(\frac{x - AM}{AM}) * 100$$

Then the annual amplitude between maximum and minimum value was calculated.

$$amplitude = \max(average(Dev.AM)) - \min(average(Dev.AM))$$

dev.AM= monthly deviation of the annual mean

x= monthly average

AM= annual mean= yearly average (of monthly averages)

max= maximum

min= minimum

Averages of all years and states were reckoned and arranged according the geographical position of the origin of the data. These calculations were based on three different kinds of values. At first the amplitude was generated out of the relative values of method three (see chapter 2.7.2.3). Next the *absolute* as well as the *relative* numbers of accidents on the way to school were used.

2.7.3.3. Part of accidents on the way to school

For looking at the distribution of accidents on the way to school the values of methods one to three were already used (see chapter 2.7.2). The distribution should be examined according to the geographical position. Correlations were made between the yearly averages of each federal state of all three methods and degrees of longitudes and latitudes.

2.7.3.4. Winter and summer

Furthermore a possible difference in the frequency of traffic accidents with children on their journey to school between winter and summer months was examined - especially in connection with different lighting conditions between Eastern and Western parts of Germany.

2.7.3.4.1. Definitions

"Winter" were called those months, in which the commute to school in the morning was in much or complete darkness. So those months with sunrises (in the middle of the month) not before 6.30 a.m. were elected. This is the case in October, November, December, January, February, and March in all federal states. According to this definition of winter month as summer months remained those between April and September.

The way to school was defined from 6 to 9 a.m. as explained before (chapter 2.3). But having taken 6 a.m. as the earliest sunrise time to define a month as belonging to winter or summer, there might have been problems. It could have been the case that sun rose already at 6.03 a.m., for example. That would have meant to include this month, although nearly all the way to school was in light. Therefore taking 6.30 a.m. as a limit was a better time, because of including months with a dark phase of at least half an hour.

2.7.3.4.2. Ratio with absolute numbers

For a first approach the *absolute* monthly numbers of traffic accidents with children between 6 and 9 a.m.[5] were used. The sum of accidents of winter months was divided by the sum of those in summer months.

$$\%(ratio) = \frac{sum(_{abs})W}{sum(_{abs})S}$$

ratio= winter-summer

abs= number of absolute accidents between 6 and 9 a.m.

W= winter= accidents from October to March

S= summer= accidents from April to September

The danger of this method was incorporating a potential bias, because of the slightly different distributions of school and free times in each federal state.

In summer there was at least one full month free, but not everywhere at the same time. In order to see the actual distribution of summer holidays throughout the different federal states the midpoints of this phase were plotted against the degrees of longitudes. The year 2000 and 2008 were selected as examples. Summer holiday time varied not too much around the dates of these two years, so there was no need to take average numbers of the last ten or so years. Times of holidays were looked up at the web page[6].

---

[5] data of Saxony between 6 and 10 a.m.

[6] www.schulferien.org

Additionally the distribution of school days in winter (October to March) had to be compared with those in summer (April to September). So a ratio was made of the average number of school days in winter and in summer months in order to see any relationship with the geographical position.

$$\%(ratio) = \frac{sum(_{schooldays})W}{sum(_{schooldays})S}$$

ratio= winter-summer
schooldays= number of school days
W= winter= October to March
S= summer= April to September

Afterwards Germany was divided vertically in two halves. The average number of winter-summer-ratios of school days below (West) and above (East) the 10th longitude were looked at. As defined before Hamburg has a mean longitude of 9.98 (see chapter 2.7.3.1). The value was rounded up and was counted to those "above 10th longitude". Additionally Germany was divided horizontally in two halves and winter/summer ratios of school days below (South) and above (North) the 50th latitude were reckoned.

This analysis was done with data of Bavaria, Baden-Württemberg, Berlin, Hamburg, Lower Saxony, Mecklenburg-Western Pomerania, North-Rhine-Westphalia, Rhineland Palatinate, Saxony, and Saarland. Averages of all available years were used. In the first line the ratios were arrayed according to their longitudes from West to East. In the next step arrangements according to degrees of latitudes were created.

In order to see the actual impact of data of the months July and August, when holiday times varied in the different federal states, winter/summer ratios were calculated like before, but this time without those two months in summer. They were plotted only against degrees of longitudes.

2.7.3.4.3. Ratio with relative numbers

Another winter/summer ratio of the numbers of accidents, which happened *relatively* between 6 and 9 a.m.[7] on school days could be made. Unlike before not the sum, but averages of the values of winter months were divided by the values of summer

---

[7] data of Saxony between 6 and 10 a.m.

months. This time any effect of discrepancies concerning school days and holiday times could be excluded.

$$\%(ratio) = \frac{average(_{rel})W}{average(_{rel})S}$$

ratio= winter-summer

rel= number of relative accidents between 6 and 9 a.m.

W= winter= accidents from October to March

S= summer= accidents from April to September

In a next step the same correlation as before (with data of all disposable federal states) was done, but without Rhineland-Palatinate and Saxony. One reason for this was the fact that data of Rhineland-Palatinate covered all ages between 6 and *15* years. So unlike all others 15 year olds, who were involved in an accident, were included. The other reason was that Saxony put accident data in two-hour steps, as explained above. Therefore the way to school had to be defined from 6 to 10 a.m. Including data between 9 and 10 a.m. might have slightly adulterated some results.

Correlations were created for averages of all available years just as for the range of years between 2003 and 2007 only. The reason for the latter was an even better comparison because of the same range of years. As mentioned above not of all of the sources contained data from 1995 to 2007, but the years 2003 to 2007 were covered by at least Bavaria, Berlin, Baden-Württemberg, Hamburg, Mecklenburg-Western Pomerania, North Rhine-Westphalia, Rhineland-Palatinate, and Saxony. Data of the year 2007 was missing of Lower Saxony and Saarland. So here exceptionally only data between 2003 and 2006 was taken. As averages of all years were used this measure was arguable.

Afterwards with the Kolmogorov-Smirnof method it was tested if the values for relative accidents were distributed normally. Data of Lower Saxony and Saarland then had to be excluded. In the subsequent one-way analysis of variance (ANOVA) test it was looked for statistically significant differences between single federal states.

Additionally the averaged winter/summer ratios of all federal states per year were listed (see Table 2.4). Those data was split in two columns representing average numbers of Western and Eastern federal states. One column included values of federal states below and one values of states above the 10^{th} longitude (see Table 2.5). Because of a lack of data before 1999 in the Western ones, the range of years between 1999 and 2007 was chosen. Afterwards a two-tail t-test was used to look for a significant difference.

federal state	Bavaria	Berlin	BWB	Hamburg	Meck W P	Low Saxony	NRW	Rh-Palat	Saarland	Saxony	average
year											
1995	0.834	0.663			0.955					0.738	**0.797**
1996	0.779	0.753			1.085					1.191	**0.952**
1997	0.734	0.678			0.920					1.046	**0.845**
1998	0.839	0.637			0.776					0.769	**0.756**
1999	0.685	0.712		0.870	0.742					0.762	**0.754**
2000	1.002	0.719	0.873	1.360	0.960	1.212	1.109			1.105	**1.042**
2001	0.866	1.068	0.654	1.373	0.720	0.901	0.980			0.877	**0.930**
2002	0.743	0.848	0.820	0.992	1.090	0.979	0.935			0.766	**0.897**
2003	0.694	0.709	0.626	0.589	1.159	0.803	1.040	1.001	1.712	0.824	**0.916**
2004	0.675	0.765	0.700	0.809	0.934	1.056	1.167	1.082	2.084	0.885	**1.016**
2005	0.808	0.724	0.707	0.849	1.132	0.899	1.133	0.755	0.780	0.794	**0.858**
2006	0.573	0.944	0.576	0.734	0.793	0.647	1.046	0.909	0.763	0.612	**0.760**
2007	0.821	0.928	0.710	0.733	1.576		1.086	0.657		0.959	**0.934**

Table 2.4: Averaged numbers of winter/summer ratios of *relative* accidents between 6 and 9 a.m. of each federal state are ranged for all years. On the *right* side averages of all federal states per each year are noted. BWB=Baden-Württemberg, NRW= North Rhine-Westphalia Meck W P= Mecklenburg-Western Pomerania, Low Saxony= Lower Saxony, Rh-Palat= Rhineland-Palatinate.

	west (<10 E)	**east** (>10 E)
year		
1999	0.87	0.73
2000	1.14	0.95
2001	0.98	0.88
2002	0.93	0.86
2003	0.96	0.85
2004	1.15	0.81
2005	0.85	0.86
2006	0.78	0.73
2007	0.80	1.07

Table 2.5: Averaged numbers of winter/summer ratios of *relative* accidents between 6 and 9 a.m. of federal states below (*left* side) and beyond (*right* side) the 10^{th} longitude during the years 1999-2007.

Back to the origin winter/summer ratios of *relative* accidents on the way to school, data of Lower Bavaria and Upper Palatinate combined and Munich was calculated additionally to give a more precise geographic containment throughout the whole federal state of Bavaria. They were arranged against degrees of longitudes and latitudes.

In a further test winter/summer ratios were made again, but with different winter months to look only at extreme light conditions. This time they were specified as those with nearly complete darkness on the whole way to school. This is the case in December and January in all federal states, when sun rises about 8 a.m. or later. Like before quotients between accidents during 6 a.m. and 9 a.m. between winter and summer months were made. It was looked for the general ratio of accidents on the way to school happening in darkness in comparison to those in full light. As already mentioned before most schools start about 8 a.m., so that between 8 a.m. and 9 a.m. most pupils are not any longer on travel. Accordingly as "summer" were defined only those months in which the way to school was in full light. This was again the same definition as before (between April and September where sunrise occurs already before 6 a.m.). In March and October there are discrepancies between different federal states in the phases of darkness in the morning. For this analysis they were excluded in order to have a look only at "extreme" lighting conditions.

All of the winter/summer ratios were applied according their geographical data.

2.7.3.4.4. Ratio with numbers of method one to three

The last winter/summer ratios were done with the numbers of method one to three (see chapter 2.7.2). Therefore the averaged monthly values of all years of each federal state were needed. Averages of winter months were divided by the averages of summer months. Then the ratios of each method were applied according the latitudes as well as the longitudes of the data source.

2.7.3.5. Different phases of darkness

Different geographical positions involve that on the way to school in Western parts of Germany there is a bigger fraction of darkness than in the Eastern ones. Data of sunrise was compared exemplary between Saarland (West) and Saxony (East). For a comparison between Northern and Southern regions as an example times of sunrise of Bavaria (South) and Mecklenburg-Western Pomerania (North) were used. Each of these two regions were in the whole data set those with the widest distance to each other.

According to the geographical degrees of latitude and longitude the calculated data of the times of sunrise (SR) was used as explained above (see chapter 2.4). Based on this the minutes in darkness (MID) before schools start could be constructed with the following formula:

$$MID = (SR(_{DST})*60 - x*60) > 0, SR(_{DST})*60 - x*60, 0$$

MID= minutes in darkness

SR(DST) = sunrise incorporating daylight saving time

x= earliest time of WTS, in the case of this study 6 (a.m.)

MID for each 0.05 (1/20) month could be reckoned and the sum of it shows the yearly amount of MID measured by the time when children left home (after 6 a.m.

like defined). So a survey of the yearly amount of MID as well as average numbers of MID of different federal states was gotten. As the geographical origin was known, MID were correlated to winter/summer ratios of *absolute* as well as of *relative* accident numbers of all federal states.

2.7.4. Possible correlations with other factors

The last interest laid on possible correlations of the number of inhabitants and density of population with traffic accidents involving children on their way to school. The number of inhabitants and density of population of each federal state was gained from the web page[8] and analyzed for a correlation with the average of *total* and *relative* accidents per school days between 6 and 9 a.m. (6 and 10 a.m. of Saxony).

2.8. Gaining literature around the topic

In order to examine the background of road traffic accidents in general and especially in connection with children several sources of literature data bases were used.

Digital libraries as for example PUBMED were browsed after the words "road traffic accidents", "daylight saving time", "school start", and "way to school". There have been found lots of articles around these topics, but nearly no study, which concerns traffic accidents on the way to school like it was done in the present study.

[8] http://www.statistik-portal.de/Statistik-Portal/en/en_jb01_jahrtab1.asp

3. RESULTS

3.1. Review about general distributions of accidents with children

The following sub-chapters present different surveys of general courses of traffic accidents involving schoolchildren in order to gain a general overlook. As already shown in Table 2.1 since 1995 in each federal state there was more or less a constant decrease in accidents rates. This corresponded to the trend in the latest report of the federal statistical office of Germany [4].

3.1.1. Hourly distribution of accidents with children

A general distribution of traffic accidents with school-aged children in average of all available years was made separately for school days and free days. The values were *relative* numbers of accidents per school (respectively free) day.

3.1.1.1. School days

In Figure 3.1 the hourly distribution of traffic accidents on school days can be seen as average numbers of all available years of ten federal states of Germany. The average lies at 0.29 accidents per hour on a school day. A main peak appears between 7 and 8 a.m. with more than one accident per day (1.05). Additional there are two increases in the afternoon: between 5 and 6 p.m. (0.87) and 1 and 2 p.m. (0.85).

3.1.1.2. Free days

Figure 3.1 also shows the average numbers of traffic accidents on free days. The hourly average on free days lies at 0.15 accidents. This is nearly half the number of those on school days, as can be seen above. On free days the peak in traffic accidents lies in the afternoon between 5 and 6 p.m. (0.44), but the school day peaks between 1 and 2 p.m. and 5 and 6 p.m. disappear.

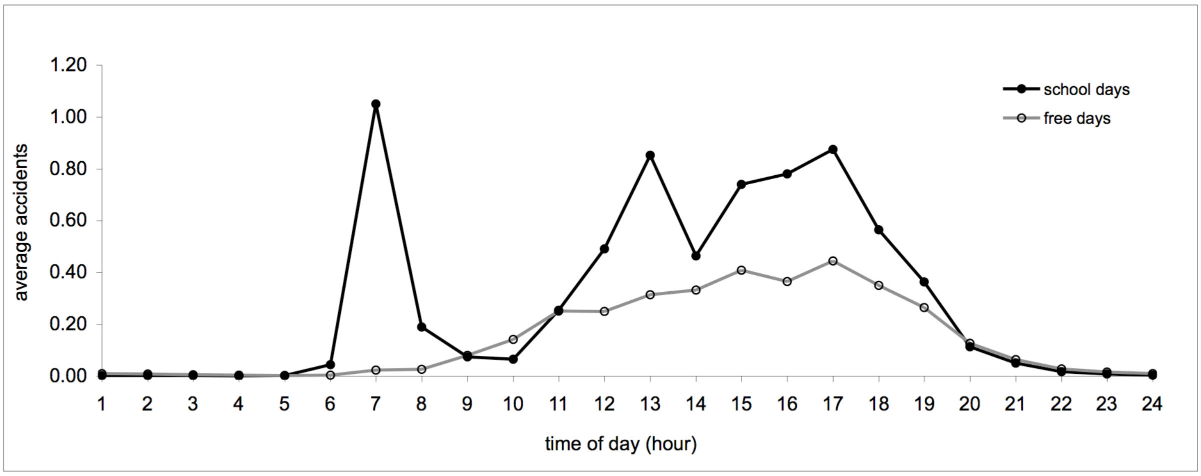


Figure 3.1: Distribution of traffic accidents with children between 6 and 14 (15) years per school and free day during the day. Average accident numbers of all available years of ten federal states of Germany are plotted against the time of day. “7” for example corresponds to the time between 7.00 and 7.59 a.m. Accordingly “24” relates to the time between 0.00 and 0.59 a

3.1.2. Monthly distribution of all accidents with children

In Figure 3.2 the *relative* distribution of average accidents of schoolchildren during all hours of day through the year can be seen. The data consist of averages of all available years. The descriptions are separated in school days and free days.

3.1.2.1. School days

The monthly average of accidents on school days is 7.20. From October to March accident rates are almost half the values (5.38 in average) of those in summer months (averagely 9.03). The major peak in summer can be seen in June (10.34).

3.1.2.2. Free days

On free days there is a monthly average of 3.59 accidents. These accidents are in all levels about half of those, which occur school days (see above). The average accident rates from May to September range from 4.79 to 5.64. In these months the relative numbers are about twice as high as those from October to March (2.19 in average).

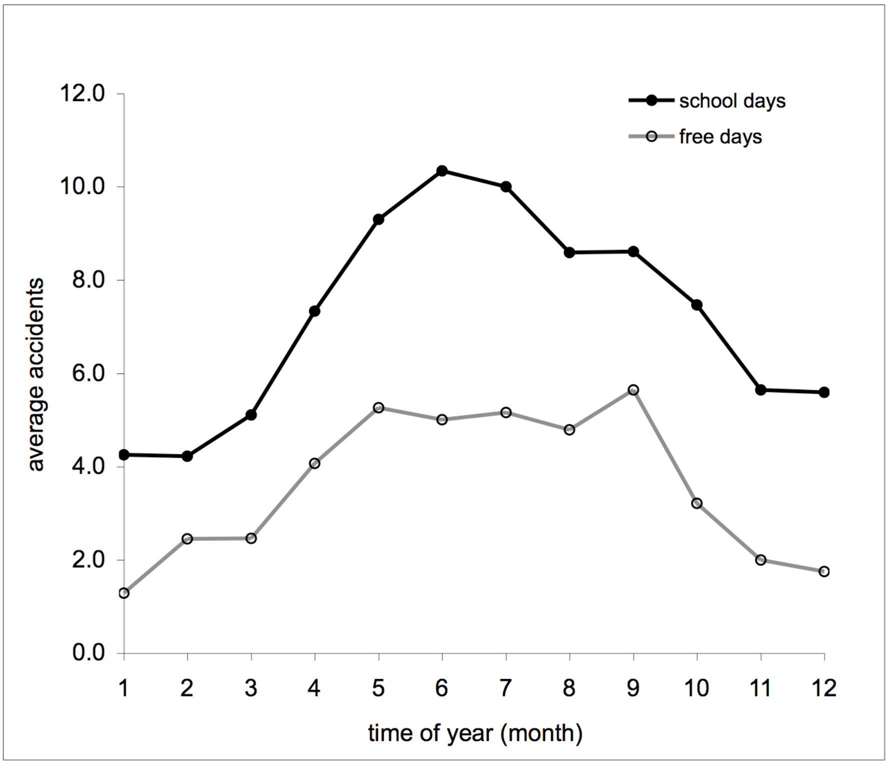


Figure 3.2: Distribution of traffic accidents with children between 6 and 14[9] years per school and free day over the course of the year. Average numbers of all available years of ten federal states of Germany are plotted against the time of year.

3.1.3. Monthly distribution of accidents on the way to school

In the following two figures there are illustrations of the average number of *absolute* and *relative* accidents between 6 and 9 a.m.[10] on school days distributed over the year.

3.1.3.1. Absolute numbers

In Figure 3.3 several increases and decreases over the course of the year can be seen. In average on the way to school there are 21.55 *absolute* accidents per month. Peaks up to 27.06 accidents in average can be seen in May, June, September, and November. The lowest accident rates can be found in August (13.94).

---

[9] data of Munich and Rhineland-Palatinate between 6 and 15 years

[10] data of Saxony between 6 and 10 a.m.

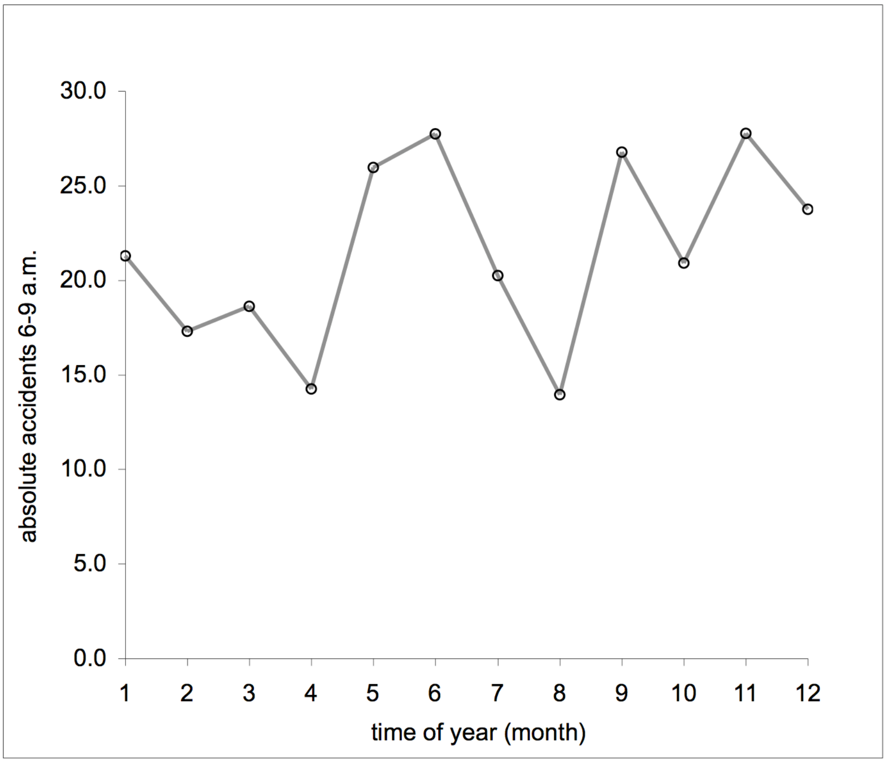


Figure 3.3: Distribution of *absolute* traffic accidents with children between 6 and 14[11] years, between 6 and 9 a.m. during the year. Average numbers of all available years of ten federal states of Germany are plotted against the time of year.

3.1.3.2. Relative numbers

Figure 3.4 shows the average number of *relative* accidents between 6 and 9 a.m. distributed over twelve months. There is a monthly average of 1.33 accidents per school day during travel to school relative to all school days. The curve shows a range between 0.93 (March) as lowest and 1.58 (June) as highest value.

[11] data of Munich and Rhineland-Palatinate between 6 and 15 years

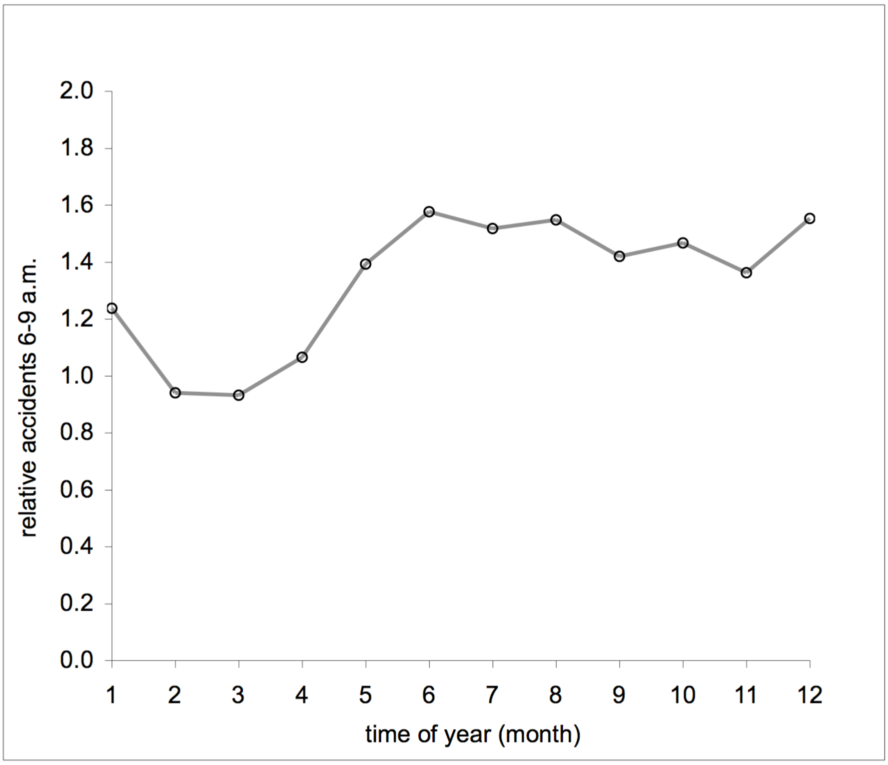


Figure 3.4: Distribution of *relative* traffic accidents with children between 6 and 14[12] years per school day, between 6 and 9 a.m. during the year. Average numbers of all available years of ten federal states of Germany are plotted against the time of year.

3.2. Way to school versus traffic accidents at different times

The following chapters present calculations about comparisons between traffic accidents, which happen on the way to school and those occurring at different other times.

3.2.1. Comparison with the remaining hours (1st method)

Figure 3.5 shows the result of the 1st method (see chapter 2.7.2.1). Accidents on the way to school were put in relation to accidents during the remaining hours of day. The monthly average of accidents on the way to school lies at 0.25. That means that accidents on the way to school account in general for 25% compared to the remaining hours of day. The range goes from 0.18 (equal from April to July) to 0.40 in January. Besides it can be seen that the percentage of 0.31 in winter (average of October to March) is more than 1.5 times higher than the percentage in summer months (0.19 average of April to September).

---

[12] data of Munich and Rhineland-Palatinate between 6 and 15 years

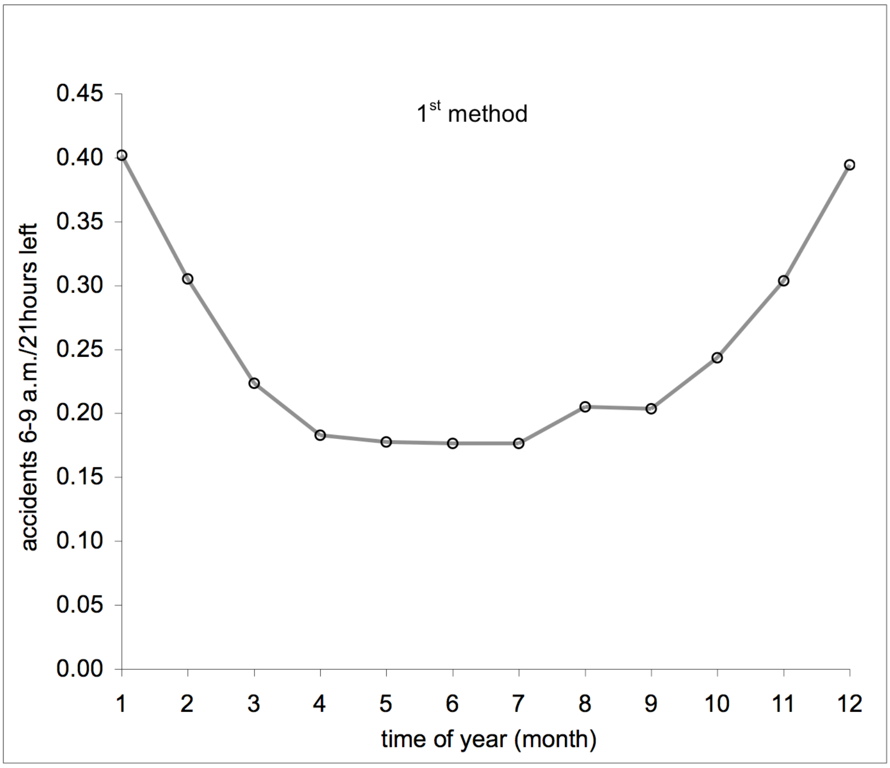


Figure 3.5: Percentage part of *relative* numbers of traffic accidents on the way to school compared to accidents of the rest of day during the year. Averages of all available years of ten federal states of Germany are plotted against the time of year.

On a separate figure the distribution of relative accidents in all ten federal states can be seen (Figure 3.6). In August two peaks appear. The decrease of the value of Saarland results from the fact that in the database there were no or only few school days in this month. The extraordinary increase of Baden-Wuertemberg comes off that in all years except for 2006 the complete August was holiday time. In 2006 at only two school days there were proportionally many accidents between 6 and 9 a.m., which contort the graph.

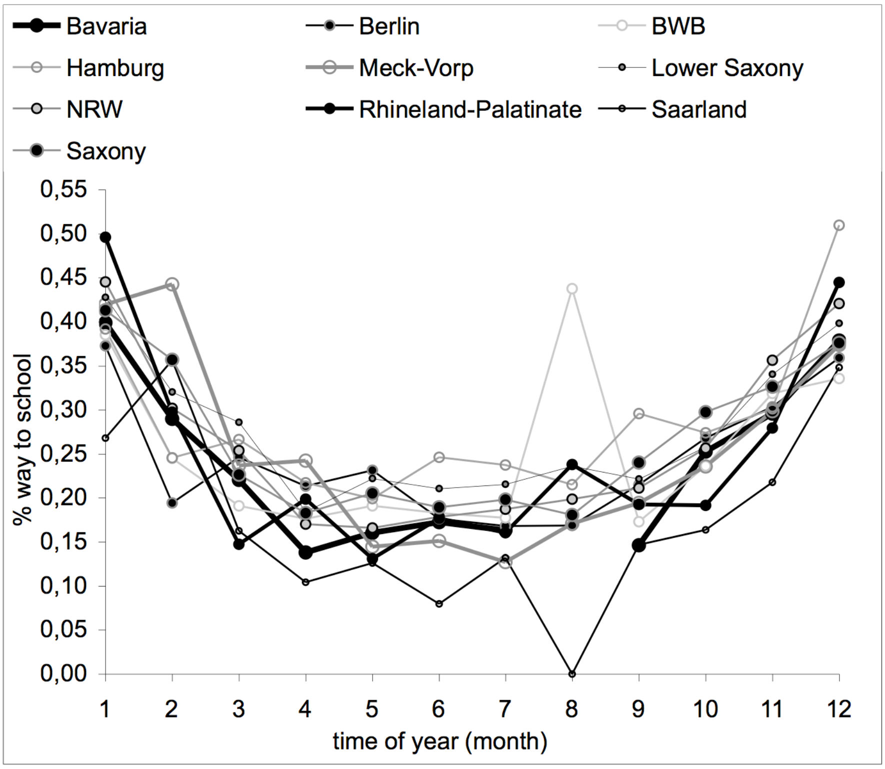


Figure 3.6: Percentage part of *relative* numbers of traffic accidents on the way to school compared to accidents of the rest of day during the year. Averages of all available years *separately* for ten federal states of Germany are plotted against the time of year.

3.2.2. Comparison with accidents on free days (2nd method)

According to the calculations of the 2nd method (see chapter 2.7.2.2) Figure 3.7 was constructed. The monthly average is 0.53. That implies that the percentage part of accidents on the way to school accounts for 53% of all accidents, which happen during free days. Comparing the part of accidents on the way to school in the summer months from April to September to the winter months (October to March) it can be seen in Figure 3.7 that in summer (0.32 in average) accidents occur more than twice as often as in winter (averagely 0.75).

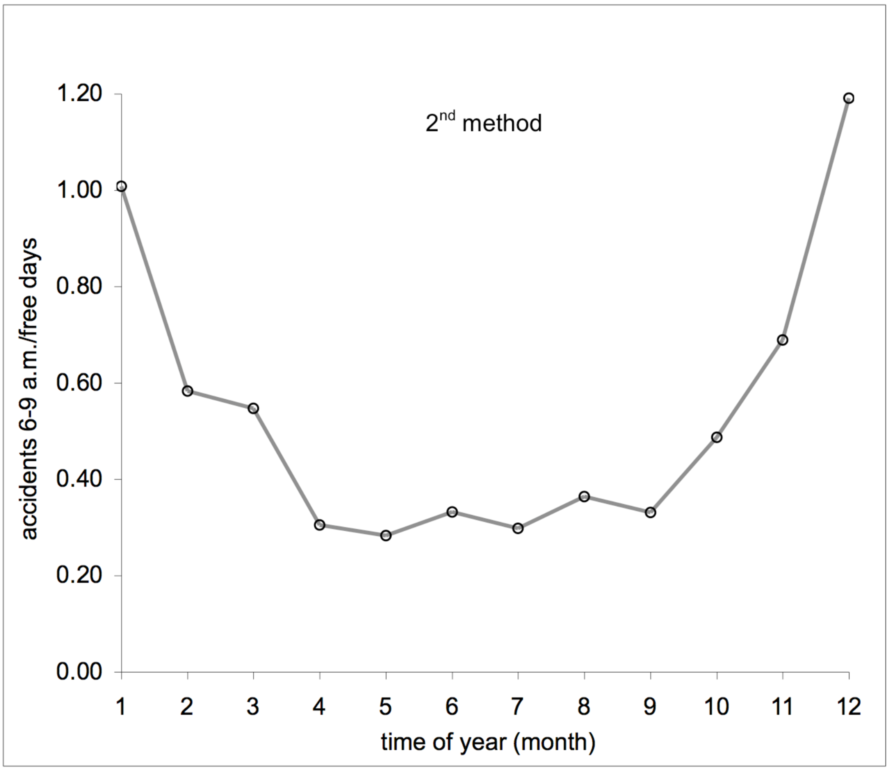


Figure 3.7: Percentage part of *relative* numbers of traffic accidents on the way to school as percentage of all free days during the year. Averages of all available years of ten federal states of Germany are plotted against the time of year.

The distribution of relative accidents separately for all ten federal states can be seen in Figure 3.8. The increase of the value of Baden-Württemberg in August has the same reason like explained above (see chapter 3.2.1). The peak in March of the value of Bavaria is just a result from the proportional high amount of accidents between 7 and 8 a.m. in the year 2007.

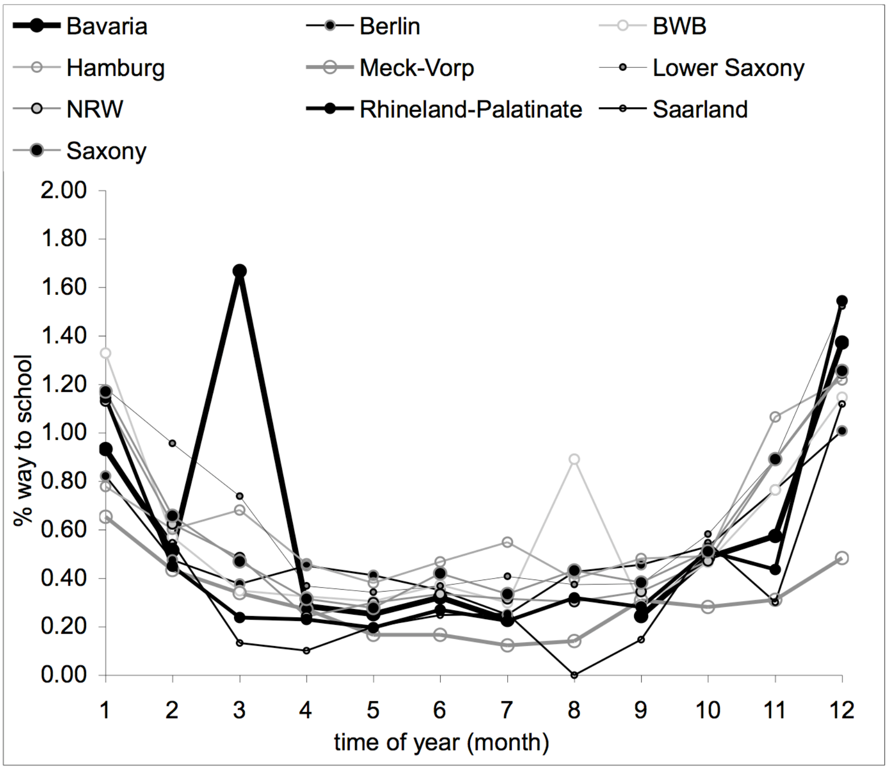


Figure 3.8: Percentage part of *relative* numbers of traffic accidents on the way to school as percentage of all free days during the year. Averages of all available years *separately* for ten federal states of Germany are plotted against the time of year.

3.2.3. Comparison with all other accidents (3^{rd} method)

The 3^{rd} method shows the relation between accidents on the way to school and accidents of the rest of the day plus accidents happening during the whole day on free days (see chapter 19). As Figure 3.9 demonstrates, the yearly distribution is similar to the preceding graphs. It shows a wide difference between winter (October to March) and summer months (April to September). The monthly average lies at 0.23. There is an average of 0.39 accidents in winter compared to 0.08 in summer. This is lower than the average of the 2^{nd} method (see above), but it is to mention that in winter the average percentage is almost five times higher than in summer.

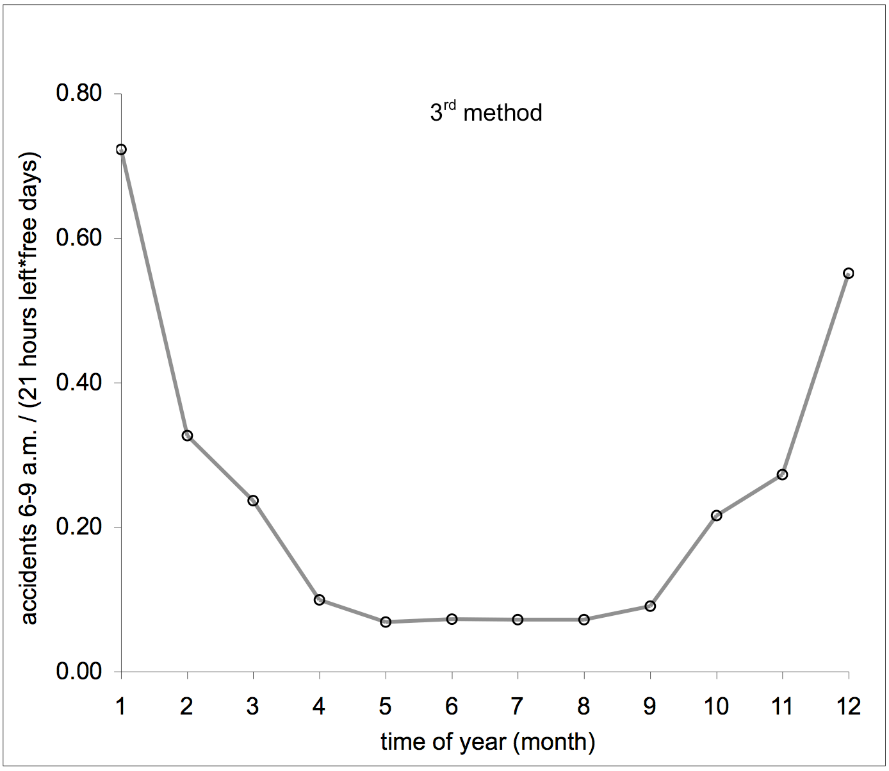


Figure 3.9: Percentage part of *relative* numbers of traffic accidents on the way to school as percentage of the accidents on the rest of day combined with free days during the year. Averages of all available years of ten federal states of Germany are plotted against the time of year.

In Figure 3.10 the same relations of the 3rd method like in Figure 3.9, but now also separately for all federal states without values of Saarland are plotted against the months of year. The distributions over the year are quite similar in all federal states. For better visualisation Saarland was excluded for the reason that there were proportionally many accidents in the mornings so that the percentage parts strongly deviate from all other federal states. An apart distribution of the values of Saarland is presented in Figure 3.11.

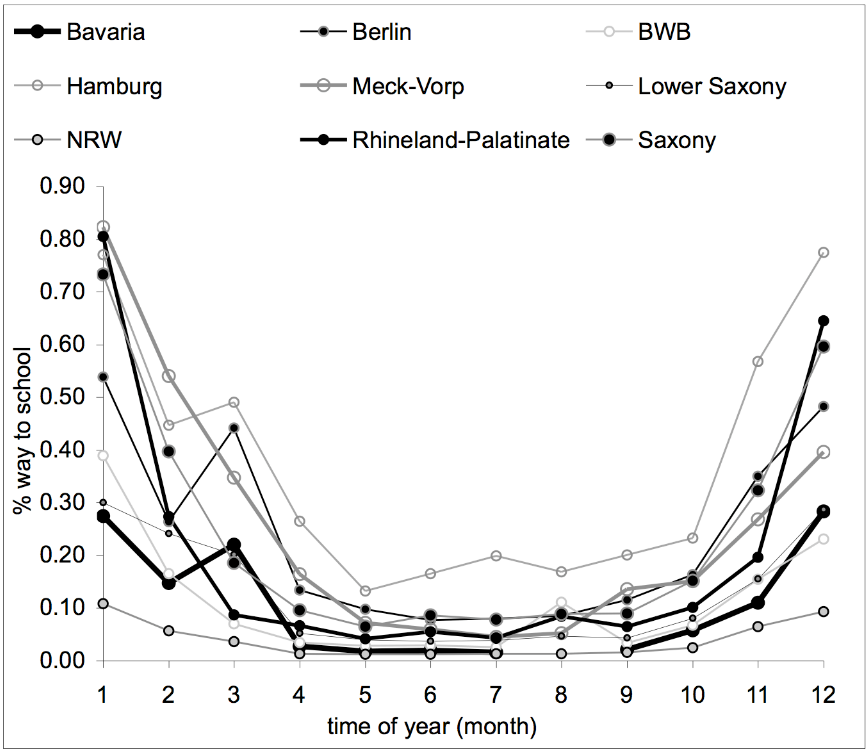


Figure 3.10: Percentage part of *relative* numbers of traffic accidents on the way to school as percentage of the accidents on the rest of day combined with free days during the year. Averages of all available years *separately* for ten federal states of Germany are plotted against the time of year.

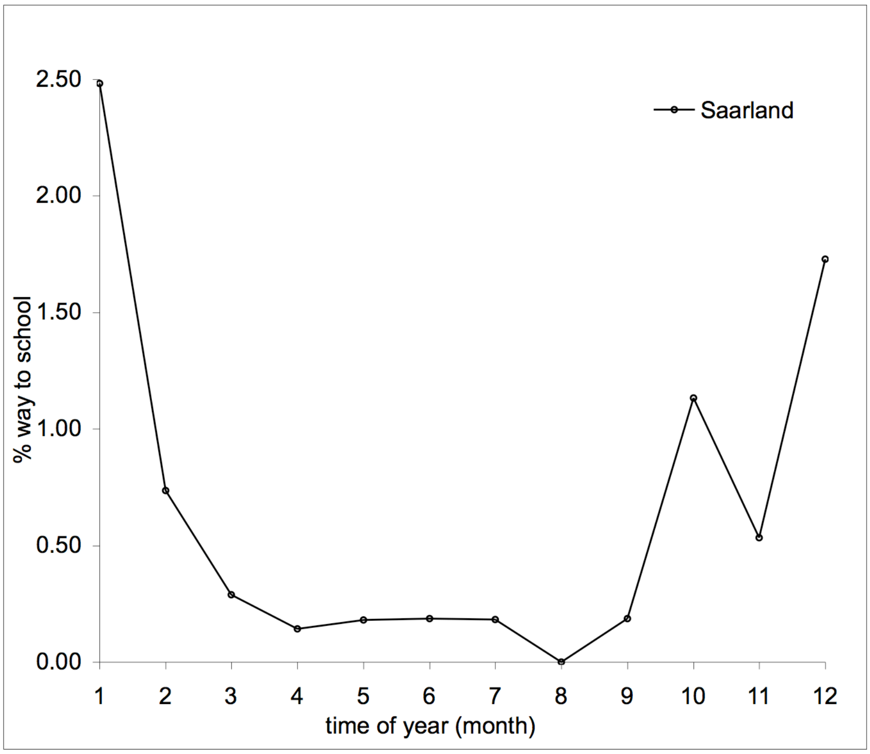


Figure 3.11: Percentage part of *relative* numbers of traffic accidents on the way to school as percentage of the accidents on the rest of day combined with free days during the year. Averages of all available years *separately* for Saarland are plotted against the time of year.

3.3. <u>Geographic diversities</u>

3.3.1. Amplitudes of the average deviation from the annual mean

As explained in chapter 2.7.3.2 the amplitudes between the extremes of monthly deviations from the annual means were arranged according the geographical distribution. The following figures show the results of calculations basing on several initial positions.

3.3.1.1. Absolute accidents on the way to school

Figure 3.12 shows that there is no significant correlation between amplitudes of the annual means generated of *absolute* accident numbers and the longitudes (p=0.32).

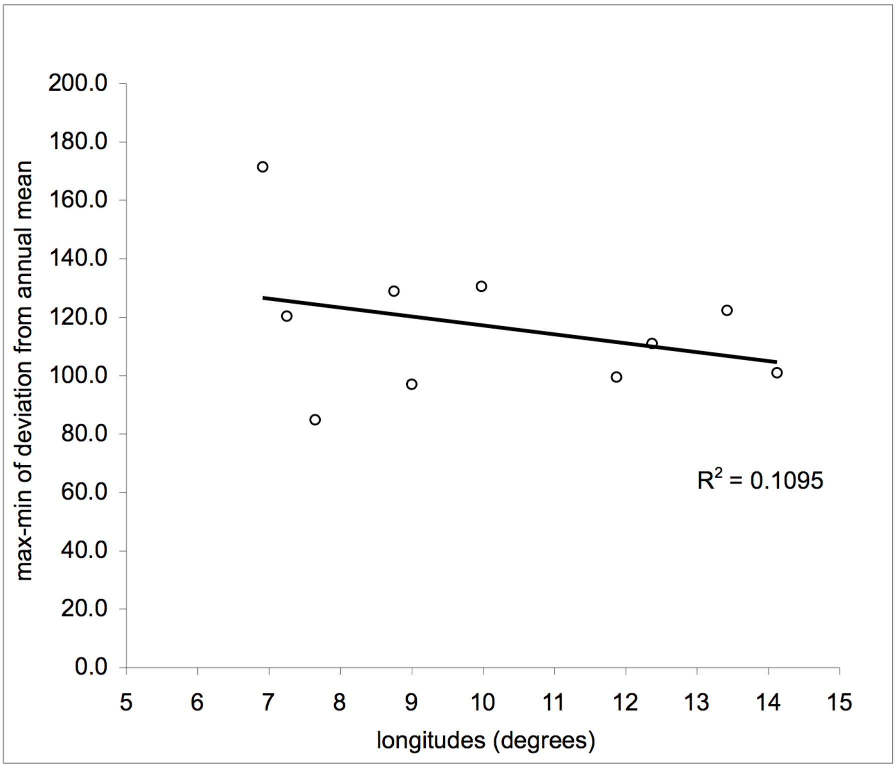


Figure 3.12: Amplitudes of maxima and minima of the annual mean are plotted against the longitudes. They are based on *absolute* numbers of accidents between 6 and 9 a.m.[13] on school days. Averages of all available years of ten federal states of Germany

---

[13] data of Saxony between 6 and 10 a.m.

3.3.1.2. Relative accidents on the way to school

Alike there is no correlation (p=0.15) between amplitudes of the annual means of *relative* numbers of accidents and the longitudes as shown in Figure 3.13.

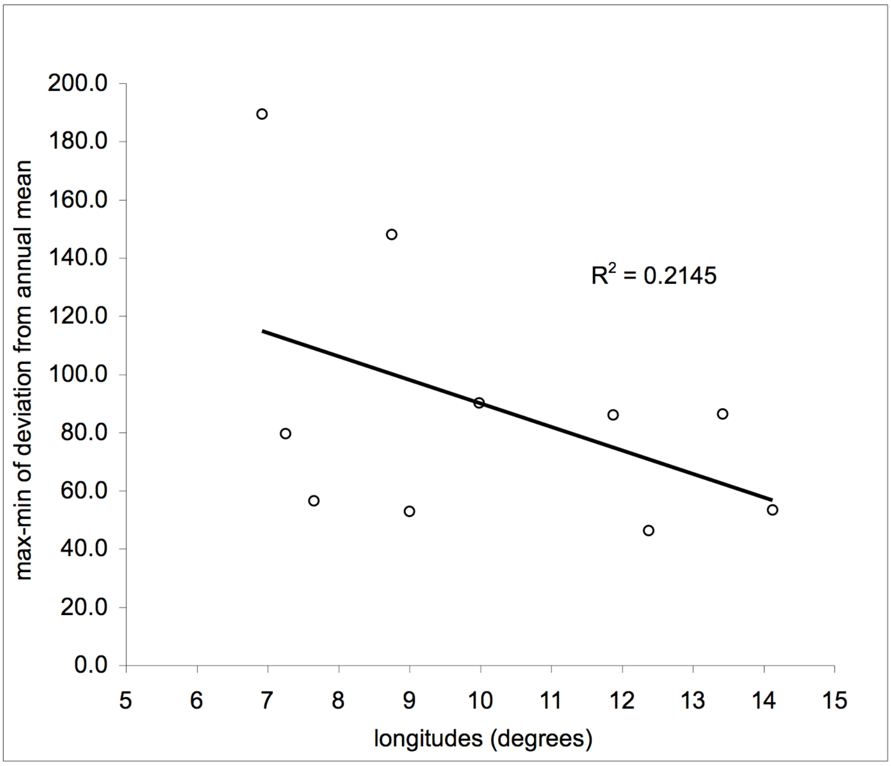


Figure 3.13: Amplitudes of maxima and minima of the annual mean are plotted against the longitudes. They are based on *relative* numbers of accidents between 6 and 9 a.m.[14] on school days. Averages of all available years of ten federal states of Germany.

3.3.1.3. Values of the 3rd method

Looking at Figure 3.14 it can be seen that there is also no correlation at all (p=0.35) between the longitudes and the amplitudes computed of the values of the 3rd method (see chapter 2.7.2.3.).

[14] data of Saxony between 6 and 10 a.m.

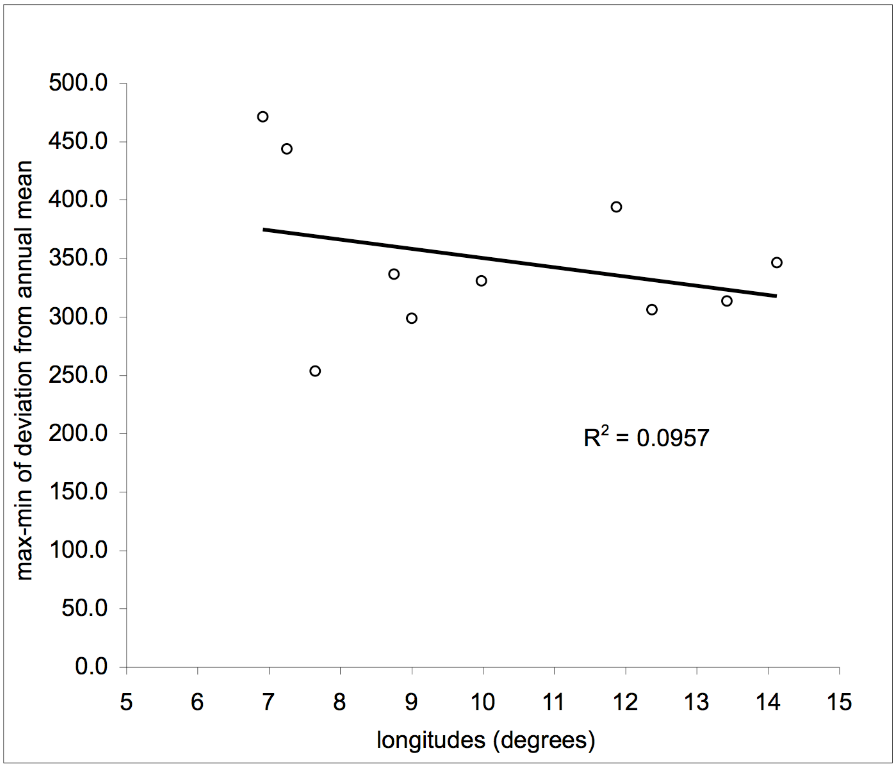


Figure 3.14: Amplitudes of maxima and minima of the annual mean are plotted against the longitudes. They are based on percentage values of the 3rd method. Averages of all available years of ten federal states of Germany.

It had to be said that – against all expectations – there could not be found any significant correlations to the degrees of longitudes, regardless on which values the arrangements were based.

3.3.2. <u>Geographical distribution of percentage parts of accidents on the way to school</u>

Figure 3.15 shows the average values of the methods one, two, and three arranged according longitudes. The trend lines show that none of them correlates to the degree of longitudes. The *p* values are p=0.38 (1st method), p=0.67 (2nd method) and p=0.92 (3rd method). Nor is there any correlation with degrees of latitudes as it can be seen in Figure 3.16. The *p* values for them are p=0.13 (1st method), p=0.76 (2nd method) and p=1.02 (3rd method).

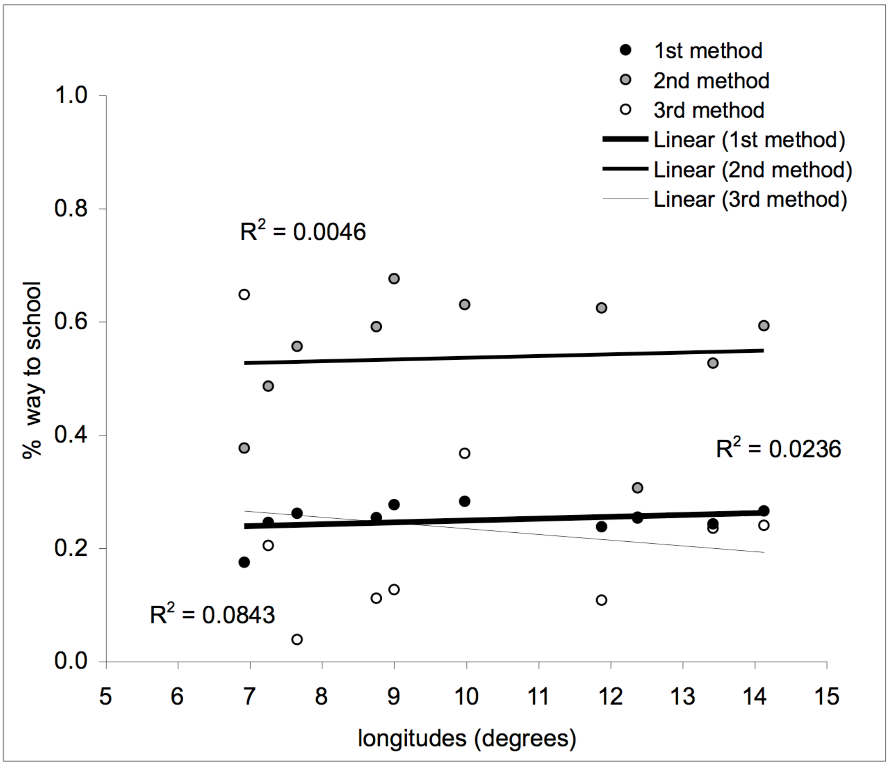


Figure 3.15: Values of the 1st, 2nd, and 3rd method are plotted against the longitudes. Averages of all available years of ten federal states of Germany.

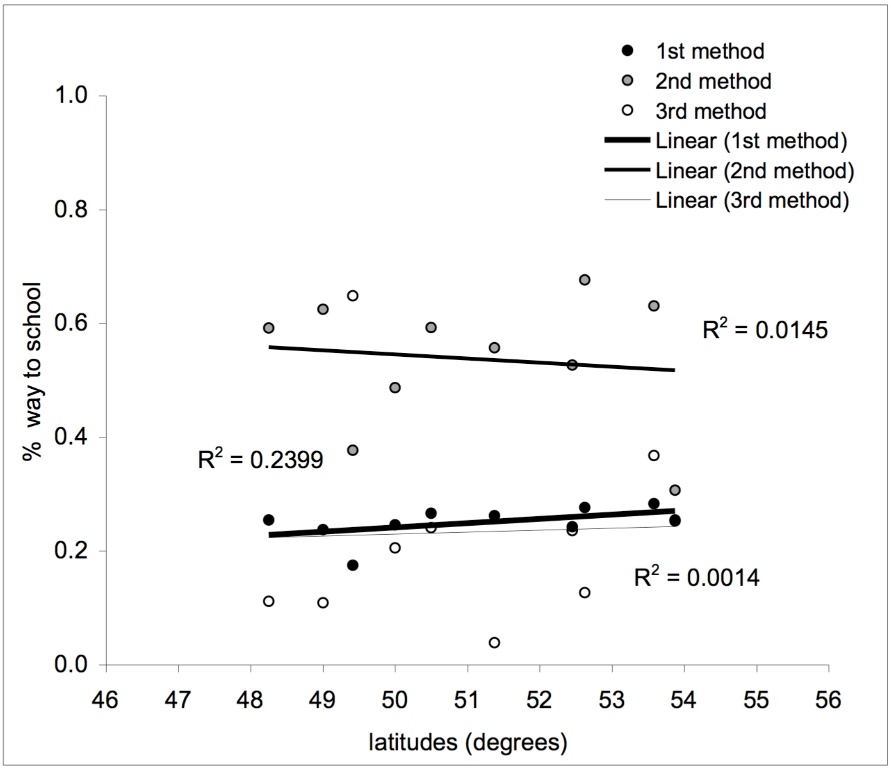


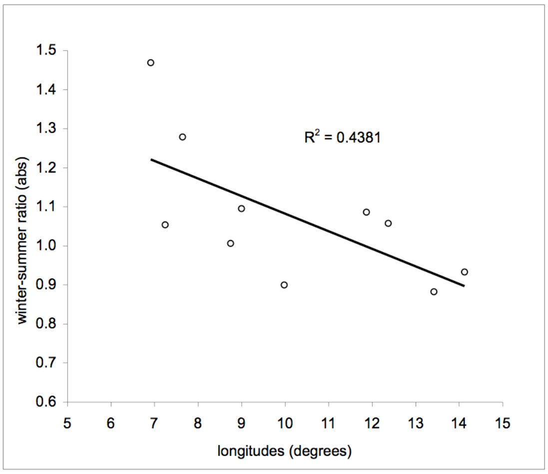
Figure 3.16: Values of the 1st, 2nd, and 3rd method are plotted against the latitudes. Averages of all available years of ten federal states of Germany.

3.3.3. Differences between winter and summer

The results of the ratios between accidents on the way to school in winter and in summer months are demonstrated in the following. Average numbers of winter/summer ratios plotted against degrees of longitudes are shown below. Correlations with different kinds of values can be seen.

3.3.3.1. Absolute numbers - average of all years

Figure 3.17 shows on the left graph an arrangement of winter-summer-ratios of *absolute* numbers according degrees of longitudes. The correlation is significant (p=0.02). "Cutting" Germany in two halves it can be seen that between the longitude degrees 5 and 10 the ratio shows averagely 1.13, while the average between the degrees 10 and 15 is 0.99. So in Eastern regions (beyond the 10th degree of longitude) in winter and summer accident rates are nearly the same while in Western regions (below the 10th degree of longitude) there are 13% more accidents in winter. The same arrangement like before, but plotted against latitudes can be seen on the right graph in Figure 3.17 no correlation (p=0.33) can be discovered here.



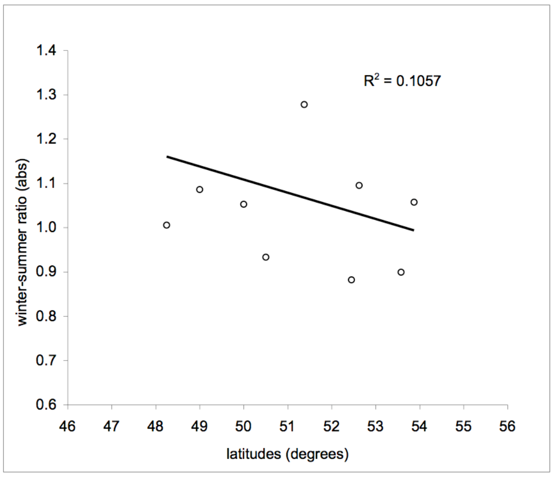


Figure 3.17: Ratio of *absolute* numbers of accidents between 6 and 9 a.m. between winter and summer months are plotted against the geographical distribution (longitudes on the *left*, latitudes on the *right* graph). Averages of all available years of ten federal states of Germany.

3.3.3.2. Distribution of school and free days

In order to get an impression of the distribution of summer holidays, their midpoints of two years are shown in Figure 3.18. The means of the holidays correlate quite significantly with the degrees of longitudes. The correlations show *p* values p=0.04 (2000) and p=0.06 (2008).

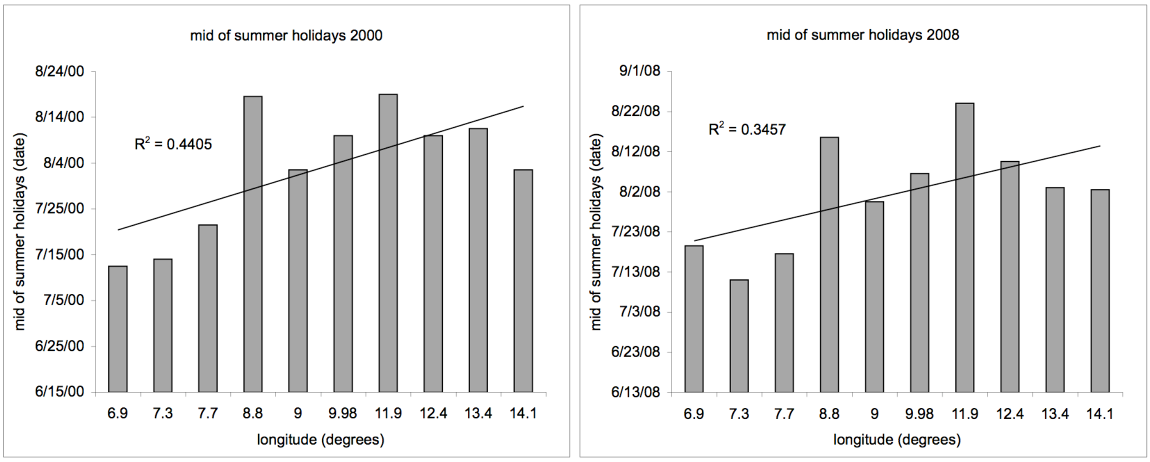


Figure 3.18: The mid of summer holidays in the year 2000 (*left* graph) and 2008 (*right* graph) are plotted against the grades of longitudes. Data of ten available federal states of Germany.

Additionally in Figure 3.19 and Figure 3.20 the ratios between school days in winter and in summer months are shown. At first they are plotted against the longitudes, where no correlation can be found (p=0.47). Alike there is no significant correlation with the latitudes (p=0.06). It can be said that in Southern regions of Germany the winter/summer ratio between the number of school days is higher than in the North, but that there is no systematic in the distribution of holidays. As already explained in chapter 2.7.3.4.2 the winter/summer ratios of school days were listed according their degrees of longitudes and latitudes as shown in Table 2.3. The average number of winter/summer ratios of school days below (1.20) and above (1.26) the 10th longitude shows nearly no difference with about 1%. A bigger difference indicates the average ratio under (1.28) and above (1.17) the 50th latitude with about 9%.

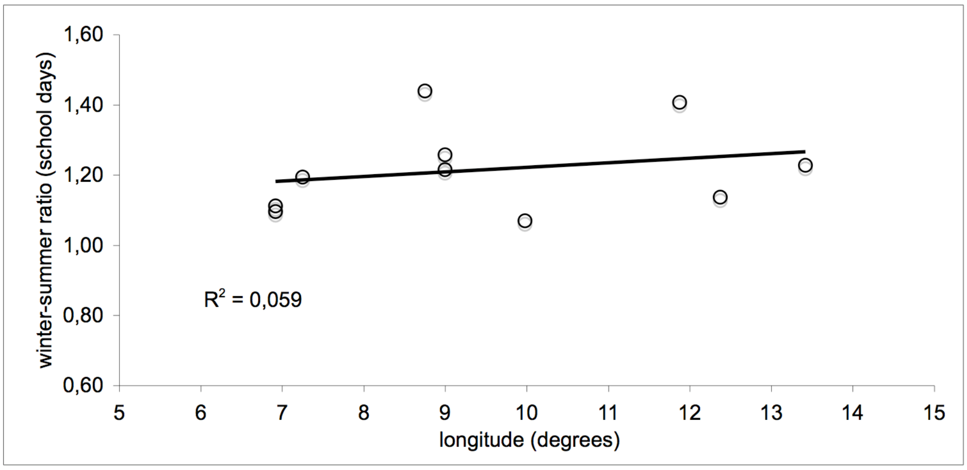


Figure 3.19: Ratios of school days in winter and summer months are plotted against degrees of longitudes. Data of ten available federal states of Germany.

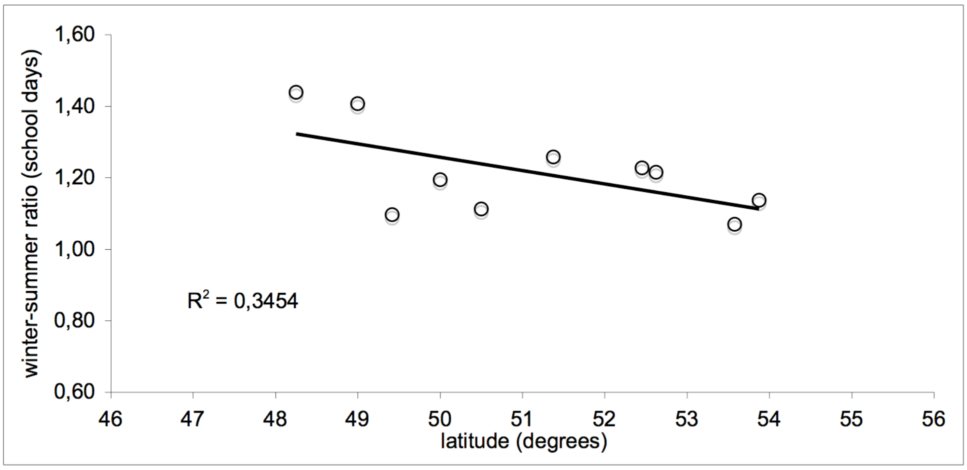


Figure 3.20: Ratios of school days in winter and summer months are plotted against degrees of latitudes. Data of ten available federal states of Germany.

longitude (E)	w-s ratio (schooldays)
6.92	1.10
6.92	1.11
7.25	1.19
8.75	1.44
9.00	1.21
9.00	1.26
9.98	1.07
11.88	1.41
12.38	1.14
13.42	1.23

latitude (N)	w-s ratio (schooldays)
48.25	1.44
49.00	1.41
49.42	1.10
50.00	1.19
50.50	1.11
51.38	1.26
52.45	1.23
52.63	1.21
53.58	1.07
53.88	1.14

Figure 3.21: Winter/summer ratios of school days listed with the longitudes (*left* table) and latitudes (*right* table). Ratios above the 10th longitude (*left* table) and above the 50th latitude (*right* table) are marked grey.

The same winter/summer ratios of *absolute* accidents between 6 and 9 a.m.[15] like before were calculated, but now without data of July and August. As can be seen in Figure 3.22 this time no significant correlation with degrees of longitudes can be found (p=0.06).

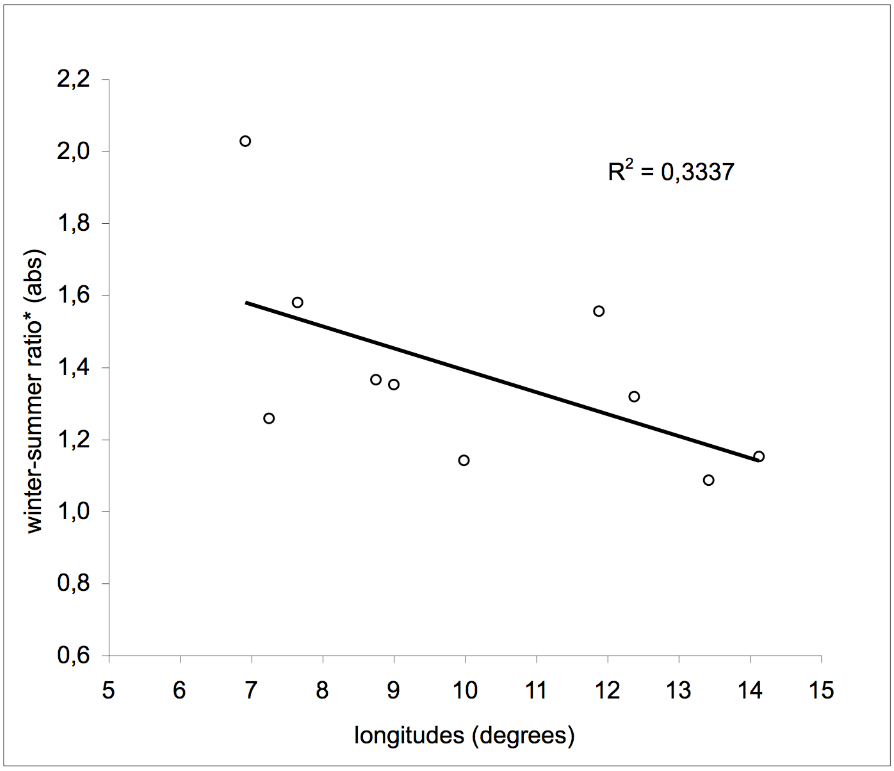


Figure 3.22: Ratio of *absolute* numbers of accidents between 6 and 9 a.m.[16] between winter and summer months are plotted against the degrees of Averages of all available years of ten federal states of Germany. Winter/summer ratio*= data of summer without July and August.

3.3.3.3. Relative accidents on school days – average of all years

Figure 3.23 shows the correlation of winter/summer ratios with longitudes. The ratios base on *relative* accidents per school days on the way to school. Unlike with absolute numbers there is no correlation (p=0.13). On the right graph the same arrangement, but with degrees of latitudes can be seen. There is also no significant correlation (p=0.78). The average value of winter/summer ratios of all ten federal states is 0.93. It means in average marginally lower accident rates in winter than in summer.

---

[15] data of Saxony between 6 and 10 a.m.

[16] data of Saxony between 6 and 10 a.m.

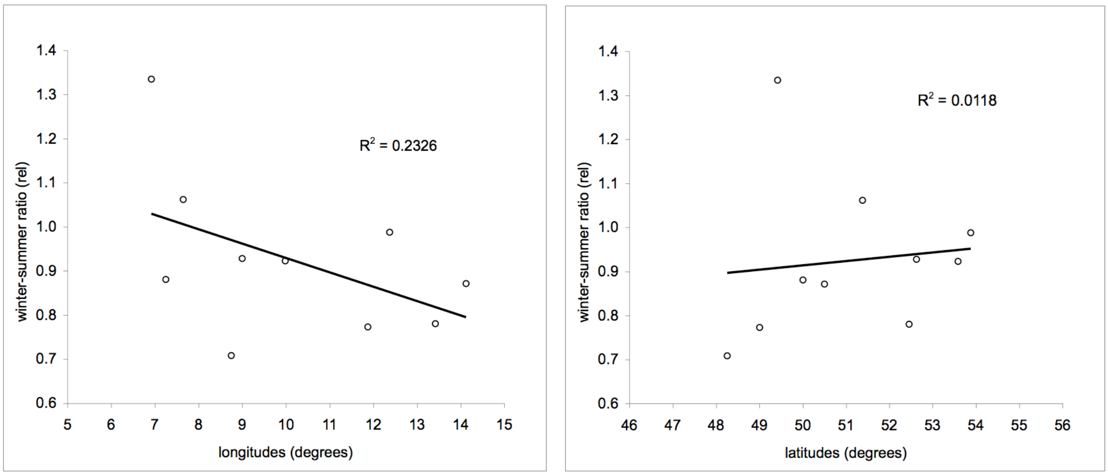


Figure 3.23: Ratio of *relative* numbers of accidents between 6 and 9 a.m.[17] per school days between winter and summer months are plotted against the geographical distribution (longitudes at the *left*, latitudes at the *right* graph). Averages of all available years of ten federal states of Germany.

3.3.3.3.1. Including Lower Bavaria and Upper Palatinate combined and Munich

In the same way like before arrangements of winter/summer ratios including two sub-regions of Bavaria were done. There is nearly a positive correlation to degrees of longitudes (p=0.05) as demonstrated in Figure 3.24, but not to the latitudes (p=0.31).

[17] data of Saxony between 6 and 10 a.m.

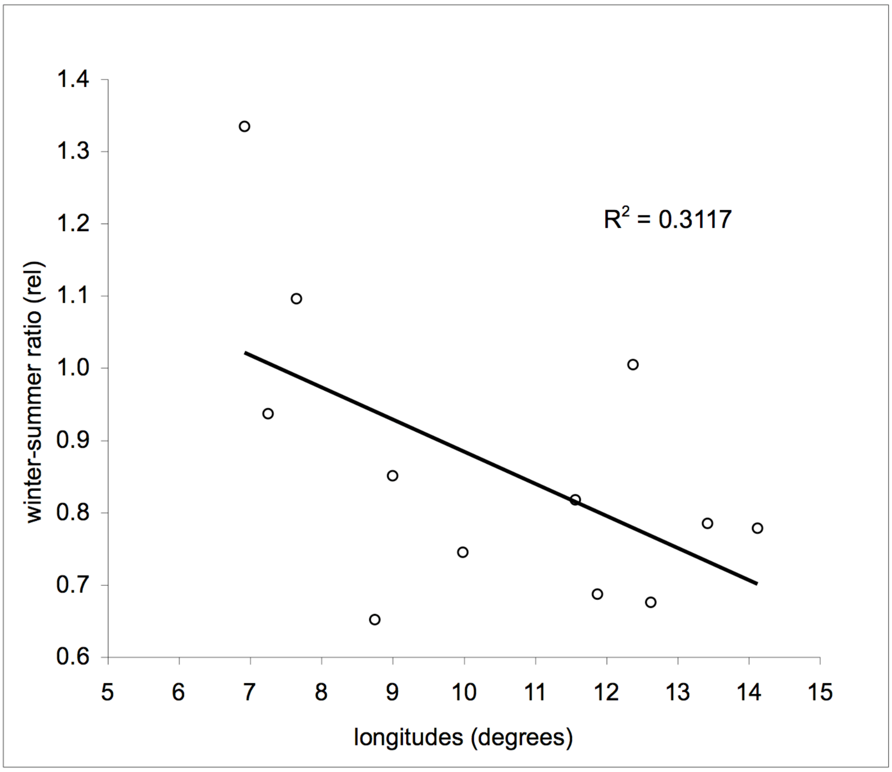


Figure 3.24: Ratio of *relative* numbers of accidents between 6 and 9 a.m. between winter and summer months are plotted against degrees of longitudes. Averages of all available years of *twelve* federal states of Germany.

3.3.3.3.2. Excluding Rhineland-Palatinate and Saxony

Winter/summer ratios of all ten available federal states were used like before, but excluding data of both Rhineland-Palatinate and Saxony for some reasons (see chapter 2.7.3.4.3). Neither a correlation to degrees of longitudes (p=0.09) nor to latitudes (p=0.90) can be seen.

3.3.3.4. Relative accidents on school days – average of the years 2003-2007

For the next calculations the nine federal states as noted in chapter 2.7.3.4.3 were taken. The next graphs show average numbers of winter/summer ratios, but this time only regarding the years 2003 to 2007. There is no correlation with degrees of longitudes (p=0.26) as shown in Figure 3.25 at the left, nor to the latitudes (p=0.73), as can be seen on the right graph.

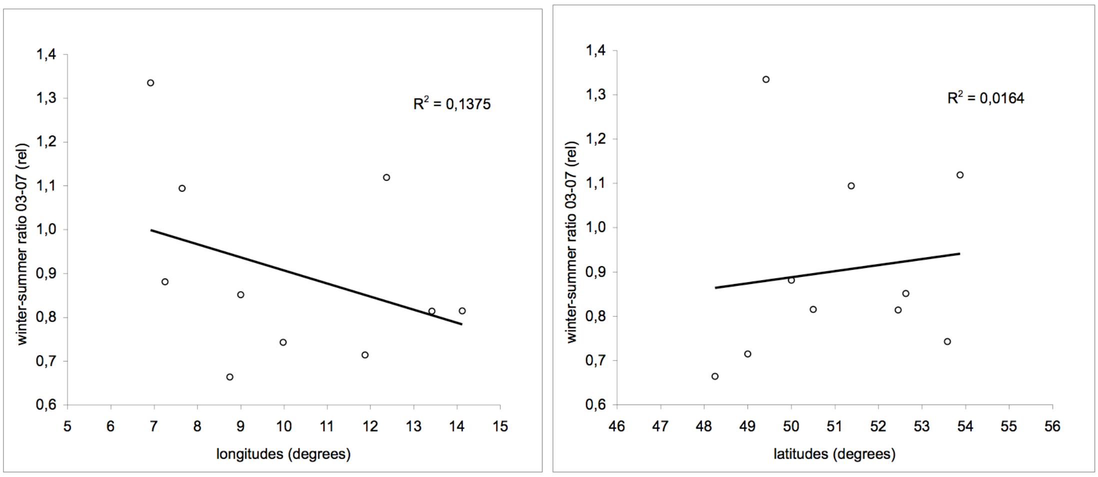


Figure 3.25: Ratio of *relative* numbers of accidents between 6 and 9 a.m.[18] per school days between winter and summer months are plotted against the geographical distribution (longitudes at the *left*, latitudes at the *right* graph). Averages of the years 2003-2007 of *nine* federal states of Germany.

Comparing averaged data of winter/summer ratios between Eastern and Western federal states between the years from 1999 to 2007 (see Table 2.5) no significant difference could be found after the t-test (*p* value 0.18).

As explained already in chapter 2.7.3.4.3 Lower Saxony and Saarland showed no normal distribution and were excluded from the following test. The one-way analysis of variance (ANOVA) test in combination with Bonferroni's multiple comparison test showed statistically significant differences ($p<0.05$) between the winter/summer ratios of the following federal states: Bavaria vs. Mecklenburg-Western Pomerania ($p<0.01$) and North Rhine-Westphalia ($p<0.05$), Baden-Württemberg vs. Mecklenburg-Western Pomerania ($p<0.01$) and North Rhine-Westphalia ($p<0.01$), Hamburg vs. Mecklenburg-Western Pomerania ($p<0.05$) and North Rhine-Westphalia ($p<0.05$).

3.3.3.5. Relative accidents on school days - "dark" versus "light" months

In average of all ten federal states the ratio of accidents on the way to school between months with darkness compared to months with full light on the way to school was 1.16. That means that averagely 16% more accidents happened throughout Germany in December and January than between April and September. The geographical distribution can be seen in Figure 3.26.

---

[18] data of Saxony between 6 and 10 a.m.

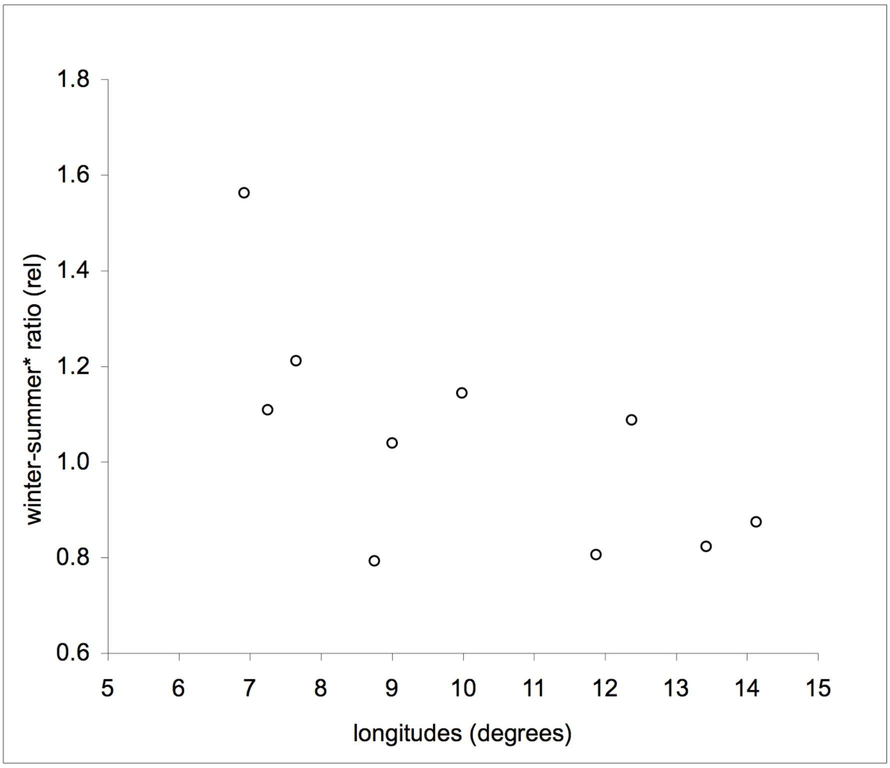


Figure 3.26: Ratio of *relative* numbers of accidents between 6 and 9 a.m.[19] per school days between "dark" (December, January) and "light" (April to September) months are plotted against the longitudes Averages of all years of ten federal states of Germany. Winter-summer* ratio means winter= December, January.

3.3.3.6. Values of the 1st, 2nd, and 3rd method

As Figure 3.27 shows there is no significant correlation against the degrees of longitudes; neither with values of the 1st ($p=0.47$), nor of the 2nd ($p=0.19$) nor of the 3rd method ($p=0.59$). The *p* values in correlation with degrees of latitudes demonstrate a similar picture as can be seen in Figure 3.28. They are $p=0.57$ (1st method), $p=0.11$ (2nd method) and 0.06 (3rd method).

Hence the winter/summer ratios based on values of the three methods (explained in detail in chapter 2.7.2) do not correlate at all to the geographical position.

[19] data of Saxony between 6 and 10 a.m.

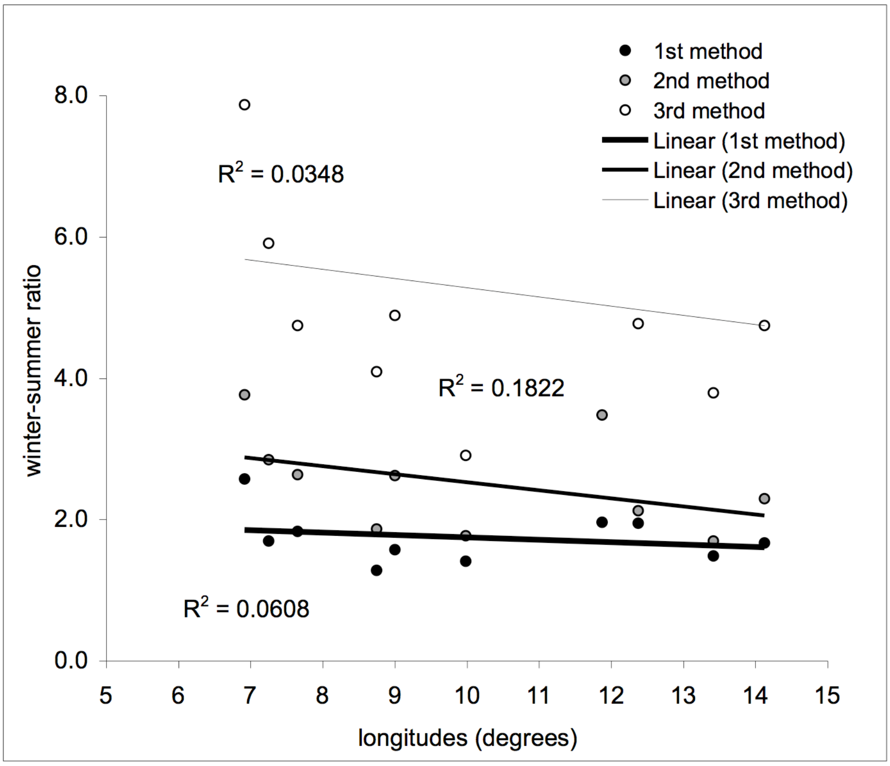


Figure 3.27: Ratios of winter and summer months basing on values of the 1st, 2nd, and 3rd method plotted against the longitudes. Averages of all available years of ten federal states of Germany.

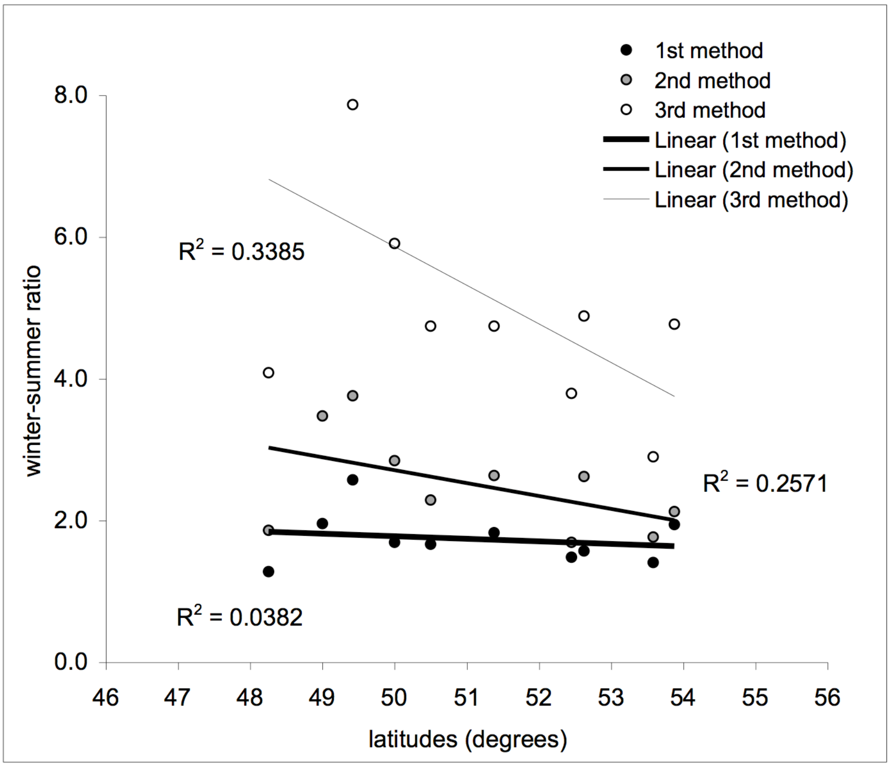


Figure 3.28: Ratios of winter and summer months basing on values of the 1st, 2nd, and 3rd method plotted against the latitudes. Averages of all available years of ten federal states of Germany.

3.3.4. Differences in sunrise and minutes in darkness

Differences in times of sunrise can be seen in Figure 3.29 exemplary for four federal states, which are located at the edges of Germany. Of all sources these four were the most Western, Eastern, Northern, and Southern located federal states. In Figure 3.29 the yearly course of sunrise of them can be seen.

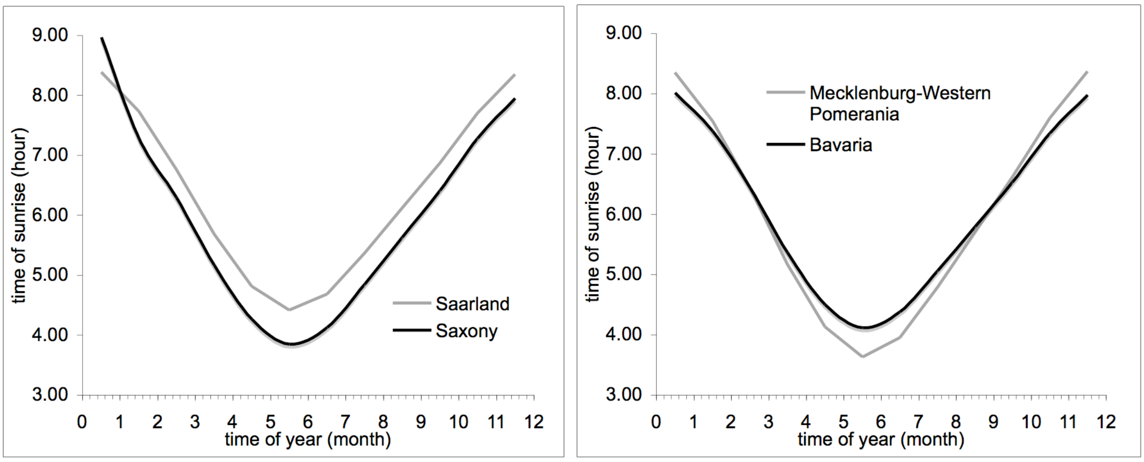


Figure 3.29: Different times of sunrise plotted against the time of year. Data of four federal states of Germany, which are geographically located at the edges of the country.

According to the calculations, sun rises in annual average 24 minutes later in the West than in the East. The North-South difference is not that simple. In the South from April to September sunrise comes in average 18.6 minutes later than in the North, but from October to February it is the other way round (in average a 14.4 minutes earlier sunrise in the South). In March there is no difference between South and North. All together it means in yearly average that sunrise is only 3 minutes later in the South.

According to different geographical positions, after 6 a.m. averagely there is a yearly range between 46.46 minutes in darkness (MID) in the East (Saxony) and 60.06 minutes in the West (Saarland). That means a difference of 13.60 minutes. The difference in MID between North (Mecklenburg-Western Pomerania) and South (Bavaria) is not that much. In the North there are 51.62 and in the South 46.46 MID. It is a difference of only 6.16 minutes. Of course these are average values, which do not respect the variance during the months/course of the year.

In Figure 3.30 an arrangement of MID against the degrees of longitudes can be seen. In the calculations for the MID (see chapter 2.7.3.5) not only the longitudes, but also the latitudes contributed to the results. So the values of MID were generated from both geographical data, but on the graph in Figure 3.30 only degrees of longitudes are presented. Each longitude incorporates one federal state.

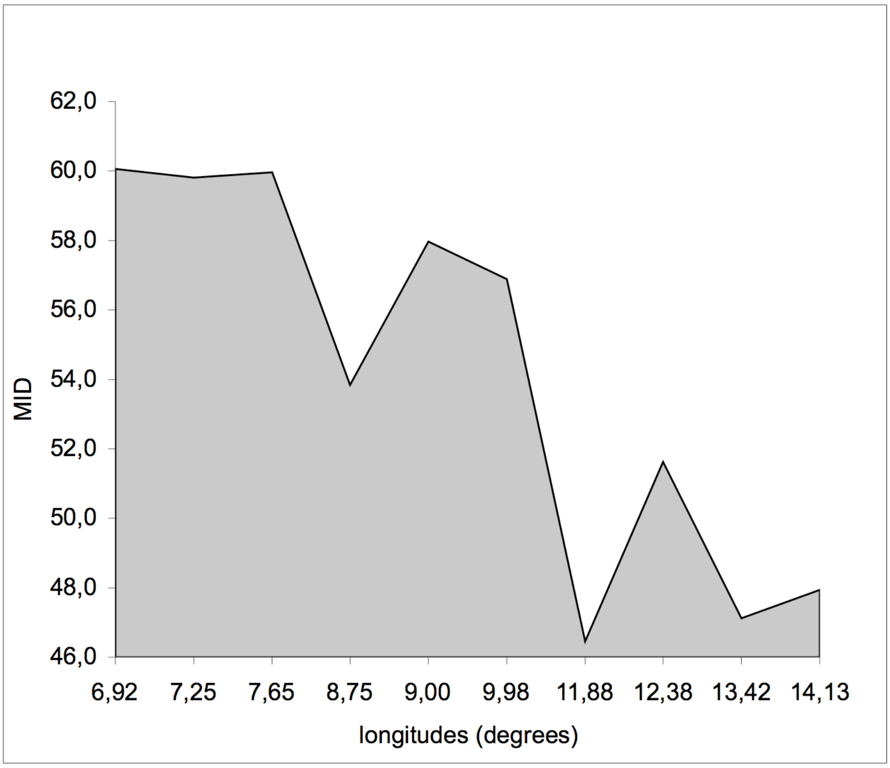


Figure 3.30: Distribution of minutes in darkness (MID) of ten federal states of Germany are plotted against the longitudes, which represent each federal state. Calculated values for MID are also dependent on the degrees of latitudes.

3.3.4.1. Correlated to winter/summer ratios of absolute accident numbers

In Figure 3.31 MID are arranged towards the winter/summer ratios based on *absolute* accident numbers. The correlation is statistically significant (p=0.05).

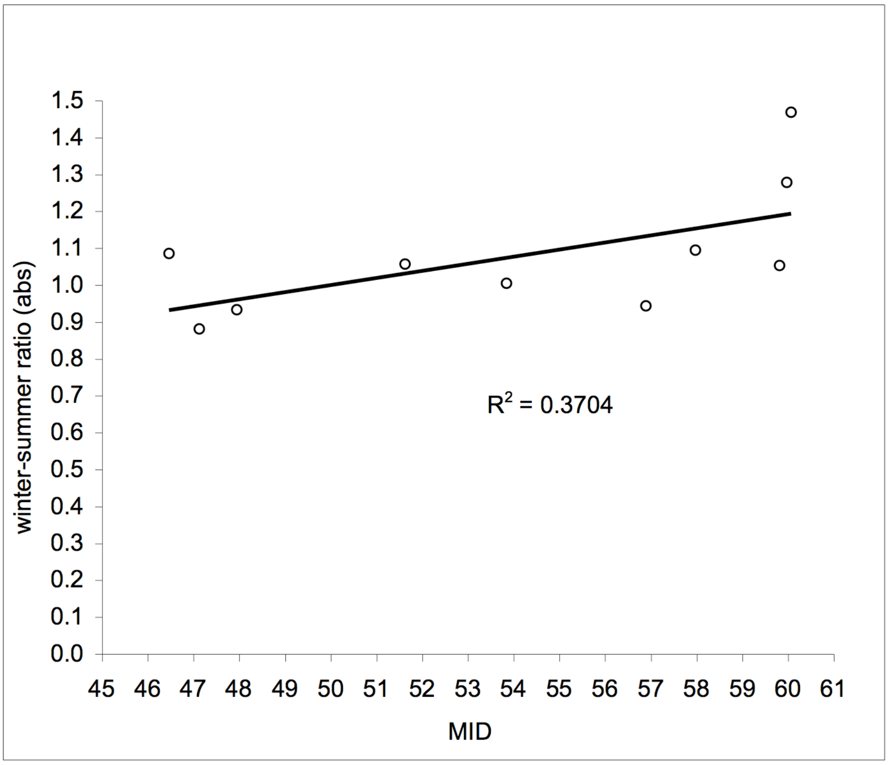


Figure 3.31: Ratio of *absolute* numbers of accidents between 6 and 9 a.m.[20] between winter and summer months are plotted against minutes in darkness (MID). Averages of all available years of ten federal states of Germany.

3.3.4.2. Correlated to winter/summer ratios of relative accident numbers

The same arrangement, but with winter/summer ratios of *relative* accident numbers can be seen in Figure 3.32. The correlation here is equally significant like above (p=0.05).

[20] data of Saxony between 6 and 10 a.m.

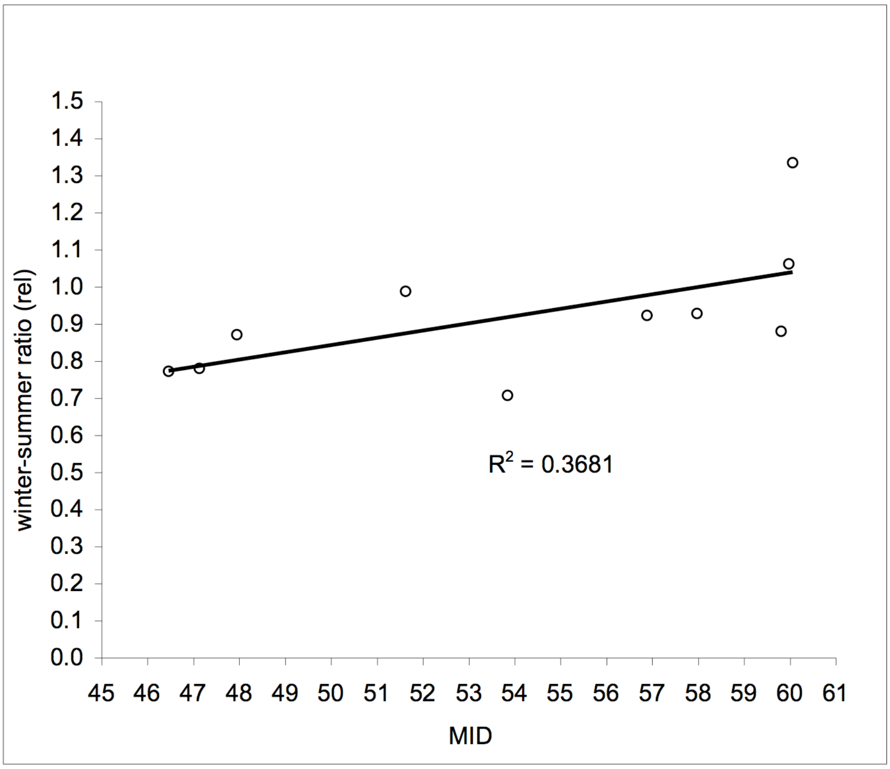


Figure 3.32: Ratio of *relative* numbers of accidents between 6 and 9 a.m.[21] per school days between winter and summer months; arrangement against minutes in darkness (MID). Averages of all available years of ten federal states of Germany.

3.4. Correlations with demographic parameters

For completing the investigation about traffic accidents some demographic parameters were taken in consideration. Therefore the average yearly numbers of *relative* accidents with children per school days as well as the same only on the way to school were plotted against to the following parameters.

3.4.1. Number of inhabitants

As in Figure 3.33 demonstrates the numbers of *relative* accidents per school days correlate statistically highly significant with the number of inhabitants of the federal states (p=0.00). In federal states with a big amount of inhabitants there are a lot more accidents per school day than in states with smaller numbers. In states with a number of inhabitants between one and two millions (Hamburg, Mecklenburg-Western Pomerania, and Saarland) in average there are 2.18 accidents per school

[21] data of Saxony between 6 and 10 a.m.

day, while states with under 10 million inhabitants have averagely 4.15 accidents. If the number of inhabitants is more than 10 million people (Baden-Württemberg, Bavaria, and North Rhine-Westphalia) an average of 14.28 accidents per school day can be seen.

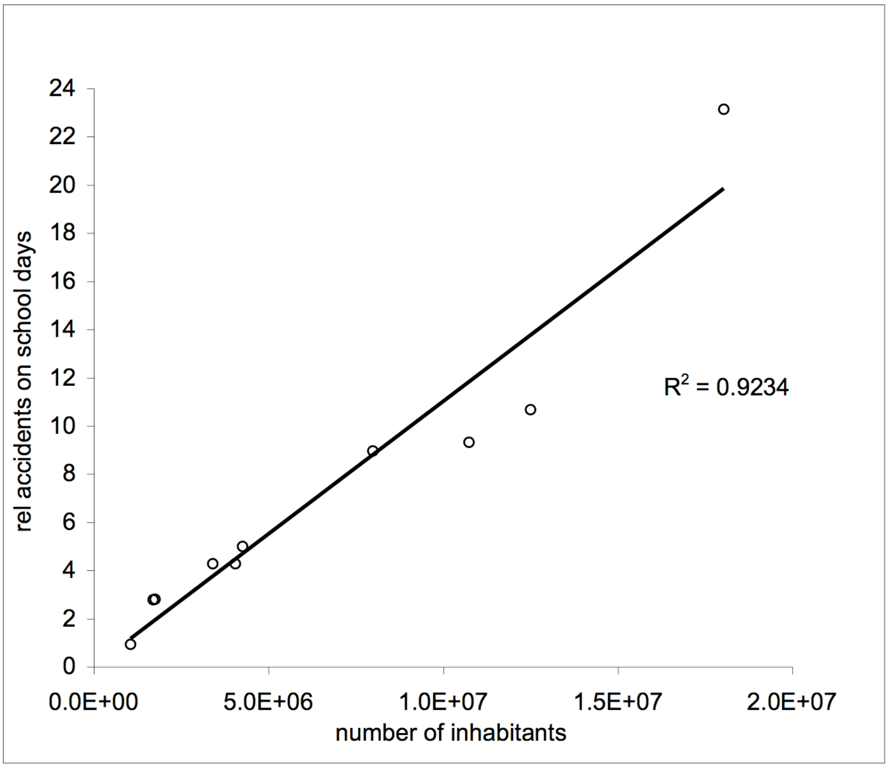


Figure 3.33: *Relative* accidents on school days are plotted against the number of inhabitants of each of ten federal states of Germany. Averages of all available years.

Between relative accidents on the way to school and the number of inhabitants no correlation can be seen (p=0.49) as demonstrated in Figure 3.34.

Figure 3.34: *Relative* accidents between 6 and 9 a.m. on school days are plotted against the number of inhabitants of each of ten federal states of Germany. Averages of all available years.

3.4.2. Density of inhabitants

Figure 3.35 and Figure 3.36 show the same compositions as before, but instead of the number of inhabitants with the density of inhabitants. In both cases no significant correlation can be found (p=0.53), neither with relative accidents on school days, nor with relative accidents on the way to school.

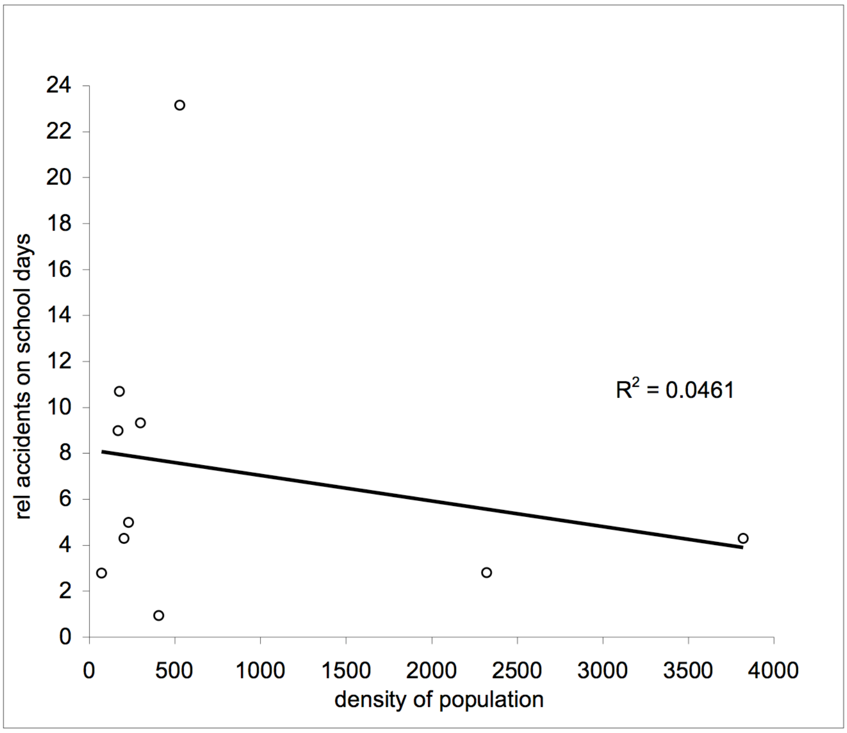


Figure 3.35: *Relative* accidents on school days are plotted against the density of population of each of ten federal states of Germany. Averages of all available years.

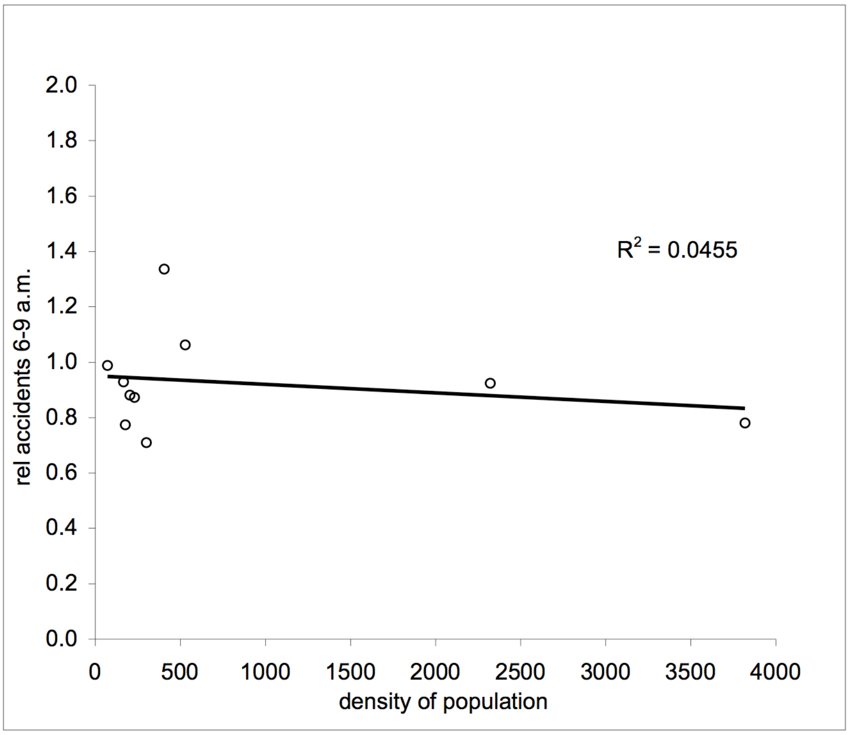


Figure 3.36: *Relative* accidents between 6 and 9 a.m.[22] on school days are plotted against the density of population of each of ten federal states of Germany. Averages of all available years.

[22] data of Saxony between 6 and 10 a.m.

4. DISCUSSION

In this study 179,625 traffic accidents of ten different federal states of Germany were investigated between 1995 and 2007 in which at least one child was involved. The main focus of interest was the time when children were on their way to school. Although there are studies about accidents on the journey to or from school [6, 51, 55] no detailed composition about daily and seasonal patterns of accident rates could be found. The aim of the present study was to illustrate such distributions and possible influence factors for them, especially in combination with differing lighting conditions.

4.1. Discussion of the methods

4.1.1. Critical reflection on applied data

Due to the fact that raw accident data was used there were, of course, some difficulties. Only ten of the 16 federal states in Germany offered adequate data for the research, but the obtained ones were quite distributed in their geographical position throughout the country. So in spite of a lack of some data a general comparison between Eastern, Western, Northern, and Southern federal states was possible.

Further there was no consistent number of years of the obtained accident data. Nevertheless the trends should have been recognizable using average numbers through all available years for each federal state.

It was found that children between 3 and 12 years had the highest relative risk ratios for having a traffic accident - with an exposure index consisting of distance travelled, duration, and number of streets crossed [30]. Besides other studies described, that children between 5 and 12 years had the highest risk for being injured by a vehicle [29, 30]. In the prevalence of the year of *general* injuries of children between 5 and 14 years (disregarding the gender), accidents have a percentage of 14.95%. The percentage of 15 to 17 years old adults lies at 16.75%. There are differences between boys and girls, especially boys in the age group 15 to 17 years have 6.3% more accidents than girls of the same age. [31] This says nothing in particular about traffic accidents, but as they amount to a major part of all accidents parallels can be drawn. The age groups according to which the federal states listed accidents with children also differed slightly. The range of the dataset used in this study covered accidents involving children between 6 and 14 years, with the exception of Munich and Rhineland-Palatinate[23]. This data were not excluded because monthly and hourly distributions showed no remarkable aberration from those of the others (see chapter 2.2). Children between 10 and 14 years are the main affected age group by traffic accidents in general [3] and also by accidents on the commute to school [23]. With the age group of the dataset most of the relevant ages having a high risk of getting involved in an accident could be included.

They were also deviations from the definition "way to school". Because of an arrangement of data from Saxony in two-hour steps the way to school in this federal state had to be defined differently. Unlike all other states, where it ranged between 6 and 9 a.m., here the time between 6 and 10 a.m. was chosen. Since it was expected that most of all children between 6 and 14[24] years were already at school between 9 and 10 a.m. the inclusion of accident data of this additional hour should not have altered the results gravely. Looking at chapter 2.3 and Figure 2.1 it can be seen that this choice included in average about 15% more accidents, but the annual distributions stayed similar. This aberration was regarded as arguable, because the results are merely based on internal comparisons of accident courses instead of absolute amounts of accident rates.

As there was no information about the grade of the damage for all incidents considered every accident where a child was involved disregarding the possible fact that the subject might have only been a participant without any damage. It was not focused on a distinction between different kinds of damage, because even harmless involvement could have meant a potential situation for worse lesions.

It could not be expected that every case of a traffic accident was registered with the precise minute of the event. In most recordings it was done in 5-minute-steps depending on the individual precision of each responsible person for accident acquisition.

Because of a lack of a uniform data collection the data sources registered traffic accidents with children not all to the accurately same definitions. As already explained in chapter 2.1.2 there were discrepancies between data of regional statistical authorities and police departments.

As a last point it has to be mentioned that traffic accidents were not distinguished for genders. On the one hand there is already a large number of studies, which examined gender difference showing that boys have in general higher injury rates than girls [31]. On the other hand there was no gender information for every accident, what would have drastically reduced the amount of useful data. It was

---

[23] between 6 and 15 years old

[24] data of Munich and Rhineland-Palatinate between 6 and 15 years

found that gender differences are less pronounced round about the beginning of school than during the rest of day [14]. As this period by itself was of the most interest, a splitting of the data separately for boys and girls was regarded as not necessary.

4.1.2. Methodical limitations

When processing the times of the accident data hour steps were regarded instead of minutes. It meant for example "10 a.m." stood for the time between 10.00 and 10.59 a.m. So it was not discriminated between accidents, which happened for example shortly after 10 and a little before 11. Those all were included as accidents that happened between 10 and 11 a.m. Maybe with this some accuracy was lost. However considering that data recording is dependent on the preciseness of individual competences and therefore not always that exactly, exploring the data hourly became a reasonable solution.

Accidents were not noted with the exact geographical position so average numbers for each federal state had to be used. Taking only one longitude and latitude to represent a federal state was a considerable simplification. Certainly some states have quite wide extensions, so taking the average geographical number set only a raw description of the real condition. Nevertheless those numbers could be used for basic comparisons between accident data of geographically different positions.

Recordings of times of sunrise vary a lot between diverse sources depending on differing definitions. In this study times of sunrise were taken from a webpage mentioned in chapter 2.4. After their definition sunrise was the time when the sun appeared above the horizon. As this is a common definition those data could be assumed being quite reliable.

Regrettably there was no way getting detailed accident data before the introduction of DST (before 1980). This would have been interesting for comparison with subsequent years. As described in chapter 1.2.1.3 a lot of studies about traffic accidents before and after the transition to DST were already done with various results

4.2. Discussion of the results – possible reasons

For various reasons it was hypothesized that the way to school is a high-risk time for traffic accidents involving children. According to the findings of this study traffic accidents with children between 6 and 14[25] years during this time account for about 25% in comparison with the rest of the day (see Figure 3.5 and Figure 3.6).

4.2.1. High amount of accidents with children on their way to school

Relative numbers of accidents on *school* days averaged for all federal states had a peak between 7 and 8 a.m. Since most schools start round about 8 a.m. it could be assumed that the majority of children were on their way to school during this hour. Another two peaks were between 1 and 2 p.m. (most schools end about 1 p.m.) and between 5 and 6 p.m., when children might have come home from afternoon lessons, sport or leisure activities.

On *free* days most of all relative accidents were found between 5 and 6 p.m. This could be explained as children might have slept longer, went outside later and leisure activities also were shifted further to afternoon hours.

Contemplating the monthly distribution of general traffic accidents with children it was found out that on average on *school* days most of all traffic accidents happened in summer (Mai to September). They were about twice the number than on *free* days (see Figure 3.2). As an explanation for the relatively low number of free days during the warm months it could be assumed that a lot of people were abroad. Aside from this at weekends children might generally spend more time at home than on the streets, so they were not exposed that much to risky traffic situations. The results showing that at school and free days more accidents happened in summer might be explained easily by the fact that in hot temperatures more people are outside as pedestrians, bikers, et cetera, in comparison with colder seasons. Therefore the possibility for getting implicated in an accident was consistently greater than in winter.

4.2.2. Traffic accidents rates on the way to school in yearly course

Regarding the results of various comparisons between the time during school travel and accident situations at other times or at free days (see chapter 3.2) several conclusions could be drawn. The percentage part of traffic accidents between 6 and 9 a.m. on school days during winter months (October to March) was much higher than during summer time (April to September). This might have resulted from the fact that in winter the journey to school was partly or even complete in darkness. As already mentioned it came out that averagely on school days most traffic accidents happened

---

[25] data of Munich and Rhineland-Palatinate between 6 and 15 years

in summer (Mai to September) as is shown in Figure 3.2. So in winter traffic accident rates with children on school days are relatively lower. The percentage part of accidents on the way to school compared to such at other times was higher in winter than in summer, though. This leads to the implication that the way to school might indeed be affected by seasonal influences – such as lighting or weather conditions.

The highest numbers of *relative* accidents on school days between 6 and 9 a.m. were found between May and December (in June, September, and November of *absolute* numbers). In February and March there were the lowest numbers (see Figure 3.4). Maybe the cold weather could be an explanation for this. Most of children might have taken the bus or have been brought by parents. So less pedestrians, bikers, et cetera might have meant less risk for accidents in those months. Confirming this it was shown that transportation in school buses was quite safe [40, 47]. Only 7% of all traffic accidents on travel to school were connected with school buses [39]. Pedestrians are at a substantial risk for getting involved in an accident. It was found that 40% of examined child fatalities under 15 years of age were pedestrians [10]. In addition to that as results of motor vehicle accidents in childhood 84% were found to be pedestrians [21]. It could be assumed that less pedestrians on the streets were a possible reason for low accident rates in winter.

4.2.3. Do accidents on the way to school depend on geographic positions?

Using only one average number of longitude and latitude in order to characterize a federal state was, of course, a reduction to a vague representation of the region. But general comparisons were possible in either case.

There is a big variety between different sources of collections of times of sunrise. Instead of gathering the sunrise time for each single day, the monthly mean was chosen and interpolated after the "least-square" procedure of Stineman [57] as explained in chapter 2.4. Also here slight discrepancies to "real" times of sunrise might have been built. But as daylight does not appear from one minute to the other, these discrepancies do not matter that much. There are differences of +0.40 hour (see chapter 2.4) between sunrise in the East and West of Germany in yearly average. Between Northern and Southern regions differences in sunrise times were smaller, as it was explained more detailed in chapter 3.3.4.

The delay of sunrise between East and West can be compared with the situation before and after transition to DST. Comparing Eastern and Western regions with certain phases before and after DST the traffic remains similar because of a certain "clock-time", but there are differences in lighting conditions. A possible impact of DST on traffic accidents was repeatedly explored, but in most studies no detrimental effect was found (see chapter 1.2.1.3).

Even though darkness was reckoned to bear great influence on traffic accidents [26, 59, 60]. It was supposed that darkness especially on the way to school was an important risk factor, having an impact mattering primarily in winter months. Thereto it could be shown that the percentage part of accidents compared to different times or to accidents on free days was rather high in winter. It could be guessed there might be a difference (concerning traffic accidents on the way to school) between Eastern and Western federal states of Germany, because of the later sunrise in the West (see Figure 3.29).

Nobody so far studied similar conditions by comparing differences in accident rates on the way to school between Eastern and Western regions of Germany. In this study the main attention was turned more closely to a possible contrast there.

4.2.3.1. Arrangement of deviations of the annual mean

For a first confrontation monthly deviations of the annual mean of *absolute* accidents between 6 and 9 on school days were used. After some considerations the amplitudes between maxima and minima of monthly averages should have rose towards smaller longitudes (West). To explain this it was anticipated that depending on a later sunrise accident rates in the West were higher in winter than during the rest of the year when the way to school was in full light. Against the expectations there was no correlation at all ($p=0.32$) with the longitudes as shown in Figure 3.12. The same correlation was again tested with *relative* accident numbers (see Figure 3.13), but also without any correlation ($p=0.15$).

The values of method one to three (see chapter 3.2) were also used in order to look for a possible correlation with the geographical position. As can be seen in Figure 3.15 and Figure 3.16 none of them either correlated with the longitudes or with the latitudes.

4.2.3.2. Winter/summer ratios of accidents on the way to school

To verify preferably all possibilities the next consideration was about comparing accident rates between winter and summer months. Looking at the winter/summer ratio of *absolute* accidents between 6 and 9 a.m. there was a significant correlation ($p=0.02$) with the longitudinal position as can be seen in Figure 3.17. As in the West sun rises later the positive correlation could indeed have resulted from the fact that those federal states had longer periods of darkness in winter months causing more traffic accidents in the morning.

For using *absolute* accident numbers it had to be respected that the federal states differ in the distribution of school days because holiday times vary. But it could be shown that the winter/summer ratio of school days did not significantly correlate either to the longitudes or to the latitudes of each federal state (see Figure 3.18). This meant there was no systematically distribution of the number of school days in winter and summer according to any geographical position. On average for all ten federal states in winter there were 1.22 times more school days than in summer. The winter/summer ratios of school days ranged between minimum 1.07 (Hamburg) and maximum 1.41 (Bavaria). Comparing winter/summer ratios between school days of federal states below (West) and above (East) the 10^{th} longitude the ratio was nearly equal (1% difference). An only slight difference of about 9% was discovered by comparing winter/summer ratios of school days between federal states below (North) and above (South) the 50^{th} latitude.

Quite interesting is a significant correlation ($p=0.04$) of the midpoint of summer holidays with the longitude position as can be seen in Figure 3.18. But according to the definition "summer" all months between April and September were included and so the actual date of holidays should not have influenced the winter/summer ratios. It was also discovered that everywhere in summer there was about one complete month free, but not always at the same time.

In the months July and August there are the longest periods of holidays. To see the actual impact on the results again winter/summer ratios were calculated, but this time in summer those two months were excluded. Unlike before, where data of July and August was retained, now there was no significant correlation to the degrees of longitudes any more. This can be a hint that those months with different holiday distributions were responsible for the positive correlation between *absolute* accident numbers and the geographical data.

Keeping the problems with absolute numbers in mind *relative* numbers of accidents per school day were used. Against the hypothesis the new winter/summer ratio showed no significant correlation, neither with the longitude nor with the latitude as can be seen in Figure 3.23. This was astonishing as there are differences in the time of sunrise according the geographical data. If darkness on the way to school influenced the number of traffic accidents negatively there was the expectation that the ratio of *relative* accident rates show a clear correlation. Yet it could be guessed that the discrepancy between the results of *absolute* and *relative* accident data is due to the variance in the distribution of school days during the seasons between the different federal states. This difference might be the cause for the diverse correlation of *relative* values. To verify the assumption we did the same tests like before, but this time we included *relative* accident data of Lower Bavaria and Upper Palatinate combined and data of Munich. A positive correlation to the longitudes was found ($p=0.05$), but none to the latitudes (see chapter 3.3.3.3.1). With data of more administrative districts and a more detailed geographical classification maybe a better statement could be given. Excluding Rhineland-Palatinate and Saxony neither a correlation to longitudes nor to latitudes was seen (see chapter 3.3.3.3.2). The same situation came up with using only data between 2003 and 2007 that are included by most federal states, as can be seen in Figure 3.25.

In order to look if there is a statistically significant difference between winter/summer ratios of Eastern and Western federal states we did the t-test with values between 1999 and 2007 and found no significant difference (p=0.18). This confirms the results of most of the correlations. Nevertheless a certain trend can be seen. In nearly all plots (winter/summer ratios) the tendency was detected that in winter months accidents on the way to school rise towards Western located states. All federal states, except Lower Saxony and Saarland, showed a normal distribution after the Kolmogorov-Smirnof test. Even if we found no statistical significant difference between all data, the ANOVA and accessory Bonferroni test showed statistically significant differences between single federal states (see chapter 3.3.3.4).

Subsequently we compared accident rates only between months with either complete darkness or full light on the way to school. Therefore the months with sunrise between 6 and 8 a.m. and so the way to school was partly dark and partly in light were excluded. The new winter/summer ratio as explained more detailed in chapter 2.7.3.4.3 showed in general 1.16 times higher accident rates in "dark" months compared to those in full light. This might be an evidence for the important influence factor "light" on traffic accidents. But we cannot prove if it really is the light or if there maybe are secondary patterns, like weather conditions, which might also play a great role in winter months.

4.2.3.3. Exact minutes in darkness on the way to school

After times of sunrise minutes in darkness after 6 a.m. were calculated according the geographical position. There might have been aberrations from the reality because of theoretical calculated values. Since we only looked for some tendencies it was justifiable to allow potentially marginal discrepancies.

As it was shown in chapter 3.3.4 there are wide discrepancies of MID after 6 a.m. between Easter and Western regions of Germany, which was the starting time of travel to school according to the definition. Like before winter/summer ratios of *absolute* and *relative* accident numbers were used, but this time applied against the actual minutes in darkness. Both correlations showed *p* values of p=0.05, which were significant (see Figure 3.31 and Figure 3.32). There seemed indeed to be a positive correlation between the MID of each single federal state and winter/summer ratios of accidents on the way to school.

4.2.4. Correlations with other factors

The number of inhabitants correlated statistically highly significant (p=0.00) with the *relative* accidents per school days as can be seen in Figure 3.33. Of all the available states of this study the biggest federal states were Baden-Württemberg, Bavaria, and North Rhine-Westphalia with more than 10 million people. The more people live in a federal state the more children get involved in an accident. This is a logical consequence as more inhabitants mean more people on the streets with a potential risk for having an accident. But using the relative numbers of accidents *on the way to school* no correlation could be found.

Looking at the same correlations with the density of inhabitants (Figure 3.35) no dependency at all could be seen. This was surprising as we expected significantly less accidents in sparsely populated areas, at least when considering the way to school. Most of the children there might have come to school rather by any vehicle (bus, parents, for example) than on foot or by bike, because of a supposed longer distance to travel. This realization is another hint that traffic accidents are influenced by so many factors, which could not be respected easily all together. There might always be patterns that change accident rates decisive. Dissimilar applications of safety measures, different social or migration status [31], distinctive habits in locomotion are only some examples for possible reasons for this.

4.2.5. Summary of the findings

According to the posted hypothesis there are more accidents with schoolchildren in the morning if there is darkness. Sullivan et al. investigated a similar question. In their findings 1333 lives per year could be saved if darkness could be turned into daylight. They examined pedestrians in general compared to other road users, but not children in particular and not this special phase of time - the way to school. Speed of vehicles in connection with limited sight distance was found to be a dangerous combination multiplying the risk of pedestrians. [59] Unlike us they used for their research also times of sunset.

The findings show that 25% of all accidents with children (compared to the rest of the day) happened between 6 and 9 a.m. On the way to school in winter there were 1.5 times more accidents than in summer (referring to the daily total). As we assumed darkness being the decisive influence factor we looked for positive correlations with the geographical position of the data source in Eastern or in Western parts of Germany.

To summarize all results of the present study significant correlations between the winter/summer ratios of *absolute* accident numbers on the way to school and the longitudes were found. But there might have been a bias because of discrepancies in the distribution of school days in winter and summer. Using *relative* accident numbers a correlation with degrees of longitudes was only seen after including additional data of two administrative districts of Bavaria. To prove the initial hypothesis statistically significant correlations with any of our *relative* accident data should have been found. There are indeed connections between the geographical position (especially comparing East and West) and the number of children getting involved in an accident before school. Due to the limitations of the available database we regrettably could not prove this with entire validity. There is a statistically connection between the number of accidents on way to school comparing Eastern and Western federal states of Germany. Some of them show a statistically significant difference among each other. It was found that in months when the way to school was in nearly complete darkness there were about 16% more accidents per school day than during months with full light at this time. This number is small, but obvious.

Since differences in sunrise times between Eastern and Western federal states make at most only about 40 minutes, the time period when there are actually decisive differences in lighting conditions might be too small to come into effect. Even if there are a lot of traffic accidents with children on the way to school maybe the rates are still too small to detect easily grave differences among several federal states of Germany. Besides traffic accidents are influenced by so many factors that it will always remain difficult to give clear statements about one single cause.

4.3. Prospects

Worldwide a lot of proposals were and are still made for improving the safety of our children on the streets, for example from the commission for global road safety. They claim for global, national, and regional activity in various directions. [1] In a policy statement about school transportation safety recommendations for American pediatrics were given, from school bus safety features to introducing new laws (for example about mandatory bicycle helmets). They made an appeal to pediatricians promoting school transportation safety to different levels: the patient and its family, the community, the state, and national. [6]

In the European Union in all countries a reduction in injury mortality for children (1-14 years of age) could be found. Germany is at the moment not the best ranking country [24]. But there are reasonable recommendations for injury prevention concerning children's risk in traffic [39], traffic regulations on school surrounding areas [38] and especially on the way to school [27, 40, 41]. Regrettably not all of protective measures were acted out properly. A recent survey of the Robert-Koch-Institute shows that the quote of wearing helmets when riding a bike or skating in the age group 5 and 15 was about 60% and dropped to only about 15% in the age group 15 and 18 years. The situation is similar with protective clothes [31].

It can be seen that there is still a lot of work to do. There is no lack of useful proposals, but the applications regrettably not always succeed.

As explained already in chapter 2 there are a lot of factors influencing traffic accidents. It was not possible to respect each of them, for we the research was restricted to available data. As mentioned several times for better analysis even more detailed and equal data of every federal state would be necessary as well as a more precise geographical attribution. For a better classification research about traffic accident rates in administrative districts or even better in towns or cities probably would be more significant than on federal states level.

Further research should be done in order to improve the limitations of this study and to concern certain parameters even more detailed. The weather, as it is determined as an important factor affecting traffic accidents (see chapter 1.2.2) should be examined more closely in connection with accidents on the way to school, to mention only one example.

So far there are hardly reliable studies about the exact school start time in relation to the amount of accidents, which happen between leaving home and arriving at school. As each school regulates the time of school start independently (see chapter 1.3) it is quite difficult to get those data. Actually it would mean that every single school and accidents with its pupils on journey to this school should be examined separately.

Further it would be interesting to detect certain chronotypes of accident victims. As it is explained in chapter 1.2.3 sleep habits of adolescents, lack of sleep and the consequences influence people's behaviour. Correlations between late types [52] and traffic accidents in the morning would be quite interesting. Since many pupils (and also a lot of adults!) lament about getting up much too early with following less alertness or even falling asleep in the first lesson [20, 62], it should not be unconsidered that sleep lack might be an important influence factor in accident rates. Possible connections between late types and accident rates with children in the morning should be examined. At present data about the chronotype is no part of standard accident registration in Germany and possibly might be stopped by data privacy protection.

5. SUMMARY

This study examines seasonal and geographical distributions of traffic accidents involving children on their way to school. Other studies have shown that darkness can strongly influence the number of traffic accidents. To test the influence of darkness on the number of accidents concerning the commute to school, the seasonality and geographical distributions of 179.625 traffic accidents involving children between the ages 6 and 14 were investigated. The database includes accidents from ten federal states of Germany collected between 1995 and 2007.

Various aspects of traffic accidents in regions all over the world have been investigated in a large number of studies. None of these focused on the question whether early morning lighting conditions changing across the seasons have an influence on the number of accidents concerning the commute to school.

The sun rises progressively later from East to West and dawn times also differ from North and South. School start times are, on average, the same across Germany. Therefore, the advantage of the geographic differences between dawn and school begin could be taken by comparing the accidents statistics for different seasons as well as for different longitudes and latitudes.

School commute accidents between the ages 6 and 14 account for approximately 25% of the daily total (referring to the same age group), in winter there are about 1.5 times more accidents than in summer.

The winter/summer ratio (normalised) increases from East to West and from South to North, though not significantly.

For each school day, one can correlate the exact time in darkness and the corresponding accident rates. Seasonal comparisons showed that between the numbers of (normalised) accidents averagely 16% more accidents happened when children went to school in darkness compared to those times of year when the sun has already risen.

The hypothesis that darkness has an influence on accident rates involving children on their way to school cannot be supported by significant results. Nevertheless the data show a clear trend of increasing accident rates from Eastern to Western states of Germany.

The observations indicate that statistical significance could be reached with more and more detailed data. Unfortunately it was not possible to get access to statistics from all the German states and those available did not show enough details about the accidents. The reasons for these difficulties were manifold, such as data privacy protection laws or lack of cooperation by statistical bureaus. Several possibilities are discussed how to improve studies on school accidents.

6. ZUSAMMENFASSUNG

Die vorliegende Studie untersucht jahreszeitliche sowie geographische Häufigkeiten von Kinderverkehrsunfällen auf dem Schulweg. Studien haben gezeigt, dass Dunkelheit einen großen Einfluss auf die Verkehrsunfallzahlen ausüben kann. Um die Auswirkungen von Dunkelheit auf die Zahl der Schulwegunfälle darzustellen, wurden die jahreszeitliche und geographische Verteilung von 179.625 Verkehrsunfällen mit Kinderbeteiligung im Alter zwischen 6 und 14 Jahren untersucht. Die Datenbasis bilden Unfälle aus zehn deutschen Bundesländern von 1995 bis einschließlich 2007.

Weltweit laufen stets unzählige Verkehrsunfallanalysen unter den verschiedensten Gesichtspunkten. Bisher wurde in keiner von ihnen gezielt untersucht, ob sich die veränderlichen Lichtverhältnisse in den frühen Morgenstunden, bedingt durch die verschiedenen Jahreszeiten, auf die Anzahl der Kinder auswirken, die auf dem Schulweg verunglücken.

Die Sonne geht schrittweise von Osten nach Westen auf und zur Sommerzeit verschiebt sich der Sonnenaufgang auch von Norden nach Süden, während in Deutschland die Schulen überall in etwa zur selben Zeit beginnen. Aufgrund der geographischen Differenzen zwischen Sonnenaufgang und Schulbeginn konnten die Unfallstatistiken im Hinblick auf die verschiedenen Jahreszeiten als auch bezüglich der unterschiedlichen Längen- und Breitengrade untersucht werden.

Der Anteil an Unfällen von 6 bis 14-Jährigen auf dem Schulweg beträgt im Vergleich zu Unfällen, die während der übrigen Zeit des Tages passieren 25% (bezogen auf dieselbe Altersgruppe), im Winter sind es etwa 1.5 mal so viele, wie im Sommer.

Die Winter/Sommer-Quotienten der einzelnen Bundesländer nehmen zwar von Ost nach West zu, dieses Ergebnis ist jedoch nicht signifikant.

Für jeden Schultag kann die genaue Zeitspanne der Dunkelheit und dazu die entsprechenden Unfallzahlen berechnet werden. Jahreszeitliche Analysen zeigten, dass die Anzahl an (normalisierten) Schulwegunfällen im Dunkeln durchschnittlich 16% höher war, als in Zeiten, in denen die Sonne bereits aufgegangen war.

Die Hypothese, dass Dunkelheit tatsächlich die Unfallzahlen der Schulwegunfälle negativ beeinflusst, konnte allerdings nicht signifikant belegt werden. Die Daten zeigen aber, dass es tendenziell in westlichen deutschen Bundesländern höhere Unfallraten auf dem Schulweg gibt, als in östlichen.

Die Ergebnisse zeigen, dass mit noch mehr und detaillierteren Daten bessere statistische Resultate erzielt werden könnten. Leider gab es keinen Zugang zu Unfalldaten aus allen deutschen Bundesländern. Es gab mehrere Gründe für den Mangel an genügend angemessenen Daten, unter anderem Datenschutzgesetze oder mangelnde Kooperation der statistischen Landesämter. Verbesserungsmöglichkeiten zu Schulwegunfallstudien werden diskutiert.

7. REFERENCES

1. *make roads safe - a new priority for sustainable development*, Commission for global road safety: London.

2. *Pedestrian roadway fatalities*, in *Ann Emerg Med*. 2003. p. 479-80.

3. *Pressekonkerenz "Unfallgeschehen im Straßenverkehr 2005"*. 2005, Federal Statistical Office.

4. *Statistical yearbook 2007 for the federal republic of Germany*. 2007, Wiesbaden: federal statistical office.

5. Adams, J., M. White, and P. Heywood, *Year-round daylight saving and serious or fatal road traffic injuries in children in the north-east of England.* J Public Health (Oxf), 2005. **27**(4): p. 316-7.

6. Agran, P.F., *School transportation safety.* Pediatrics, 2007. **120**(1): p. 213-20.

7. Akerstedt, T. and G. Kecklund, *Age, gender and early morning highway accidents.* J Sleep Res, 2001. **10**(2): p. 105-10.

8. Akerstedt, T., G. Kecklund, and L.G. Horte, *Night driving, season, and the risk of highway accidents.* Sleep, 2001. **24**(4): p. 401-6.

9. Andrey, D.J., B. Mills, and J. Vandermolen, *Weather Information and Road Safety*. 2001.

10. Bockholdt, B. and V. Schneider, *The injury pattern to children involved in lethal traffic accidents in Berlin.* Leg Med (Tokyo), 2003. **5 Suppl 1**: p. S390-2.

11. Brodsky, H. and A.S. Hakkert, *Risk of a road accident in rainy weather.* Accid Anal Prev, 1988. **20**(3): p. 161-76.

12. Brudvik, C., *Child injuries in Bergen, Norway.* Injury, 2000. **31**(10): p. 761-7.

13. Bruehning, E., L. Hippchen, and G. Weißbrodt, *Auswirkungen der Sommerzeit auf die Verkehrssicherheit.* Straße und Verkehr, 1981. **9**: p. 360-366.

14. Brühning, E. and R. Völker, *Unterschiede in der Unfallbeteiligung von Jungen und Mädchen als Fußgänger und Radfahrer.* Zeitschrift für Verkehrssicherheit, 1980. **26**(1): p. 4-11.

15. Calandrillo, S.P. and D.E. Buehler, *Time well spent: congressional daylight saving time legislation saves lives, not just oil*. 2007.

16. Carskadon, M.A., *Sleep deprivation: health consequences and societal impact.* Med Clin North Am, 2004. **88**(3): p. 767-76.

17. Carskadon, M.A., et al., *Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days.* Sleep, 1998. **21**(8): p. 871-81.

18. Coate, D. and S. Markowitz, *The effects of daylight and daylight saving time on US pedestrian fatalities and motor vehicle occupant fatalities.* Accid Anal Prev, 2004. **36**(3): p. 351-7.

19. Coren, S., *Sleep deficit, fatal accidents, and the spring shift to daylight savings time*, in *INABIS '98 - 5th Internet Wold Congress on Biomedical Sciences at McMaster University*. 1998: Camada.

20. Dean, L., *High school start times: how to get them on the same schedule as adolescents' biological clocks.* The York Scholar, 2006. **3**: p. 12-22.

21. Dickerson, D.A., D.H. Bass, and A.F. Rodrigues, *Motor vehicle accidents - an avoidable cause of injury in childhood*, in *S Afr Med J*. 1990. p. 431.

22. Eisenberg, D. and K.E. Warner, *Effects of snowfalls on motor vehicle collisions, injuries, and fatalities.* Am J Public Health, 2005. **95**(1): p. 120-4.

23. Ellsäßer, G., *Unfälle von Schülern auf öffentlichen Verkehrswegen*, in *Public Health Forum*. 2007.

24. Ellsasser, G. and R. Berfenstam, *International comparisons of child injuries and prevention programs: recommendations for an improved prevention program in Germany.* Inj Prev, 2000. **6**(1): p. 41-5.

25. Everett, S.A., et al., *Trends and subgroup differences in transportation-related injury risk and safety behaviors among high school students, 1991-1997.* J Adolesc Health, 2001. **28**(3): p. 228-34.

26. Ferguson, S.A., et al., *Daylight saving time and motor vehicle crashes: the reduction in pedestrian and vehicle occupant fatalities.* Am J Public Health, 1995. **85**(1): p. 92-5.

27. Gliewe, R., M. Limbourg, and B. Pappritz, *German examples of safter routes to school*, in *Road Safety Education Conference*. 1998: York.

28. Harruff, R.C., A. Avery, and A.S. Alter-Pandya, *Analysis of circumstances and injuries in 217 pedestrian traffic fatalities.* Accid Anal Prev, 1998. **30**(1): p. 11-20.

29. Howarth, C.I., D.A. Routledge, and R. Repetto-Wright, *An analysis of road accidents involving child pedestrians.* Ergonomics, 1974. **17**(3): p. 319-30.

30. Jonah, B., A. and G.R. Engel, *Measuring the relative risk of pedestrian accidents.* Accid Anal Prev, 1983. **15**: p. 193-206.

31. Kahl, H., R. Dortschy, and G. Ellsasser, *[Injuries among children and adolescents (1-17 years) and implementation of safety measures. Results of the nationwide German Health Interview and Examination Survey for Children and Adolescents (KiGGS)].* Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz, 2007. **50**(5-6): p. 718-27.

32. Kantermann, T., *Challenging the human circadian clock by Daylight Saving Time and Shift-Work.* 2008.

33. Kapp, C., *WHO acts on road safety to reverse accident trends. Traffic accidents kill 1.26 million people each year; 2nd leading cause of death among those aged 15-29.* Lancet, 2003. **362**(9390): p. 1125.

34. Keay, K. and I. Simmonds, *The association of rainfall and other weather variables with road traffic volume in Melbourne, Australia.* Accid Anal Prev, 2005. **37**(1): p. 109-24.

35. Kraus, J.F., et al., *Child pedestrian and bicyclist injuries: results of community surveillance and a case-control study.* Inj Prev, 1996. **2**(3): p. 212-8.

36. Lambe, M. and P. Cummings, *The shift to and from daylight savings time and motor vehicle crashes.* Accid Anal Prev, 2000. **32**(4): p. 609-11.

37. Lenne, M.G., T.J. Triggs, and J.R. Redman, *Time of day variations in driving performance.* Accid Anal Prev, 1997. **29**(4): p. 431-7.

38. Limbourg, M., *Schulwegunfälle: Häufigkeit, Ursachen und Prevention.* Psychologie der Arbeitssicherheit, 1996: p. 510-526.

39. Limbourg, M., *Kinder unterwegs im Verkehr - Ansätze zur Erhöhung der Verkehrssicherheit im Kindesalter.* Verkehrswachtforum, 1997. **3**: p. 1-38.

40. Limbourg, M., *Mehr Sicherheit auf Schulwegen.* Grundschule, 1999. **31**(7-8): p. 73-74.

41. Limbourg, M., et al., *Müssen Kinder verunglücken, damit Schulwege sicherer werden?* Sicher Leben (Hg.), 1997: p. 227-241.

42. Meyerhoff, N.J., *The influence of daylight saving time on motor vehicle fatal traffic accidents.* Accid Anal Prev, 1978. **10**: p. 207-221.

43. Mitler, M.M., et al., *Catastrophes, sleep, and public policy: consensus report.* Sleep, 1988. **11**(1): p. 100-9.

44. Monk, T.H. and D.J. Kupfer, *Which aspects of morningness-eveningness change with age?* J Biol Rhythms, 2007. **22**(3): p. 278-80.

45. Morrison, A. and D.H. Stone, *Trends in injury mortality among young people in the European Union: a report from the EURORISC working group.* J Adolesc Health, 2000. **27**(2): p. 130-5.

46. Nofal, F.H. and A.A. Saeed, *Seasonal variation and weather effects on road traffic accidents in Riyadh city.* Public Health, 1997. **111**(1): p. 51-5.

47. Pan, S.M., S. Hargarten, and S.K. Zhu, *School bus and children's traffic safety.* Chin J Traumatol, 2007. **10**(4): p. 250-6.

48. Peden, M., *World report on road traffic injury prevention: summary* 2004, World Health Organization: Geneva.

49. Pfaff, G. and E. Weber, *[More accidents due to daylight saving time? A comparative study on the distribution of accidents at different times of day prior to and following the introduction of Central European Summer Time (CEST) (author's transl)].* Int Arch Occup Environ Health, 1982. **49**(3-4): p. 315-23.

50. Powell, N.B., et al., *The road to danger: the comparative risks of driving while sleepy.* Laryngoscope, 2001. **111**(5): p. 887-93.

51. Preston, B., *Child pedestrian casualties with special reference to casualties on the journey to or from school in Manchester and Salford, England.* Accid Anal Prev, 1989. **21**(3): p. 291-7.

52. Roenneberg, T., et al., *A marker for the end of adolescence.* Curr Biol, 2004. **14**(24): p. R1038-9.

53. Saß, A.-C., *Accidents in Germany.* Deutsches Ärzteblatt, 2008. **105**(36): p. 604-608.

54. Satterthwait, S.P., *An assessment of seasonal and weather effects on the frequency of road accidents in california.* Accid Anal Prev, 1976. **8**: p. 87-96.

55. Schofield, G.M., et al., *The incidence of injuries traveling to and from school by travel mode.* Prev Med, 2008. **46**(1): p. 74-6.

56. Sood, N. and A. Ghosh, *The Short and Long Run Effects of Daylight Saving Time on Fatal Automobile Crashes* The B.E. Journal of Economic Analysis & Policy, 2007. **7**(1).

57. Stineman, R.W.A., *A consistently well behaved method of interpolation.* Creative Computing, 1980. **6**(7): p. 54-57.

58. Stutts, J.C., et al., *Driver risk factors for sleep-related crashes.* Accid Anal Prev, 2003. **35**(3): p. 321-31.

59. Sullivan, J.M. and M.J. Flannagan, *Characteristics of pedestrian risk in darkness*. 2001. 25 p.

60. Sullivan, J.M. and M.J. Flannagan, *The role of ambient light level in fatal crashes: inferences from daylight saving time transitions.* Accid Anal Prev, 2002. **34**(4): p. 487-98.

61. Varughese, J. and R.P. Allen, *Fatal accidents following changes in daylight savings time: the American experience.* Sleep Med, 2001. **2**(1): p. 31-36.

62. Wahlstrom, K., *Changing times: Findings from the first longitudinal study of later high school start times.* NASSP Bulletin, 2002. **86**(633): p. 3-21.

63. Wazana, A., et al., *A review of risk factors for child pedestrian injuries: are they modifiable?* Inj Prev, 1997. **3**(4): p. 295-304.

64. Whittaker, J.D., *An investigation into the effects of British Summer Time on road traffic accident casualties in Cheshire.* J Accid Emerg Med, 1996. **13**(3): p. 189-92.

65. Wolfson, A.R. and M.A. Carskadon, *Sleep schedules and daytime functioning in adolescents.* Child Dev, 1998. **69**(4): p. 875-87.

8. ABBREVIATIONS

AM= annual mean

BWB= Baden-Württemberg

DST= daylight saving time

GMT= Greenwich Mean Time

Low Saxony= Lower Saxony

max= Maximum

Meck W P= Mecklenburg-Western Pomerania

MID= minutes in darkness

min= Minimum

NRW= North Rhine-Westphalia

Rh-Palat= Rhineland-Palatinate

SR= sunrise

WTS= way to school

9. ACKNOWLEDGEMENTS – DANKSAGUNG

- I would like to thank my doctoral father Professor Till Roenneberg for all his patience with introducing me to science, for his steady support. Thank you very much, especially for your imperturbable motivation and your refreshing humor
- I thank Professor Ernst Pöppel that I got the possibility to work at his institute and to be a member of a really nice working group for a great time during and after studying
- I would like to say thanks to all members of the institute for all your kindness and helpfulness
- Very special thanks from heart to you, Susanne and Thomas Kantermann, Astrid Stück, Julia Diegmann, Ildiko Meny, Manfred Goedel, Karla Allebrandt, Cornelia Madeti, Celine Vetter, Myriam Juda, Gesa Hoffmann and Tim Kühnle for your creativity and spontaneity, for having always an open ear and for the great time you shared with me
- I thank many people from the Innenministerium (Pressestelle), Innenministerium Brandenburg, Innenministerium Baden-Württemberg, Innenministerium Sachsen-Anhalt, Statistisches Bundesamt Wiesbaden, Statistisches Landesamt Berlin, Statistisches Landesamt Bremen, Statistisches Landesamt Sachsen-Anhalt, Statistisches Landesamt Hessen, Statistisches Landesamt Saarland, Statistisches Landesamt Mecklenburg-Vorpommern, Niedersächsisches Landesamt für Statistik, Statistisches Landesamt Rheinland-Pfalz, Thüringer Landesamt für Statistik, Polizei Hamburg, Polizei München, Polizeipräsidium Oberbayern, Polizei Niederbayern/Oberpfalz, Polizei Nordrhein-Westfalen, Bundesverband für Unfallkassen München, Unfallkasse Hamburg, Bundesanstalt für Straßenwesen, Meteorologisches Institut der LMU, Kreisverwaltungsreferat München, Bayerisches Forschungsdatenzentrum
- Special thanks to Frau Ahus, Frau Asbeck, Herr Bauer, Herr Blümel, Herr Bernhardt, Herrr Brutscher, Frau Bergmann, Herr Blümke, Herr Ciesielski, Herr Dawid, Frau Feist, Herr Ganserer, Herr Giese, Frau Gassner, Frau Gerth, Frau Grandjean, Frau Gossen, Herr Halbritter, Herr Habig, Frau Hindl, Frau Kresse, Frau Krauskopf, Frau Kerzel, Herr Kaiser, Frau Kersting, Herr Kreuser, Frau Kilb, Frau Kübler, Herr Köppen, Herr Lösslein, Herr Leiding, Frau Mercker, Herr Maier, Herr Mohr, Frau Meyer, Herr Nolde, Herr Ötting, Herr Dr. Rödel, Herr Scherer, Herr Standke, Herr Sommer, Herr Schmittel, Herr Dr. Scholtyssek, Herr Seidel, Frau Schlegel, Frau Schulz, Frau Schöner, Herr Schubert, Frau Thaler, Herr Poliwoda, Herr Podzun, Herr Peetz, Herr Wiemer and Herr Zelzer for sending me the data, because without that this study never could have be done

- I thank my parents and relatives who enabled my study and who helped me during writing this thesis with great patience and financial support
- Thanks to all my friends for the support and refraction
- Very thanks to you, Fabian Bajfus for your love, for all hours we were spending discussing things together and for your constructive help and motivation for completing my thesis

10. CURRICULUM VITAE - LEBENSLAUF

Silke Sondermayer, geboren am 29.06.1981 in Freising

Schulbildung:

1992-2001 Camerloher-Gymnasium Freising

Studium:

2001-2007 Studium der Humanmedizin an der Ludwig-Maximilians-Universität München

2003 Ärztliche Vorprüfung

2007 Ärztliche Prüfung

Praktisches Jahr:

- 1. Tertial: Innere Medizin im Sanitätsbetrieb Bozen und im Klinikum Dritter Orden, Nymphenburg
- 2 Tertial: Radiologie im Universitätsklinikum der Innenstadt München
- 3. Tertial: Chirurgie im Klinikum Pasing

Wissenschaftliche Tätigkeit:

Seit Sommer 2004 Mitarbeit als medizinische Doktorandin in der Arbeitsgruppe Prof. Dr. rer.nat. Roenneberg (Chronobiologie), LMU München

Berufliche Tätigkeit:

Seit Oktober 2008 Assistenzärztin in der Radiologischen Abteilung im Klinikum Freising